

MANI-002
PHYSICAL
ANTHROPOLOGY

Block

2**HUMAN EVOLUTION**

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BLOCK 2 HUMAN EVOLUTION

Introduction

The Darwinian theory of evolution by natural selection, which states that organisms become progressively adapted to their environments by accumulating beneficial mutants, is now firmly established. Indeed this theory is serving as a great unifying principle in the biological sciences. When Darwin formulated his theory in the middle of the 19th century, the mechanism of inheritance and the nature of heritable variations were unknown, preventing him from being over-confident about the role of positive natural selection. In fact, Darwin gradually came to accept the Lamarckian view that the inheritance of acquired traits also plays some role in evolution.

In the initial days of human evolutionary deliberations of Huxley, Broca and Duckworth, the chief line of substantiation to surface was that of comparative anatomy, which established without reservation that man's place in nature was amongst primates and particularly that his nearest relatives were the great apes. Direct evidence on human origins awaited acceptable fossil material which provided skeletal support for descent of man from a forefather common to the anthropoid apes. All this was before there was any real application of genetic concepts to human evolution. In fact, the study of human evolution advanced independently of human genetics and this was largely owing to the discrepancy in time. The Mendelian genetics began with the rediscovery of Mendel's work at the beginning of the 20th century, explaining the concepts and mechanism of inheritance.

Because of the development of modern genetic theory, evolution is now viewed as changes in gene (allele) frequencies between ancestral and decedent populations. The processes by which these changes come about are natural selection, mutation, sampling error (genetic drift) and migration. But it is virtually impossible to measure directly the changes in gene frequencies. Therefore, evolution is also necessarily viewed as changes in the morphology of organisms through time. Analyses of degrees of morphological similarities and differences have always been part of evolutionary studies. Besides, evolution may also be represented as changes in numbers and kinds of animals within major lineages. The origin of discontinuities between animal populations, that is speciation, is a major concern of biologists. After the establishment of the development of genetic concepts, today we are possessors of the synthetic theory of evolution, which states that evolution led to the functional adaptation of the diverse and variable forms of life through the continuous production of variation and the action of natural selection.

This Block comprises four Units on Principles of Evolution, Theories of Organic Evolution, Human Evolution and Palaeoanthropology which give a detailed account of evolutionary principles and theories, especially with reference to humans. The units are lucidly written and it is hoped that the learner will find this material on evolution useful.

UNIT 1 PRINCIPLES OF EVOLUTION

Contents

- 1.1 Introduction
- 1.2 Pre-Darwinian Theories of Evaluation
- 1.3 Principles of Evolution
 - 1.3.1 Speciation
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 - 1.3.3 Parallelism and Convergence
 - 1.3.4 Adaptive Radiation
 - 1.3.5 Extinction
- 1.4 Summary
- References
- Suggested Reading
- Sample Questions



Learning Objectives

It is expected that after reading this unit, you would be able to understand the

- various Pre-Darwinian theories and the evolutionary principles; like
- speciation;
- irreversibility;
- parallelism and convergence;
- adaptive radiation; and
- extinction.

1.1 INTRODUCTION

Physical Anthropology has two principal aspects of study: human evolution and human variation. Human evolution is the evolution of *Homo sapiens* from their ancestors whereas human variation refers to the differences that exist among individual populations. Anthropologists are interested in understanding both cultural and biological variation. Coming to the present unit, it deals with various pre-Darwinian theories and the principles of evolution. Before that, a brief account on evolution is presented.

Physical Anthropology is the branch of anthropology that deals with human evolutionary biology, physical variation, and classification.

Evolution

Herbert Spencer, an English philosopher, first used the term ‘evolution’ to denote the historical development of life. Evolution is nothing but change. Changes within the organism over a period of time is termed ‘micro-evolution’ and changes from one being to the other i.e. transformation, is termed as ‘macro-evolution’. The term evolution may be defined in several ways. Thus, we can speak of the geological evolution or evolution of planet earth, evolution of solar systems and

the evolution of the automobiles, radios and telephones etc. The changes involved in the rise of human civilisation can be called cultural evolution. In the same manner, the term ‘organic evolution’ is applied to the changes that have taken place in the living things, viz. plants and animals. In this connection the definition of Charles Darwin (1859) is worthwhile and he defined evolution as “descent with modification” i.e., closely related species resembling one another because of their inheritance; and differing from one another because of the hereditary differences accumulated during the separation of their ancestors. But according to Dodson and Dodson (1976), evolution is the process by which related populations diverge from one another, giving rise to new species (or higher groups). Dobzhansky (1951) stated “evolution is the development of dissimilarities between the ancestral and the descendant population”.

1.2 PRE-DARWINIAN THEORIES OF EVOLUTION

The evolutionary thought has a very long history, from that of Aristotle to Darwin to the synthetic theory of evolution (Neo-Darwinism). Theories of evolution that existed before Darwin are said to be ‘Pre-Darwin’ theories of evolution. These were based on speculation and keen observation over living and non-living matters of the earth and biosphere. They assume importance as they serve baseline information in understanding the evolution of life and its diversity. The Pre-Darwinian theories of evolution are also referred to as ‘old theories of evolution’.

Greek thinkers and evolution

The idea of evolution and the continuity of life forms is found in the writings of Greek philosophers such as Aristotle (384-322 B.C), Herodotus (484-425 B.C) and Empedocles (504-433 B.C). Aristotle believed in old forms of life giving rise to new forms. He felt that organisms have certain inner instinct which enables them to transform towards better by adaptation. He observed this phenomenon among the plants, animals and man. The credit goes to Aristotle for coining the term ‘Anthropology’ and hence he is known as ‘Father of Anthropology’ as he first highlighted the insights of man.

Herodotus and Empedocles developed certain ideas relating living beings to biological concept of evolution. Their thoughts covered traces of concept of adaptation; plants evolving before animals indicating gradual evolution of higher organisms, and finally man. This hierarchical system suggests an evolutionary concept. Besides these two scholars, there are others also who contributed their ideas regarding origin and evolution of man.

Medieval theories

The medieval times, also called “the Christian era”, witnessed diametrically opposite views of evolution of Greeks, since the time was dominated by the Christian Theory of Special Creation. Accordingly, all living things came into existence in unchanging forms due to the Divine Will. Nevertheless, medieval thinking could not explain fully the idea of spontaneous creation. However, this traditional version of creationism was strongly reinforced by James Ussher, a 17th century Anglican Archbishop of Northern Ireland. He fixed the date of creation at October 23, 4004 B.C. Further to this, Dr. Charles Lightfoot of Cambridge University in England had added the exact time of creation, i.e., 9 a.m. on October

23, 4004 B.C. These strongly held views were there in public mind throughout the 17th and 18th centuries and to certain extent till the present.

However, the acceptance of biological evolution of organisms had crept in the scientific world by mid 18th century with Carl Linnaeus (1707-1778) a Swedish Botanist, through his immortal work “The Systema Nature” published in 1735. It was Linnaeus who designated each living organism two Latin names (binary nomenclature), one for Genus and the other for Species. Thus, from the days of Linnaeus, Man has been scientifically known as Homo Sapien. The tenable work of Linnaeus received good support and attention from the scientific community all around the world.

Late in the 18th century, the French scientist, Comte de Buffon (1707-1788), contemporary to Carl Linnaeus, suggested strongly that life forms are not fixed. He strongly believed that this could be the influence of the environment on living organisms. He explained this in his voluminous work, “Historic Naturelle” completed in 44 volumes. He had more clear ideas on the physical features of man than Linnaeus. He explained them in his book “Varieties Humanies”.

Thereafter, Erasmus Darwin (1731-1802) another 18th century scientist, an evolutionist and the grandfather of Charles Darwin, suggested through his work the evolutionary aspects of animals and strongly contended that the earth and life on it must have been evolving for millions of years and the history of mankind is the latest.

Lamarck (1744-1829), a French naturalist, was the first evolutionist who confidently put forward his ideas about the process leading to biological change in the organism. He opined that the structure of a living being is dependent on its function. He used the example of Giraffe, saying that it got long-neck structure for its constant use of reaching to higher foliage. Based on this observation, he propounded two theories, namely: i) use and disuse of characters and ii) the acquired characters are inherited. For him, Giraffe’s long neck is an acquired character and snake’s smooth body has resulted due to disuse of its limbs as it chose to live in burrows. Unfortunately, Lamarck’s theory was not tenable among scientific community as it raised number of queries and to establish it more evidence was required. However, the Lamarck theory of evolution is an important milestone for the evolutionary biology.

George Cuvier (1769-1832) another French scientist objected to Lamarck strongly but held views on fossil evidence and biological relationship. The disappearance of dinosaurs, he felt, was due to ‘fixity’ of species. He further advocated the theory of ‘Catastrophism’ but again not to the full extent of scientific explanation. Charles Lyell (1797-1875), an English lawyer and geologist disproved Cuvier’s Catastrophism theory. Lyell in his three volume book on ‘Principles of Geology’ (1830-1833), documented the fact that the earth must be considerably old; and natural processes through time, like, erosions, earthquakes, glacial movements and volcanoes have changed the shape of the earth and its living units. He provided conclusive evidence for the theory of uniformitarianism. He explained this saying that the present would be the key for understanding the past. He argued that the natural changes were the same in the past and the present. This led Charles Darwin (1809-1882) to think of nature and selection on living beings and he later propounded his famous theory of natural selection and the Origin of Species in his book published in 1859.

Thus, the above explained are some of the old theories of evolution prior to Darwin, hence these are referred to as Pre-Darwinian theories of evolution. Darwin's theory of evolution (Origin of Species through Natural Selection) was the start of new era for understanding biological evolution through genetic mechanisms.

1.3 PRINCIPLES OF EVOLUTION

In the following text, various evolutionary principles like speciation, irreversibility, parallelism and convergence, adaptive radiation and extinction are discussed.

Speciation, irreversibility, parallelism and convergence, adaptive radiation and extinction are some of the important evolutionary principles.

1.3.1 Speciation

Mayr (1970) defined speciation as the creation of species. Speciation can also be defined as creation of two or more species from one. Among different evolutionary principles, speciation plays a major role. The entire evolution depends on the origin of new populations from their ancestors and since it is from their ancestors, it is difficult to understand many of them in detail due to lack of sufficient resources. Before we discuss the speciation process, the definition of the term species is presented; species is one of the basic units of biological classification and a taxonomic rank and is often defined as a group of organisms capable of interbreeding and producing fertile offspring.

According to Mayr (1970), true speciation or multiplication of species may occur by the following agencies:

- A) *Instantaneous speciation* (through individuals)
 - 1) Genetically
 - a) By single mutation in asexual species
 - b) By macrogenesis
 - 2) Cytologically, in partially or wholly sexual species
 - a) By chromosomal mutations or aberrations (translocations, etc.)
 - b) By polyploidy
- B) *Gradual speciation* (through populations)
 - 1) Geographical speciation
 - 2) Sympatric speciation

However, the process of speciation is possible by four different mechanisms viz., allopatric, parapatric, sympatric and quantum speciation discussed below.

Allopatric Speciation

It is also called geographic speciation. Allopatric isolation is a key factor in speciation and a common process by which new species arise. In this scenario a population splits into two geographically isolated populations by some geographic

barrier, such as mountain range or river for terrestrial organisms, or a land mass for aquatic organisms. The isolated populations are then liable to diverge evolutionarily over many generations as (a) they become subjected to dissimilar selective pressures and (b) they independently undergo genetic drift and (c) different mutations arise in the two populations. When the populations come back into contact, they have evolved such that they are reproductively isolated and are no longer capable of exchanging genes. The allopatric speciation is the almost exclusive mode of speciation among animals, and most likely the prevailing mode even in plants, and is now quite generally accepted (Mayr, 1970).

Darwin's finches (Fig.1.1) is the best example for allopatric speciation. The Ground finches are numbered from 1–7. These finches look for food on the ground or in low bushes. The tree finches are numbered from 8–13. They survive mostly on insects.

- 1) Large cactus finch (*Geospiza conirostris*)
- 2) Large ground finch (*Geospiza magnirostris*)
- 3) Medium ground finch (*Geospiza fortis*)
- 4) Cactus finch (*Geospiza scandens*)
- 5) Sharp-beaked ground finch (*Geospiza difficilis*)
- 6) Small ground finch (*Geospiza fuliginosa*)



Fig.1.1: Darwin's finches

Source: www.dls.ym.edu.tw

- 7) Woodpecker finch (*Cactospiza pallida*)
- 8) Vegetarian tree finch (*Platyspiza crassirostris*)
- 9) Medium tree finch (*Camarhynchus pauper*)
- 10) Large tree finch (*Camarhynchus psittacula*)

- 11) Small tree finch (*Camarhynchus parvulus*)
- 12) Warbler finch (*Certhidia olivacea*)
- 13) Mangrove finch (*Cactospiza heliobates*)

Parapatric speciation

In this mode of speciation, a small population enters into a new habitat, but differs in physical separation between these two populations. Individuals of each species may come in contact or cross habitats from time to time. The best-known example of incipient parapatric speciation occurs in populations of the grass *Agrostistenuis* which span mine tailings and normal soils. Individuals that are tolerant to heavy metals, a heritable trait, survive well on contaminated soil, but poorly on non-contaminated soil. The reverse occurs for intolerant populations. Gene flow occurs between sub-populations on and off mine tailings, but hybridisation is inhibited by slight differences in flowering time between the two locations (McNeilly and Antonovics 1968).

Sympatric Speciation

In the case of sympatric speciation two or more descendant species form, from a single ancestor and these occupy same geographical locality. In this kind of speciation even a small amount of gene flow may eliminate genetic differences between parts of a population. Numerous examples for this type of speciation are observed in the invertebrates, particularly the insects; the insects that becomes dependent on diverse host plants in the same area. Cichlids in East Africa is one of the examples and thought to be due to sexual selection.

Quantum Speciation

Grant (1971) defined quantum speciation as “the budding off a new and very different daughter species from a semi isolated peripheral population of the ancestral species in a cross fertilisation organism”. This speciation frequently occurs through adaptive radiation, by the discharge of genetic variability surrounded by ecologic islands. Quantum speciation is speedy and requires only few generations. The ancestors of the new species do not include a large proportion of the population, and may consist of only one or few individuals. In quantum speciation genetic drift plays a key role.

1.3.2 Irreversibility

In the year 1893, Louis Dollo, a French born Belgian palaeontologist proposed the principle of Irreversibility. This is also called Dollo’s law of Irreversibility or Dollos law which states “An organism is unable to return, even partially, to a previous stage already realised in the ranks of its ancestors.” That is, once an animal has passed through a number of stages, a reversion, stage by stage, to the original ancestral condition does not occur. A structure that changes its form in evolution will not revert to its earlier form. Irreversibility is a descriptive generalisation, it is not a law of nature and one must realise that it is not a property of living organisms.

In studies of primate evolution, irreversibility is an important principle. The dentition of a given form is often crucial evidence of its ancestral or descendant status with respect to another form. Once a tooth of a particular series (incisor, canine, premolar or molar) is lost, it does not recur again in the same series in the

same form. Changes in dentition are irreversible. This does not mean that similar structures or the same adaptive patterns will not be repeated a second time in the evolutionary record. Another example is the flying reptiles. After these reptiles became extinct, wings and adaptation to an airborne way of life occurred in two other distinct lineages – the birds and mammals.

1.3.3 Parallelism and Convergence

Similar structures, similar adaptive relationships, or similar behaviours occur in different groups of animals as a result of similar evolutionary opportunities. A fundamental principle of evolutionary biology is that, if there is a close similarity in the total morphological pattern of two organisms, there is a reasonably close phylogenetic relationship between them. The problem which this phenomenon of similarity brings up is whether such similarities are examples of parallelism or convergence or whether they are evidence of evolutionary affinity between the organisms. Parallelism and convergence imply that a close phylogenetic relationship does not exist.

The term parallelism is usually restricted to the development of similar adaptive features in animals that are related, such as animals belonging to the same order. The parallel resemblances are, most likely, the realisation of a genetic potential that is present in the entire group. On the other hand, the term convergence is defined as development of similarities in adaptive relationships or structures in two animal species or major groups that are not closely related.

It is not easy to classify all cases of similarity as convergent or parallel. The following examples show the difficulties in attempting to categorise similarities. The two kinds of photoreceptors in the vertebrate eye are the rods, which are highly sensitive and function in very little light, but have little power of discrimination, and the cones are sensitive to higher intensities of light and have high degree of discrimination of spatial relationships, colors and textures. Rods have been found in the eyes of many nocturnal vertebrates such as owls, bats and lorises and of those that must live in dim light such as whales, cats and some fishes. The question is, in which of these animals are the rods convergent and in which are they parallel development? The answer depends upon how we define parallel and convergent and detailed study of the rods in these various eyes. It is convergent when the rods in each of the various animals noted may have evolutionary derivations from different structures and it is parallel if they are derived from the same parts of the basic vertebrate eye. Another example which shows problem is the 'song' or territorial call of Indri, a lemur and the hoot of the gibbon. Both belong to the same order and at the same time it is difficult to make a case for close evolutionary affinity between Indri and the gibbon as little is known of the fossil lineage of the Indri.

The old world monkeys and new world monkeys provide an excellent example of parallelism between groups living today, since they appear to have evolved in parallel from a prosimian ancestor that probably lived at least 35 million years ago. Clear example for convergent evolution is the incisor tooth comb of the flying lemur (order Dermoptera) and the tooth comb of various prosimian primates (formed by lower incisors and canines). Another example is brachiation, locomotion by swinging arm over arm through the trees in some monkeys of both old world and new world and in certain apes.

The North American wolves and Tasmanian wolves (Fig. 1.2) is another example for the similar appearance and predatory behaviour. The North American wolves is a placental mammal and the Tasmanian wolves is an Australian marsupial. The common ancestor lived during the age of the dinosaurs some more than 100 million years ago and was very dissimilar from these descendants today.



Fig.1.2: Tasmanian wolf or tiger (now extinct)

Source: anthro.palomar.edu

Further the terms homologous and analogous are often used to describe particular structures in animals. Homologous structures are those that are related by evolutionary descent and divergence. The wing of a bat and the forelimb of a monkey are homologous – they are descended from same ancestral structure. The wing of a bat and the wing of a butterfly are analogous – they have similar functions and similar forms, but they are not related by descent from the same ancestral structure. Perhaps thinking of parallelism as homologous evolution and convergence as analogous evolution would help us distinguish the two processes.

1.3.4 Adaptive Radiation

Adaptive radiation is the name given to the rapid increase in numbers and kinds of any evolving group of animals. A group of animals – a species, a genus, a super family, may take advantage of environmental changes and exploit a number of new places in the planetary living space. These places in the environment are called niches and eco-niches. But according to Simpson (1953), adaptive radiation is the rapid proliferation of new species from a single ancestral group. In Adaptive radiation species evolves into progressively dissimilar organisms. The descendants of a single species sometimes evolve to take advantage of many different environments and opportunities, and rapid changes in the external environment may cause new forms of animals to develop from a single ancestral form. The evolution of a trait that opens up many new possibilities may also give rise to adaptive radiation.

Adaptive radiation is well exemplified by the history of the mammals. With the geological revolution that marked the end of the Mesozoic era (the age of the reptiles) and the start of the Tertiary, the previously stable climates became changeable. The dinosaurs did not adapt and so became extinct, while the mammals evolved in many distinct lines. The rodents specialised for gnawing, the carnivores for hunting, the hoofed animals for grazing, the primates and sloths took to the trees, the whales, seals, and sea cows adapted for life in the oceans, and the bat took to the air. Furthermore, each of these mammalian orders in turn gave rise to sub lines that colonised new environments by acquiring new modes of life. Many of today's mammals are far different from their primitive common ancestors to the Paleocene epoch.

An adaptive radiation need not to be a planet-wide event such as the example just cited. The spread of arboreal primates, the old world monkeys, into trees of the tropical forests is an example of a more limited but no less important radiation. An adaptive radiation is said to have occurred when a group of organisms fits into a part of the planetary living space into which it could not have moved earlier, as result of changes in the group's relationship to environment. These changed relationships can be deduced from the lines of evidence such as the morphology of the fossils and comparative studies of the living forms which are the most likely descendants of these fossils.

In addition, various orders and sub-orders of mammals have undergone further differentiation, branching or 'radiating' into types adapted to different habitats. Thus, all the chief groups of primates today include species with contrasting dietary habits. Insect eating, seed eating, leaf eating, and more or less omnivorous genera recurred in different branches of the primates as these branches departed more or less from the ancestral line. This adaptive radiation within the branches is thus accompanied by *parallelism* between the branches and by *convergence* of adaptations towards those of some non primate lines.

1.3.5 Extinction

Extinction is a name we give to the disappearance of an animal group, such as species, from the evolutionary record. Extinction is considered to be the death of the last individual of that species. Extinction is not an unusual event, as species are created by speciation, and disappear through extinction. Extinction is a natural phenomenon, it is estimated that 99.9% of all species that have ever lived are now extinct. Nearly all animal and plant species that have lived on earth are now extinct, and extinction appears to be the ultimate fate of all species. These extinctions have happened continuously throughout the history of life, although the rate of extinction spikes in occasional mass extinction events. There are at least two ways in which a species may become extinct. First, the species may develop a way of life such that a change in the environment would prevent its persistence. This is the negative role of environmental selection in evolution. Second, one species may become extinct when it is transformed into another. A species may be a segment of a continuous, progressive evolutionary lineage. The species of one time period in which this lineage exists is the ancestor of the succeeding species in the next time period. The ancestral species becomes extinct through the processes by which it is transformed into its descendants. The early Pleistocene hominids, the australopithecines are extinct, yet it is likely that some direct descendants of australopithecine genetic material exist in modern *Homo sapiens*.

The Cretaceous–Tertiary extinction event, during which the non-avian dinosaurs went extinct, is the most well-known, but the earlier Permian–Triassic extinction event was even more severe, with approximately 96 percent of species driven to extinction. The Holocene extinction event is an ongoing mass extinction associated with humanity's expansion across the globe over the past few thousand years. Present-day extinction rates are 100–1000 times greater than the background rate, and up to 30 percent of species may be extinct by the mid 21st century. Human activities are now the primary cause of the ongoing extinction event; global warming may further accelerate it in the future. The role of extinction in evolution is not very well understood and may depend on which type of

extinction is considered. The causes of the continuous “low-level” extinction events, which form the majority of extinctions, may be the result of competition between species for limited resources (competitive exclusion). If one species can out-compete another, this could produce species selection, with the fitter species surviving and the other species is driven to extinction. The intermittent mass extinctions are also important, but instead of acting as a selective force, they drastically reduce diversity in a non-specific manner and promote bursts of rapid evolution and speciation in survivors.

Pseudoextinction

Extinction of a parent species where daughter species or subspecies are still alive is also called *pseudoextinction*. Many of prehistoric extinct species have evolved into new species; for example the extinct *Eohippus* (an ancient horse like animal) was the ancestor of several extant species including the horse, the zebra and the donkey. The *Eohippus* itself is no more, but its descendants live on. It is therefore said to be pseudoextinct. (www.wordiq.com).

1.4 SUMMARY

Evolution simply means change. Organic evolution is the study of changes that have taken place in living things i.e., plants and animals. While understanding the evolution, the principles of evolution like speciation, irreversibility, parallelism and convergence, adaptive radiation and extinction are important. In this unit these principles of evolution are discussed with examples.

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Sample Questions

- 1) Write a brief note on the pre-Darwinian theories of evolution.
- 2) What is Speciation? Describe different mechanisms of speciation with suitable examples.
- 3) Write a note on irreversibility, parallelism and convergence, adaptive radiation and extinction.
- 4) What is extinction? Critically discuss this evolutionary process with examples.



UNIT 2 THEORIES OF ORGANIC EVOLUTION

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- 2.2 Lamarckism
- 2.3 Neo-Lamarckism
- 2.4 Darwinism
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- Suggested Reading
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Learning Objectives



After reading the unit, you would be able to understand the following theories of organic evolution:

- Lamarckism;
- Neo-Lamarckism;
- Darwinism; and
- Neo-Darwinism.

2.1 INTRODUCTION

The problem of the origin and evolution of man, strictly in its biological view point, needs the review of the origin of life in its broadest sense and of the different explanations given for this phenomenon earlier. Paleontology is one of the sciences which have made the greatest contribution to the knowledge of the genesis of life on earth and of its gradual evolution and complication. The earliest fossils found in the earliest of the earth's layers of Archaeozoic era, belong to diversified creatures that give evidence to an already existing complex and highly developed organic life.

Many theories were floated to explain the concept of evolution. But most of them are of historical significance. Some important ones are here.

Theory of spontaneous generation or Abiogenesis

The theory of spontaneous generation is as old as human thought. It is well known that life arises only from pre-existing life (principles of bio-genesis) and assumes that life originated from inert, inorganic matter as a result of a series of physico-chemical conditions which must have existed at a given moment during the evolution of earth. According to this theory worms generated from manure; insects from dew, rotten slime, dry wood, sweat and meat; frogs and salamanders from coagulated slime; and toad, snakes and mice from the mud of the river Nile. The scientists Aristotle, Thales, Plato and Von Helmont believed this idea

of abiogenesis until the 17th century. Later this theory was disproved by Francesc Redi, Spallanzani and Louis Pasteur.

Theory of Eternity of Present Condition

This theory argues for the unchangeableness of the universe. It holds that organisms remain unalterable throughout their individual existence and will continue in the same unchanging state throughout eternity.

Theory of Special Creation or Creationism

According to this theory the living organisms on the earth were created by divine power in six days. Father Suarez (1548-1671) is strong supporter of this theory. The created organisms exist unchanged from the day of their creation. This concept of special creation was followed until middle of the 19th century.

Theory of Catastrophism

Cuvier (1769-1832) and Osbinge advocated that the earth was subjected to periodic catastrophes. These catastrophes destroyed the life from time to time and created new and special form of life after each destruction.

Organic Evolution

Generations of philosophers, natural historians and biologists have contributed to the development of evolutionary theory. From the time man became conscious of himself, he has probably thought and speculated about his origins.

2.2 LAMARCKISM

Lamarckism is the first truly comprehensive theory of evolution. It was proposed by a French born biologist, Jean Baptiste de Lamarck (1744-1829). This theory is also called Inheritance of Acquired Characters and explains the origin of new species.



Fig. 2.1: Jean Baptiste Lamarck (1744-1829)

Source: www.kirksville.k12.mo.us

Lamarck, specialised in animal classification, realised that the various species could be fitted into an orderly relationship that formed a continuous progression extending from the simplest little polyp at one end to man at the other. He was

the first naturalist to become convinced that animals could be modified in order to adapt to the environment and that species were not constant but were derived from pre-existing species. He expounded these views of evolution in his book “Discours d’ouverture de cours de zoologie, de L’an (1800). He did not believe, however, that this environmental influence acted “directly upon the organisms but rather that the transformations they underwent were due to use or disuse of organs motivated by individual needs in response to environmental influences. His theory was not well-received and he suffered social and scientific ostracism for his convictions; nevertheless he maintained his position until his death.

Lamarckism is the first truly comprehensive theory of evolution proposed by Lamarck. This consists of four principles which are: internal urge of the organism, direct environment and new needs, use and disuse theory and inheritance of acquired characters.

In 1809, Lamarck put forth a complete thesis of evolution in his master work and classic book *Philosophie Zoologique*. It is popularly known as *Inheritance of Acquired Characters*. This book included his theory explaining the changes that occur in the formation of new species. Lamarck still occupies a prominent place in the history of evolutionary thought, though his evolutionary ideas are outdated. He was the first evolutionist to conclude that evolution is a general fact covering all forms of life.

The salient features of the Lamarckism are:

- ❖ species change under changing external influence,
- ❖ there is a fundamental unity underlying the diversity of species and
- ❖ the species progressively develops.

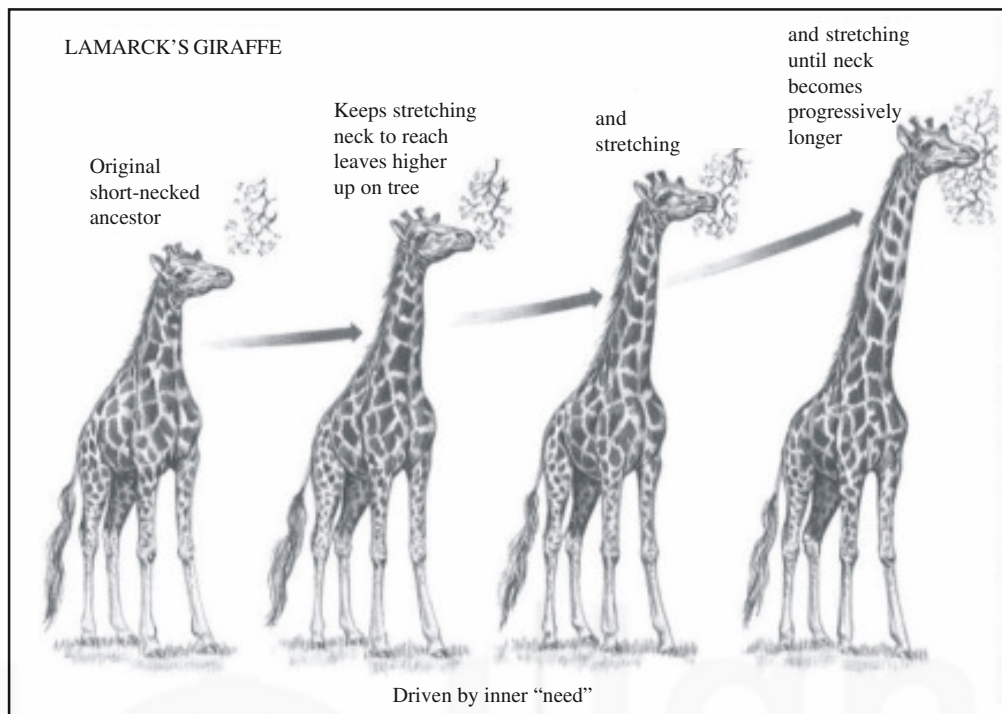
Lamarckism consists of four principles which are briefly discussed.

- ❖ **Internal urge:** The internal forces of life tend to increase the size of an organism, not only as a whole, but in every part as well up to the limit of their function;
- ❖ **Direct environment and new desire:** Each organ or part is the outcome of a new movement which in turn is initiated by a new and continuous desire or want. Thus, formation of a new organ (or part) becomes necessary to produce the newly desired movement;
- ❖ **Use and disuse:** The development of an organ is in direct proportion to its use. Continued use strengthens the organ little by little until its full development is attained, while disuse has the opposite effect, the organ diminishing until it finally disappears;
- ❖ **Inheritance of acquired characters:** All that has been acquired or altered in the organisation of individuals during their life is preserved and transmitted to new individuals who proceed from those who have undergone these change.

In support of his theory, Lamarck cited the following examples.

- ❖ The most frequently cited example of Lamarckism is that of the long neck of giraffe. An original deer-like ancestor of giraffe found the supply of grass and herbs inadequate. Hence the giraffes were forced to feed on the foliage of trees. In the process of reaching the leaves of higher branches, its neck

got stretched and the forelegs were raised. This process of stretching the neck was continued for generations to reach the foliage of taller trees and resulted in longer neck leading to the origin of modern species.



Source: withfriendship.com

- ❖ He explained the webbed feet of aquatic birds as being initiated by hunger (the need for food) driving the birds to swampy areas to seek food. In this environment the birds would have made efforts to swim by spreading their toes. In this process, the toes were spreading out generation after generation. The continued stretching of the skin between the toes gradually produced the webbed condition as an acquired characteristic that was then passed on to future generations.
- ❖ The origin of snakes was explained as a loss of limbs stemming from the habit of moving along the ground and concealing themselves among the bushes. This habit led to continued efforts to elongate the body in order to pass through narrow places and, as result, the animals acquired a long narrow body. Since long legs would have been useless and short legs would have been incapable of moving the elongated body, continued disuse finally caused total loss of limbs.
- ❖ The development of long legs in the wading birds through generations of sustained stretching to keep the body above the water level.
- ❖ Eyes are reduced in moles because they live underground. Since the cave is completely dark, the animals in the cave can not use eyes. So eyes become degenerated and in extreme cases eyes disappear completely.
- ❖ The absence of wings in the non-flying birds. For example, Kiwi of New Zealand is believed to have descended from flying birds. When these birds reached New Zealand, they were able to fly. On settling down and availability of plenty of food and there were no enemies they did not find any need to fly. In due course of time, these birds lost their ability to fly and wings got degenerated.



Fig. 2.3: Kiwi, flightless bird

Source: goaustralia.about.com

- ❖ In blacksmiths, biceps muscles in the right arm are more developed because of their continuous use.
- ❖ Lamarck applied his theory to the human species as the human beings, for a series of generations were obliged to use their feet exclusively for walking purpose and ceased to use their hands as feet. Such quadrumana would undoubtedly be transformed eventually into bimana and their toes would no longer be separated or opposable since their feet would only be utilised for walking.

It is unfortunate that Lamarck had to give such unnatural explanations. It is indeed unfortunate again that Lamarck is best known for his incorrect theory of heredity by acquired characteristics. But one must remember that his concepts were set forth in the early nineteenth century, when the intimate structure of organisms as well as the true mechanism of fertilisation and sexual reproduction was as yet unknown. Although many of his arguments are unacceptable, the magnitude of his work and the brilliance of his hypothesis cannot be denied.

Criticism of Lamarckism

Lamarckism faced severe criticism and Lamarck had to defend them until his death. Some of the objections raised against the Lamarckian theory are as follows.

- ❖ The first principle on the tendency to increase in size is true in case of many organisms. However this is not universally accepted and there are instances to show reduction in size of the organs also.
- ❖ The second principle 'new organs develop upon new desires' is also not true. If every human being who desires to fly in the air should develop wings, but such is not the case.
- ❖ The third principle of Lamarckism, the use and disuse theory, has met with strong objections. If this theory is correct then the size of the eyes of a person should also increase with age who reads the books frequently. Again, we know it is incorrect.
- ❖ The fourth and final principle 'the inheritance of acquired characters' has met with much contradiction.
 - August Weismann (1890), the German biologist cut the tails of white mice for more than 20 generations and saw the consequence on the length of tail in the coming generations. In all generations the length of the tail was found to be normal. Hence, he believed that the acquired character was not inherited. Weismann differentiated the protoplasm into somatoplasm and germplasm. Somatoplasm is in the somatic cells (other than the sex cells). It does not play any role in heredity. Germplasm is

the protoplasm in the sex cells. It plays an important role in heredity. He established that the changes occurring in the somatic cells acquired during the life time of the organism are not transmitted; only the changes that occur in reproductive cells i.e. the germplasm are transmitted.

- The boys of Jews and Muslims have been practicing the circumcision (cutting of the prepuce of penis) for the last several years. But the boys of both Jews and Muslims are born with normal prepuce.
- Chinese women wear iron shoes to keep their feet short for many generations. But the young ones are born only with normal feet.
- It is a practice among the ancient Indian women to pierce their ears to wear ornaments. If this is an acquired character then most of the Indian girls should be born with pierced ears. But this has not happened.

2.3 NEO-LAMARCKISM

A group of evolutionary biologists such as McDougall, Spencer, Cope, Packard, Kammerer, and Sumner etc. further studied and modified the Lamarckism. This modified version of Lamarckism is called Neo-Lamarckism. The following are some of the evidences for inheritance of acquired characters.

- ❖ In order to prove the inheritance of acquired characters McDougall conducted experiments on rats. During his experiments, he used a tank filled with water and dropped the rats into it. The tank was provided with two exits, one exit was lighted and the other was dark. The lighted exit was provided with electric shock and the dark one without electric shock. The rats tried to escape through the lighted route which was provided with electric shock but could not. After repeated trials the rats learned to escape through the dark route. These rats were then bred and the offspring were given the same type of training. It appeared that the speed of learning was increased from generation to generation. Thus he concluded that the learning habit was inherited by rats.
- ❖ Kammerer did some experiments with *Proteus anguinus*, which lives in complete darkness. This amphibian is a blind and colourless. He observed in *Proteus anguinus*, the development of normal eyes and colour of the skin when exposed to day light. These somatic characters were inherited to the next generation.
- ❖ Griffith and Detleofson conducted experiments on rats by placing them on the rotating table for several months. Consequently, the rats slowly adapted to the rotating condition to the extent that even after the rotation stopped, the rats showed signs of dizziness. Then the offspring of these rats also exhibited dizziness and irregularity in gait. Then the scientists concluded that this is an acquired character and is inherited to the offspring.
- ❖ The white mice were exposed to the higher temperature say 20-30°C by Sumner. The body, hind limbs and tail of the mice increased in length. Further he observed that this character was transmitted to their offspring.

2.4 DARWINISM



Charles Robert Darwin (1809-1882)

Source: scienceworld.wolfram.com

Charles Robert Darwin (1809-1882) was born on 12th Feb, 1809 at Shrewsbury in England. As a student, he studied the Greeks and encountered the views of Thales, Empedocles, and Aristotle. He also read the view of his grandfather and the comprehensive theory of Lamarck. With this background, it is apparent that Darwin had at least been exposed to much of the past development of evolutionary thought. Darwin was given an opportunity by British government in 1831 to travel by HMS Beagle for a voyage of world exploration. He went on voyage from 1831 to 1833 and explored the fauna and flora of a number of continents and islands of which Galapagos Islands are the most important. Here Darwin found a living laboratory of evolution.

The publications of T.R. Malthus, Sir Charles Lyell and Alfred Russel Wallace influenced Darwin very much. Malthus (1798) published an essay titled “On the Principles of Populations” which states that populations increase geometrically and the food sources increase arithmetically. Lyell wrote a book entitled “Principles of Geology” which explained the gradualism (earth has changed slowly and gradually through ages) and uniformitarianism (fundamental laws operate today on the earth in the same way as they did in the past). Wallace wrote a paper entitled “On the tendency of varieties to depart from original types”.

Darwinism consists of five principles which are: Prodigiousity of over production, Variation and Heredity, Struggle for existence, Survival of the fittest and Modifications of species. Darwin published “The Origin of Species”. Darwinism is the term coined for the explanation offered by Charles Darwin for the origin of species by natural selection. Darwin’s theory of natural selection is based on several facts, observations and inferences. Darwin published his concept of evolution in his book entitled “The Origin of Species”. Darwinism consists of the following five principles.

- ❖ *Over-production or prodigiousity of over-production:* Many more individuals are born each generation than will be able to survive and reproduce (The writhing of Thomas Malthus influenced Darwin on this point and provided him with the idea of a struggle for existence).

- ❖ *Variation and Heredity:* There is natural variation among individuals of the same species. (This had been noted by naturalists from Aristotle through Lamarck but Darwin's own observations made the greatest impression of this fact upon him). Many of the favourable adaptations are hereditary and are passed on to the progeny of future generations. (Darwin, like Lamarck, believed in an incorrect theory of heredity; however, he interpreted the process in the proper context. Darwin himself was not satisfied with his blending theory of inheritance and as early as 1857 he wrote a letter to Huxley for an alternative to it).
- ❖ *Struggle for existence:* Organic beings increase by a geometrical ratio, while food production only increases in an arithmetic ratio. So that in a very short time, an area will be overpopulated with any one species, unless some thing happens to check the increase. As a result there is a struggle for existence which is three fold as given below.
 - *Intraspecific struggle:* The intraspecific struggle is found among the individuals of the same species. The competition is heavy in case of intraspecific struggle, because the needs and requirements of the members of the same species are same who live in the same environment. It is the most severe check on the rate of reproduction.
 - *Interspecific struggle:* It is found among organisms of different species living together. Members of one species struggle with other species for similar requirements i.e., food, shelter and mating.
 - *Struggle with the environment:* Living organisms struggle with the adverse environmental conditions like floods, cold waves, heat waves and earthquakes, etc.
- ❖ *Survival of the fittest or natural selection:* Individuals with certain characteristics have a better chance of surviving and reproducing than others with less favorable ones. (This is the concept of the survival of the fittest through favourable adaptations to the conditions of life).
- ❖ *Modifications of species:* Gradual modification of species could have occurred over the long periods of geological time through additive process occurring in the past in the same manner as they are occurring in the present. (Charles Lyell's geological interpretations provided knowledge of the long span of time necessary for evolution to proceed and supplied Darwin with the concept of uniformitarianism as a *modus operandi* for the process of biological evolution).

In the 'Origin of Species,' Darwin makes no reference to the human problem, but his thesis clearly led both his supporters and opponents to think that man must be subject to the same laws that attempt to explain the evolution of plants and animals. In 1863, Thomas H. Huxley (1825-1895), staunch defender of Darwin, published his book 'Evidence as to Man's Place in Nature' in 1871, Darwin himself especially described his own point of view in 'The Descent of Man.'

Criticism of Darwinism

Several objections were made to the Darwin's theory.

- ❖ Darwin's explanation is inadequate because selection creates nothing. It merely eliminates or preserves already existing variations without indicating their cause, which is the main question.
- ❖ Individual difference that may give rise to variations affect the reproductive cells little or not at all.
- ❖ A number of useless or non-adaptive characters or organs could not have arisen by natural selection. In this connection, Darwin said that we are not sure of the non-adaptive nature of these organs.
- ❖ Overspecialised organ such as the huge antlers of the Irish deer cannot be explained on the basis of natural selections.
- ❖ It cannot account for degeneracy of certain characters.
- ❖ There is doubt about the struggle for existence being as fierce as it had been supposed to be.
- ❖ The superiority or inferiority of one individual as compared to another of the same species is apparently not the result of the development of a particular characteristic, but rather of the general capacity of the organism.

2.5 NEO-DARWINISM

Subsequently, adherents of Darwinism tried to rejuvenate and modify Darwin's views. The modern theory of origin of species or Evolution is known as Neo-Darwinism. The Neo-Darwinists like August Weismann, Earnest Heckle, Lyell, Huxley, Wallace and Simpson supported the natural selection. Later R.A Fisher, Sewall Wright, and J.B.S. Haldane explained natural selection by modern synthesis, or neo-Darwinism.

There are many lines of evidence supporting Darwin's theory that natural selection is the basis for evolutionary change.

- ❖ *Fossils*: Geology and paleontology have contributed one line of information which supports current concepts of evolution. Evidence embodied in fossils shows gradual changes associated with geological change. This has led to conclusions about the progression of life forms that have evolved during the history of the earth and about the evolutionary relationships between various phyla and species.
- ❖ *Similarities between embryos of different species*: There are stages in the embryonic development of related species, such as the various species of vertebrates that reveal structures so similar among the embryos of these species that even trained scientists would find it difficult to distinguish one from another. Even terrestrial organisms, such as man, possess in the embryonic stages what appear to be gill-like structures and a tail. Because the human embryo manifests these similarities to lower forms of life during embryogenesis, these changes are believed to reflect man's evolutionary history leading to its present form. This has led to the coining of the phrase 'Ontogeny recapitulates phylogeny' by Earnest Heckle in the 'Biogenetic Law' meaning that the progressive changes of the embryo sum up the progressive changes that the species underwent during its evolution. Although the statement is not altogether accurate (since man is not believed

to be a direct descendent of fishes) there is no doubt that some evolutionary relationship between species is reflected in these embryonic stages.

- ❖ *Adaptation in living organisms:* Perhaps the strongest evidence, and certainly among the most interesting in support of the theory of natural selection, consists of the innumerable examples of structural variations and behaviour patterns found in animals and plants, which are of particularly adaptive advantage to the lives, habits and environment of the individual. Examples are (a) parasitic birds: cuckoo birds and sparrow bird, (b) adaptation in colouration: moths in different environments (industrial melanism) and (c) physiological adaptation: animal's native to desert regions, rats and camels.

Even though natural selection is recognised as the paramount factor in the diversification of organisms, some questions still remain to be answered:

- ❖ the existence of complex structures, such as organs found in highly developed organisms e.g. eye of a vertebrate,
- ❖ the structures which have been rendered less important because of decreasing need for them as the species evolves e.g. vestigial organs, wisdom teeth and the appendix of men and
- ❖ the existence of traits which do not appear to have any selecting advantage in nature such as existence of the different blood groups.

These difficulties, however, have not caused scientists to abandon the neo-Darwinism concepts of evolution. Much is not understood about natural phenomena, but this is not sufficient to render invalid concepts that have much support in other biological phenomena. It is more likely that these problems will eventually be found to have some basis in natural selection.

Difference between Darwinism and Neo-Darwinism

It must, however, be noted that the modern concept of natural selection has been considerably broadened and refined and is not quite the same as Darwin's. Darwin recognised the fact that natural selection involves differential reproduction but he did not equate the two. In the modern theory natural selection is differential reproduction, plus the complex interplay in such phenomena as heredity, genetic variation, and all the other factors that affect selection and determine its results. In the Darwinism system, natural selection was mainly elimination, death of the unfit and survival of the fit in a struggle for existence, a process included in natural selection as it is now known but not forming all or even the major part of that process.

2.6 SUMMARY

Evolution that has taken place in living things i.e., plants and animals is called organic evolution. Various concepts (theories) explain the process of Organic Evolution; the important ones are Lamarckism, Darwinism and Synthetic Theory of Evolution. In this Unit we discussed the Lamarckism and Darwinism. The former consists of four principles of evolution viz., internal urge of the organism, direct environment and new needs, use and disuse theory and inheritance of acquired characters. Darwinism consists of five principles viz., prodigality of over production, variation and heredity, struggle for existence, survival of the

fittest (natural selection) and modifications of species. In this unit the Lamarckism, Neo-Lamarckism, Darwinism and Neo-Darwinism are discussed with examples. The difference between Darwinism and Neo-Darwinism is also presented.

Suggested Reading

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Sample Questions

- 1) Discuss Lamarckism.
- 2) Describe briefly the Neo-Lamarckism.
- 3) Describe briefly the Darwin's theory of natural selection.
- 4) Write an essay on Neo-Darwinism
- 5) Write short notes on the following
 - a) Lamarck
 - b) Darwin

UNIT 3 SYNTHETIC THEORY

Contents

- 3.1 Introduction
- 3.2 Historical Development of the Concept of Evolution
- 3.3 Synthetic Theory
- 3.4 Mechanism of Evolution
- 3.5 Guiding Forces of Evolution
- 3.6 Neo-mutationism
- 3.7 Summary
- References
- Suggested Reading
- Sample Questions

Learning Objectives



In this lesson we are going to understand

- what we really mean by the synthetic theory of evolution; and
- in a simple way the various concepts of evolutionary biology leading to the modern evolutionary synthesis.

3.1 INTRODUCTION

Essentially, the concept of evolution implies the development of an entity in the course of time through a gradual sequence of change, from a simple to a more complex state. The idea was initially applied to the historical development of life and word evolution was first applied to this process by the Herbert Spencer, an English philosopher. The term “evolution” can be used in several ways. For example, the planet earth as we know it now is the result of several historical changes, which could be called as ‘Geologic evolution’. Similarly the historical changes leading to the rise of human civilisation could be called as ‘cultural evolution’. Various kinds of evolution may resemble one another in having the characteristic of sequence of development stages. However, none of these can be compared with the organic evolution because of the unique qualities of living organisms. In this lesson, we shall be dealing with the organic evolution, which is responsible for the unity and diversity of life.

Broadly, organic evolution means changes over time. It can be understood as descent with modifications, i.e., some form of change within a lineage. It may be defined as “progressive change in organism over time”. Evolution is the unifying principal of biology that provides an explanation for differences in structure, function and behaviour among organisms.

Evolution is the process by which populations of organisms develop (or acquire) unique traits and pass them from generation to generation, which over long stretches of time leads to new species, resulting ultimately into the vast diversity of biological world. The concepts of evolution took some time to develop and several finer points linked to evolutionary biology are still debated.

3.2 HISTORICAL DEVELOPMENT OF THE CONCEPT OF EVOLUTION

The idea of evolution is not entirely of recent origin. The essence of the idea appears in Greek writings of pre-Christian Era, such as those of Anaximander (600 BC), but it was never generally accepted. The scientific theory of evolution was not established until the eighteenth and nineteenth centuries. Major contributions towards developing and establishing evolutionary concepts were made by Lamarck and Darwin. During the post-Christian medieval period and until the 18th century, the Christian theory of *special creation* was the dominant thought. According to this theory, all living things come into existence in unchanging form due to Divine Will. The theory was notably in opposition to the concept of evolution. Another theory that received support during this period was the theory of *spontaneous generation*, which proposed that living organisms, at least the lower forms, arose spontaneously from non-living matter. The example of appearance of maggots in uncovered meat in a few days and tadpoles swimming in a puddle all of a sudden, were used to support spontaneous generation. However, experiments by Francesco Redi in 1668, Spallanzani in 1765 and finally Louis Pasteur in 1868 provided evidence that disproved this theory.

Contribution of Jean Baptist Lamarck: The first clear recognition and demonstration of the facts of evolution was made by the French naturalist Jean Baptist Lamarck (1774-1829). Lamarck discerned that all life is the product of evolutionary change, that evolution resulted in the taking on of new adaptations to the environment, and that the diversity of life was the result of adaptation. Lamarck's theory, popularly known as the "Theory of the Inheritance of Acquired Characters", basically consisted of two parts.

- ❖ New structures appear because of an 'inner want' of the organism.
- ❖ These structures are acquired in response to need and are then inherited by subsequent generations.

He suggested that inner usage and need led to greater use or disuse of certain organs and tissues bringing about some modifications in the organism, which were passed on to the next generation. So an organism could pass on to its offspring any characteristic it had acquired in its lifetime. The elongation of neck from an original short-necked ancestor to the modern long-necked giraffe due to stretching to reach leaves higher up on trees, driven by 'inner need', is a common example of Lamarck's theory. Lamarck was correct as far as the significance of evolution was concerned. But his theory of inheritance of acquired characters fails when subjected to scientific tests. Its failure was demonstrated by August Weismann (1834-1914), a German biologist, by cutting tails of mice for several generations. The offspring of tailless mice were always born with tails, thus experimentally disproving the inheritance of acquired characters. Though Lamarck was right in his insight as to the significance of evolution, but his theory does not stand up under investigation.

Contribution of Charles Darwin: The key theory of evolution was provided by genius of his time Charles R. Darwin (1809-1882), which converted the scientific and intellectual worlds to accept the fact of evolution. Darwin's masterpiece book, "On the Origin of Species", which appeared on November

24, 1859 had profound impact and changed our thinking forever in establishing the concept of evolution. Darwin's theory is popularly known as the 'Theory of Natural Selection'. Alfred Russell Wallace also came to similar conclusions independently and he communicated his thoughts about natural selection in a paper entitled "*On the tendency of varieties to depart independently from the original type*" to Darwin. Darwin communicated his own documents along with that of Wallace to the Linnaean Society and a joint presentation of two papers was made to the Linnaean Society on July 1, 1858. Their joint paper "*On the tendency of Species to form Varieties; and on the Perpetuation of Varieties and Species by Natural Selection*" was subsequently published in August 1858 in the 'Journal of the Proceedings of the Linnaean Society'. This also prompted Darwin to publish in 1859 his theory of Natural Selection, which he had been developing for the last 20 years, in the form of a landmark book "*On the Origin of Species*". According to Darwin, the prime force for evolutionary change was natural selection. Darwin's theory of natural selection was based on two observations and two facts:

- ❖ All organisms reproduce many more offspring than can survive.
- ❖ Organism within a population exhibits variability and this variation affects an individual's ability to survive and reproduce.
- ❖ The individuals best fitted to an environment survive, while individual variants less-suited fail to reproduce (natural selection).
- ❖ The traits (variations) thus favored by selection are passed on to the next generation (www.scienceforums.net).

Darwin gathered evidence for this theory during his voyage on the ship H.M.S Beagle. Darwin's ideas were influenced by the work of economist Thomas Malthus (1766-1834). In his famous work, '*An Essay on the Principal of Population*', Malthus explained how populations produce many more off springs than can possibly survive on the limited resources generally available. According to him, a fast growing population that reproduces too quickly can outstrip its resources and then crash (due to poverty, famine and disease) until the population size settles to a level which the resources can support. Darwin called this a "struggle for existence".

Darwin realised that it was not chance alone that determined survival. Instead survival depended on the traits of an individual, which may aid or hinder survival and reproduction. Well-adapted or "fit" individuals are likely to leave more off springs than their less well-adapted competitors. Darwin realised that unequal ability of individuals to survive and reproduce could cause gradual change in a population. The characters (variations) that help an organism to survive and reproduce would accumulate in a population while those that hinder survival and reproduction would decrease or even disappear. Darwin used the term 'Natural Selection' to describe this process and perceived natural selection as the basic mechanism of evolution. Darwin correctly understood that natural selection is usually the most powerful mechanism of evolution but he did not completely comprehended how it operated (www.scribd.com).

One of the major weaknesses of Darwin's theory was its inability to explain the sources of variations in traits within a species and how these variations were

inherited. The hereditary mechanism (pangenesis) proposed by Darwin could not find wide acceptance. Darwin died before the mechanism of heredity was established in the late 19th and early 20th centuries.

Mutationism: ‘Mutationism’ refers to the theories of evolution where mutations are the main driving force of evolution. The concept of mutationism was first proposed in 1901 by Hugo de Vries, the pioneer geneticist. Though later associated with Mendelian genetics, idea of mutationism began in the 1890s (before the rediscovery of Mendel’s laws) through the works of Hugo de Vries and William Bateson on naturally occurring discontinuous variations. This particular form of mutationism adopted by Hugo de Vries is often called ‘macromutation theory’ where suddenly large mutations could change radically a species into another. The ‘mutationist view’ began by abandoning Darwin’s idea of automatic fluctuations, embracing instead the concept that variation emerges by rare events of mutations. This view was expressed in the writings of important founders of genetics, which included Thomas Hunt Morgan, Hugo de Vries and William Bateson, among others. Mutationists assumed that heritable variation could not be taken for granted. They understood evolution as a two-step process involving chance occurrence of a mutation, followed by its persistence or elimination. The mutationists denied that selection is creative and they conferred on mutation some extent of control over course of evolution. Unfortunately, early geneticists discarded all of Darwin’s ideas because they believed they knew something that Darwin did not know. It even became fashionable to talk of death of Darwinism during the first couple of decades of 20th century. Mutationist view was very popular in the first three decades of the 20th century but it was eventually replaced by the Darwinian view expressed in the ‘Modern Synthesis’ or ‘Neo-Darwinism’ or ‘Synthetic Theory’.

Contribution of Mendel: For any discussion on the synthetic theory of evolution, the contribution of Mendel cannot be ignored. Darwin laid down the foundation of evolution by hypothesizing that if a trait is advantageous it will increase in frequency in a population because the offspring with the trait will survive and reproduce better and will pass on that trait to their offspring. However, at that time no one could explain how those traits could be passed over to the future generations. The credit for discovering the mode of inheritance of traits goes to the Austrian monk J. Gregor Mendel (1822-1884) who, through his breeding experiments on garden pea plants developed a few simple rules of inheritance. Mendel, the father of Modern Genetics, published his findings on inheritance in 1866 but his work remained largely ignored until it was rediscovered in 1900 by Hugo de Vries and Carl Correns. Mendel was a pioneer who laid the foundation for the whole of modern genetics. Rediscovery of Mendel’s principles led to the rapid and explosive growth of the discipline of genetics and established the basis for unraveling the deep secrets of biological reproduction and heredity. Mendel’s experiments helped him realise a few simple rules of inheritance.

Mendel proposed that there were discrete “factors” of heredity that united during fertilisation and then separated again in the formation of sperm and egg. It is remarkable how correct Mendel was, particularly in view of the fact that he knew nothing about DNA, chromosomes or meiosis (even the term ‘gene’ was not introduced until 1909). He was convinced that organisms inherit two units of each ‘factor’, one from each parent. Now we understand these ‘factors’ as genes and that most complex organisms are diploid, that is, they can have two copies of a particular gene or two different alleles and that alleles are not blended.

On the basis of his experiments, Mendel proposed the '*Law of segregation*'. According to this law, when the gametes are formed in the parents, the heritable factors (genes) separate from each other so that each sperm or egg gets one unit of each pair. Mendel was correct. Today we understand that sperm and egg are haploid, with only half the number of chromosomes and genes of the parents. He also proposed what came to be known as the '*Law of independent assortment*', which states that the factors (genes) for various traits assort independently of each other during the formation of sperm or egg. Mendel was partially right in this respect. It is because approximately 25,000 genes of the human genome do not float independently in the nucleus of the cell. Each gene is part of a homologous pair of chromosomes, and normally in humans there are only 23 pairs of chromosomes. Only genes meant for different traits, which are located on different chromosomes always truly assort independently.

Mendel published his findings in 1866, just seven years after Darwin's '*Origin of Species*'. These findings went unnoticed until 1900, when eventually the mechanism of inheritance could be combined to natural selection. Shortly thereafter, a theoretical evolutionary model known as the '*Modern Synthesis*' or '*Synthetic Theory*' was born. Once in 1953, James Watson, Francis Crick and Rosalind Franklin explained the model of DNA molecule, the basic genetic component of evolution was revealed.

3.3 SYNTHETIC THEORY

With the foregoing background of the basic concepts of evolution, let us now understand the synthetic theory of evolution. This theory of evolution is essentially a combination of Charles Darwin's concept of natural selection, Gregor Mendel's basic understanding of genetic inheritance, along with evolutionary theories developed since the early 20th century by field biologists, population geneticists, and more recently by molecular biologists. It is the present understanding of the process of evolution, which has been referred differently by different workers as '*Neo-Darwinism*', '*Modern Synthesis*' and '*Synthetic Theory*' etc. This is a combination of Darwinism selection with theoretical population genetics. The concept, also called as neo-Darwinism, was fundamentally developed by three founders of theoretical population genetics namely R.A. Fisher in 1930, Sewall Wright in 1931 and J.B.S. Haldane in 1932 and later supported by others, especially Theodosius Dobzhansky. In fact, the scientists who were important in shaping the '*modern synthesis*' theory included Theodosius Dobzhansky, Ernst Mayr, R.A. Fisher and George Simpson. The book, '*The Genetical Theory of Natural Selection*', by Fisher is considered a classic. The current understanding of the mechanism of evolution, though acknowledging the role of natural selection, differs considerably from the theory first outlined by Darwin. The advances in genetics, pioneered by Gregor Mendel, have led to a sophisticated understanding of the basis of variations and understanding of the basic of variations and the mechanism of inheritance. Researchers have identified DNA as the genetic material, through which traits are passed from parent to offspring, and identified genes as discrete elements within DNA. Though largely faithfully maintained within organism, DNA is both variable across individuals and subject to a process of change or mutation (www.newworldencyclopedia.org).

In Neo-Darwinism, natural selection is assumed to play a more important role than mutation, sometimes creating new characters in the presence of genetic

recombination. Most geneticists believed that the amount of genetic variability contained in natural populations was so large that any genetic change could occur by natural selection without waiting for new mutations. Further mathematical geneticists showed that the gene frequency change by mutation was much smaller than the change by natural selection (www.mbe.oxfordjournals.org).

With a more complete understanding of mechanism of inheritance, the biological sciences now generally define evolution as the sum total of the genetically inherited change in the individuals who are the members of the gene pool of a population. It is now understood that the effects of evolution are felt by the individuals but it is the population as a whole that actually evolves. Evolution, as per modern synthesis, can be expressed simply as a change in frequencies of alleles in the gene pool of a population. The modern synthesis also emphasises the definition of species as a reproductively isolated group of organisms that share a common gene pool (www.phsgirard.org). The modern theory of the mechanism of evolution differs from Darwinism in the following three significant aspects:

- ❖ It recognises several forces of evolution in addition to natural selection, of which gene drift is equally important.
- ❖ It recognises that characteristics are inherited as discrete entities known as genes and that variation within a population is due to the presence of multiple alleles of a gene.
- ❖ It suggests that formation of new species is usually due to the gradual accumulation of small genetic changes.

In other words, modern synthetic theory is basically about how evolution operates at the level of genes, phenotypes and populations.

3.4 MECHANISM OF EVOLUTION

The synthetic theory explains evolution as consisting of two basic types of processes: those that introduce new genetic variations in a population, and those that affect the frequencies of variations already existing in a population. The raw materials for evolution are the variations. Without genetic variation the population cannot evolve.

Sources of variations

The various processes (or sources) that are responsible for introducing variations in a population are mutations and gene flow.

Mutations

Mutations are considered as the ultimate source of all genetic variation. Broadly speaking mutation is alteration of genetic material. These are permanent, transmissible changes to the genetic material of a cell (usually DNA and RNA). These can be caused by 'copying errors' in the genetic material during cell division and also by exposure to radiation, chemicals or viruses. In multicellular organisms, the mutations can be divided into 'germline mutations' (that occur in the gametes and can thus be passed on to the next generation) and 'somatic mutations' (which

often lead to malfunction or death of a cell and can cause cancer). The mutations may be classified as ‘gene mutations’ and ‘chromosomal mutations’.

- 1) **Gene Mutations:** The spontaneous appearance of a new gene expression is called a gene mutation. It is the result of a slight change in the chemical structure of the segments of the DNA molecules that constitute a gene. It may be substitution, insertion or deletion of single base. For example, an adenine can be accidentally substituted for a guanine. Such errors in copying DNA are referred to as gene mutations or point mutations. Although there is self correcting mechanism in the replication of DNA that repairs such small errors but it may not always find and correct every one of them.

Mutations can occur naturally as a result of occasional errors in DNA replication. Sometimes extra copies of one or more genes are produced when a DNA molecule is replicating. More often, however, sections of non-protein coding DNA regions are duplicated or inverted, which is an important source of genetic variation for a species. Spare copies of genes can mutate and change their function overtime thereby producing a new variation (www.anthro.palomar.edu).

Mutations appear to be spontaneous in most instances. Point mutations may occur even in healthy people. Majority of them do not confer any significant advantage or disadvantage because they occur in non-gene coding regions of DNA molecules.

- 2) **Chromosomal mutations:** These are spontaneous changes in the structure or number of chromosomes. Chromosome mutations differ only in degree from gene mutations. The effect is more pronounced if the chromosomes undergo spontaneous modifications, than if only single gene mutates. Chromosome mutations are inherited once they occur. These can be of various types given as below:

A) Change in number of chromosomes:

- 1) Gain or loss of a part of chromosomal set
- 2) Loss of an entire set of chromosomes (Haploidy)
- 3) Addition of one or more sets of chromosomes (Polyploidy)

B) Structural change in chromosomes:

- 1) Change in number of genes
 - a) Loss of genes, usually termed as ‘deletion’
 - b) Addition of genes, often called as ‘duplication’
- 2) Changes in arrangement of genes
 - a) Exchange of parts between non-homologous pairs of chromosomes, termed as ‘translocation’
 - b) Rotation of a group of genes by 180 degrees within one chromosome, often known as ‘inversion’.

Any of these major changes contributes to variability by changing the pattern of gene interaction. Structural modification of chromosomes generally occurs as a consequence of crossing over process during cell division. Normally, there is an

equal exchange of end sections of homologous chromosomes. But sometimes, there is a reunion of an end section onto a chromosome that is not homologous. Similarly there can be an orphaned end section that does not reattach to any chromosome and the genes on such section are functionally lost (www.phsgirard.org).

Irregular number of chromosomes can occur as a consequence of errors in meiosis and the combining of parental chromosomes at the time of conception (www.anthro.palomar.edu). For example, there could be three instead of normal two autosomes for pair number 21, leading to a condition known as 'Down Syndrome' in humans.

For a mutation to be inherited, it must occur in the genetic material of a sex cell. Mutations provide genetic variability for various forces of evolution, such as natural selection, to operate upon. For a mutation to be subject to natural selection, it must be expressed in the phenotype of an individual. Selection favours mutations that result in adaptive phenotypes and eliminates non-adaptive ones. Even when mutations produce recessive alleles that are seldom expressed in phenotypes, they become part of a vast reservoir of hidden variability that can show up in future generations. Such potentially harmful recessive alleles add to the genetic load of a population, even mutations that have a natural effect could become advantageous or harmful if the environment changes to select for or against them. The great diversity of life-forms seen in the fossil record is the evidence that there has been an accumulation of mutations producing a somewhat constant supply of variations upon which natural selection has operated for billions of years. Thus, mutation has been a significant prerequisite for the evolution of life. Another source of variation is recombination.

Recombination

It is the process of mixing or recombining the existing genes into a variety of new genotypes. It is responsible for producing genetic combinations not found in earlier generations. Biologists recognise the importance of recombination as a source of genetic variation and as a significant partner with mutation, in manufacturing the materials for evolution.

Recombination does not produce new variations (or alleles) but only rearranges the existing genes in combinations not present earlier, thus adding to variability. New combinations of existing genes are produced at beginning of meiosis during crossing over when the ends of chromosomes break and reattach, usually on their homologous chromosome. This crossing-over process results in an unlinking and recombination of parental genes. Crossing over of the chromosomes is a phenomenon that only occurs during meiosis by chiasmata. Crossing over does not occur in asexual reproduction. During this process parental DNA gets exchanged and the resulting chromosomes contain a mosaic of genes from the mother and the father. The offspring has new combination of genes that did not exist in either of the parents. Crossing-over and recombination are crucial for maintaining genetic variability in successive generations. Recombination, thus adds greater diversity to the gene pool of a population. The recombination is significant to evolution. A single mutational change may be lost or passed without any significant effect on a population. However, its effect may be enhanced or modified by recombination. Thus variation is the raw material for evolutionary change, and gene recombination and mutation its principle source. Mutation

alone may not have that pronounced effect without the impact of recombination in spreading it in a population.

Another source responsible for genetic variation is gene transfer. It is the movement of genetic material across species boundaries, including horizontal gene transfer, antigenic shift, and reassortment is considered as gene transfer. Viruses can transfer genes between species whereas bacteria can include genes from other dead bacteria or exchange genes with living bacteria thereby adding to dissimilarity.

Thus, variations are the raw materials on which various forces of evolution operate to effect evolutionary changes.

3.5 GUIDING FORCES OF EVOLUTION

Natural selection and genetic drift are the major guiding forces of evolution that act upon the existing genetic variability within a species to cause evolutionary change.

Natural Selection

It is one of the strong forces of evolution. Natural Selection as guiding force of evolution was the principle contribution of Charles Darwin to the evolutionary biology given as early as 1859 in his book “*On the Origin of Species*”. However Darwin did not fully comprehend how it operates, as mechanisms of genetics were not known at that time. Natural selection favored those features of an organism that brought it into a more efficient adaptive relationship with the environment. Through the process of natural selection, species become better adapted to their environments.

Under standard environmental conditions all genes in the gene pool of a population come to equilibrium, and this equilibrium is maintained. In other words, gene pool frequencies are inherently stable and do not change by themselves. The gene or allele frequencies will remain unaltered unless evolutionary mechanisms, such as natural selection and mutation, cause them to change. This understanding was largely developed through mathematical modeling based on probability in the early 20th century by an English mathematician Godfrey Hardy and a German physician Wilhelm Weinberg. Hardy and Weinberg postulated that gene frequencies in a population will remain stable if:

- ❖ all matings are random;
- ❖ mutation is not occurring;
- ❖ natural selection is not occurring;
- ❖ the population is infinitely large;
- ❖ all members of the population breed;
- ❖ there is no migration in or out of population; and
- ❖ every one produces the same number of offspring.

That means evolution will not occur if no mechanisms of evolution are acting on a population, and the gene pool frequencies will remain unchanged. Hardy and Weinberg developed a simple equation that can be used to find out the probable

genotype frequencies in a population and to track generational changes in them. This came to be known as the Hardy-Weinberg equilibrium equation ($p^2 + 2pq + q^2 = 1$). In this equation, 'p' is defined as the frequency of dominant allele and 'q' as the frequency of the recessive allele for a trait controlled by a pair of alleles (A and a).

However, it is highly unlikely that any of these seven conditions, let alone all of them, is actually fulfilled in the actual world. Thus, evolution is inevitable. The natural processes that result in changes in gene pool from one generation to the next are the mechanisms that cause evolution. Natural selection is one such mechanism or force that brings about evolutionary change by favouring differential reproduction of genes, which produces change in gene frequency from one generation to the next. Natural selection on its own does not produce heritable genetic change, but once genetic change has occurred it acts to favour some genes over others. When two or more gene combinations are present, selection favours increased reproduction of the gene combinations most efficient under the environmental circumstances, thus bringing about improvement in adaptive relations between organisms and their environment.

Since the environment is never stable for greater period of time, the nature of selection process also fluctuates. In a changed environment a trait may lose its adaptive value and may not be encouraged by selection, which may start favouring another trait that improves 'fitness'. It is probably that many of the slight changes in gene frequencies between generations may be due to changing selection pressures. The example of peppered moth (*Biston betularia*) in connection with industrial melanism in moths provides insight into the operation of selection under natural conditions. In England, until 1845, all known specimens of this moth were light in colour, but in that year a single black moth was taken at the growing industrial centre of Manchester. It is presumed that its highest frequency at that time in the moth population was not more than 1 percent. However, frequency of black moths increased to nearly 99 percent of Manchester moth population by 1895. This change in gene and genotype frequencies corresponded with the spread of industry in England. The change from light to dark color in dirty coal-dust covered areas of England is a good example of natural selection favouring dark pigmentation of moths, which provided better camouflage from predatory birds against dark background of soot-covered vegetation.

Natural selection moulds the genotypes of organisms so that they produce phenotypes best fitted to their environments. Consequently, the gene pool frequencies shift in the directions of their more adaptive alleles. But natural selection does not operate directly on the genotypes. It acts through the phenotypes of individuals and their gametes. It may be noted that whereas mutation and genetic drift are random, natural selection is not, as it preferentially selects for different mutations based on differential fitnesses.

Sexual Selection

It occurs when organisms which are more attractive to the opposite sex, because of certain features, reproduce more and thus increase the frequency of those features in the gene pool. These features may not always have a conspicuous link to fitness. In humans, people usually select mates non-randomly for traits that are easily observable. Cultural values and social rules normally guide mate selection. Most commonly, mates are selected from among people who are like

themselves phenotypically with respect to traits such as skin colour, stature and personality, etc. This is referred to as positive assortative mating. The net result of this type of mating is a progressive rise in the number of homozygous genotypes and equivalent decline in heterozygous ones in a population. Like recombination, non-random mating can act as an ancillary process for natural selection as a consequence evolutionary change. This is because any deviation from random mating upsets the equilibrium distribution of genotypes in a population thus affecting change in gene frequency or in other words causing evolution to occur. However, the downside is that positive assortative mating results in an increase in homozygosity of deleterious alleles if they are present in the gene pool, particularly in some reproductively isolated small societies.

Gene Flow

The phenomenon of transference of genes from one population to another is termed as gene flow. Evolution can occur due to gene flow as it can easily change gene pool frequencies even if no other mechanisms of evolution are operating. Gene flow takes place when there is migration of individuals into (immigrations) or out of (emigration) the population. This physical movement of alleles, called gene flow, tends to mix pools of genes that might not otherwise mingle. The prevalence of international travel now a days has markedly increased the possibility of gene flow in human population. Human gene flow is regulated to a certain extent by culture, which determines how frequently populations interact and interbreed. Gene flow mixes the alleles of different gene pools, thus stopping them from diverging into separate species.

Genes may occasionally also flow between species. For example, segments of DNA may be transferred from one species to another by viruses as they invade cells of other organisms. This rare form of gene flow has been reported for some species of fish, reptiles, insects, mammals and microorganisms, but it has yet to be conclusively demonstrated for humans.

Genetic Drift

Although natural selection is a significant natural force; but it is not the only force acting upon variation to produce evolutionary change. One such force is genetic drift. It refers to the random changes in allele frequency because of chance events. In small, reproductively isolated populations, chance factors produce rapid changes in gene frequencies totally independent of mutation, recombination, and natural selection. The smaller the populations, the more susceptible it is to such random changes. The genetic drift operates in both large and small populations, but it is only in the latter that these processes produce a significant evolutionary effect. Studies in population genetics, principally by Sewall Wright, have led to the recognition of the force of genetic drift or Sewall Wright effect that plays an important role in population evolution.

Genetic drift, usually referred to as drift in evolution, mainly occurs in small populations and may fix certain non-adaptive or neutral genes. The essential feature of genetic drift is that the smaller the population, the greater are the random variations in gene frequencies from one generation to the next. Thus, drift must have played a major role in the early stages of human populations which were numerically very small. However, even in populations of today, there are culturally isolated groups, such as Jarwa and Onge of Andaman Islands of India in which drift can still be an important evolutionary mechanism.

One cause of genetic drift is the 'founder effect' or the 'founder principle'. It occurs when a few individuals leave the original group and begin a new population in a different location, or when some environmental change isolates a small population from a larger one. The new gene pool may not be a representative of the original population. The resultant new population usually contains high frequencies of specific genetic traits inherited from the few common ancestors who first had them.

Another cause of genetic drift is the 'bottleneck effect', which occurs when a major catastrophe such as sudden climatic change, fire, devastating earthquake or a new predator wipes out most of a population without regard to any previous measure of fitness. When this happens, the few genes left in the gene pool may no longer represent the original population, nor do they necessarily represent the fit genes. The few survivors of such evolutionary bottlenecks may reproduce resulting in a large population in subsequent generations. The consequence of the bottleneck effect is the drastic reduction in genetic diversity of species since most variability is lost at the time of bottleneck.

Speciation

The evolutionary process of formation of two or more species from one is known as speciation. A species is basically a taxonomic classificatory category. There are several species concepts that use different criteria to define a species. The biological species concept is the most commonly used concept to group living animals. According to this concept, a species is a natural population in which individuals are actually or potentially capable of breeding with one another to produce fertile, viable offspring and, under natural conditions; do not normally interbreed with individuals of other species.

The accumulated microevolution or changes in allele frequencies in a population lead to macro-evolution, which is speciation. In a sense, variation that exists within populations increases to become variation between populations. Evolution at the species level is the outcome of cumulative microevolution. The accumulated changes may ultimately lead to reproductive incompatibility and thus to the creation of species. For speciation to occur, some form of isolating mechanism, even if only partial or spatial, is necessary for evolutionary divergence. Without isolation the gene flow precludes evolutionary divergence. With isolation, microevolution within the population groups (demes) may produce morbidly divergent populations. The formation of two or more species often requires geographical isolation of subpopulations of the species. Only then mechanisms of evolution such as natural selection or genetic drift produce distinctive gene pools. Isolation is therefore the key factor in the origin of new populations and ultimately new species. Populations of a species may get isolated due to geographic barriers like river and desert etc or by sheer distance in populations having large geographic distribution, or islands separated by rising sea levels to isolate subset of the population, or by mountain chains, etc. Depending upon the extent of geographic isolation, four different modes of speciation are commonly understood viz., allopatric speciation, parapatric speciation, paripatric speciation and sympatric speciation.

Allopatric speciation

It occurs when a geographic barrier like a river, sea, mountain chain or desert strip isolates a subset of the population and the forces of evolution start operating independently on it.

Parapatric speciation

It is a type of speciation in which subsets of a population that covers a large geographic distribution, over a variety of habitats, become isolated by distance and selection and drift act differently on the gene pool in accordance with their different environments. In this case, distance itself acts as a barrier to free gene flow.

Peripatric speciation

It occurs when new species are formed in isolated, smaller peripheral populations, which are prevented from exchanging genes with the main population. Genetic drift is assumed to play an important role in this type of speciation.

Sympatric speciation

It is a rare mode of speciation because it occurs without geographic or physical barriers. It refers to the formation of two or more descendant species from a single ancestral species, all occupying the same geographic location. Behavioural boundaries, like differences in vocalisations or courting rituals that prevent complete gene flow can permit natural selection and sexual selection to operate differently within the population, resulting in a subpopulation becoming a different species.

Polyploidy and speciation

It is a change in chromosome number, characterised by the addition of one or more sets of chromosomes than the normal number. Hybridisation between related angiosperms is sometimes followed by doubling of the chromosome number. The resulting polyploids are fully fertile with each other but are unable to breed with either paternal type. Thus a new species is formed. Polyploidy appears to have been a frequent mode of speciation in angiosperms.

3.6 NEO-MUTATIONISM

Mutationism, which began in the 1890 with the studies of Hugo de Vries and William Bateson, was very popular view in the first three decades of the 20th century. It was eventually replaced by the 'Modern Synthesis' or 'Synthetic Theory', which is currently a widely accepted theory of evolutionary mechanism.

The contemporary view corresponding to mutationism could be termed as Neo-Mutationism. With the arrival of molecular biology, interest in mutations as an important factor in protein evolution has been shown by some scientists. A new view is emerging that uses recent molecular studies of phenotypic evolution to support the basic ideas of mutationism put forth by Thomas Morgan in 1932. This is a new form of mutation theory on the role of mutation in the evolution and is often referred to as neo-mutationism. One of the strongest advocates of neo-mutationism is Masatoshi Nei. Scientists studying molecular evolution began to suggest mutational explanation for patterns such as genomic nucleotide composition. Phrases such as 'new mutations' or 'mutation-driven evolution' have emerged in the recent few decades that advocate a departure from the 'changing gene frequencies' view of 'Modern Synthesis' or 'Synthetic Theory'. These contemporary workers suggest that mutation plays a role in evolution that was initially proposed by 'mutationists' but rejected by Modern Synthesis.

A main feature of this theory is how single mutations can have significant effects to influence evolution.

While neo-Darwinism regards mutation as merely raw material and natural selection as the creative force, the Neo-mutationism of Nei assumes that the most fundamental process for adaptive evolution is the production of fundamentally more efficient genotypes by mutation (especially birth and death process of duplicated genes) and the recombination. Neo-mutationism suggests that the basic genetic factor of phenotypic evolution is the mutational change of protein-coding regulatory regions of genes and that evolutionary change of phenotypic characters is caused by the so called 'major-effect mutations'. It further assumes that natural selection occurs as a consequence of mutational production of different genotypes, and therefore it is not a cause of evolution. According to Nei's view, mutation (including gene duplication and other DNA changes) is the driving force of evolution at levels of genes as well as phenotypes.

3.7 SUMMARY

Evolution is the unifying principle of biology, which provides an explanation for differences in structure, function and behaviour among organisms. A major breakthrough in the development of the concept of evolution was the Darwin's 'Theory of Natural Selection'. Before Darwin, during post-Christian Medieval Period until the 18th Century, the Biblical theory of 'Special Creation' was the dominant thought. The ideas of Lamarck and Wallace also significantly contributed to the development of the concept of evolution. Darwin perceived natural selection operating on natural variations as the basic mechanism of evolution. However, he could not explain the sources and means of inheritance of the variations. The credit for discovering the mode of inheritance of traits goes to Gregor Mendel, whose laws of inheritance that were developed in 1866 were reinvented in 1901 by Hugo de Vries. 'Mutationism', which maintained that mutations were the main driving force of evolution, was a popular view in the first three decades of the 20th Century until it was replaced by the 'Synthetic Theory', which is the present understanding of the concept of evolution.

Synthetic theory of evolution is basically a combination of Darwin's concept of natural selection, Mendel's genetics, and the evolutionary theories developed by population genetics and more recently the concepts of molecular biology. It explains evolution as consisting of two basic processes: those that introduce new variations in a population, and those that influence the frequencies of variations already present in the population. The source of variations include gene and chromosomal mutations and recombination, while the guiding forces of evolution that act upon the existing variations include natural selection, sexual selection, gene flow and genetic drift. The accumulated changes (variability) in a population may ultimately lead to reproductive incompatibility and thus creation of a new species. For speciation to occur, some form of isolating mechanism is necessary for evolutionary divergence. The contemporary view regarding mutationism is neo-mutationism, which competes with neo-Darwinism to explain evolution. The basic difference between neo-mutationism and synthetic theory or neo-Darwinism is about the relative importance of the main three mechanisms of evolution, viz. the mutation, genetic drift and natural selection.

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Sample Questions

- 1) Define evolution and trace the historical development of the concept of evolution.
- 2) Explain the contribution of Darwin to the development of evolutionary concept.
- 3) What is synthetic theory of evolution? Describe the fundamental mechanisms of evolution as explained by the synthetic theory.
- 4) What is genetic drift? Discuss its role in evolution.

UNIT 4 PALAEOANTHROPOLOGY

Contents

- 4.1 Introduction
- 4.2 Definitions of Palaeoanthropology
- 4.3 Principles of Palaeoanthropology
- 4.4 Scope of Palaeoanthropology
- 4.5 Human Evolution with Respect to Hominid Fossils
- 4.6 Ramapithecus
- 4.7 Australopithecus
- 4.8 Homo Erectus
- 4.9 Homo Neanderthalensis
- 4.10 Homo Sapiens
- 4.11 Summary
- Suggested Reading
- Sample Questions

Learning Objectives



This unit is designed to provide:

- fundamental concepts of Palaeoanthropology;
- introduction to the subject of Paleoanthropology: definition, principles, scope and applications;
- fundamental concepts of Paleoanthropology to appreciate the advanced concepts of Paleoprimateology and human evolution; and
- diagnosis, description, distribution through time and space, and phylogenetic status of *Ramapithecus*, *Australopithecus*, *Homo erectus*, *Homo neanderthalensis* and *Homo sapiens*.

4.1 INTRODUCTION

The pivot around which the whole evolutionary story rotates is the fossils. The word ‘fossil’ comes from the Latin verb *Fodre* meaning “dig up”. Fossils are the prehistoric remains of man and his ancestors found preserved today in the earth’s crust of the geological past.

The palaeoanthropologists are in search of human origins, finding clues to the mystery of our evolution. As more and more fragments of our past have been recovered, the story of human evolution has been unraveled; the more fossils, the greater our knowledge. New discoveries often create opportunities for reassessing the existing data.

Palaeoanthropology can be broadly considered as the fusion of two separate branches of anthropology viz., physical (biological) anthropology – especially the study of fossil humans and archaeology – the study of human behaviour

from human material remains. Despite their apparent common aim, i.e. the understanding of early man, these two disciplines historically have been divided both by subject matter and by theoretical orientation. An interdisciplinary approach to palaeoanthropology is based on the expanding application of physical (especially ecological) concepts to the study of early man. Palaeoanthropology brings new light to the scientific community regarding human evolution each time a new fossil is discovered.

4.2 DEFINITIONS OF PALAEOANTHROPOLOGY

The meaning of the word palaeoanthropology is lexically deciphered as ‘palaeo’ (meaning ancient) + ‘anthropos’ (meaning man) + ‘ology’ (meaning science). It is the science that deals with the study of evolution of man by unearthing the fossilised remains left by our early ancestors.

Palaeoanthropology has been defined firstly by Comas (1960) as “the study of hominid and anthropoid fossil remains, their proper interpretation and consequently, the possible establishment of phylogeny for our own species”. Howell (1967) defined palaeoanthropology in a much better way as “investigation of biological relationships and the evolutionary history of the Hominidae and of the developments among the Hominidae the capacities and capabilities for culture”.

4.3 PRINCIPLES OF PALAEOANTHROPOLOGY

Any palaeoanthropologist should always have at least the following six principles/objectives in mind while dealing with the subject of palaeoanthropology.

- ❖ Identification
- ❖ Form and function
- ❖ Associations of plants and animals
- ❖ Evolution in the different groups of organisms
- ❖ Dispersal and distribution of plants and animals in time and space and
- ❖ Correlation

Identification

Any investigator must know as precisely as possible what he is dealing with since inaccurate information leads to erroneous conclusions. Frequently the fossil is too incomplete or the group to which it belongs is not known well enough for species identifications. Nevertheless, class, order and family can usually be recognised by any one conversant with his field of study. For this careful comparison is needed. If the species can be recognised, the specimens will be much more useful than if only their generic status can be established. Identification will be done by recognising the class, order and family and not only so, better identification can go up to genus and species level.

Example: Identification is done only if we know the anatomical details of any fossil specimen which we are dealing with. The dentition of fossil equids (*Equus* and *Hipparion*) although are very similar but one must be able to distinguish between genus *Equus* and *Hipparion*. In case of upper molars of *Hipparion*, the

protocone is isolated but it is united and continuous in *Equus*. The morphological details between the genera can lead to correct identification otherwise it may lead to wrong conclusions.

Form and function

By studying the structure of a fossil and drawing a parallel with living organisms the habits of extinct primates as well as other animals or plants can be realised. The form of the fossil then offers clues to how it functioned in the environment in which it lived.

Example: Man's pelvis (hip bone) is designed to transmit weight from the trunk to the legs in comparison to the pelvis of the quadrupeds or brachiators (animals who walk on four toes). The early human fossils indicate that such modification of structure of pelvis over those of quadrupeds and brachiators was responsible for bipedalism (walking erect on two legs as is done by the humans).

Associations of plants and animals

Assemblages of plants and animals and the nature of the sediments in which they are entombed offer evidence of local environmental conditions of the past. It must be realised that fossils are not dead objects in the eyes of a palaeoanthropologist because he visualises them as they existed in their environment in the past.

Example: The palaeoecological conditions of fossil primates (Adapoid primates, *Ramapithecus*, *Sivapithecus* and *Gigantopithecus*, etc.) known from India and elsewhere can be reconstructed by taking into consideration both faunal and floral remains. It is also possible to reconstruct the community structure as well as inter and intra specific competition for food and space amongst various groups during the ancient time.

Evolution in the different groups of organisms

It has been shown that any type of plant and animal developed from an earlier and simpler ancestral form by transmission and change of hereditary characters. Changes were more rapid in some groups of organisms and slow in others or they may have been greatly accelerated in some at certain times. Some groups of marsupials (pouched animals) like the *Opossum* and fish with lung like structures have changed very little in the last 100 million years or more.

Example: The cranial capacity of our ancestors has gradually increased from 5 million years to 2 million years (350 to 400 cc) and then from 780 to 1020 cc by 1.8 million years before present and ultimately up to 1300 cc in the present day man. So the cranial capacity has greatly been accelerated in *Australopithecus* to *Homo erectus* and *Homo erectus* to *Homo neanderthalensis* and finally to *Homo sapiens sapiens* (i.e., from 350 to 1300 cc).

Dispersal and distribution of plants and animals in time and space

Much of the evidence for dispersal and distribution is based on the evolutionary progression of animals and plants in the orders, families and genera and the occurrence of their fossils in the rock sequence of the earth crust.

Example: Most primitive primates, i.e. the Pleisadapoid and Adapoid primates which originated and lived during the Eocene and Paleocene of America and

Europe later on dispersed and migrated to reach the Indian subcontinent as well as China during the Miocene times. From Miocene onwards these primitive primates might have branched to give rise to monkeys, apes and finally man.

Correlation

Much of the palaeoanthropologist's time is spent in efforts to recognise synchrony of biological and geological events demonstrated by evidences in the rock units of the earth's crust and in determining whether these events occurred in different continents or in adjacent mountains and valleys. The biological events demonstrated by the black Hawk Ranch fauna may be fairly clear in one's mind, but palaeoanthropologist would want to know what kind of primates, animals and plants were living in the other parts of world, that is, Europe, America and Australia. So a correlation between the areas of one particular region may not be different, because of the proximity of the two areas and they may have numerous genera and species in common. However, it is difficult to correlate different continents since the distance between them is greater and in all probability no primate species could be found in these different continents.

Example: It is thought that the North America, South America and Australia were once connected with each other but following the geographic separation the *Opossum* developed into various marsupials which now inhabit Australia. The time of their migration is not well known yet.

4.4 SCOPE OF PALAEOANTHROPOLOGY

Every science is beneficial to the human being in one way or the other. Palaeoanthropology is also very useful in the following ways.

- ❖ Education and Relaxation
- ❖ Economic applications
- ❖ Knowledge of past nature

Education and Relaxation

People show great interest in knowing about the past life, their culture, habits, etc. This is well demonstrated by thousands of people who visit museums throughout the world to see something of the past life and some other forms of life, which is truly unknown to them. Palaeoanthropology helps in satisfying curiosity of general public about the evolution of the mankind and other major mammals. Palaeoanthropology also finds application in exhibiting the fossils in the museums for display purposes as well as it also provides great relaxation to the palaeoanthropologist when he finds some rare fossil primate including other mammals that no man has ever found.

Economic applications

Knowledge of the fossils as a guide to the sequence of rocks in the earth's crust has been used in locating gold and other ore-deposits, for example, gold occurs in auriferous conglomerate at the base of the Cambrian over vast areas in Australia. Proximity to these gold bearing formations can be determined by the age of the fossils in the overlying sedimentary rocks. Coal beds have been located by similar methods in the U.S.A and elsewhere. When polished, many limestone and fine grained sandstones with well preserved fossils make some of the most beautiful

interior wall surfaces. Rich concentrations of uranium in fossil wood have also been discovered. Bones of dinosaur and other mammals also contain uranium.

Knowledge of past nature

Palaeoanthropologist with their knowledge of the past life can reconstruct the palaeology, 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. Most of the knowledge about the climatic conditions in the geological past comes from the study of fossils.

4.5 HUMAN EVOLUTION WITH RESPECT TO HOMINID FOSSILS

Human evolution is a lengthy process. The origin of man on this planet is a topic of great curiosity to researchers as well as to common man, as new fossils are discovered every year. Fossil evidence shows that the physical and behavioural traits shared by all people originated from ape-like ancestors and evolved over a period of at least 5 to 6 million years ago.

The subject matter and problem of human evolution as well as the human origins has long fascinated the common man in general and the scientific world in particular. Palaeoanthropologists have of late made significant discoveries in Asia, Europe and Africa and elsewhere inferring relationship between man, apes and monkeys in order to document the human evolution. On the basis of these discoveries it has been possible to reconstruct various bodily dimensions and also to identify major evolutionary trends responsible for transformation from lower to higher primates. It is also important to gain an insight into the ecological setting from which man evolved million of years ago.

Some questions which are being asked by every man and in every age are what is the age of our planet? Or for that matter, also the duration of the history of man on this planet along with their planetary spread.

The most telling evidence in support of the evolution of man as a continuous biological phenomenon is supplied by palaeoanthropology. The reconstruction of the story of evolution of man is a great jigsaw puzzle because to fit all pieces of fossil evidence together is not an easy task. Consequent upon important additions in the primate fossil record as well as the progress made in molecular phylogenetics in the last almost one and half decades have witnessed some significant changes in our understanding of the origins and evolution of not only man, but also great apes from the common hominoid stock.

There are two categories of scientists: lumpers and splitters, depending upon the usage of different types of methodologies and theoretical stand adopted by them. There has been a lot of confusion in the mammalian taxonomy including those of primates and it will continue until such time they are viewed as biological entities that lived through time and space. Many scientists including anthropologists dealing with fossil primates view the morphological differences only in terms of new species/generas even when a lot of morphological and statistical variability exists which in turn is attributable to aspects like sex, age,

population size, etc. The need of the time is that they have to be found consistent with observed as well as predictable behavioural and ecological patterns of the primates in time and space. The primate fossil record is poor and within it, the record of fossil man is still poorer.

4.6 RAMAPITHECUS

Class	Mammalia	Linnaeus, 1758
Sub class	Theria	Parker and Haswell, 1897
Infra class	Eutheria	Gill, 1878
Order	Primates	Linnaeus, 1758
Suborder	Anthropoidea	Mivart, 1864
Family	Hominidae	Gray, 1825
Genus	<i>Ramapithecus</i>	Lewis, 1934

Time and space: Middle and late Miocene.

Distribution: India, Pakistan, China, Kenya, Hungary, Turkey, Germany.

Known Species: Following species (a taxonomic category below the genus. Theoretically members breed with one another but not with members of another species) are included under genus *Ramapithecus*.

1) *Ramapithecus punjabicus* Pilgrim, 1910

Localities: Nagri Haritalyanagar, Ramnagar, Chinji, Kanatti, Sethi Nagari and Gondakas Hsiaolungtan, Rudabanya, Melchingen.

2) *Ramapithecus wickeri* Louis Leakey, 1962

Localities: Pasalar, Maboko, Candir, Fort Ternan.

Diagnosis

Lewis (1934) diagnosed *Ramapithecus* as a “Small primate with delicate jaws and teeth. Jaws short, dentition approaches the human type; dental arch divergent; face only slightly prognathous; no diastema in dental series; incisors relatively small, canines very small, root of upper canine ellipsoidal in cross-section, with long axis normal to dental arch; upper premolars progressive; molar cusps broad and rounded and of medium relief, side walls of molar crowns relatively steep and crowns of medium height”.

Later Szalay and Delson (1979) diagnosed the same genus (a taxonomic category between the family and species) mainly on the basis of jaws and teeth. *Ramapithecus* shares characters with Sugriviapithecini with a complex of broad, thick-enameled, rather high crowned cheek teeth, and apparently large cheek teeth. *Ramapithecus* shares with other hominines further reduction of canine crown height and general incisor size; which is partly incorporated into the incisor row, the mandible robust, but not very deep, while the maxillary alveolar processes are deep and inflated, and the cheek teeth may have quite vertical sides and low relief, the extreme reduction of incisors and narrow palate with elongated tooth-rows.

General description

Ramapithecus can be described as a relatively small hominid sharing certain derived characters only with Homininae; most of the reported fossils are fragmentary dental and jaw elements, with broad thick enamel, rather high crowned cheek teeth and low anterior pre-molars. In addition to these, *Ramapithecus* also shares few characters with other hominines and with *Gigantopithecus* in having a small metaconid on lower anterior pre-molar as well as further reduction of crown height and general incisor size. It is, however, distinguished from *Gigantopithecus* and linked to hominines by the role of canine which is partly incorporated into the incisor role rather than assuming occlusal function with anterior premolar. The mandible of *Ramapithecus* is robust, but not very deep and inflated, cheek teeth have relatively vertical walls (sides) with low relief.

Phlogenetic status

The taxonomic position of the genus *Ramapithecus* has been a subject of discussion. It has recently been widely considered as Miocene ancestor of hominines, but the evidence does not yet permit the ready acceptance of this view. Instead, it would appear that *Ramapithecus* shares a number of features only with later hominines and thus can be considered the sister-genus of *Australopithecus* and *Homo*, of course among known genera. Due to paucity of fossil remains of *Ramapithecus* there is and was a lot of controversy as to its taxonomic status.

It was Lewis (1934) who described and created a new genus i.e. *Ramapithecus* discovered from Haritalyangar situated in the Bilaspur district of Himachal Pradesh, Northern India; and classified the same as a Pongid but also emphasised that it displayed some human traits. Later in the years 1960 and 1961, Simons after careful consideration of *Ramapithecus* material treated it to be the earliest known hominid in the world. Similar finds came from Southern Germany in North Central Spain, Hungry, Candir (Turkey), China and Kenya, among others.

Now with the acceptance of the time scale presented by the immunological evidence; a more and more complete fossil record as well as further analysis of these remains from China and Siwaliks of Pakistan, there has now been an almost consensus amongst a select group of researchers that *Ramapithecus* was non hominid and needs to be included under the genus *Sivapithecus* known from the Siwalik deposits of the Indian subcontinent. This has happened as a result of the discovery of more complete skull and mandibular material as well as some postcranial remains. Due to the fact that *Ramapithecus* and *Sivapithecus* are almost indistinguishable from each other that is why all the fossil *Ramapithecus* remains are now synonymized under the genus *Sivapithecus*. The genus *Sivapithecus* also has a priority in the literature because it was created in the year 1910, while *Ramapithecus* was created in 1934.

The pongids and hominids cannot be distinguished on the basis of dentition; postcranial remains can be of great importance to assign the fossil specimen to either Pongid or Hominid lineage. Much more material of the genus *Ramapithecus* is required before more definite suggestions can be made out of the genus.

Finally the phylogentic status of Siwalik fossil specimens once assigned to the genus *Ramapithecus* are now considered by most researchers to belong to one or

more species of *Sivapithecus* and is no longer regarded as an ancestral form of hominids or the earliest known hominid in the world.

4.7 AUSTRALOPITHECUS

Family	Hominidae	Gray, 1825
Subfamily	Homininae	Linnaeus, 1758
Genus	<i>Australopithecus</i>	Dart, 1925

Time and space: Pliocene to early Pleistocene.

Distribution: Southern and Eastern Africa

Included Subgenera:

Australopithecus (Australopithecus) Dart, 1925 and *Australopithecus (Paranthropus)*

I) *Australopithecus (Australopithecus)* Dart, 1925

Distribution: Later Pliocene, Southern and Eastern Africa.

Known Species: *Australopithecus (Australopithecus) africanus* Dart, 1925

Localities: Laetolil, Omo Usno, Shungura member, Hadar, Makapan, Sterkfontein, East Rudolf Koobi Fora Lower member, Taung, Olduvai Bed I.

II) *Australopithecus (Paranthropus)* Broom, 1938

Distribution: Late Pliocene to Early Pleistocene, Southern and Eastern Africa.

Known Species: *Australopithecus (Paranthropus) robustus*, Broom, 1938

Localities: East Rudolf Koobi Fora Lower member, Omo Shungura, Olduvai Bed-I, Lower Bed II, Swartkrans, Peninj, Kromdraai, Chesowanja.

Diagnosis

Australopithecus basically shares the major morphologically derived characters of the Homininae, including large brain to body weight ratio, large posterior and relatively small anterior dentition, with canines not honing but incisiform, parabolic dental arcades, flexion of the cranial base and increasing cranial height, anterior placement of the foramen magnum, development of upright, bipedal posture as reflected in the pelvis, femur, and lumbar vertebrae, elongated lower limb compared to body size (referring to the fact that growth in some parts of the body is related to growth in other parts e.g. cranial and cerebral) and compaction of the foot with loss of hallux mobility.

From *Homo*, *Australopithecus* is differentiated by smaller estimated body size, relatively and absolutely small brain size (range 400-600+ cc); absolutely and relatively large teeth, especially molars and premolars, face much larger as compared to neurocranium with anterior placed sagittal crest in most robust individuals, maximum calvarial width about at mastoid level, mandibular fossa transversally elongated and especially laterally positioned; supraorbital tori prominent, but neither massive nor incorporated into steep frontal bone, nasal bones “V” – upwards toward glabella, mandible more massive with internal

contour either “V” or pointed “U” – shaped not an “open –U”, stronger internal tori and longer alveolar planum, corpus deepening somewhat mesially somewhat more constant in depth; in fact more distinct sexual dimorphism, particularly in canine and other dental dimensions; pelvis with relatively small sacroiliac articular surface and acetabulum, relatively large iliac fossa, and widely splayed iliac blades; femur with relatively small head, long neck, and low neck angle, and possibly, relatively long forelimbs, at least in robust forms.

Description

The bones of the skull are relatively thin, cranial capacity usually ranges between 442 and 530 cc, braincase lacks the high vertical forehead of *Homo sapiens* and high roundness of the skull vault. From the back, the widest point of the skull is quite low on the brain case. The suture between the nasal and frontal bones has the shape of an upside-down V. The brow ridges are poorly developed and behind the brow ridges is a notable postorbital constriction. The facial skeleton is large relative to the size of the brain case, often assuming a concave or dish shaped contour. The jaw is relatively large, as are the jaw muscles. This is reflected in the development of a sagittal crest in some individuals and the expansion and flaring of the zygomatic arches. The molars and premolars are relatively large, while the canines are small relative to the premolars. The pelvis is bowl-shaped and shortened from top to bottom, similar in basic structure to the pelvis of *Homo sapiens*. Evidence from pelvis, leg and foot bones leaves no doubt that *Australopithecus* was perhaps an erect biped.

Phylogenetic status

Australopithecines were morphologically diverse group; the diversity is indicated by the various taxonomic schemes devised to accommodate their numbers. Different researchers have different ideas, most of the ‘lumpers’ recognise only one genus called *Australopithecus* to accommodate at least four distinct species at present i.e. *Australopithecus africanus* in South Africa, *Australopithecus robustus* in East Africa, *Australopithecus afarensis* in Hadar (Ethiopia) and Laetoli (Tanzania) and *Australopithecus ramidus* in Afar (Ethiopia) region.

The overall pattern of early human evolution in Africa appears to have taken the following course. First was the early *Australopithecus ramidus*, the apparent ancestral stock which appeared about 5 to 6 million years before present; later came another smaller but better developed form, *Australopithecus afarensis* which appeared around 3.75 million years ago; after that came the gracile and robust forms i.e. *Australopithecus africanus* and *Australopithecus robustus* which appeared about 2 to 1 million years before present, respectively.

Some investigators argue that the important differences in dental proportions between *Australopithecus africanus* and *Australopithecus robustus*, the gracile and robust forms, respectively, do not correspond with allometric trends noted among modern primates. According to them these differences may be morphologically significant adaptations, perhaps indicating dietary modifications or may be even social behaviour.

The genus *Homo* appeared to be and was apparently the descendant of one of the *Australopithecus* forms, but, it is still not clear what led to the evolution of the genus *Homo*. The phylogenetic position of *Australopithecus* is quite clear that it

is a hominid and that is why it is included under the subfamily Homininae and the family Hominidae to which the present day humans also belong.

General Description

Raymond Dart, a young Professor of Anatomy at Johannesburg on 7th Feb, 1925 announced the discovery of an early Pliocene- Pleistocene hominid with a small brain case. The general reaction of the world was one of the disbelief at that time. The type specimen, an infant skull (about six years old), was discovered in the end of year 1924 by workers in a lime stone quarry at Taung (Ta- ung = place of lion), in what is now Botswana, South Africa. Dart named his find as *Australopithecus africanus* (Southern African ape) and mentioned the many ape-like feature of the skull including the small size of the brain (380- 500 c.c) and pointed to its pongid affinities; albeit he also emphasised the fact that there were a number of features of the skull and the dentition which were man-like. He placed this new genus and species in a family intermediate between hominids and pongids i.e. *Homo-simiidae*. It took Dart 73 days to work the skull out of lime stone matrix and a total of four years to separate the lower jaw from the rest of skull and it was in this year i.e. 1929 that his judgment was strikingly vindicated and an unquestionably hominid dentition was revealed. The teeth of the juvenile are very large, but morphologically similar to those of later hominids. No more hominids were discovered at Taung and unfortunately now this fossil site has been destroyed by quarry operations.

The gracile type and the robust forms of *Australopithecus* can be differentiated as follows. The gracile form is small and light (20-40 kg), with an estimated stature of 145 cm (4 feet and 9 inches). Its estimated cranial capacity is 442 cm³. The facial skeleton is small, but the jaws are large in proportion to the rest of the skull. The disk shaped profile is obvious. Gracile forms mostly occur between 3 and 2 millions of years before present. On the other hand, the robust form is larger and more heavily built (35-55 kg). Its estimated stature is 153 cm (5 feet) and the average cranial capacity is 530 cm³. The heavier jaw of robust form is associated with very large molar and premolars but relatively small incisors and canines. The massiveness of the jaw musculature is seen in the frequent development of a sagittal crest. The above variability can be explained on the basis of generic or species or subspecies or geographic variation or sexual dimorphism or dietary differences. The robust forms range between 2.1 and 1.3 million years before present.

4.8 HOMO ERECTUS

Family	Hominidae	Gray, 1825
Subfamily	Homininae	Linnaeus, 1758
Genus	<i>Homo</i>	Linnaeus, 1758
Species	<i>Homo erectus</i>	Dubois, 1891

Time and Space: 1.8 million years ago to 150,000 years ago.

Distribution: Asia, Africa and Europe.

Known Subspecies

The following subspecies (subdivision of a species, consisting of individuals in a given geographical area, which differ slightly from, but which can interbreed

with other subspecies of the same species) are included under the *Homo erectus*.

Homo erectus javanensis Eugene Dubois, 1891

Locality: Trinil (Java)

Homo erectus pekiensis

Locality: Choukoutien (China)

Homo erectus narmadensis Arun Sonakia, 1984

Locality: Hathnnora (India)

Besides the above subspecies known from Asia, *Homo erectus* is also known from Africa and Europe. The various localities are listed below.

Localities in Africa: Swartkrans (South Africa) Olduvai Gorge, Koobi fora, Ndutu, Afar region (East Africa) Morocco and Algeria (North Africa)

Localities in Europe: Heidelberg (Germany), Vertesszollos (Hungary),

Greece- Petralona (Greece), Prezletice (Czechoslovakia) and Vergranne (France)

Diagnosis

Skull is large, with pronounced bony relief and predominance of facial region over cranial. Cranial capacity is 750-1200 cm³ with a mean of 929 cm³. Skull roof flattened; forehead falls away strongly rearwards; occipital region bulges rearwards in the form of chignon. Maximum length of braincase 175-182 mm; maximum breadth (found at the base of skull) 126-131mm, height of cranial cavity 90-100 mm, sharp postorbital constriction and walls of braincase thick to very thick are observed. Supraorbital ridge shaped like an awning, sharply projecting and thickened towards sides; occipital ridge well developed. Upper edge of squamosal slightly curved; mastoid processes small. Palate about 80 mm, face more prognathic (forward protrusion of lower face and jaw) than in modern populations. Lower jaw was massive, with high and thick horisontal branch and without a trace of mental prominence, ascending ramus broad to very broad and low, a small diastema in the upper teeth, teeth large and human type, femur about 450 mm long with completely straight diaphysis and well-marked linea aspera.

General Description

Based on the various skeletal remains known from various parts of Asia, Africa and Europe, *Homo erectus* shows a marked flattening of skull vault which is noticeable besides the sagittal ridge that runs across the skull midline meant for attachment of large chewing muscles. The bones of the skull are quite thick. The greatest width of the skull is low on the skull vault. The cranial capacity in *Homo erectus* varies from 700-1200 cc, lower values are found among earlier representatives and higher values among later representatives of this genus and species. The mean cranial value in Asian skulls comes to 929 cc. The face of *Homo erectus* is characterised by large brow ridges above the eye orbits and behind these large brow ridges the skull is marked by postorbital constriction. The nasal bones are broad and flat and the face is more prognathic in comparison to modern man. The mandible is heavily constructed and lacks chin. The teeth are larger than those found in the present day man. The canines are sometimes slightly projecting with a small diastema (a gap) in the upper dentition. The first lower premolar is bicuspid with sub equal cusps. The second upper molar may

be larger than the first and the length of the third molar may exceed the second molar. The mandible is also reduced in size. The limb bones are essentially modern.

Phylogenetic status

The definition of *Homo* has been enlarged to accommodate all *erectus* species from Asia, Africa and Europe with only distinctions at the subspecies level such as *Homo erectus javanensis* (Java), *Homo erectus pekiensis* (China) and *Homo erectus narmadensis* (India). Phylogenetically speaking there is only one genus and one species with different subspecies belonging to different geographical areas, which may differ slightly from each other, but which can interbreed with other subspecies of the same species. The Asian remains assigned to *Homo erectus* exhibit common morphological characters. The oldest sample of *Homo erectus* appears in East Africa (dated 1.9 or 1.8 million years ago) while the Asian dates are more of the order of 400,000 to 300,000 years ago.

This genus and species is probably the intermediate evolutionary step between the lower Pleistocene *Homo habilis* and *Homo sapiens*. Although the line is still quite hazy but some fragments of the transition can be seen in Africa, Asia and Europe. A minority opinion states that *Homo erectus* was not on the direct evolutionary line of *Homo sapiens* and some suggests that human evolution bypassed *Homo erectus* in Asia. Although this means *Homo sapiens* arose directly from African *Homo habilis* but further information and evidences are still awaited to settle this point.

General Description

The first evidence of *Homo erectus* was discovered at Trinil along Solo river in central Java by Eugene Dubois in 1891. Dubois named his find as *Pithecanthropus erectus* meaning 'The Erect Ape-Man' because the fossil femur resembled that of the modern *Homo*. Later, this species was renamed as *Homo erectus javanensis*. The *Homo erectus* seems to have been cave dweller and was big-game hunter associated with the Acheulean tool tradition. There are evidences of fire use. Cooking of meat suggests that less food was eaten on the spot and more carried back to the camp. The *Homo erectus* thus represents a level of cultural adaptation that allowed its possessors to expand into new niches.

Morphologically *Homo erectus* conforms very well with the theoretical postulates for an intermediate stage in the evolution of later hominids. In addition to this, the existence of *Homo erectus* in the early part of the Pleistocene, antedating any well-authenticated *Homo sapiens*, also provides it with an antiquity conforming well to its supposed phylogentic relation. Some of the *Homo erectus* materials illustrate a satisfactory graded series of morphological change from one type to another and is probably chronologically and morphologically intermediate between the Lower Pleistocene *Homo habilis* and *Homo sapiens*.

4.9 HOMO NEANDERTHALENSIS

Family	Hominidae	Gray, 1825
Subfamily	Homininae	Linnaeus, 1758
Genus	<i>Homo</i>	Linnaeus, 1758

Species *Homo sapiens neanderthalensis* King, 1864

Time and space: 75,000 to 35,000 years ago.

Distribution: Europe and the near East and possibly Asia.

Diagnosis

The Neanderthal face is extraordinarily robust, had a receding chin (or lacking chin), large cheek bones, prominent brow ridges connected across the nasal bridge, and a large nasal cavity (possibly an adaptation to the cold); have very large canines and incisors relative to their molars and premolars; face and jaw morphology may have been shaped by their use of the front teeth as tools; teeth are arranged in a very broad U-shaped arch with the canines set in the curve rather than on the sides of the arch, they are not projecting; lower jaws are massive without simian-shelf; the skulls were more capacious than those of modern populations; the zygomatic arches which encloses the temporal fossae are stouter and much less curved than in modern man. Their brains were larger than ours; the cranial capacity varies from 1300-1600 cc, skull was shaped differently than ours: it had a low crown and bulged on the side and back; a characteristic trait was the presence of an occipital 'bun' at the rear of the skull; another frequent feature of Neanderthal molars was taurodontism (enlarged molar root cavity and perhaps fusion of the molar roots); the bones of the trunk and limbs are well preserved; pelvis was very high relative to its breadth, the iliac blades were much flattened; the collar bones are long and arched.

General Description

Broadly defined, the Neanderthals and their culture have been traced from Near East, Africa, Europe and possibly Asia.

Western European Neanderthal remains are found in sheltered and well watered valleys of Southern France and similar parts of the Spanish and Italian peninsulars. Neanderthals can be described as having large cranial capacities, ranging from 1525 to 1640 cc in males and 1300 to 1425 cc in females. The skulls are more capacious. Neanderthal cranium has lower, flatter crown. Occipital bun which is usually present has always been considered to be a Neanderthal trait. In addition to this form major traits distinguish the Neanderthal face i.e. chin is definitely receding or is absent, there are large cheek bones, the prominent brow ridges curve over the eye orbits and connect across the bridge of the nose and there is rather large nose and nasal prognathism. Their jaws and teeth also have some distinguishing traits, such as, the jaws are usually large, the structure of teeth is as in present day man but are large in size. Major distinction occurs in incisors and canines, their anterior dentitions are differently larger than modern *Homo sapiens* especially in breadth. Neanderthal postcranial skeletons mark them as having been short, powerfully built individuals when compared with modern human populations. They were just over five feet tall, their extremities were short and stubby and their feet similar to ours.

Phylogenetic status

The neanderthal problem regarding its phylogenetic status has been circulating for many years and some of the major questions are these: What is the evolutionary position of the western European Neanderthals? Were they too specialised to be in our evolutionary lineage? How does one interpret the intrapopulation and

interpopulation variability? In which areas of the world did *Homo sapiens sapiens* evolve?

Although some answers to these questions are becoming clearer with the discovery of new forms and the re-examination of others; other questions are becoming more difficult to answer. Earlier the term Neanderthal was originally applied to, and designed to describe, forms from Western Europe only, but now it is used to describe a wide array of fossils, many of which barely resemble the original material.

There are conflicting view points concerning the taxonomic placement of the western European Neanderthals. Some designate them as a separate species, *Homo neanderthalensis*; most others refer to them as *Homo sapiens neanderthalensis*. A major reason for this disagreement is the recognition of transitional forms that cannot be satisfactorily assigned to either the Neanderthal or archaic *Homo sapiens sapiens*.

Concerning the various interpretations of the Neanderthal material, the unilinear school advocated by Hrdlicka (1927) was first to be proposed. This theory argues that modern *Homo sapiens sapiens* arose directly through a number of evolutionary stages, including the Neanderthals. It eliminates extensive side branching and discounts most cases of argued extinction and vigorously argues that the Neanderthal population, as typified in western Europe, formed a large part and parcel of the genetic ancestry of modern *Homo sapiens*.

The two other view points, Preneanderthal and Presapiens (A theory suggesting that *Homo sapiens* is a distinct, completely separate line from that leading to the Neanderthals) school (Keith, 1925, Nallois, 1958) have much in common. Both spilt the main stem of human evolution back to the time of Steinheim man and Swanscombe man. Both consider western European Neanderthals to be dead ends in human evolution, becoming extinct as the climatic conditions to which they were adapted ameliorated. The Presapiens school, suggest that modern *Homo sapiens* originated as distinct lineage, completely separate from the line leading to the Neanderthals. Unlike the Preneanderthal school, the Presapiens school holds that this divergence occurred before the Eemian Interglacial, if not before the Mindel glacial. Both schools employ the same evidence but differently. Some adherents of the Presapiens school argue that Steinheim man led to the Neanderthal population and that Swanscombe man, through Fontchevade man, led to modern *Homo sapiens*.

Adherents of the Preneanderthal school view Steinheim man and Swanscombe man as leading to another interglacial stem, for example, Ehringsdorf man, of a basically Neanderthal nature. In this view, there was a broad and varying population, one segment of which was an isolated European cold-adapted group (the western European Neanderthals): the other segment inhabited the Near East and become modern *Homo sapiens*. There are three morphological bases for the Preneanderthal schools the so-called “overspecialisation” Neanderthals into “modern” Upper Palaeolithic populations within a short time, and the coexistence in other parts of the world of more modern-looking populations. The factor-appearance of more modern-looking humans in other parts of the world is essentially correct.

It is now generally recognised that the Neanderthals were a worldwide grade intermediate between the earliest *Homo sapiens* and the earliest *Homo sapiens sapiens* samples. The Neanderthal ancestors of *Homo sapiens sapiens* were forms possessing modern-size brains coupled with an archaic-looking skull. The time span of this group was from about 75,000 or perhaps 100,000 to 35,000 years ago. The earliest possible ancestors of the European Neanderthals may be represented by the Saccopastore and Krapina samples. These skulls show some typical Neanderthal facial features, although the most complete specimens are small brained compared to the later Neanderthals.

Recent redating of the Mousterian (Cultural assemblage commonly associated with the Neanderthals) stone tool assemblage has not only doubled the time span of the Mousterian but also expanded the time span of the Mousterian tool manufactures, the Neanderthal man. The redating suggests that the period between the last Neanderthals and emergence of *Homo sapiens sapiens* was long enough for the evolution of *Homo sapiens neanderthalensis* into *Homo sapiens sapiens*. This calls into question the view that the Neanderthals disappeared after immigration of modern *Homo sapiens* into Europe. The redating also suggest that Mousterian industries remained virtually unchanged over a long time period, in marked contrast to the speed with which modern *Homo sapiens* tool industries advanced during the Upper Palaeolithic times. This suggests fundamental differences in Neanderthals and modern *Homo sapiens* societies that make it more difficult to see how one could have evolved into the other.

General Description

The first described Neanderthal find came from Germany in 1856. Further finds came to light in 1866 when a jaw accompanied by a Mousterian cultural assemblage was recovered from a Belgian cave. In 1886 two additional skeletons appeared from Spy cave in Belgium. Their culture was Mousterian which itself is a complex derivative of earlier tool making complexes. Most of the European Neanderthal material was recovered from the Dordogne region of southwestern France. Other finds came from Spain, Italy, southeastern Europe, Russia and Turkey. Until the 1930s it was assumed that European Neanderthals were slowly driven to extinction by subsequent populations.

Neanderthals have been classified into three main types as under:

- 1) Western European (Classic) Neanderthals
- 2) Central and Eastern European Neanderthals
- 3) Eastern (Progressive) Neanderthals

Neanderthals were a heterogeneous population with more capacious skulls than those of modern populations, accommodating a larger brain than common to modern *Homo*. The skull shows a lower crown and a bun shaped protuberant occiput besides a bulging on the side and back.

The face of Neanderthal man can be distinguished by a receding chin or lacking the same, large cheeks besides prominent brow ridges curving over the eyes and connected across the bridge of the nose. The nose appear to be large and it may a functional adaptation to severe climates, serving to warm and moisten inhaled air, since in cold climates the brain can be endangered by inhalation of cold air. The jaws are large and give evidence of strong muscle attachments and even

certain dental traits suggest use of teeth as tools. The incisors are broader than those in modern populations and may have been important tools in environmental manipulation. Lower jaws are massive and without simian-shelf. Teeth are arranged in a very broad U-shaped arch with the canines set in the curve rather than on the sides of the arch. They are also not projecting. The cranial capacities were large, ranging from 1525- 1640 cc in six male skulls and 1300 to 1425 cc in three female skulls. On an average the cranial capacity varies from 1300-1600 cc. The zygomatic arch which encloses the temporal fossae is stouter and much less curved than in modern man. The postglenoid process is large and keeps the mandibular condyle from butting against the ring like tympanic bone. The mastoid process is small and almost rudimentary. European Neanderthal postcranial skeletons mark them as short, powerfully built individuals just over five feet tall. Their extremities were short; the hands and fingers were short and stubby. Their feet were similar to ours, since we have a remarkably preserved Neanderthal foot print cast in the wet clay of an Italian cave. The spine is short and massive. Pelvis bone generally show hominid features. The pelvis was very high relative to its breadth. The iliac blades were much flattened. The collar bones are long and arched. Some researchers suggest that Neanderthals may have weighed 160 pounds or more.

Phylogentic status

Although less numerous remains were discovered from East and Central Europe than from Western Europe, nevertheless they are very important. New fossil finds from this area have filled some of the geographical and chronological gaps in the fossil record. They have also blurred the boundary between classical European Neanderthals and fully modern *Homo sapiens* populations. Major eastern and central European materials come from Czechoslovakia and Hungary. Some refer to them as transitional specimens, between modern and Neanderthal populations.

Taxonomically speaking the transitional status of these materials suggests that hominid evolution in eastern and central Europe was proceeding towards modern *Homo*. The transitional forms are important since they display many traits found in anatomically modern populations to varying degree. Chronologically, it extend to the time period in which the oldest finds of fully modern *Homo sapiens* appear even forms designated fully modern *Homo sapiens* exhibit some cultural and morphological links to the past.

Such findings indicate that the appearance of *Homo sapiens sapiens* in Central and Western Europe need not be explained in terms of a sudden east to west migration but rather as local evolution in Neanderthal populations sharing basic traits but differing in intensity and detail. As far as the Middle Eastern (Progressive) Neanderthal are concerned some of the Middle Eastern populations appear to be transitional. Middle Eastern forms are considered to be the members of a late non-cold adapted Neanderthal group imperceptibly grading into fully modern *Homo sapiens sapiens*. The most complete finds come from Israel and Iraq; other remains come from six caves listed below.

Zuttiya near the Sea of Galilee

Tabun and Skhul at Mount Carmel.

Jebel Gafza near Nazareth.

Shukba, 17 miles northwest of Jerusalem.

And Amud near Lake Tiberias.

Although from the same geographical area and dating from approximately the same time period, the skulls differ from one another. The richest and deepest fossil sites are in areas where vegetation and game were most abundant. They can be seen at two major sites at Mount Carmel viz., the Cave of et-Tabun (Cave of the oven) and Cave of es-Skhul (Cave of the Kids).

It is difficult to generalise about the skeletal characteristics of Near Eastern and Central Asian Populations contemporaneous with the Neanderthals of Europe. Some specimens' like-Tabun, Shanidar and Amud shared more features with western Neanderthals than did Skhul. It has been suggested that physical differences in the populations of the Near East and Central Asia may be of the order of subspecific (or) racial variation. These populations constitute one part of the species range that had more ties with the western European Neanderthals and another variety with closer ties with populations in the direct line to Upper and post-palaeolithic *Homo sapiens*.

The results of experiments on the effect of cold on the skin temperature suggest that reduced frontal sinus area and an exposed nose and streamlined malar region all Neanderthal features, act to reduce the effects of chilling. Relatively short limbs are also features of modern human populations adapted to cold climates. The broad anterior teeth, combined with reduced size of the cheek teeth and lung, strongly buttressed cranium of the Neanderthals have been proposed as unified response to the use of teeth for holding and fixing objects during tool manufacture and food preparation.

4.10 HOMO SAPIENS

Family	Hominidae	Gray, 1825
Subfamily	Homininae	Linnaeus, 1758
Genus	<i>Homo</i>	Linnaeus, 1758
Species	<i>Homo sapiens sapiens</i>	

Time and space: 40,000- 10,000 years ago.

Distribution They appeared in various places of Europe, Africa, Asia and Australia and the Americas.

Diagnosis

Because of the burial practices, many almost complete skeletons are preserved and available for study and description. The diagnosis of *Homo* depends, to a greater extent than usual on which specimens are included in the genus. The diagnosis given is rather broad and major distinguishing features of *Homo* are: The skull is high and well rounded. The forehead rises vertically above the eye orbits and does not slope as in Neanderthal. The brow ridges are small. The face does not protrude very much (an orthognathic face) and a strong chin is evident. Modern humans have small faces tucked under enlarged brain cases. They possessed large heads with modern cranial capacities (1300 to 1600 cc approximately) wide faces, prominent chin's and high bridged noses. The teeth progressively become reduced in size, a change that is synchronised with the

reduction of the masticatory apparatus. This entails reduced chewing and perhaps a reduction in the use of teeth as tools. Canines become less sexually dimorphic (marked differences in the characteristics of males and females) and they no longer protrude past the occlusal plane. Modern pelvic girdle, that is adapted to both bipedal striding and the birth of large headed infants; the acetabulum and associated femoral head are large, as is the sacral articulation, while the iliac fossa is small, femoral neck small and iliac blades are not splayed. Although the stature of these *Homo sapiens sapiens* populations varied but the males appeared to have attained a height comparable with the modern males, but the females seems to have been somewhat shorter. The limb proportions are also as variable as is found in the modern populations.

Some of the fossil forms possessed long face; long high and narrow heads with strong jaw and seems to have been of medium to small body size. Some skulls (i.e. Brno skull) belonging to a male shows primitive as well as progressive features and they possess more accentuated brow ridge, a less rounded occipital region, some alveolar prognathism and a low placed maximum breadth of the skull, the forehead is high and bulging, the mastoid processes are large and the chin is prominent.

Phylogenetic status

It is still being debated where populations of fully modern *Homo sapiens* evolved but the only likelihood is that they appeared in different places during the Upper Pleistocene times. During this period *Homo sapiens sapiens* populations were largely migratory hunters and gathers; however, some evidences are also available to point towards a sedentary life style as well. It is a well known fact that *Homo sapiens sapiens* provides us with many beautiful examples of their artistic expressions; like cave paintings, engravings and also sculptures.

These groups of *Homo sapiens sapiens* lived in larger groups and their social organisation may also have been much more complex in comparison to their predecessors.

Although exact dates of entry of *Homo sapiens sapiens* into Australia and New world (Latin America) are still being revised but Australia appears to have been inhabited by *Homo sapiens sapiens*. Their entry into New World via the Bering land bridge might be even less than 40,000 years ago; some estimates are not more than 20,000 years ago or even less.

General Description

The French and Italian fossil remains appeared first in the 19th century but were discarded as modern burial. Close to 90 individuals are known. The famous Cro-Magnon shelter located in the lime stone cliffs by the French Village of Les Eyzies yielded some of the first remains. The remains (total skeletons, 3 males, 2 females and one fetus) were uncovered in 1868 while workers were building a railroad through the valley. The Upper Palaeolithic sample is indistinguishable from modern populations. They had small, non projecting face, broad, high foreheads, protruding chins and cranial capacity estimated to a 1590 cc; their variable height has been estimated as between 5 feet and 4 inches and 6 feet.

Other traces of French Upper Palaeolithic people come from the Combe Capelle and Chancelade sites. The Combe Capelle individuals had a long face a long,

high, narrow forehead. They appear to have been of medium to small body size. The Chancelade remains belong to late Upper Paleolithic stage than Combe Capelle and Cro-Magnon. Chancelade apparently lived when cool weather prevailed in Europe and their tools and reconstructed way of life originally led to the suggestion that they were ancestral to Eskimo. Chancelade was short, about 4 feet 11 inches, had wide cheek bones, and a heavy jaw, indicating heavy chewing stress. The skull was long and narrow, the nose narrow. If such traits are simply listed the material looks Eskimo, however the total morphological pattern of the skull does not support this assumption. The Eskimos like traits may simply be responses to heavy chewing stresses and the use of teeth as tools.

A pair of interesting skeletons, possibly a mother and teen-aged son, comes from the Grotte des Enfants, one of the Grimaldi caves on the Riviera. These skeletons were originally called the “Grimaldi Negroids” because they supposedly exhibited African traits. However the most likely explanation is that resemblance is a coincidence due to limited population sample as well as the reconstruction errors.

Dwellings

Now it is very clear that Upper Palaeolithic population inhabited a great variety of dwellings, rock shelters, (rocks overhangs as distinguished from deep caves) were widely used. Trees were felled and propped against the rock face, perhaps trellised by branches and skins. Large caves were inhabited; huts or tents built inside caves were heated with wood or bone fires where rock shelters were rare as in central and eastern Europe, remains of permanent dwellings were found. Long shaped huts which are sometimes sunk into the ground have been found at Pushkari in USSR. One hut measures 39 × 13 feet. At another site i.e. the Kostenki I site there are traces of 2 dwellings each 120 × 49 feet plus 9 hearths situated on the long axis and numerous silos of varying shapes and heights were discovered. It is unlikely that this complex was accommodated under one roof.

Tool inventory

Upper Palaeolithic people produced such a culture which in variety and elegance, far exceeded anything of their predecessors. Upper Palaeolithic groups made fine tools and delicately worked bones. The Eurasian Upper Palaeolithic was essentially a blade-tool assemblage characterised by an abundance and variety of long parallel-sided implements called “blades”. The blade tool industry was partially devised for working bone and wood. Out of the functional tool types burins (chisel shaped blades) were probably utilised for engraving and working wood, bone or antler, which might have been employed as handles or shafts by scarping or shaving wood or hollow out wood or bone. Lateral-leaf blades were carefully made into thin sharp-edged knives or arrowheads, which the Upper Palaeolithic people might have used as daggers.

New tools and weapons

New items such as polished pins or bone or antler awls are found in Upper Palaeolithic tool kits. New types of points were probably hafted to sticks. The late Magdalenian inventory (a cultural complex from western Europe dating from 12,000 to 17,000 B.P.) included hooked rods employed as spear throwers, barbed points, and harpoons for fishing, fishhooks, needles with eyes, bone and ivory bodkins (large eyed blunt needles), belt fasteners, and tools of undetermined use. Many of these tools were highly decorative depicting hunt animals and may

have served as ceremonial items. The use of bow and arrow is first verified for the latter part of Late Palaeolithic people. Some 100 wooden arrows have been recovered at the Mesolithic Stellmoor site, a former lake near Hamburg, Germany (10,500 B.P.) 25% of arrows were designed to use with anterior tip, one such arrow was found in situ in a wolf vertebra. The arrows were fire hardened. The flint-tipped arrows may have been used for large game only, the untipped for smaller game.

4.11 SUMMARY

Palaeoanthropology is the science that deals with the study of evolution of man by unearthing the fossilised remains left by our early ancestors. It is the fusion of physical anthropology and archaeology. Palaeoanthropologist should follow certain principles/objectives like identification, form and function, associations of plants and animals, evolution in the different groups of organisms, dispersal and distribution of plants and animals in time and space and correlation while dealing with the subject. Fossil evidence shows that the physical and behavioural traits shared by all people originated from ape-like ancestors and evolved over a period of at least 5 to 6 million years ago. Because of the burial practices, many almost complete skeletons are preserved and available for study and description. It is still being debated where populations of fully modern *Homo sapiens* evolved but the only likelihood is that they appeared in different places during the Upper Pleistocene times. During this period *Homo sapiens sapiens* populations were largely migratory hunters and gathers; however, some evidences are also available to point towards a sedentary life style as well. It is a well known fact that *Homo sapiens sapiens* provides us with many beautiful examples of their artistic expressions; like cave paintings, engravings and also sculptures. *Homo sapiens sapiens* lived in larger groups and their social organisation may also have been much more complex in comparison to their predecessors.

Suggested Reading

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Sample Questions

- 1) Define Palaeoanthropology and discuss its objectives and scope.
- 2) Write a detailed essay on *Ramapithecus*.

- 3) Discuss the geographical distribution and morphological description of *Australopithecus*.
- 4) Write brief essay on *Homo erectus*.
- 5) Discuss the geographical distribution, salient features, tool kit and life ways of *Homo neanderthalensis*.

