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Indira Gandhi National Open University
School of Social Sciences

BANC-104

HUMAN ORIGIN AND EVOLUTION

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School of Social Sciences
Indira Gandhi National Open University

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Course Contents

HUMAN ORIGIN AND EVOLUTION

The modern humans are products of a very long evolutionary history. Our rich evolutionary past begins with the origin of primates, divergence of human clade from apes, evolution of genus *homo* and finally leading to the emergence of modern humans. Paleoanthropologists use different methodological approaches to trace and reconstruct the major evolutionary events in the origin and development of archaic and modern human species.

The present course on human origin and evolution has been well organized into three blocks revisiting the key events during the evolutionary history of primates. This under graduate course addresses the origin of primates, differentiation of human lineage from apes, the rise and fall of Australopithecines and *Homo habilis*, the origin and dispersal of *Homo erectus* and *Neanderthals*, and eventually the origin of modern humans through hominization process.

The first block (Unit 1 through Unit 3) offers an introduction to the sub-discipline of anthropology, palaeoanthropology and develops an understanding of dating methods. The block also reflects upon how primates diversified and radiated along with other mammals during the Cenozoic Era. Unit 1 explores the branch of palaeoanthropology and discusses its scope and relationship with other disciplines. The unit also provides an account of fossils by explaining the preservation and the process of fossilization. Unit 2 elaborates on the evolution and radiation of primates with a special focus on the Cenozoic era. This unit also delineates the basic principles of dating fossils, including the significant methods used by professionals. The last unit (Unit 3) of the block outlines the origin of early primates and evolution of Miocene hominoids. This unit also provides a description of significant hominoids from Siwalik hills along with an exploration of the hominid status of *Ramapithecus*.

Block two (Unit 4 to Unit 6) demonstrates the course and trends of evolution after the process of hominization. Unit 4 begins with surveying the history of human evolution and progresses to an understanding of pre modern humans and all the evidences and elementary changes associated with the process of hominization. In unit 5 and 6, a comprehensive review of early hominids, Australopithecines and *Homo habilis* have been presented. This review includes their distribution, age, major morphological characteristics, phylogenetic position and lifeways. Unit 5 also describes various *Australopithecus* finds such as *A. anamensis*, *A. afarensis, A. africanus*, *A. robustus* and *A. garhi.*

Block three (Unit 7 through Unit 10) proceeds chronologically from *Homo erectus* to modern Humans who inhabit the world today. These four units deal with the fossil evidences, age, geographical distribution, morphological features, characteristics and lifeways of *Homo erectus, Neanderthal and archaic* and *modern Homo sapiens.* Significant cultural and evolutionary practices have also been discussed.

BLOCK 1

PALAEOANTHROPOLOGY AND PRIMATE EVOLUTION

UNIT 1 INTRODUCING PALAEOANTHROPOLOGY*

Contents

Learning Objectives:

After reading this unit, you will be able to:

- understand the definition, aim and subject matter of Palaeoanthropology;
- comprehend the relationship of Palaeoanthropology with other disciplines; and
- know what are fossils, their process of preservation and fossilization and significance of fossils.

1.0 INTRODUCTION

Paleoanthropology emerged as a science during the late nineteenth century. The discovery of prehistoric artifacts in Pleistocene deposits soon led to the excavation of fossilized human bones. The archaeologists and geologists who unearthed these artifacts were primarily concerned with determining whether the human fossils and the artifacts found by them actually dated from the Pleistocene, thus offering evidence for the geological antiquity of humans. Prehistoric archaeologists reconstructed the way of life of prehistoric peoples through the artifacts found, while anthropologists examined the human fossils. They wanted primarily to identify the races of prehistoric humans. It was within this context that French anthropologists began to use the term *"pale΄o-anthropologie"* to refer to a new scientific discipline devoted to the study of prehistoric human races and human paleontology.The field of paleoanthropology studies origin and development of early humans as an interdisciplinary branch of anthropology (Goodrum, 2014).

The field draws from and combines paleontology, biological anthropology, and cultural anthropology. As technologies and methods advance, genetics plays an ever-increasing role, in particular to examine and compare DNA structure as a vital tool of research of the evolutionary kinship lines of related species and genera.

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1.1 DEFINITION

The term paleoanthropology derives from Greek *palaiós* (παλαιὸς) “old, ancient”, *ánthrôpos* (ἄνθρωπος) “man, human” and the suffix -logía (-λογια) “study of”. Louis Lartet was one of the first to use the term “*pale´o-anthropologie*.” Paleoanthropology emerged within the context of the growing archaeological evidence from the late 1850s and early 1860s for the presence of humans in Europe during the Pleistocene. Thus as the name indicates, Palaeoanthropology is the study of man of ancient times. Now how do we study ancient man in current times, its evolution through the fossils of our early ancestors. Now what are fossils? It’s a Latin word *Fodre* which means dig up.

Paleoanthropology is commonly considered as the study of human fossils and a descriptive and broadly narrative discipline that is dominated by poorly researched and media-friendly “findings” that cause changing views on the process of human evolution. Today’s paleoanthropology or human palentology is a sub discipline of evolutionary biology that aims to describe, analyze, and interpret the process of human evolution mainly through a vast set of inductive approaches and deductive hypothesis testing. The palaeoanthropological approach helps to reconstruct our evolutionary history from the recovery and analysis of any relevant fossil evidence. Current palaeoanthropological research does not only ask what our forerunners looked like and when, where, and how they evolved but also specifically asks, for example, why humans evolved while other primate species died out. In paleoanthropology-as in other life sciences with a chronological perspective-the experiment is the historical process of nature itself(Henke and Tattersall, 2007).

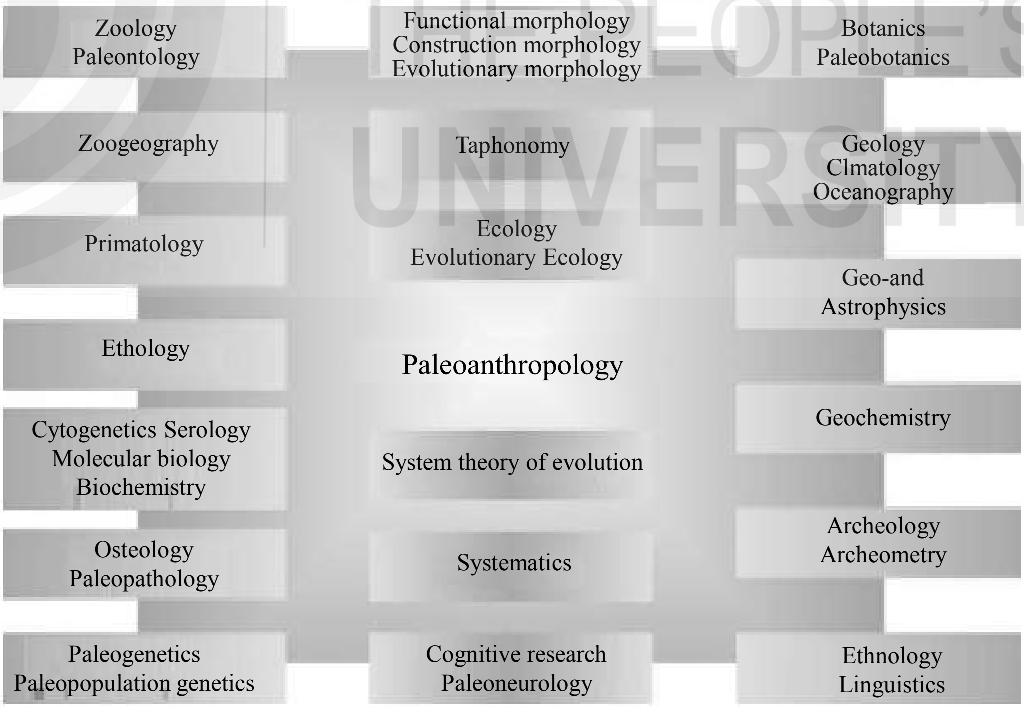

Fig. 1: Scientific disciplines that participate in the approach to reconstruct the process of human evolution (After Henke and Rothe, 1994)

In the early beginning of paleoanthropology, the main question was quite simple: is there a fossil record which proves the existence of our ancestors from ancient times? The protagonists of paleoanthropology soon recognized the need for a sophisticated empirical approach. The best basis for such a development existed in France, where Pierre Marcelin Boule (1861-1942), a qualified geologist, paleontologist, and archaeologist, unified *in persona* all necessary attributes to establish the Discipline of Paleoanthropology. His classical processing of the *Neandertal* skeletons from La Chapelle-aux-Saints (Boule 1911-1913) became a landmark in the history of human palentology. He aimed to understand the patterns of variation and the significance of anatomical differences. For this reason, Boule, invented special instruments for qualification(s) and simple statistical concepts to analyze the variation in human skeletons. Boule established a palentology of humans, later on called paleoanthropology, as a scientific discipline (Henke and Tattersall, 2007).

Check Your Progress

1) What is meant by Paleoanthropology?

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2) How does the field of Paleoanthropology reconstruct human past?

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1.2 AIM

Paleoanthropology is the study of human evolution and that of our closest living relatives, the other primates. Humans, of course are primates and paleoanthropologists recognize the importance of understanding primate evolution as a necessary condition in understanding human evolution. This is the reason primate evolution is most commonly considered a part of paleoanthropology as opposed to the larger field of vertebrate paleontology. Paleoanthropology also includes a variety of other fields that contributes to the study of various areas like human evolution and variation. These include primate biology, systematics, ecology, genetics and geology. And of course, since paleoanthropologists are interested in the behavior of fossil humans, and since many of these humans left material evidence of their behaviour in the fossil record, the analysis of this record. Paleolithic archeology is also a major part of paleoanthropology. Because the material evidence of the behavior of fossil humans is so ubiquitous, while it is essentially non-existent in other animals, paleoanthropology is unique among the historical sciences (Begun, 2013).

1.3 SCOPE OF PALEOANTHROPOLOGY

To adequately understand human bio-cultural evolution, we need a broad base of information. Paleoanthropologists recover and interpret all the clues left by early hominins. It is a diverse multidisciplinary pursuit that seeks to reconstruct every possible bit of information concerning the dating, anatomy, behaviour, and ecology of our hominin ancestors. In the past few decades, the study of early hominins has marshaled the specialized skills of many different kinds of scientists. This growing and exciting adventure includes, but is not limited to, geologists, vertebrate paleontologists, archeologists, physical anthropologists and paleoecologists.

Geologists, usually working with other paleoanthropologists, do the initial survey to locate potential early hominin sites. Many sophisticated techniques can contribute to this search, including aerial and satellite photography. Vertebrate paleontologists are also involved in this early survey work, for they can help find geological beds containing faunal remains where conditions are favorable for the preservation of bone from such species as ancient pigs or baboons, conditions may also be favorable for the preservation of hominin fossils. Paleontologists can also (through comparison with known faunal sequences) give quick and approximate ages of fossil sites in the field without having to wait for the expensive and time-consuming chronometric analyses.

Once identified, fossil beds likely to contain hominin finds become the focus for further extensive surveying. For some sites, generally those postdating 2.6 mya (the age of the oldest identified human artifacts), archaeologists take over in the search for hominin material traces. We don't necessarily have to find remains of early hominins themselves to know that they consistently occupied a particular area. Such material clues as artifacts inform us directly about early hominin activities. Modifying rocks according to a consistent plan or simply carrying them around from one place to another over fairly long distances (in a manner not easily explained by natural means, like steam or glaciers is characteristic of no other animal but hominins (Jurmain et al., 2011).

We have learnt that Palaeoanthropology being an offshoot of anthropology and archaeology focuses on the reconstructing the modern human on evolutionary lines working on biological indicators e.g.petrified skeletal remains, bone fragments, footprints and cultural information as stone tools, artifacts, and settlement localities. With such broad spectrum of this branch, palaeoanthropology is broadly of significance in educating about our past and that of nature and economic applications.

1.4 FOSSILS AND THEIR PRESERVATION

The term fossil (Lat. *Fossils* = to dig up), according to Lamarck, is defined as remains of plants and animals which have existed on the earth in prehistoric times and are found preserved within sedimentary rocks or superficial deposits of the earth, not only mostly as petrified structures of organisms but also whatever was directly connected with or produced by these organisms. Fossils provide some idea about the shape, size, appearance and activities of the organism (Jain and Anantharaman, 1996).

Much of what we know about the history of life comes from studying fossils. Fossils are traces of ancient organisms and can be formed in many ways. The oldest fossils found thus far date back to more than 3 billion years ago, because they are the remains of microorganisms, they are extremely small and are called *microfossils* (Jurmain et al., 2011).

Fossils are the most important link between our past and present, in fact it's around fossil only that we can trace our evolutionary history. Fossils occur in two forms: the actual remains of organisms, which are generally incomplete, including three-dimensional molds of their external body, and the remains of an animal's activity, such as trackways. The remains of an animal's activity are called trace fossils (Cachel, 2015). Fossils are assessed by the techniques of physical anthropology, comparative anatomy, and the theory of evolution.

Types of Preservation

The study of the formation and preservation of fossils is called *taphonomy*. There are several different types of preservation and several different approaches to classification. It is important to be able to understand the different ways that fossils can be formed in order to know what they can look like. It is also worth noting that a single fossil may fall into more than one of these categories.

Original preservation, preservation of the original chemical composition, is typically confined to geologically young fossils where the associated sediments have not yet undergone lithification. Examples of this type of preservation include *soft-tissue preservation* and *original hard part preservation*. Soft-tissue preservation, where organic materials such as organs, skin, and hair are preserved, only occurs under exceptional conditions. Forms of this type of preservation include *encasement* in *amber* and *mummification* via freezing, chemical reaction, lack of oxygen, extremely arid conditions, or dehydration and preservation in oily plant debris (as in the *Geiseltal* Formation in Germany) or tar (as in the *Rancho La Brea tar pits* in Los Angeles). This only occurs for geologically young specimens that date back at most a few million or tens of millions of years, beyond which time nothing but chemicals residues of organic matter will remain. Most well-known examples of this type of preservation are not technically considered fossils. Otzi, the Iceman is a famous example of soft-tissue preservation. Also in this category are finds of ice age mammals such as woolly mammoths, horses, caribou, and several other species in the Tundra of Siberia, Alaska, and the Canadian Yukon which presents the famous examples of soft-tissue preservation. They are sometimes mistaken for modern animals but break roughly into two groups, those aged 50,000-25,000 years old and those aged 15,000-10,000 years old.

Much more common is preservation of original hard parts. Sometimes, organic materials can be preserved intact or nearly intact, without any significant alteration. Teeth, bones, and shells may survive for many millions of years almost unchanged if they are incorporated into suitable, low-oxygen sediment. The enamel that coats teeth is very resistant, as is calcium carbonate and the calcium phosphate that forms bones. Pollen and some microfossils can also survive for long periods virtually unaltered from their original form. Geologically speaking, fossils in this state of preservation are still quite young. The longer a fossil is subjected to burial, compression, and differing chemical environments, the more likely the original material is to be changed.

The older the fossil, the more likely it is to be in a state of *altered preservation*. As sediments are buried deeper in the Earth and gradually lithify into rock, the associated fossils also undergo alteration to a greater or lesser extent. Examples of this type of preservation include permineralization, recrystallization, replacement, formation of casts and or molds, and carbonization. *Permineralization*, the most common form of alteration, is a process in which porous organic structures, such as wood and bone, have their microscopic pore spaces, left vacant by decay, filled by minerals precipitated from groundwater. The original hard parts remain but are encased in extra material that fills in the pores. The resulting fossil is heavier and denser than the original material. With this type of fossilization, the fine details of microscopic structure are generally preserved, occasionally even preserving details of cell structure. *Petrified wood* is a fairly common example of permineralization.

Recrystallization is a type of preservation where the crystalline minerals forming an organism's hard parts fuse to form larger, more stable crystals. The original chemical composition can sometimes be preserved, but in other cases, unstable minerals, such as aragonite, recrystallize into a more stable, chemically identical form, such as calcite. The original chemical composition remains, and much of the original shape of the fossil is preserved, but the texture difference is obvious under the microscope and much of the fine detail of the structure is lost.

Replacement is a process in which an organism's original hard parts are dissolved by chemical action and replaced by another mineral, such as calcite, silica, iron, or pyrite. The result is a chemically different replica of the original fossil. The replacement process takes on the name of the secondary mineral, for example *silicification*, which is the most common form, entails replacement of the original mineralogy by silica; *pyritization* is the replacement of calcite or softtissues with pyrite (like the sand dollars that you often see in stores); *phosphatization* usually involves replacement of low-phosphate apatite with high-phosphate apatite; and *dolomitization* is usually the incorporation of magnesium into hard parts that were originally calcite-forming dolomite. Growth of a replacement mineral occurs at the expense of the original mineral components, destroying fine detail while preserving the original size and shape of the fossil.

Sometimes the original material dissolves away completely, leaving a void in the surrounding sediment and leading to the formation of molds and/or casts. Molds are surface impressions created in the sediment surrounding the original material. Think, for example, of leaving a footprint in the sand. Molds can be found around extant fossils or, if the original material dissolved from the rock matrix, are left behind as impressions called external molds. If the original fossil material becomes filled with sediment internally, an impressions of the inside, called an internal mold, can also form. If a cavity in a fossil is completely filled in, it can form a nodular internal mold called a steinkern. A complete mold forms when internal and external mold surfaces are compacted together to produce impressions in the same layer of sediment.

Casts are formed when a mineral, sediment, or some other material fills in a mold and hardens to form a copy of the original structure. True casts are relatively rare in the fossil record, and internal molds (especially steinkerns) are often confused with them. A mold is a negative image of the original, while a cast is a positive image, or duplicate of the original. Since molds and casts occur as a result of the dissolution or destruction of the original material after the surrounding matrix of sediment has hardened, only a limited amount of fine detail is usually preserved.

Carbonization occurs when organic material is preserved through rapid burial in an anoxic (very low or no oxygen) environment. The organics do not decay. Instead, the volatile elements, such as hydrogen, oxygen, and nitrogen are driven off, leaving behind organic-rich hard parts and soft parts to be preserved as thin, black films of organic carbon. The fossil loses its three-dimensional shape, but this process often will preserve the outline of soft tissues, hair, or feathers, and can reveal fine details that would have been destroyed by other form of fossilization. Plants are also often preserved in this way. Some of the fantastic details of the 47-million-year-old fossil primate called Ida (incorrectly cited in the media as a missing link), such as the hair and skin shadow (an outline of an animal's soft tissue or flesh), are due to carbonization of the soft tissue around an animal's preserved bones. This combination gives an unprecedented amount of information about extinct organisms. Carbonized fossils are most commonly found on the bedding planes of sandstone and shale.

Different organisms have differing potential for fossilization. Organisms with hard parts are much more commonly preserved than organisms with no hard parts. The number and size of hard parts also affects preservation. Organisms with one or two large, robust shells are more likely to be preserved intact than organisms with lots of smaller, more delicate parts. The environment in which an organism lives also plays an important role in preservation. Organisms that live in environments where there is lots of chemical and physical weathering, and/or substantial erosion, such rapid burial and are preserved by lithification of the host sediments themselves, hopefully without significant distortion. Study of trace fossils (ichnofossils) is a specialized area of palentology called ichnology. Because trace fossils are very rarely found directly in contact with the organisms responsible for their creation, ichnologists have developed their own separate methods of classification.

1.5 PROCESS OF FOSSILIZATION

The very early traces of life are fragile and very rare. Most of our evidence comes later in time, and usually these fossils are pieces of shells, bones, or teeth, all of which, even in a living animal, were already partly made of mineral. After the organism died, these "hard" tissues were further impregnated with other minerals, being eventually transformed into a stone like composition. This process is mineralization (Jurmain et al., 2011).

Fossilization is the process by which the body of an organism is converted into a fossil by petrification or by gradual addition or replacement of organic material by inorganic substance. For the process of fossilization normally the organisms must have hard parts like skeleton, nail, tooth, bone etc. because the soft parts shall generally be decomposed. After the death of an organism, it must be immediately buried so that it does not get destroyed. Since most of the dead organisms get deposited in water, therefore, the most favorable conditions for fossilization are present in sea. Fossilization takes place when the tissues of an organism are replaced by minerals. Sometimes replicas of soft tissue are preserved by bacteria that leave a mineral coat of phosphate or pyrite over the surface of the tissue. Alternatively, fine-grained sediments may sometimes preserve a hardened external cast of an organism. In addition to hard parts (pollen, shell, bone, teeth) that are more apt to fossilize, other materials, such as wood, may also sometimes be fossilized. Fossil wood may be so abundant in some areas that partial reconstruction of an ancient forest may be possible. Sometimes the fossil wood is not mineralized. The cellulose has decayed, but the lignin may still be present. A partial fossil forest of the swamp cypress (Taxodium) has been preserved as lignin stumps in 8 mya deposits in Hungary. The trees had been quickly buried in sands that partly preserved the plant material up to the point of burial. Similar swamp forests from the Late Miocene of Hungary once housed *Rudapithecushungaricus*, one of the last survivors of the once diverse European fossils ape radiation (Cachel, 2015).

There are, however, many other ways in which life-forms have left traces of their existence. Sometimes insects were trapped in tree sap, which later became hardened and chemically altered. Because inside the hardened amber there was little or no oxygen, the insects have remained remarkably well preserved for million of years, even with soft tissues and DNA still present. This fascinating circumstance led author Michael Crichton to conjure the *Jurassic Park* novel and motion pictures. Leaf imprints in hardened mud, or similar impressions of small organisms, or even the traces of dinosaur feathers are fossils (Jurmain et al., 2011).

1.5.1 Physico-chemical Conditions For Fossilization

Environmental conditions: Preservation of fossils is a fairly exceptional phenomenon that necessitates particular conditions. The body must be rapidly isolated from oxygenated environment, immediate burial by fine grained sedimentary deposits, the subsequent deposition of large quantities of sedimentary deposition (load) leading to prevent oxidation, the expulsion of water and to compaction. However, the best sediments for good preservation are (a) the water borne sediments from the degradation and decomposition of older rocks in the form of argillaceous and (b) the wind borne material in the form of loess or volcanic ashes has yielded fossils of terrestrial organisms.

Geographic, topographic and climatic conditions also influence preservation, winds and currents in particular encourage accumulation of organic remains. Similarly, certain modes of life are shown to lend themselves to a greater or lesser extent to fossilization. Colonising, gregarious, fixed, boring or burrowing organisms are more easily preserved than those which live in isolation or lead a wandering existence(Jain and Anantharaman, 1996).

Chemical conditions: Soon after death the soft parts of organism undergo decomposition by the activity of bacteria. Similarly, organic matter associated with the mineralized parts like proteinaceous material of shells, bones, tests etc. often disappear, regarding these initially hard parts porous and brittle. Chemical exchanges also occur between the decomposing organism and the sediment which contains it. The organic matter engaged in this process infact results from photosynthesis by phytoplankton; about a million tons of organic substances having this origin are deposited annually in the oceans in present day conditions. However, it has been known for some years that organic substance themselves have been able to "fossilize" in many sediments and preservation of the substance of the soft parts can occasionally occur. The constant refinement of methods of investigation in chemical analysis makes it possible to reveal the preservation of an ever increasing number of constituents of living matter. Palaeobiochemistry has thus grown up, the results of which are of interest to various branches of modern palentology. The absence of fossils in the Pre-Cambrian formations may have resulted from the absence of proteins in the hard parts of the organisms (Jain and Anantharaman, 1996).

Check Your Progress

3) How do geologists and paleontologists contribute to the field of Palaeoanthropology?

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4) Explain one important technique of fossil preservation?

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1.6 SIGNIFICANCE OF FOSSILS

The value of any fossil depends upon its position in the geologic column and geographic location. There is definite relation between the fossil contents of rocks and the position of those rocks in geologic column. Older rocks have simpler organisms and recent rocks have more complex and varied assemblage of the contained fossil organisms (Jain and Anantharaman, 1996).

- ***Study of Chronostratigraphy:*** The purpose of chronostratigraphy is to organize the sequence of rocks on a global scale into chronostratigraphical units so that all local as well as worldwide events can be related to a single standard scale. It is concerned with the age of strata and their time relations. The organisms now represented as fossils lived at definite times during the geologic past and hence have chronological sequence. The character of the included fossil indicates conclusively the time when the sediments were laid down.

- ***Study of Biostratigraphy:*** Marine sediments have several fossil species occurring in a particular sequence; each species confined to one part of the succession only and representing the time when that species was living. Here in lies the application of palaeontology: Biostratigraphy. Using the sequence of fossil fauna/flora, the geologic column has been divided into geochronological units (era, period, epoch and age). In biostratigraphy fossil contents of the beds are used in interpreting the historical sequence.

- ***Study of Paleogeography:*** The adaptations of organisms are characteristic of particular environments, hence those shown by fossil forms may indicate the extent and boundaries of former lands, water deltas, mountains, deserts, lakes, rivers, shore lines and the positions of deep and shallow seas(Jain and Anantharaman, 1996).

- ***Study of Palaeoclimate:*** The variation of temperature and the degree of moisture is perhaps most clearly indicated by fossil plants and animals. The palm fossil indicates warm climate, corals exhibit warm tropical climate and forams exhibit temperate climate. It is also provided by the rapid diminution in the number and kind of growing animals and the increase of grazing forms after the beginning of Miocene.

- ***Study of Palaeoecology:*** Palaeoecology is the study of ancient organisms in relation to their total physical, chemical and biological environment. It also explains how these organisms have adapted to a particular ecological niche in which they feed and breed. It also helps to find out the nature of these adaptations and the relationships of the animals with each other and their environments.

- ***Study of Organic Evolution:*** No line of evidence more forcefully and clearly supports the fundamental postulate of evolution-"descent with accumulative modifications"- than that furnished by fossils. The panorama of organic evolution is visualized by paleontologists from the study of the fossil record left in the rocks by former organism(Jain and Anantharaman, 1996).

Check Your Progress

5) What do you understand by fossilization?

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6) Write a short note on significance of fossils.

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1.7 SUMMARY

The field of Palaeoanthropology emerged in Europe during the Pleistocene period for the discovery of humans from the growing archaeological evidences. Paleoanthropology is an interdisciplinary branch of anthropology that is concerned with the origins and development of early humans. Paleoanthropologists reconstruct the way of life of prehistoric peoples through the artifacts and fossils found. The field draws from and combines geology, vertebrate paleontology, archeology, physical anthropology, and paleoecology. Paleoanthropology finds applications in education, economy and in reconstruction of human past. Palaeoanthropologist with their knowledge of the past life can reconstruct the palaecology, palaeoenvironment and community structure which can provide important clues about early humans and their interaction and competition with past fauna and flora as well as about the evolution of man.Much of what we know about the history of life comes from studying fossils. This unit explores how fossils are formed and preserved. Examples are drawn from human body, fossil halls of natural museum and Dinosaur fossil remains.

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1.9 ANSWERS TO CHECK YOUR PROGRESS

1) The field of paleoanthropology studies origin and development of early humans as an interdisciplinary branch of anthropology. For further details refer section 1.1.

2) The field of Paleoanthropology reconstruct past of humans by gaining information from fossil record of primates, genetics analysis of humans and other surviving primate species, and the history of changing climate and environments in which the human species evolved.

3) Geologists do the initial survey to locate potential early hominin sites. Many sophisticated techniques can contribute to this search, including aerial and satellite photography. Paleontologists can also (through comparison with known faunal sequences) give quick and dirty approximate ages of fossil

sites in the field without having to wait for the expensive and time-consuming chronometric analyses.

4) Recrystallization is a type of preservation where the crystalline minerals forming an organism's hard parts fuse to form larger, more stable crystals. For further details refer section 1.4.

5) Fossilization is the process by which the body of an organism is converted into a fossil by petrification or by gradual addition or replacement of organic material by inorganic substance. For further details refer section 1.5.

6) Fossil records are widely used in the study of the following: (a) Chronostratigraphy (b) Biostratigraphy (c) Paleogeography (d) Palaeoclimate (e) Palaeoecology and (f) Organic Evolution. For further details refer section 1.5.

UNIT 2 LIFE THROUGH AGES AND DATING METHODS*

Contents

Learning Objectives

Once you have studied this unit you will:

- know the chronology and position of Cenozoic Era in Geological Time Scale;
- understand different periods of Cenozoic Era;
- know about different dating methods that assist archaeological study; and
- know how these methods provide an understanding of the chronological order of events.

2.0 INTRODUCTION

The Cenozoic Era is also known as Caenozoic or Cainozoic. Cenozoic literally means 'new life' after the Greek roots '*kainos*' meaning 'new' and '*zoico*' meaning 'animal life'. The Cenozoic Era is of substantial interest for anthropologists since the evolution and diversification of fossil Primates, including humans, took place during this era. Besides primates, a significant portion of the evolution and radiation of various groups of mammals also happened during the Cenozoic. It is for this reason that sometimes the Cenozoic is also termed as the 'Age of Mammals' who were the dominant animal life of earth during the Cenozoic Era. The era began about 65 million years ago and continues into the present. The existing locations of the continents and the distribution of current flora and fauna acquired its present-day configuration during this time period.

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The era began at the end of Cretaceous, the last phase of the Mesozoic. The end of Cretaceous was marked by large-scale extinctions, when the non-avian dinosaurs, along with several other types of fauna, were completely wiped out. Several types of ecological niches vacated by the reptilian extinction were gradually occupied and exploited by the mammals, which flourished, diversified and came to dominate Earth's faunal life.

During early part of the Cenozoic, Earth was largely populated by small fauna, which also included small mammals. However, over a period of time the mammals diversified and radiated taking advantage of the absence of dinosaurs who had dominated the earth during the Mesozoic Era. The mammals occupied almost all the ecological niches, which were earlier the domain of the dinosaurs. Over time, a few of the mammals greatly increased in size and grew much larger than even some of the largest mammals of today, such as whales and as elephants. Of all the twenty orders of the class mammalian, of special interest for an anthropologist are the primates, which also evolved, diversified and radiated along with other mammals during the Cenozoic Era.

2.1 POSITION OF CENOZOIC IN THE GEOLOGIC TIME SCALE

The Cenozoic Era is the most recent of the three major subdivisions of animal history. The other two are the Mesozoic and Palaeozoic Eras. Before we discuss the Cenozoic, it would be useful to understand, in brief, the various divisions of the earth's geologic history and the position of Cenozoic in it. The history of the Earth is divided into parts based on certain geologic or faunal/floral events. The generally accepted divisions are eon, era, period, epoch, and age, as progressively smaller units of geological time. The major divisions of time are termed eons. In succession these are: Hadean, the Archean, the Proterozoic and the Phanerozoic. The first three of these can be collectively called as the Precambrian super eons. Eons are further divided into eras. The eras are in turn divisible into periods, epochs and ages. The various divisions of geologic time, along with their ages, and the position of Cenozoic in it are depicted in Table-1.

Table 1: Position of Cenozoic in Geological time scale

Epoch	Era	Period	Epoch	Major Fauna	Age (myr)
		Quaternary	Holocene	Ice Age recedes, present interglacial begins. Rise of human civilization; domestication of animals and agriculture. Stone Age cultures give way to Bronze Age (3300 BC), Iron Age (1200 BC), many pre-historic cultures world-wide and industrial revolution.	0.0117
			Pleistocene	Pleistocene megafauna first flourishes and then becomes extinct. Anatomically modern humans evolve. Emergence of human stone-age cultures. Quaternary Ice Age continues with glacial and interglacial phases.	2.58

PHANEROZOIC	CENOZOIC	*Neogene*	Pliocene	Several of the existing genera of mammals present. Hominids appear and diversify. Cool and dry climate.	5.3
			Miocene	Horses and mastodons diversify. Modern mammal and bird families become identifiable. First apes appear. Grasses spread.	23
		Palaeogene	Oligocene	Rapid evolution and diversification of mammalian and other fauna. Major evolution and dispersal of flowering plants	34
			Eocene	Archaic mammals flourish and continue to evolve; several "modern" mammalian groups appear. First grasses appear.	56
			Palaeocene	Mammals diversify into a number of primitive lineages. Many modern plants appear. Indian plate collides with Eurasian plate ~55 myr. Himalayan orogeny begin	66
	MESOZOIC		Cretaceous	Many new types of land dinosaurs evolve (*Tyrannosaurs*, duck-billed and horned dinosaurs). Flowering plants proliferate.	145
			Jurassic	Many types of dinosaurs. First birds and lizards. Small mammals common. Gymnosperms and ferns common.	201
			Triassic	First mammals and crocodiles appear. Reptiles dominant on land, seas and in the air. Modern corals and teleost fish appear. Many large aquatic amphibians; ammonoids very common.	252
			Permian	Synapsid reptiles become plentiful, amphibians common; cone-bearing gymnosperms replace earlier flora.At ~251 myr, major life, including trilobites, graptolites, blastoids, extinct.	299
			Carboni-ferous	Amphibians diversify, first reptiles and coal forests. Winged insects radiate, first land vertebrates. Early sharks diversify, echinoderms abundant; trilobites and nautiloids decline.	359
			Devonian	First clubmosses, ferns,seed-bearing plants (progymnosperms) and first insects (wingless) appear . Trilobites and armoured agnaths decline, jawed fishes and early sharks rule the seas. First amphibians still aquatic.	419
			Silurian	First vascular plants. First jawed fishes and many armoured jawless fish in seas. Corals, brachiopods, crinoids, Sea-	444

				scorpions, abundant. Trilobites and molluscs diverse.	
		PALAEOZOIC	Ordovician	Invertebrates diversify. Early corals. bivalves, nautiloids, articulate brachiopods, trilobites, ostracods, bryozoa, many echinoderms. First green plants and fungi on land.	485
			Cambrian	Major diversification of life. Most modern phyla appear. First animals with hard parts. First chordates. Trilobites, worms, sponges, brachiopods present. Prokaryotes, fungi, algae go on.	541
PRECAMBRIAN			Proterozoic	In upper part, fossil of complex multicelled organisms. Stromatolite fossils common. First multicellular organisms (~1200 myr). First Eukaryotes (~2000 myr).	2500
			Archean	Simple single-celled life (prokaryotic life such as bacteria and blue-green algae). Oldest probable microfossils.	4000
			Hadean	Formation of Earth. There is no evidence for life in this Eon. Oldest known rocks 3500-4000 myr.	4600

Source: Modified after Cohen et al. (2013)

2.2 CHRONOLOGY OF CENOZOIC ERA

From an anthropological perspective, Cenozoic Era is very important because, the entire primate evolution and subsequently the human evolution occurred during this Era. Besides primates, the evolution and radiation of mammals, birds and most flowering plants and grasses took place during this phase of Earth's history. The Cenozoic is divided into three periods, namely the Palaeogene, the Neogene and the Quaternary, and seven epochs, viz. Palaeocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Holocene. The Cenozoic is sometimes called the 'Age of Mammals', because the largest land animals – the mammals appeared on earth during that time. The Palaeogene is subdivided into three epochs: the Palaeocene, the Eocene and the Oligocene. The Neogene is subdivided into two epochs: the Miocene and Pliocene. The Quaternary is divisible into two epochs: the Pleistocene and the Holocene.

a) Palaeocene Epoch

The Palaeocene is the first epoch of the Cenozoic, which began at about 66 million year before present (myr). It begins at the end of Cretaceous when large-scale extinctions of life occurred. Dinosaurs on land, large swimming reptiles in seas, nektonic ammonites and most microscopic planktons died out at the end of Cretaceous leaving many ecological niches vacant for evolution and radiation of mammals, which had existed for more than 100 million years before the Cenozoic Era.

Palaeocene saw mammals growing bigger and occupying a wider variety of ecological niches. The mammals were small rodent-like to medium-sized mammals. Fossil evidence from the Paleocene is scarce. Small early primates, plesiadapids, marsupials and monotreme mammals were present.

b) Eocene Epoch

The Eocene began at around 56 myr ago and ended at around 34 myr ago lasting nearly 22 million years, the longest of all the epochs of the Cenozoic Era. For most of the Eocene Epoch, the global climate was warm and rainy. Among the mammal groups that first appeared in the fossil record during this period are the perissodactyls, artiodactyls, proboscideans, rodents, and many primates. Adaptive radiation of adapid and the omomyid prosimians took place during this epoch. It is thought that the intense global warming allowed warm-adapted mammals to migrate between continents via land connections at very high latitudes. Early perissodactyls, such as the horse relative *Hyracotherium*, appeared right at the very beginning of the Eocene. By the end of the epoch, the planet was much cooler and the rainforest-like habitats that covered much of the continents gave way to more open woodland.

c) Oligocene Epoch

The Oligocene Epoch extends from about 34 myr ago to about 23 myrs. A cooling trend is prevalent throughout Oligocene. Mammals such as horses, deer, camels, elephants, cats, dogs, and primates began to dominate continents, except in Australia. Early forms of amphicyonids, horses (*Miohippus*) canids, camels, tayassuids, protoceratids, and anthracotheres appeared. In late Oligocene there was an expansion of grasslands and prairies that was linked to the expansion of grazing animals. Earliest new world monkeys, early anthropoids (*Parapithecus, Apidium, Aegyptopithjecus*), known largely from Egypt, emerged.

d) Miocene Epoch

The Miocene Epoch is the first geological epoch of the Neogene Period and it extends from about 23 myrs back to 5.3 myrs ago. It was a time of warmer global climates than those in the preceding Oligocene or the following Pliocene. The grasslands continued to expand and forests continued to decrease. During later part of Miocene, mammals were more modern, with easily recognizable canids, bears, procyonids, equids, beavers, deer, camelids, and whales. Apes arose and diversified during the Miocene, becoming widespread in the Old World (e.g. *Gigantopithecus, Sivapithecus*, *Dryopithecus*). A large number of ape species existed in Africa, Asia and Europe during this time. The first hominins appeared in Africa at the very end of the Miocene, which included *Sahelanthropus* and *Orrorin*.

e) Pliocene Epoch

The Pliocene epoch is the second epoch of the Neogene Period, which began about 5.3 myrs ago and extended to about 2.58 myrs back. During the Pliocene, continents continued to drift toward their present positions and Africa's collision with Europe cut off the remaining part of the Tethys Sea and formed the Mediterranean Sea. During the Pliocene, climates became cooler, drier, and seasonal, similar to modern climates. In Eurasia, primate distribution declined. Elephants, gomphotheres, and stegodonts were successful in Asia. Horse diversity declined, while cattle and antelopes were successful. During Pliocene, hominids became increasingly well-documented in the fossil record (e.g. *Ardipithecus ramidus, Australopithecus anamensis, Australopithecus afarensis, Australopithecus garhi*, *Australopithecus africanus, Homo habilis*).

f) Pleistocene Epoch

This epoch is the first epoch of the Quaternary Period that started about 2.58 myr ago and lasted up to 11700 years before present. The Pleistocene was a relatively short span of geologic time, which was a time of great global cooling, commonly known as "Ice Age". During the epoch, immense glaciers and ice sheets occurred at the North and South Poles and at all high altitudes. The cold periods or glacial were interspersed with warmer phases or interglacial. The evolution of anatomically modern humans (*Homo sapiens*) took place during the Pleistocene, who then spread to different parts of the Earth. In addition to the woolly mammoth, mammals such as sabre-toothed cats (*Smilodon*), giant ground sloths (*Megatherium*) and mastodons roamed the Earth during this period. By the end of this epoch, a major extinction event of large mammals (e.g. mammoths, mastodons, sabre-toothed cats, ground sloths, cave bears, etc.) occurred (probably due to over hunting by humans and climate change) and continued into the Holocene.

g) Holocene Epoch

Holocene is the second of the epochs of the Quaternary Period that started about 11700 years ago and is continuing. It is a period of warming in which the global climate became warmer. During this period many mega mammals, such as woolly mammoth and woolly rhinoceros, became extinct. Humans developed agriculture and domestication of animals, which was followed by bronze and iron ages, development of civilizations, urban centres, governments, rapid population growth and the development of industrial revolution in 19th century.

Check Your Progress

1) In how many period and epochs Cenozoic era can be divided?

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2.3 DATING METHODS

Studies in Palaeoanthropology or archaeological anthropology have little meaning unless the chronological sequence of events is reconstructed effectively. Whenever a new fossil or a new archaeological artifact is discovered it is very important to find out how old it is. In modern day palaeoanthropology or archaeology, the scientific interest rests not so much in the fossil or the artifact itself but the information it can provide to the questions that the scientist may be asking. One of the principal questions an archaeologist will certainly ask is "how old the artifact and the site are"? In fact, without a chronological framework, a fossil or an archaeological artifact loses its true scientific significance. It is important to understand where a fossil or an artifact fits into the scheme of human morphological or cultural evolution. For a specialist, finding out the age of rocks is critical to reconstruct the history of the earth. To find out the age of fossils, artifacts or rocks, the scientists depend upon several dating methods. These methods can be divided into two broad categories:

a) relative dating methods and

b) absolute dating methods.

Check Your Progress

2) What are the two types of dating methods?

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2.3.1 Relative Dating Methods

Relative dating is a technique of determining the relative sequence of past events or past objects without actually knowing their absolute age. It is the stratigraphical or archaeological age of a specimen or formation (Oakley, 1964). In an assemblage of fossils or artifacts, these methods can be used to find out their relative age without knowing their actual age in absolute terms. Employing these methods a palaeontologist may be able to ascertain, which fossil is older than the other in an assemblage without knowing their actual age in years. In other words, relative dating determines the age of a fossil, an artifact or a site, as older or younger or of the same age as others, but does not provide specific dates (in years). Before the discovery of radiometric dating techniques, in the second half of the twentieth century, archaeologists, palaeontologists and geologists had to mainly rely upon relative dating techniques. As a result, it was difficult to chronologically compare fossils from different parts of the world. Though relative dating technique can only provide information about the sequential order of occurrence of events and not the actual time of occurrence of the events, it still remains useful for materials that lack properties for absolute dating. Even now these can be useful for relating palaeontological or archaeological finds from the same or nearby sites with similar geological histories. Stratigraphy and fluorine dating are among the common relative dating methods.

2.3.1.1 Stratigraphy

It is one of the oldest and the simplest relative dating methods. Stratigraphy is a branch of geology that is concerned with stratified soils and rocks, i.e. soils and rocks that are deposited as layers. Stratigraphy is basically the study of the sequence, composition and relationship of stratified soils and rocks. If we go to the countryside where there are some hills, we can see different layers of rocks which may be horizontal or inclined. Each layer can be differentiated from the other layer on account of the difference in colour, chemical composition or texture. Each layer represents a time period when the process of deposition of sediments continued uninterrupted in one manner. The next layer represents a change in the process of deposition. There are two fundamental principles of stratigraphy: *uniformitarianism* and *superposition*.

Uniformitarianism is a fundamental unifying doctrine of geology, which was originally conceived by British geologist James Hutton in 1785 and subsequently developed and explained by Sir Charles Lyell in 1830 in his '*Principles of Geology'*. According to this principle, the geologic processes now operating to modify the Earth's crust have acted in the same manner and with essentially the same intensity throughout geologic time, and that past geologic events can be explained by phenomena and forces observable today. In a nutshell the expression, "present is key to the past", explains uniformitarianism.

Superposition is one of the principles of stratigraphy, which is commonly utilized in a relative dating method. The principle was first given by a Danish scientist, Nicholas Steno in 1669, who is also considered to be the father of stratigraphy. According to this principle, the oldest layer lies at the bottom and the youngest layer lies at the top, in undisturbed strata. He also pointed out that beds of sediment deposited in water initially form as horizontal (or nearly horizontal) layers. As layers accumulate through time, older layers get buried underneath younger layers. This principle can be clearly seen in Figure-1.

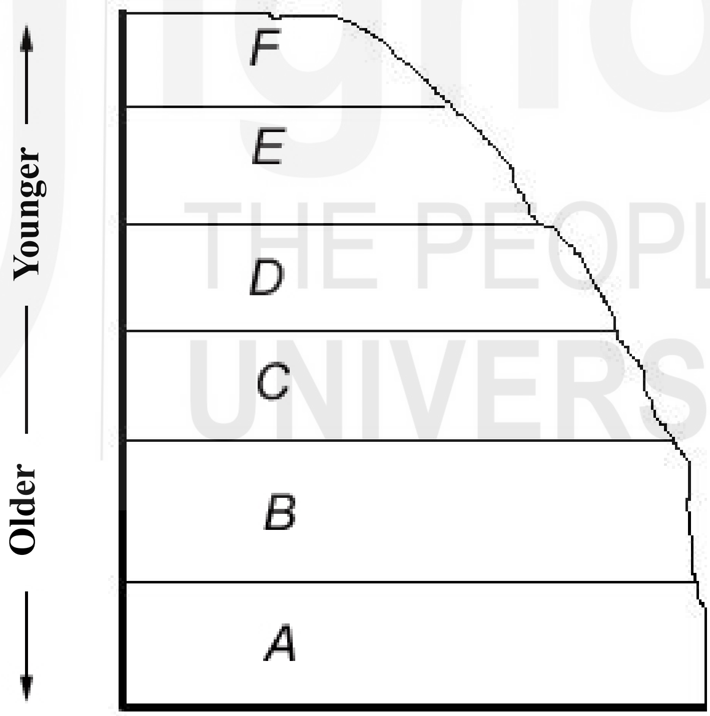

Fig. 1: Diagrammatic representation of a sequence of rock layers showing superposition where lower layer A is older than upper layer F.

The layer-A that was deposited earlier lies at a lower level and is, therefore, older than the overlying layers B to F which were deposited subsequently. Though we may not know how old each layer is but, among the layers A to F, we can tell which one is older than the other. In this way the relative time relationship of rock layers and the fossils or artifacts buried in them can be understood. But this principle should not be applied blindly. The principle is applicable where the normal order of superposition of the rock layers has not been disrupted by natural or human agencies. It is well known that natural diastrophic movements can disrupt the normal order of superposition through folding and faulting of the rock strata. As a consequence older rocks may come to lie over younger rocks. Human or animal agencies can also disturb normal order of rock layers through digging for burials where relatively younger artifacts may come to lie at relatively older levels.

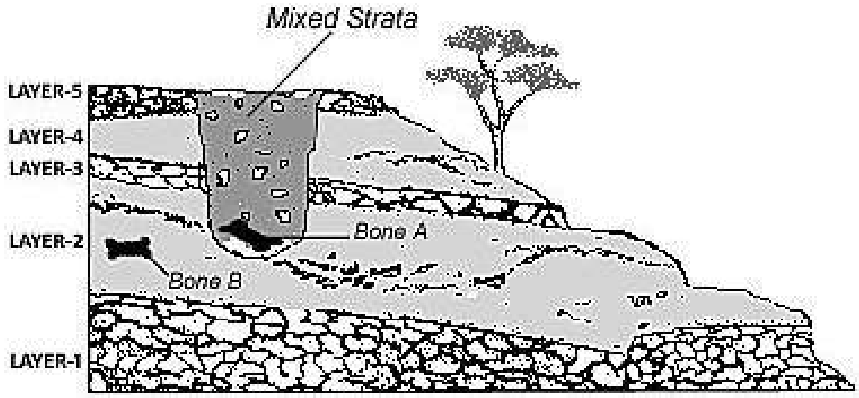

Fig. 2: Disturbance of original disposition of rock strata. Bone-A and Bone-B, though lie in the same layer-2 but may not of the same age due to mixing of strata. Under such situations principle of stratigraphy is not applicable.

Figure-2 shows the disturbance of original strata. In this case the bone-A and bone-B may not be of the same age even though they both are buried in the same layer, i.e., layer-2. Therefore, before applying the principle of superposition for relative dating one must ensure that the original sequence of rocks layers has not been disrupted.

Check Your Progress

3) What do you understand by stratigraphy?

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4) What do absolute dating methods provide?

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2.3.1.2 Fluorine Dating

It is a relative (chemical) dating method that compares the accumulation of fluorine content in bones. Fluorine dating method probably developed due to the collaborative efforts of Emile Rivière and Adolphe Carnot in the 1890s (Goodrum and Olson, 2009). But it was not until the 1940s and early 1950s that this method was improved and widely implemented by Kenneth P. Oakley to resolve several problems in palaeoanthropology (Goodrum and Olson, 2009).

Water soluble fluorides are found in trace quantities (parts per million-range) in ground water around the world. The skeletal elements buried in the ground absorb fluorine from the percolating ground water. In case of bones or teeth, fluoride ions replace the hydroxyl-group of hydroxy-apatite, the main component of bones and teeth, and are locked in place in the mineral matrix of these tissues principally composed of calcium hydroxyapatite. Hydroxyl ions slowly are displaced with a form of soluble fluorides. These ions form fluorapatite which is markedly less soluble and more stable. Once they enter the bone substance they are not released, unless the whole bone becomes dissolved. The process goes on continuously, and the fluorine-content of the bone or tooth increases in course of time. The older a bone is, the more fluorine content it will accumulate.

$$Ca_5\,(PO_4)_3OH + \text{Fluorine ion} \rightarrow Ca_5\,(PO_4)_3F$$

One can argue that since the fluorine content of bones increase with time why this method cannot be used for absolute dating. This is simply because of the reason that the fluorine concentration of ground water varies from place to place. Younger bones in a fluorine rich area may accumulate more fluorine than even older bones in a different area where ground water fluorine concentration is comparatively very little. It is therefore not possible to date bones in terms of years.

However this method is very useful means of distinguishing fossilized bones of different ages occurring at a particular place. If, however, one is interested in separating bones of different ages at one locality, estimation of fluorine-content is helpful as it can provide ages of bones at a site relative to each other based on their fluorine content. Older assemblage would be distinguishable from the younger assemblage on the basis of their fluorine content. Bones that have been buried at a place for some length of time will have broadly comparable fluorine content. Moreover, contamination of the assemblage by younger or older bones will be revealed by anomalously higher (older bones) or lower fluorine (younger bones) contents.

2.3.2 Absolute Dating Methods

Absolute dating methods provide the precise age of a fossil, artifact or a rock in years. These are obviously more useful methods than the relative dating methods. Unlike relative dating methods which provide only an order of events, absolute dating methods provide a numerical age with reference to a calendrical system. There is a diversity of methods that provide actual calendrical dates for fossils or artifacts. Most actually assign dates to the strata the bones are in, or associated materials, and not the fossils themselves. Absolute dating methods are frequently based on the physical or chemical properties of the fossils or materials of artifacts or rocks themselves. These may be radiometric or non-radiometric. Radiometric dating is based on the decay of radioactive isotopes into their radiogenic daughter isotopes at a known and constant decay rate. Examples of radiometric dating methods are Radiocarbon dating, Potassium/Argon dating, Fission-track dating, etc. Non-radiometric methods are based on some chemical or physical properties of the materials. Dendrochronology is one of the common non-radiometric dating methods.

2.3.2.1 Radioactive Carbon Method

Radioactive carbon or carbon-14 dating is probably one of the earliest and one of the best-known radiometric dating methods. In certain respects, radiocarbon dating has been one of the most noteworthy discoveries of the 20th century science. The method was developed by a team of scientists led by the late Professor Willard F. Libby of the University of Chicago in years immediately after World War II. Libby later received the Nobel Prize in Chemistry in 1960. Radiocarbon dating was the first chronometric technique widely available to archaeologists and palaeoanthropologists and was especially useful because it allowed researchers to directly date the organic remains often found in palaeoanthropological and archaeological sites, which besides fossils also include artifacts made from bone, shell, wood, and other carbon based materials. Its development revolutionized palaeoanthropology and archaeology by providing a means of dating fossils and artifacts, which allowed for the establishment of world-wide chronologies of human biological and cultural evolution in the Pleistocene.

Radiocarbon dating is a radiometric dating method that makes use of the decay of carbon-14 (an isotope of normal carbon) to estimate the age of organic materials, such as bone, teeth, wood, etc. There are three principal isotopes of carbon which occur naturally, viz. C^{12}, C^{13} (both stable) and C^{14} (unstable or radioactive). This concentration of these isotopes in the atmosphere is as follows: C^{12} - 98.89%, C^{13} - 1.11%, and C^{14} - 0.00000000010%. Thus, in nature, for every 1,000,000,000,000 normal carbon atoms (C^{12}) in living material there exists one radioactive carbon atom (C^{14}). The radiocarbon method is based on the rate of decay of the radioactive or unstable carbon-14 isotope (C^{14}). The half-life of C^{14} is about 5,730 years, during which C^{14} is reduced to half of its original amount. Thus, the concentration of C^{14} in the atmosphere might be expected to reduce considerably over tens of thousands of years. However, that is not the case, because C^{14} is constantly being produced in the lower stratosphere and upper troposphere of earth's atmosphere by cosmic ray activity. Therefore its concentration remains roughly constant in the atmosphere.

In the upper atmosphere the cosmic rays generate neutrons which strike nitrogen atoms resulting in the creation of a radioactive carbon C^{14} atom, through loss of a proton and subsequently an electron.

$$\text{Cosmic rays} \rightarrow \text{Neutron} \rightarrow + \text{Proton}$$

Carbon-14 spreads evenly throughout the atmosphere and reacts with oxygen to get oxidized into carbon dioxide ($C^{14}O_2$). It also dissolves in the ocean. Radiocarbon present in molecules of atmospheric carbon dioxide enters the biological carbon cycle. It is absorbed from the air by green plants during photosynthesis and then passed on to animals through the food chain. Radiocarbon decays slowly in a living organism, and the amount lost is continually replenished through food and air. After the death of the organism, the absorption of carbon-14 ceases and there is no replenishment of radioactive carbon (Figure 3). As a consequence, the amount of the radiocarbon in its tissues steadily decreases.

Because carbon-14 decays at a constant rate, an estimate of the date at which an organism died can be made by measuring the amount of its residual radiocarbon and comparing it to available levels in the atmosphere. The carbon-14 eventually beta-decays into nitrogen with a half- life of 5730±40 years.

Radiocarbon dating works by accurately measuring the ratio of radiocarbon to stable carbon in a sample.

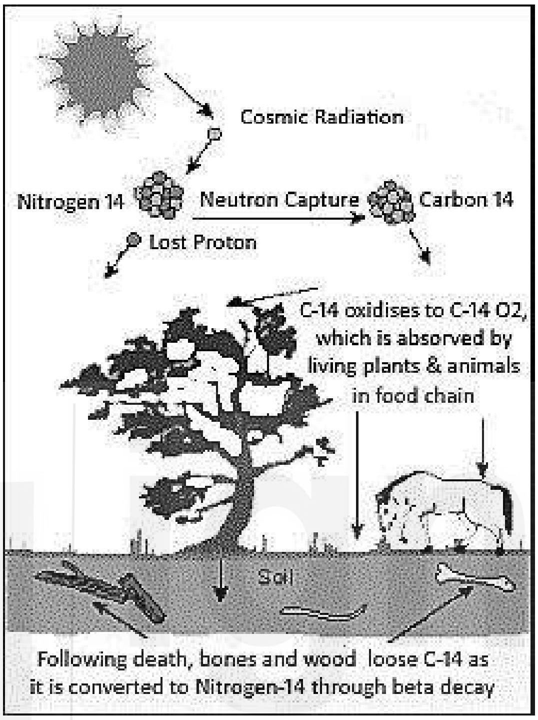

Fig. 3: Diagrammatic representation of carbon cycle in food chain

Source: Modified from: http://www.theenergylibrary.com/node/11296

Limitations:

1) Since the method is applied directly to organic material, fossils of any value cannot be subjected to this method as it involves partial or complete damage to the specimen.

2) The range of this method is ordinarily 50,000 years; therefore it is not suitable for older fossils.

3) The assumption that the amount of radioactive carbon in atmosphere is constant is not exactly true because it is known that it was more than 6000 years old. Solar cycles leading to changes in intensity of cosmic radiation or changes in earth's magnetic field may be responsible for these changes. Variations can also occur due to the fossil fuel burning effect (also called Suess effect after its inventor Hans Suess who reported it in 1965) and the nuclear testing above ground that created extra C^{14} (also sometimes called as 'bomb carbon').

4) There is always chance of contamination of the sample with modern materials, such as through rootlet intrusion, and handling of the specimens in the field or lab (e.g., accidental introduction of modern organic material such as tobacco ash, hair, or fibres) can potentially affect the age of a sample.

Despite these limitations radiocarbon remains a very useful technique to date later Pleistocene or younger organic materials.

2.3.2.2 Potassium/Argon Dating Method

Potassium/Argon dating method is one the most widely used radiometric dating methods for dating rocks, especially igneous that have solidified from molten lava. It is an invaluable tool for geological, archaeological and palaeoanthropological investigations. This technique is very useful to archaeologists and paleoanthropologists when lava flows or volcanic tuffs form layers that overlie strata bearing the evidence of human activity. This method is based upon the decay of radioactive potassium-40 (^{40}K) to argon-40 (^{40}Ar) in minerals and rocks. By comparing the proportion of K-40 to Ar-40 in a sample of volcanic rock, and knowing the decay rate of K-40, the date when the rock was formed can be estimated.

Potassium (^{39}K) is one of the most abundant elements in the Earth's crust. There are three naturally occurring isotopes of potassium namely ^{39}K (93.2581%), ^{40}K (0.0117%) and ^{41}K (6.7302%). Out of these isotopes, ^{40}K decays into two 'daughter elements': stable ^{40}Calcium and ^{40}Ar in an approximate ratio of 89:11. Simply stated, for every 100 ^{40}K atoms that decays, 11 become ^{40}Ar. Argon is a noble gas. When ^{40}K decays, the ^{40}Ar that is produced remains trapped in the crystals of the minerals of volcanic rocks. When the magma is molten whatever argon is produced boils off into the atmosphere. However, after the cooling and solidification of lava into rock, the argon produced due to the decay of ^{40}K accumulates within the rock and the radiometric clock of rock begins. As the rock ages, it accumulates more and more ^{40}Ar atoms. The amount of ^{40}Ar atoms is measured and used to compute the amount of time that had elapsed since the solidification of volcanic rock sample.

The half-life period of ^{40}K is 1,300 million years or 1.3 billion years, i.e. in this time the amount of radioactive potassium-40 is reduced to half of its original quantity. Due to its long half-life, this method is very suitable to estimate the age of even planets. However, it may not be suitable for measuring age of rocks younger than 100,000 thousand years as the quantity of argon produced by this time is too little to be accurately measured.

Limitations:

1) This method is applicable on rocks and not on fossils themselves.
2) This method is more suitable for rocks of volcanic origin and inapplicable to non-volcanic regions.
3) It has to be assumed that all the argon produced due to the decay of ^{40}K has remained trapped within the rock.
4) The method works well for almost any igneous or volcanic rock, provided that the rock gives no evidence of having gone through a heating-recrystallization process after its initial formation.
5) Rocks younger than 100,000 years cannot be dated with this method.

In addition to radiocarbon and potassium/argon methods there are other absolute dating methods such as amino acid racemization, fission-track dating method, palaeomagnetic dating method and thermoluminescence dating method, which can be used to find out the age of archaeological or palaeoanthropological sites.

2.3.2.3 Amino Acid Racemization

It is based on the fact that amino acids, such as isoleucine, present in bones, teeth or other organic remains undergo gradual change (racemisation) from L-form to D-form over time after the death of an organism. The ratio of the two is measured to indicate age.

Check Your Progress

5) Name a tree with a very long life which is useful to understand tree ring chronologies.

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6) Name some of the radiometric dating methods.

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2.3.2.4 Palaeomagneting Dating

The earth's magnetic field varies through time, therefore, the magnetic north pole changes position. At the time of deposition, the ferro-magnetic particles acquire the magnetic field of the day and also align in its direction. The method involves the measurement of the direction of the palaeomagnetic fields of the rock layers of a stratigraphic column and then matching the pattern with a palaeomagnetic reversal patterns of a stratigraphic section whose time relationships are better understood. Usually one absolute date is required to match the undated column with a well-dated column.

2.4 SUMMARY

Earth's history is divided by the geologists into several phases. The Cenozoic Era is the most recent of the three major subdivisions of animal history. The Cenozoic is divided into three periods, namely the Palaeogene, the Neogene and the Quaternary. The Cenozoic is sometimes called the 'Age of Mammals', because the largest land animals mammals, appeared on earth during that time. Dating methods play a significant role in archaeological and palaeoanthropological investigations by placing the fossils and artifacts in a chronological framework. Several dating methods are now available that can be used to date fossils, artifacts or the rocks from which these were recovered. These can be broadly grouped into relative and absolute dating methods. Relative dating methods, such as stratigraphy and fluorine methods, can help us to determine the relative sequence of past events or past objects without actually knowing their precise age. Absolute dating methods on the other hand provide us exact age of a specimen or an event in years before present. Absolute dating methods can be non-radiometric or radiometric. Dendrochronology, palaeomagnetic dating and amino acid racemisation are some of the commonly used non-radiometric absolute dating methods. The radiometric methods, such as radiocarbon, potassium/argon, fission track methods, are based on the decay of the radioactive isotopes of some elements.

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2.6 ANSWERS TO CHECK YOUR PROGRESS

1) The Cenozoic is divided into three periods, namely the Palaeogene, the Neogene and the Quaternary, and seven epochs, viz. Palaeocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Holocene.
2) The two types of dating methods are Relative Dating Method and Absolute Dating Method.
3) Stratigraphy is basically the study of the sequence, composition and relationship of stratified soils and rocks.
4) Absolute dating methods provide a numerical age with reference to a calendric system.
5) Bristle Cone Pine tree (*Pinusaristata*) has an exceptionally long life and has proved to be very useful to develop tree ring chronologies.
6) Some of the radiometric dating methods are radioactive carbon method, potassium/argon method, uranium/lead method and fission track method.

UNIT 3 PRIMATE ORIGINS AND MIOCENE HOMINOIDS*

Contents

Learning Objectives

After reading this unit, you will be able to:

- learn origin and characteristics of primates;
- know the early primates and their characteristics; and
- understand the evolution of Miocene Hominoids.

3.0 INTRODUCTION: PRIMATE AND THEIR CHARACTERISTICS

Primates are mammals with grasping hands, large brains, a high degree of learned rather than innate behavior, and a suite of other traits. However, the primates are a diverse group, and not all species share the same set of traits (Stanford et al. 2018). It includes lemurs, tarsiers, monkeys, apes, and humans. Non-human primates live primarily in the tropical or subtropical regions of South America, Africa, and Asia. They range in size from the mouse lemur at 30 grams (1 ounce) to the mountain gorilla at 200 kilograms (441 pounds). The characteristics and evolution of primates is of particular interest to us as it allows us to understand the evolution of our own species. Primates share some common characteristics such as large brain size, keen vision, dexterous hands and a generalized skeleton for great physical agility. They also tend to have smaller litters than other animals, devoting more care and attention to the rearing of their off springs. The unique combination of traits found in the primates distinguishes them from other animals.

Primate evolution has produced some key physical and anatomical traits that represent adaptations to arboreal conditions i.e. life in trees. Among the most important physical characteristics of primates is their generalized skeletal structure which allows for a great deal of flexibility in movement e.g. in primates, the clavicle provides both support and flexibility which enable them to rotate their shoulders and arms to perform a range of movements such as ability to reach for branches and food while roaming through treetops in the wild. The same

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development in man enhances their ability to drive cars, catch baseballs, etc. (Stanford 2006, Beard 2004). Dexterity in the digits (fingers and toes) of the feet and hand, another key primate trait makes it easy for primates to grasp and manipulate objects. All primates have sensitive pads on their fingertips rather than claws and many have five digits on their feet and hand which can be used for grasping objects. An important distinguishing element of the primate hand is the opposable thumb found in humans and many other primates which makes them adept at manipulating small objects (Stanford 2006, Fleagle 1998).

The dental structure of primates is consistent with an omnivorous diet made up of a variety of foods such as plants, fruits, nuts and seeds insects and other animals. Refined vision also sets primates apart. Primates have large eyes oriented to the front protected by bony structures rely heavily on vision. This visual orientation favours binocular and stereoscopic vision in which the visual fields of eyes overlap, transmitting images to both sides of the brain. A distinguishing trait of the primates is size and complexity of the brain. Primates have large brains relative to body size compared to other land animals. The brains of marine mammals have comparable brain size. In primates, the neo-cortex, the surface portion of the brain associated with sensory messages and voluntary control of movement features a large number of convolutions or folds which maximize the surface area. As they evolved, these larger brains undoubtedly helped primates to locate food and to avoid predators. In contrast to most other animals, primates produce few offspring and these undergo long period of gestation i.e. the length of time the young spend in the mother's womb.

3.1 EARLY PRIMATES

The true early primates evolved by 55 million years ago or a little earlier, around the beginning of Eocene Epoch. This period coincides with rising temperatures by more than 11° F. The fossils of early primates were found in North America, Asia and Europe. These primates looked different from the primates today and were probably about the size of a small domestic cat and had grasping big toe with a flat nail at its extremity that were more efficient in manipulating objects and for climbing trees. This enabled them for better mobility and improved the speed of these primates. Consequently, it added new routes when they needed to escape predators and it also permitted them to reach fruits that were beyond the reach by others. The position of their eyes shows that they were also developing more effective stereoscopic vision.

Some of the important characteristics of early primates include:

- Improvement of sensitive tactile pads on their digits.
- Greater than before independence and mobility of the fingers with an opposable thumb to aid grasping.
- Uprightness of the trunk, which is an adaptation to vertical positioning in the trees that was an indication towards future bipedalism i.e. walking on two feet.
- Reduction of the snout and reduction of olfactory capacities.
- Major improvement in vision.

Between the new primate species, many somewhat resembled the modern prosimians such as lemurs, lorises, and possibly tarsiers. The Eocene was the epoch of maximum prosimian adaptive radiation.

There were around 60 genera of primate species belonging to two families i.e. *Adapidae*, those similar to lemurs and lorises and the *Omomyidae*, possibly, like galagos and tarsiers. This is the time period when there were nearly four time greater prosimian diversity than today and they were more widely distributed around the world. They lived in Africa, Asia, Europe and North America. During this epoch they reached the island of Madagascar, from where they flourished up to modern times. It is widely believed that the Eocene prosimians did not have competition from monkeys and apes, therefore, there is a great diversity in their distribution across the world.

Some important evolutionary changes took place among the Eocene prosimians that indicated about the species yet to come. Their eyes and brains were becoming bigger, whereas their snouts were getting smaller. The position of foramen magnum, in some primate species was started to kove from the back of the skull towards the center. The foramen magnum is a hole found at the base of the skull and through which the spinal cord passes. This implies that while hopping and sitting, these primates were starting to hold their bodies erect, as it is seen among the lemurs, galagos and tarsiers.

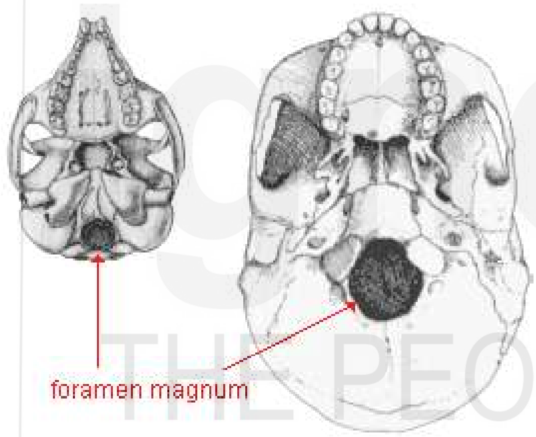

Fig. 1: Eocene Era primate (on left) and modern human skull

Source: Liberman et.al., 2000

But, many of the prosimian species had become extinct by the end of the Eocene Epoch. This may be attributed to cooler temperatures and the appearance of monkeys i.e. during the transition to the next geological epoch, the Oligocene, about 34 million years ago.

Check Your Progress

1) What are key physical and anatomical traits of primates that represent adaptations to arboreal conditions?

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2) Write down the significant features of early primates.

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3.2 MIOCENE HOMINOIDS

The Miocene epoch, which lasted for about 18 million years (23.0–5.3 million years ago), characterizes the evolution of primitive apes. One of the important features of this period is the cycles of expansion and reduction in the size of primate habitats in the Mediterranean and Eurasia. The land bridges between Africa, Europe and Eurasia formed and then disappeared. Throughout early stages of the Miocene, the climate was very much similar to conditions of the present day, but a somewhat warmer. But, then about 15 million years ago, the climate became significantly cooler and drier as glaciers formed in Antarctica. As a result, tropical forests transitioned to a mosaic of woodland savannah, trees and grass (Lieberman 2000). The expansion of savannah-woodland environments in Africa and Eurasia was formed due to this cooling. In this period, apes and Old World monkeys diverged, and these apes then underwent an adaptive radiation into around 80 to 100 species.

3.3 HOMINOIDS FROM SIWALIKS

As far as hominids from Siwalik Hills is concerned, there are at least four species found namely, *Ramapithecus punjabicus, Sivapithecus sivalensis, Sivapithecus indicus and Gigantopithecus bilaspurensis*. They belong to a period between about 14 mya and 6 mya.

3.3.1 *Sivapithecus*

Sivapithecus is best known from later Miocene deposits of Greece, Turkey and Indo-Pakistan, dating back from 7 to 11 million years. Included with it here is another group of fossils called *Ramapithecus*, once thought to be distinct, but now recognized as belonging to same group. The name *Sivapithecus* has priority over *Ramapithecus* because it was established in the scientific literature first, so this is the name that is used. Their names were derived from the Indian gods Rama and Siva, as the first fossils of this group were found in India, but the most significant recent finds have come from Pakistan and Turkey. From the latter there is a very large collection dating back as far as 13 million years, which provides both the earliest record of hominoids living outside Africa, and the first record of *Sivapithecus*. *Sivapithecus* was a relatively large hominoid, and apparently there were considerable differences in size between the sexes, as there are in the orang-utans today. It lived at similar latitudes to *Dryopithecus*, but never at the same place and time suggesting that the two groups had different requirements that kept them separate. *Dryopithecus* lived in warm temperate to subtropical woodlands of southern Europe in the Miocene, and *Sivapithecus* occupied more open and probably more seasonal woodlands. In this sort of open woodland it would not be possible for an animal the size of *Sivapithecus* to live entirely up in the trees, and it seems likely that it lived part of the time on the ground. It still had limbs mainly adapted to arboreal life, however, and probably never moved far from the protection of the trees (Andrews & Stringer, 1989).

Recent finds of Sivapithecus (including *Ramapithecus*) provide strong evidence for shared ancestry with orang-utans. This relationship is indicated by the many characters of the face, nose and palate that are uniquely shared by orang-utans and *Sivapithecus*, while being absent from other primates. It was previously thought that *Ramapithecus* was an early hominid, ancestral to humans, but since the orang-utan shares ancestors with this group and is only distantly related to humans (Andrews & Stringer, 1989).

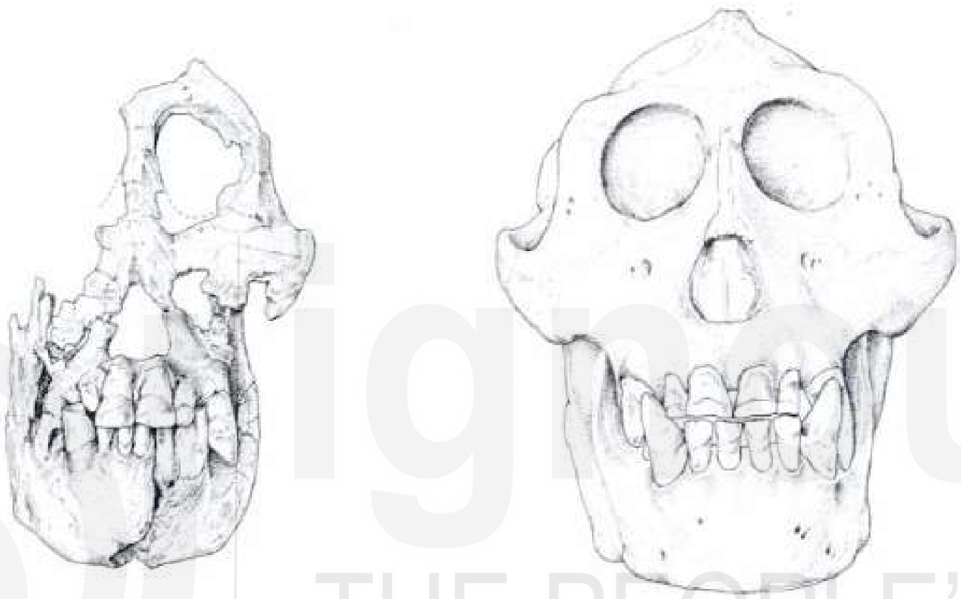

Fig. 2: Face of Sivapithecus from the Potwar Plateau in Pakistan and Face of an orang-utan

Source: Andrews & Stringer, 1989

The Sivapithecus specimens are identified from four regions in the Siwalik hills: the Potwar plateau of Pakistan, Ramnagar and Hari Talyanagar in India, and the Churia in Nepal. Most Potwar plateau specimen come from three precisely dated intervals separated by temporal gaps of approximately 0.7 to 1.0 million years ago. As far as the Siwalik group of India is concerned, most specimens are found at Hari Talyanagar and a few from near Ramnagar. Hari Talyangar's primate bearing level is penecontemporaneous with the "U" sandstone level of the Potwar section centered at the base of Chron, giving an age of up to 9 million years ago. The Ramnagar area is generally temporally equivalent to the Chinji formation.

3.3.2 *Gigantopihecus*

In the year 1935, GHR von Koeningswald discovered *Gigantopithecus*. The two species, *Giganopithecus blacki*, (named after Davidson Black) and *Giganopithecus giganteus* (formerly *bilaspurensis*), are known primarily by teeth and jaws. The first tooth discovered in a Hong Kong apothecary, where traditional Chinese pharmacists use fossils, referred to as "dragon bones", in medicinal recipe. As the name suggest, these fossil apes were vast. Based on the teeth and jaws, Gigantopithecus is expected to have been 9 to 10 feet tall (3 m) and 600 to 1,200 lbs (270 – 550 kg). They were the largest primates known, more than twice the size of a mountain gorilla.

Gigantopithecus is considered to be a sister genus of *Pongo*, the genus that contains living orangutans, in the subfamily Ponginae of the family Hominidae. The species is known from four partial mandibles and nearly 2,000 large molars, canines, and other teeth. which date to between about 2 million and 300,000 years ago, and possibly a piece of distal humerus. The remains of *G. blacki* have been largely excavated from caves in southern China, which suggest to some paleontologists that the species was restricted to that region. Similar fossils discovered in northern Vietnam and Thailand, however, could represent additional specimens that point to a larger geographic range and longer survival time. Some studies arguing that the teeth found in northern Vietnamese caves do in fact belong to *G. blacki* posit that the species survived until as late as 100,000 years ago and possibly shared the same landscapes with *Homo erectus*. *G. blacki* is thought to have succumbed to extinction after cooler temperatures in the region reduced and later eliminated the forests upon which it depended for food.

G. blacki likely lived in forested habitats, because it possessed powerful grinding and chewing teeth for processing leaves and other plants. Measurements of the fossil teeth allowed paleontologists to estimate the primate's height and weight at about 3 metres (about 9.8 feet) and 200–300 kg (441–661 pounds), respectively. Such calculations point to *G. blacki* as being the largest hominid yet known.

The second species, *G. bilaspurensis*, which was later changed to *G. giganteus*, was part of the genus from 1969 until roughly 2003, after which time the scant fossil remains were judged to be too different from *G. blacki* to place it in the same genus. The species was later placed in its own genus and renamed *Indopithecus giganteus*. Studies suggest that *I. giganteus* inhabited grassland landscapes in northern India and Pakistan between about 6 million and 5 million years ago near the Miocene-Pliocene boundary. *I. giganteus* was significantly smaller than *G. blacki*. Height and weight estimates derived from tooth measurements suggest that *I. giganteus* was of roughly the same height as a modern gorilla (about 1.7 meters [5.5 feet] tall) and weighed at least 150 kg (331 pounds). Most paleontologists acknowledge that *I. giganteus* and *G. blacki* were related but that *G. blacki*was a late-surviving species in the lineage.

Check Your Progress

3) Write down the name of four Hominid species obtained from Siwalik hills?

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4) Who discovered Gigantopithecus? What are his important characteristics?

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3.3.3 *Ramapithecus*

Simons and Pilbeam in 1965 re-examined much of the known fossil hominoid material and a more rigorous evolutionary scheme for the hominids was produced. Simons and Pilbeam undoubtedly did the palaeoanthropological profession a great service in their landmark revision of the then known hominoids. This revision, however, was based partly on a desire to stamp the evolutionary significance on '*Ramapithecus*' as the Miocene human ancestor. Originally discovered in the Siwaliks of India in the 1930s, '*Ramapithecus*' was argued by Lewis (1934, 1937) to represent the earliest identifiable Miocene proto-human. Simons argued on the basis of the anatomical features of the dental complex that '*Ramapithecus*' was a Miocene early human ancestor. Simons and Pilbeam argued that the presence of human features such as small canine teeth, thick molar enamel, enlarged premolar and molar dental complex and a parabolic (rounded) dental arcade placed '*Ramapithecus*' at the stem of the human evolutionary tree (Cameron, 2004).

Geographical Distribution: For a while it looked as if *Ramapithecus* was a hominid genus restricted to India. However, in 1961 Dr. Leakey reported the discovery of some fossil maxillae, parts of which contained teeth. This material came from the Fort Ternan site in Kenya, about 40 miles east of Lake Victoria. Leakey called his new form "*Kenyaoithecus*". He designated it a hominid and most paleontologists agree with his hominid designation. However, many disagree with his generic designation and prefer to include the material within the genus *Ramapithecus.* Fossil traces of *Ramapithecus* occur not only in Africa and India, but also in the coal beds of human province in China, the Jura Mountains of southern Germany, and perhaps in north-central Spain. There is also the possibility of *Ramapithecus* in Greece. This latter material, which was found by German soldiers during the Greek occupation in World War II, is now in the possession of Dr. G. H. R. von Koenigswald in Holland. Since it seems likely that *Ramapithecus* moved freely about the world's savannas and forests, they may have had a rather widespread geographical distribution. This indicates that they must have been highly adaptable and quite capable of dealing with a variety of circumstances (Poirier, 1973).

The generic status (that its place in the taxonomic scheme) of *Ramapithecus* from India is based upon the following characteristics, most of which Lewis noted in his 1934 description. The jaws are short, small, and delicate. The teeth are small in comparison with pongid teeth and they approach the hominid condition. Among the many dental features of *Ramapithecus* that are common to later hominids but atypical of pongids, Simons (1968) notes the following: very small canines, small premolars relative to the molars, and a P3 (first premolars) not markedly larger than P4 (second premolar). The premolars manifest anterior, central, and posterior foveae (depression of the crown), the occlusal (crown) surfaces of the cheek teeth are expanded, the molars are steep-sided and the lingual (tongue side as opposed to the buccal, which is the cheek side) cingula (that is, raised portion of enamel) are vertical or absent, and there is marked interstitial wear (wear between adjacent teeth), which indicates a crowded teeth row. In addition, the dental arch is divergent (or parabolic, the distance between the rear teeth is greater than the distance between the front teeth) while that of pongids is parallel. It is possible, from the degree of dental wear, to postulate that the delayed maturation characteristic of modern man was already present in his early ancestors. The delay in maturation rates is important, for the slower the growth rate, the longer the infant is dependent upon its mother. This is a basic first step for a longer period of socialization, which is a prerequisite for culture (Poirier, 1973).

Controversy Regarding the Taxonomy of *Ramapithecus*: There are controversies regarding the taxonomy of *Ramapithecus* and they are based on several facts. The existing understanding of *Ramapithecus* is based on a little more than two dozen fragments, primarily of teeth and parts of jaw that have been discovered since the first discovery reported in 1934 by G. Edward Lewis. The early discovery made Lewis to make out a new form that he termed as *Ramapithecus* (Wolpoff, 1982). Thereafter, a number of fossils were found from different localities and each was recognized as new forms and were attributed a series of names such as, *Kenyapithecus, Graecopithecus, Rudapithecus, Sivapithecus*, based on the geographical localities at which they were found (Conroy and Pilbeam, 1975). But, in 1965, Simon and Pilbeam analyzed the entire series and suggested that all the forms actually consist of two species groups i.e. *Sivapithecus* and *Rudapithecus.* They considered *Sivapithecus* as ape like and hence as an ape ancestor and *Rudapitheicus* possessing a number of hominid- like features were thus entered as an early hominid ancestor.

In 1968, Simons noted the main alternative views concerning *Ramapithecus* are two. First, *Ramapithecus* may be some sort of aberrant, relatively small-faced ape that is only coincidentally morphologically like the hominids. And second, there are not now enough pieces available to judge conclusively whether or not *Ramapithecus* is a hominid. (This second difficulty is sometimes met by calling *Ramapithecus* a dental hominid, referring to the fact that all we possess is dental evidence that looks hominid.) Simons answers these qualifications in the following manner (Poirier, 1973):

Naturally, the alternative that the taxonomic relationship of known specimens of *Ramapithecus* is uncertain can be considered a form of scientific caution and is a point of view which may be adopted for other reasons as well. Nevertheless we should not overlook the fact that a primate reason for so doing is that is the easiest course of action to take. Considering these forms intermediate requires neither anatomical knowledge nor study of the actual materials (Simons, 1968).

The Hominid Status of Ramapithecus: Pilbeam (1972) discusses the question of the hominid status of *Ramapithecus* as follows: Morphologically the *Ramapithecus* material suggests that it was an animal with dental and facial features characteristic of later hominids. On scanty paleontological evidence it can be on the line leading to *Australopithecus* and *Homo*, after this lineage split from the other hominoids. Therefore, the question of whether or not *Ramapithecus* is hominid depends upon where one chooses to recognize the split of the hominids from hominid-pongid stock. This boundary is likely to be arbitrary, and of the three sets of paleontological criteria used to differentiate hominids from pongids, cranial features, dentition, and postcranial remains, only the dentition from *Ramapithecus* is known. This dentition is more hominid than pongid like. It has been suggested that perhaps *Ramapithecus* is simply a female representative of *Dryopithecus indicus*. However, Simons and Pilbeam (1972) note that all the material indicates that D. indicus was a much larger animal than Ramapithecus and their teeth were also much larger than those of Ramapithecus (Poirier, 1973).

3.4 SUMMARY

The origin of the order Primates has been an area of considerable activity during the past two decades. Earlier theories regarding primate origins and early evolution have been questioned from a variety of standpoints, and new discoveries and methods of analysis have given us a much better understanding of the morphology and habits of the earliest fossil primates. The role of arboreal locomotion in primate evolution plays a very important role (Ciochon & Fleagle, 1987). The Miocene epoch, which lasted for about 18 million years (23.0–5.3 million years ago), was a period of dramatic evolutionary change characterizing the evolution of primitive apes. One of the important features of this period is the first appearance of the ape species and the expansion and diversification of species in the Mediterranean, Eurasia and Africa. However, by the end of the Miocene epoch, majority of the members of the clade had become extinct and the geographic range of hominoids greatly reduced.

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3.6 ANSWERS TO CHECK YOUR PROGRESS

1) The most important physical characteristics of primates that represent adaptation to arboreal conditions is their generalized skeletal structure which allows for a great deal of flexibility in movement. For more details refer section 3.0.

2) Some of the important characteristics of early primates include: Improvement of sensitive tactile pads on their digits; Greater than before independence and mobility of the fingers with an opposable thumb to aid grasping; Uprightness of the trunk, which is an adaptation to vertical positioning in the trees that was an indication towards future bipedalism i.e. walking on two feet. For more details refer section 3.1.

3) Four important hominid species obtained from Siwalik hills are, *Ramapithecus punjabicus, Sivapithecus sivalensis, Sivapithecus indicus and Gigantopithecus bilaspurensis*. They belong to a period between about 14 mya and 6 mya. For more details refer section 3.3.

4) GHR von Koeningswald in the year 1935, discovered *Gigantopithecus*. The two species, *Giganopithecus blacki,* named after Davidson Black) and *Giganopithecus giganteus* (formerly *bilaspurensis*), are known primarily by teeth and jaws. Based on the teeth and jaws, *Gigantopithecus* is expected to have been 9 to 10 feet tall (3 m) and 600 to 1,200 lbs (270 – 550 kg). They were the largest primates known, more than twice the size of a mountain gorilla. For more details refer section 3.3.2.

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