BANC-101

Introduction to Biological Anthropology

School of Social Sciences
Indira Gandhi National Open University

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November, 2019

ISBN-

Further information about the School of Social Sciences and the Indira Gandhi National Open University courses may be obtained from the University's office at Maidan Garhi, New Delhi-110 068, India or the Official Website of IGNOU : www.ignou.ac.in

Printed and published on behalf of the Indira Gandhi National Open University, New Delhi, by Director, School of Social Sciences.

Lasertypeset by Rajshree Computers, V-166A, Bhagwati Vihar, Near Sec. 2, Dwarka, Uttam Nagar, New Delhi.

Printed at :

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INTRODUCTION

Biological anthropology is the study of human variations, adaptations and evolution of our living and fossil relatives from a biological perspective. The subject matter of biological anthropology encompasses a wide range of topics such as human palentology, evolutionary biology, primate behaviour, human genetics and biological variations. In order to understand the contemporary human biological variations and the evolutionary history of humans, biological anthropologists study fossil hominin records as well as the nonhuman primates. The discipline also analyses individual human behaviour in terms of evolution and adaptation to understand the human uniqueness and distinctiveness.

With this backdrop, the present course on biological anthropology has been organized into four blocks keeping in mind the necessities of understanding the important aspects of human evolution and variations. The first block provides a detailed introduction of biological anthropology in four units. Unit 1 introduces Anthropology and its various branches, with a special reference to physical anthropology. The historical development, aim and scope of the discipline and as well as a discussion of the usage of the term "physical or biological anthropology" have been presented in this introductory unit. In Unit 2, the interdisciplinary approach of physical or biological anthropology in relation with other disciplines like biological sciences, earth sciences, chemical sciences, health sciences, medical sciences have been discussed. Unit 3 provides a detailed exploration of fundamentals and sub-fields of biological anthropology. Unit 4 expands on the traditional and modern approaches of biological anthropology and highlights the new methods to study human variations and evolution.

In the second block (Unit 5 through 7) a balanced coverage of the major components of human evolution and variation has been presented. Unit 5 describes the early ideas and theories on the origin of life. This unit also deals with the major sources of human variations that are responsible for racialization of humans. The last section of the unit gives an account of the racial classifications proposed by Francois Bernier, Carl Linnaeus and De Buffon. In unit 6, important theories that explained the process of organic evolution have been critically discussed. Unit 7 explains the basic principles of evolution that are crucial in understanding the mechanism of evolution. These principles include speciation, irreversibility, convergence and parallelism, adaptive radiation and extinction.

The third block comprises three units (Unit 8 through 10) on our evolutionary cousins, the non-human primates. Unit 8 focuses on the characteristics and taxonomic classification of primates. This unit also provides a detailed discussion on the origin of primates and how modern humans have developed from other living primates with which they share so many physical and behavioural similarities. Units 9 and 10 give a comparative exploration of human and non-human primates and provide additional information on how they are closely connected to us anatomically and behaviourally.

In the last block of this course (Unit 11 through 13), a detailed description on the concept of race has been presented. Unit 11 provides information on the major racial groups of the world along with a discussion on the criticism of racial classification. Unit 12 gives an account of important racial classifications proposed by various scholars. The unit also delineates the biological basis of

proposed racial classifications. Finally, Unit 13 deals with the social construct of the concept of race and racism. Various statements on race given by renowned international organizations like UNESCO and American Anthropological Association have been also included in the unit.

There is a manual concerning the practicals for this course. The practical manual on physical anthropology comprises of three sections. The first section provides the illustration and description of various instruments that are used for taking accurate and precise measurements on human body. Second section deals with Somatometry, the metric study of living human body. In the third section, a description of Somatoscopy has been given which is defined as the visual observation of physical features of various parts of human body. The practical manual also contains various diagrams and drawings depicting somatometric landmarks and standard charts of somatoscopic features for the better understanding. This practical manual will enable to understand various tools and techniques required for metric and visual observations of human body. You will be able to enumerate and describe the significant measurements of human body. Furthermore this practical manual will help to acquire knowledge of the somatoscopic features and their subsequent classification in standard forms/ categories.

Block 2

Understanding Human Variation and Thoughts and Theories of Evolution

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UNIT 5 HUMAN VARIATION AND EVOLUTION*

Contents

Learning Objectives

After going through this unit you will :

- trace the early origin of life;
- gain insight into different theories of origin of life;
- understand the human variations and racialization of humans; and
- comprehend the racial classifications given by Francois Bernier, Carl Linnaeus and Comte De Buffon.

5.0 INTRODUCTION

The origin of life cannot be dated as precisely, but there is evidence that bacteria-like organisms lived on earth 3.5 billion years ago and they may have existed even earlier, when the first solid crust formed, almost 4 billion years ago (Noffke et al., 2013). From the biological point of view, the problem of origin and evolution of life requires a prior review and possible explanation. Scientists have always considered this question but no conclusive proof concerning this problem has been furnished. Though paleontological discoveries have greatly contributed to the question of gradual evolution, very little information is available on the earliest form of life due to severe changes that occurred in Archaeozoic era.

* Prof. A K Kapoor, Department of Anthropology, University of Delhi, Delhi

"The question of evolution of life on the Earth and elsewhere in the Universe has ever been as challenging as the question of evolution of the Universe itself. Science does not provide authentic explanation regarding the origin of Universe in the controversial 'Big Bang' theory for evolution of the Universe, nor does it provide any satisfactory explanation regarding the origin of life despite considerable advancements in the fields of astrobiology, astrophysics and molecular biology in recent years. The hot inflationary 'Big Bang' model for evolution of the Universe is not secure enough to serve as a foundation for beliefs about the origin of life, which is exemplified very much by the fact that the most distant galaxies, we can see today, look as rich and fully evolved as our own, even though they are barely 5% of the current age of the Universe, i.e. about 700 million years after the Big Bang. Among the several factors leading to beginning of life on this planet, 'panspermia' appears to provide the most favoured hypothesis for emergence of life on our planet." It hypothisis that the primitive life may have originally formed extra terrestrially. As per this concept seeds of life are ubiguitous, and they may have delivered life to the Earth as well as to the other heritable bodies in the Universe (Lal, 2008).

The problem of creation has two aspects: the origin of life itself and the origin of forms of life. H. F. Osborn in 1960 posed the problem of the origin of life in the following questions:

- Does the appearance of life on earth constitute a new factor or it is rather the evolutionary continuation of forms of energy and matter found on the earth itself, on the sun and on other stars?
- Can the development of life be considered as part of the evolutionary process in the same sense as inorganic evolution or it is fundamentally a different phenomenon?
- Is there a creation in the strict sense of the term or that some new form of energy arises?
- Does life develop in an orderly fashion subject to certain natural laws or its development is due to chance? (Shukla and Rastogi, 1990)

Many of the potential researchers attempted to clarify the early evolutionary process but these clarifications are yet to be confirmed.

5.1 EARLY THEORIES ON THE ORIGIN OF LIFE

"Many religious persons, including many scientists, hold that God created the universe and the various processes driving physical and biological evolution and that these processes then resulted in the creation of galaxies, our solar system and life on Earth. This belief, which sometimes is termed "theistic evolution," is not in disagreement with scientific explanations of evolution. Indeed, it reflects the remarkable and inspiring character of the physical universe revealed by cosmology, palaeontology, molecular biology and many other scientific disciplines" (Smith, 2014). Let us learn some of the major proposed theories on the origin of life:

5.1.1 Theory of Spontaneous Generation

The Theory of Spontaneous Generation is as old as human thought and has been a subject matter of great controversy and much discussion. The idea

of spontaneous generation can be traced back to Greek philosopher and scientist Aristotle. According to this theory, 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. For example life was generated in slime, compost and mud under the influence of moisture and heat. However, such a hypothesis was negated by Lazzaro Spallanzani, Francisco Redi and Louis Pasteur. These scientists disapproved the Theory of Spontaneous Generation by performing well designed scientific experiments. In a certain sense, ideas about spontaneous generation are still not quite dead. Many pseudo explanations for the origin of life due to 'inherent properties of matter', 'emergent properties', or self-organizing principles are still common in the literature (especially authored by non-biologists) that reflects a more less continuous tradition going back to Aristotle **(**Fenchel, 2002).

5.1.2 Theory of Extra Terrestrial Origin of Life

"The Swedish chemist Svante Arrhenius suggested in 1908 that life had originated somewhere else in the Universe and in fact permeates all of Cosmos. According to this view, the Earth had been colonized by microbes that had somehow escaped from their home planets and driven by light pressure, had arrived on the Earth at some time in the past. This idea, the so called Panspermia hypothesis, has haunted most of the 20th century". Supporters of extra-terrestrial origin theory include many prominent persons such as Francis Crick (who together with James Watson and other discovered the structure of DNA) and Fred Hoyle (author of many science fiction novels) **(**Fenchel, 2002). It should also be noted here that the possibility of life in our immediate cosmic neighbourhood i.e. solar system is very unlikely. But even if it is considered against all odds then it is also extremely unlikely that any microorganism could survive exposure to cosmic radiation. It is hard to make the extra-terrestrial origin of life appear probable, but it represents only an attempt to export the problem to somewhere outside Earth without explaining how life could arise.

5.1.3 Life Had No Beginning

According to some philosophers, life had no beginning and it always existed. Life is as eternal as energy and matter and possibly may be considered a special manifestation of both. Such a theory in fact leads into the realm of imagination and metaphysics (Shukla & Rastogi, 1990).

5.1.4 Theory of Eternity of Present Conditions

This theory proposes the view that the universe is unchangeable. The organisms remain unalterable throughout their individual existence and will continue in the same unchanging state throughout eternity. J. Hutton (1726-1797) was the supporter of this view. This theory was accepted only by few because of its erroneous explanation.

5.1.5 Theory of Creationism

Creationism theory advocates that all forms of life were created by Almighty God. According to the 'genesis' book, Adam and Eve were the first man and woman created by God. Christians, Muslims and Jews have a common

agreement on the seven days creation of universe by God. According to this view, the world and all living things originated in a singular event of creation by God. The Spanish Jesuit, Father Suarej (1548-1617) was one of the believers and defenders of the theory of creationism. The great Naturalist Carl Linnaeus (1758) also believed that all genera and species are always the creation of God. He also supported the view of inalterability of the species. However, he did not rule out the possibility of the appearance of new forms or life by hybridization (Shukla & Rastogi, 1990).

5.1.6 Theory of Catastrophism

This theory is considered as an extension of the Theory of Special Creation. According to this theory, life is originated by the creation and it is followed by catastrophe due to many geographical disturbances. Each catastrophe destroyed life completely and each creation led to a higher level of organization that is different and complex from the previous one. George Cuvier (1769-1832), Professor of Comparative Anatomy, Paris University, was the main supporter of this theory. He believed that in the beginning there were corals, molluscs and crustaceans on the earth. Plants emerged in the beginning which was followed by fishes, reptiles, birds and mammals. He believed that man appeared after the last geological revolution. Cuvier's theory of catastrophism was attacked on many grounds by the researchers as the question of initial origin of life and its origin after subsequent metamorphosis was left unexplained.

5.1.7 Theory of Organic Evolution

During the middle ages and at the beginning of the modern era new versions of organic evolution emerged. Avicenna, the foremost representative of Arabic Science (979-1037) considered fossils to be the rough draft of living beings. Albert von Bolletadt also known as Albertus Magnus (1206-80) accepted that plant and animal remains might have been transformed to fossils by petrification. The famous French Scientist Bernard Palissy also had the idea of lost species and extinct forms. Similarly Roberthook (1635-1703) and Leibniz (1646-1716) reflected an evolutionist tendency and believed that fossils can reveal earth's past. These contributions indicated that all natural beings form a chain within which different classes are formed. J. Monboddo (1714-1790) suggested theories concerning the origin of species and the evolution of man. J. W. Goethe's (1749-1832) ideas on evolution are also well known and hence he was considered a predecessor to Darwin. Immanuel Kant (1724-1804) had greatly influenced the biological doctrines of his time. Furthermore, Charles Darwin (1731-1802) in 1794 outlined the idea of heredity and natural selection and linked these to the concept of evolution (Shukla & Rastogi, 1990).

Charles Lyell (1797-1875) favoured the idea of considering majority of geological phenomena as a result of small gradual changes. This idea formed the basis of evolution and it demonstrated evolution as a universal law of living nature. Evolution was also considered the great intellectual achievement of 19th century. Lamarck and Darwin independently propounded the theory that all animals have been evolved from simple types. These simple types underwent gradual changes due to successive development in form and function. This theory of organic evolution brought a great revolution in the scientific world and was ultimately accepted. Contributions of Lamarck and Darwin remain supreme even today (Shukla & Rastogi, 1990).

Check Your Progress 1

1) ..... was the main supporter of theory of Catastrophism.

2) The loss of genes through "sampling" accidents is defined as .....

3) J. W. Goethe was considered a predecessor to ..... .

5.2 HUMAN VARIATIONS AND ORIGIN OF RACES

Biological Anthropologists primarily deal with the human physical variations. These variations are produced by the combined action of heredity and environmental forces that have been at work throughout evolution. The major sources of human variations include:

- Mutation, that is alterations in the molecular structures of the cell resulting in new genes or in the rearrangement of the number and order of genetic material.
- Selection, that is, pressures in the environment which favour the survival and reproduction of individuals with certain genes and impede the survival and reproduction of individuals with others.
- Gene flow, that is the acquisition by the population of new genes through occasional matings with members of other populations and
- Genetic drift, that is, the loss of genes through "sampling" accidents **(**Beals & Hoijer, 1959).

These sources of human variations result into many anatomical or morphological differences between humans and their population that also reflect underlying biological differences. "Some morphological differences are visible to the naked eye, including skin, eye and hair colour and body size and shape. Some other biological differences are just as real but are not as easily seen; these include blood type, fingerprint patterns and disease susceptibilities. Considering the differences in all of these traits, there is no doubt that *Homo sapiens* is a species with considerable biological variation. At a deeper level, these biological variations can be seen in relation to the geographical pattern of individuals for example people with dark skin color can be found in high frequencies in sub-Saharan Africa, Australia and certain islands in the Pacific, while people with very fair skin are more frequent in other parts of the globe, including Scandinavia and northern Europe and Asia. This kind of geographically patterned biological variation formed the traditional raw material for racial classification system (Anemone, 2015)**.** Geographical variations in many biological traits that assisted in differentiation of human populations led to the origin of races.

5.3 RACIALIZATION OF HUMANS

The concept of race progressively evolved from genealogical sense to encompass a growing trend of "biologization". The history of the concept includes a shift from lineage-based thinking to a naturalist approach which was first applied to humans and then extended to the rest of the animal kingdom (Hoquet, 2014)**.** The explorations of the 15th, 16th and 17th centuries brought Europeans in contact with many new people and finally scholars became interested in the problem of finding order in the bewildering variety

of peoples with whom they were confronted. This led to attempts at more or less exhaustive classifications of the races of mankind (Slotkin, 1944). The idea of formation and formulation of races was first propounded by three "early taxonomists": Francois Bernier (1625-1688), Carl Linnaeus (1707-1778) and G. L. Leclerc de Buffon (1707-1788). Many other potential scholars including Immanuel Kant, Johann Friedrich Blumenbach, John Locke and Thomas Hobbes also tried to explain the concept of race and human diversity. The following section describes the racial classifications proposed by Francois Bernier, Carl Linnaeus and De Buffon:

5.3.1 Francois Bernier

The first classification of the races of man was given by a French traveller, Francois Bernier. In 1684, the journal of the French Academy of Sciences, the *journaldes scavans* published an anonymous article entitled "A New Division of the Earth, according to the Different species or Races of Men Who Inhabit It" written by Francois Bernier. This short piece of work has been cited as the first presentation of the modern concept of race, but it is usually mentioned as a mere curiosity (Boulle, 2003). In this article Bernier proposed anthropology a key for geography, by dividing the world according to "species or races of men". Bernier's first race included the people of Europe except a part of Muscovy; it also included those living in a broad band of territory extending from the Mediterranean coast of Africa to parts of Borneo, via Arabia, Persia, India and Siam. This first race was left undefined and the other three races consisted of the Africans, the Asians and the Samoeds of Lapland. Each of these three races was characterized by the combination of physical features and skin color.

According to Bernier, under the first species, all Europe was comprehended except a part of Muscovy. Under this group, the Egyptians and the (East) Indians are very black, or rather copper coloured, that colour is only an accident in them and comes because they are constantly exposed to the sun; and for those individuals who take care of themselves and who are not obliged to expose themselves so often as the lower class, are not darker than many Spaniards. It is true that most Indians have something very different from us in the shape of their face and in their color which often comes very near to yellow; but that does not seem enough to make them a species apart, or else it would be necessary to make one of Spaniards, another of the Germans and so on with several other nations of Europe.

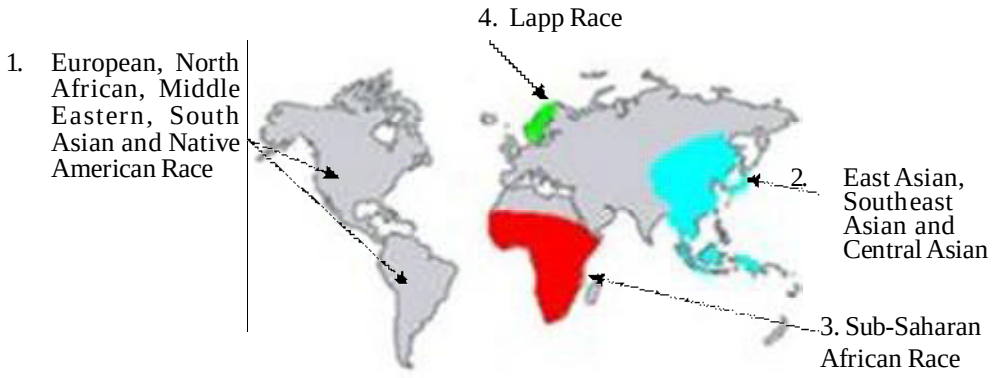

Fig. 1: Racial classification scheme of François Bernier

Source: https://fi.wikipedia.org/wiki/Fran%C3%A7ois_Bernier

Under the second species, Africans are included who have peculiar features like thick lips, squab noses, black skin which is smooth and polished. There are very few among them who have aquiline noses or lips of moderate thickness. They have three or four hair of beard which is not properly hair, but rather a species of wool. Their teeth are whiter than the finest ivory, their tongue and all the interior of their mouth and their lips are as red as coral.

The third species comprehends people of Asia where people of all countries are truly white; but they have broad shoulders, a flat face, a small squab nose, little pig's eyes long and deep set and three hairs of beard. The Lapps make the fourth species. They are little stunted creatures with thick legs, large shoulders; short neck and a face elongated immensely. As to the Americans, most of them are olive-coloured and have their faces modelled in a different way from ours. Besides, as in Europe, the stature, turn of the face, the colour and the hairs are generally very different **(**Burton & Loomba, 2007).

The division was rather disproportionate, as the first "species" included Europe, North Africa, the Middle East and India, along with part of Southeast Asia; the second, Africa; the third, a part of Asia (China etc.); the fourth, Lapland. Distinctions between "species" were not based on color, given that two among them were white: the Mongols, the Chinese and the Japanese are described as "veritably white," despite the very major differences in their corporal disposition. Bernier's racial classification was based on the continents but he did not strictly follow them. Inhabitants of Africa (the entire Mediterranean coast) were grouped in the first division while position of Native American was not clear; they were kept at the end of enumeration by creating a fifth division. Bernier's text was generally recognized for "launching" the idea of racial divisions of humanity in Europe. But the way in which he divided humanity was rather idiosyncratic and did not really presage what racial division would look like in the eighteenth and nineteenth centuries (Hoquet, 2014).

5.3.2 Carl Von Linnaeus

The first scientific classification of human races was given by Carl Von Linnaeus which was published in 1758 in the tenth edition of *Systema Naturae*. This taxonomic system which was based on the criterion of skin colour, laid the foundation for nineteenth century racial classification. In 1735, the first edition of *Systema Naturae* proposed four varieties of Homo: Europaeus albesc (white), Americanus rubesc (red), Asiaticus fuscus (dark) and Africanus nigr (black). After 1735, this edition was constantly reedited and transformed throughout the eighteenth century. Carl von Linné properly began the science of Anthropology by introducing the color based classification of races. Linnaeus's taxonomy was referred to as first modern study of man by Anthropologist. In his publication he named and described four major geographical races of mankind that are still recognized and continued into the nineteenth century anthropological vocabulary. Linnaeus classified geographical races or subspecies on the basis of a curious collection of traits, including physical features, personality traits and aspects of culture. The four geographical races were described as:

- *Homo Americanus:* Reddish, choleric, obstinate, contented and regulated by customs

- *Homo Europeans:* White, fickle, sanguine, blue-eyed, gentle and governed by laws
- *Homo Asiaticus:* Sallow, grave, dignified, avaricious and ruled by opinions
- *Homo Afer:* Black, phlegmatic, cunning, lazy, lustful, careless and governed by caprice **(**Haller, 1971**)**

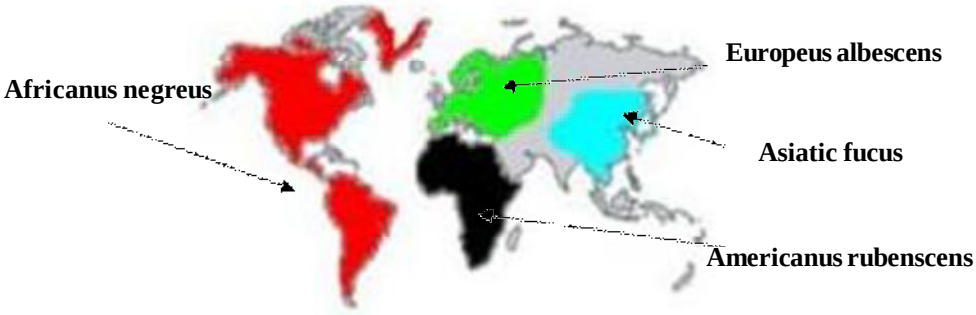

Fig. 2: Racial classification scheme of Carl Von Linnaeus

Source: https://fi.wikipedia.org/wiki/Fran%C3%A7ois_Bernier

A consideration of Linnaeus's classification suggests that one of the unspoken pedestals on which it is built is the notion of hierarchy and inequality. With respect to many of the personality and cultural traits that he used, a clear Eurocentric bias was present. The linear hierarchy of Linnaeus's classification was influenced by the Judeo-Christian concept of the "great chain of being" or "ladder of creation". In this conception, all of God's creatures, from the simplest and most primitive life forms to the most complex, were thought to be arrayed in a linear fashion, like the links in a chain or rungs of a ladder. When Linnaeus created his four subspecies or races of humans and under the influence of notions like the great chain, it was natural for him to build into his scheme a linear hierarchy, with some races closer to angels and others closer to the apes. So it seems that the first scientific classification of race resembles modern racial classifications in several important aspects, including the notion of inequality with respect to innate intelligence and a linear raking or hierarchy of races and the broad-brush stereotyping of millions of people with supposedly platonic essences (Anemone, 2015).

5.3.3 G. L. L. Comte de Buffon

In 1749 G. L. L. Comte de Buffon introduced the word race into the literature of Natural History. Buffon recognized the difference between species, which could not mate with each other and reproduce and varieties within a species, which could. Like Linnaeus, Buffon was a believer in single origin of *Homo sapiens*, with racial differentiation occurring at some later time after human population had multiplied and spread across the globe. An advocate of the unity of the human species, Buffon's categories for man included Laplanders, Mongolians, Southern Asiatics, Europeans, Ethiopians and Malays. As with other racial writers, Buffon gave a central role to value judgements of the relative worth of the races in his writings. He argued that the original race was the European one and others could be understood as "degenerations" from that norm. Americans were perhaps the least degenerated by the climate in which they lived, Africans and Lapps perhaps the most. Assuming the colour white to be norm, Buffon blamed the vagaries of climate for other

skin tones. According to Buffon climate, food, soil, air and other aspects of the local environment had a direct effect on human morphology and physiology. Thus, the differences in racial type, particularly skin color, can be readily attributed to environmental characteristics. Buffon's classification system was structured primarily around geographic placement. Indeed, Buffon was, like Linnaeus, a firm believer in the notion of *special creation* of all the kinds or species of living things by a divine creator and in the *fixity of species*. They both envisioned biological change occurring only at the level of the divinely created species (d'Souza, 1996; Jackson & Weidman, 2004; Anemone, 2015).

The earlier classifications of mankind did not differ essentially from the present day classification, either in regard to methodology or criteria. The greatest improvement has been in the refinement of the criteria employed as the basis for classification, both qualitative and quantitative (Slotkin, 1944).

Check Your Progress 2

4) Who propounded the Theory of Eternity of Present Conditions?
   a) Francis Crick
   b) J. Hutton
   c) Francois Bernier
   d) Theodosius Dobzhansky

5) Who introduced the word race into the literature of Natural History?
   a) Comte de Buffon
   b) Francois Bernier
   c) Carl Von Linnaeus
   d) Theodosius Dobzhansky

6) Who wrote the book *Systema Naturae*?
   a) Carl Von Linnaeus
   b) Comte de Buffon
   c) Charles Lyell
   d) Erasmus Darwin

7) How many varieties of Homo species were proposed in the first edition of *Systema Naturae*?
   a) Three
   b) Four
   c) Two
   d) Five

5.4 SUMMARY

Theories and statements about the origin and early evolution of life date back to antiquity. These theories ranged from religious and spontaneous origin of life to evidential organic evolution of man. Evolutionary process created the fundamental basis for human diversities and variations. Globally, human

species consist of many biological variations in terms of genes and morphology. Many human biologists and anthropologists have attempted to analyse and describe these human variations. In pre-Darwinian times, major emphasis was placed on the enumeration and classification of human races, an approach that stressed variation between groups in a typological framework. Many researchers attempted to reduce human variations to a set number of discrete races. The fact that there have been centuries of debate over the number of human races is a reflection that the underlying model of discrete variation expected at a level of subspecies is not the most suitable means of analysing human variation.

5.5 REFERENCES

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5.6 ANSWERS TO CHECK YOUR PROGRESS

1) George Cuvier
2) Genetic Drift
3) Charles Darwin
4) b)
5) a)
6) a)
7) b)

UNIT 6 THEORIES OF ORGANIC EVOLUTION*

Contents

Learning Objectives

After going through this unit you will:

- understand the concept of organic evolution;
- comprehend patterns of evolution; and
- know about different theories of organic evolution.

6.0 INTRODUCTION

Biological evolution is one of the major concerns of Physical/Biological Anthropology. Let us first understand about evolution. Evolution simply means 'change'. Herbert Spencer (1857) first used the term evolution to refer to the development of more complex forms of life (plants and animals) from simpler and earlier forms. Evolution is the term used in a variety of fields, but when we talk of evolution of organisms, the plants and animals, it is called organic evolution. Organic evolution or bio evolution is 'Descent with modification' or 'Continuity of life with constant modifications'. Organic evolution implies that 'the present complex and highly organized living beings have evolved from simpler and less organized living beings of the past by gradual modification accumulated through successive generations over millions of years.

It suggests that environmental conditions in nature are ever changing. Organisms have an inherent character of changing to the changing environmental conditions. This is called adaptability or adaptations. Such adaptive changes in organisms lead to the 'Origin of new species' (Evolution). Since changes in the organisms are due to adaptations, new species are always better adapted and more organized than their ancestors. Different members of a species, on being adapted to different environments, diversify and evolve

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along several divergent lines. All the present day species had a common ancestor at some or other time of their evolution. Individuals migrate from their place of origin to varied geographical areas in search of food or because of predators and then gradually adapt to different environmental conditions. This results in the formation of several new species from one ancestral species. Comparative anatomy and morphology shows similarities and differences among organisms of today and those that existed years ago (Mondal, n. d.). Such similarities can be interpreted to understand whether common ancestors were shared or not.

Evolution can be classified into five different patterns: Divergent, Convergent, Coevolution, Parallel evolution and Adaptive Radiation.

- *Divergent Evolution: It occurs when a population isolated (for a reason) from the rest of the species and becomes exposed to new selective pressures, causing it to evolve into a new species. Homologous structures are evidence of divergent evolution. For example whales, bats, cheetah and human (all mammals) share similarities in the pattern of bones of forelimbs. Though these forelimbs perform different functions in these animals, they have similar anatomical structure –Hence, in these animals, the same structure developed along different directions due to adaptations to different needs.*
- *Convergent Evolution: When unrelated species occupy the same environment, but they are subjected to similar selective pressures and show similar adaptations. Wings of butterfly and of birds look alike. They are not anatomically similar structures though they perform similar functions. Hence, analogous structures are a result of convergent evolution - different structures evolving for the same function and hence having similarity.*
- *Coevolution: Coevolution is the mutual evolutionary set of adaptations of two interacting species. Pollinator-plant relationships are one example. While feeding on the nectar from a flower, an insect, bird, or bat inadvertently ensures the reproductive success of the flower.*
- *Parallel Evolution: Parallel evolution describes two related species that have made similar evolutionary adaptations after their divergence from a common ancestor. North America and the Tasmanian wolf, a marsupial, of Australia present a notable example. They share a common ancestor and evolved in similar environments, thousands of miles apart.*
- *Adaptive Radiation: Adaptive radiation is the emergence of numerous species from a single common ancestor introduced into an environment. An example of this phenomenon was made famous by Charles Darwin on the Galapagos Islands. Darwin discovered 14 species of finches each filling a different ecological niche. The most striking difference among the species is the variation in their beaks, which are adapted for different diets. They all evolved from a single ancestral species and that radiated to fill 14 different niches (Goldberg and Goldberg, 2009).*

Evolution is a very complex and extremely slow process. It is not possible to see one type of animals changing to other, but presence of intergrading organisms supports the concept of evolution.

Check Your Progress 1

1) Evolution can be described as:

   a) Process of gradual adaptive changes in organisms

   b) History of races

   c) Variations in races

   d) Change in genetic composition

2) Analogous structures indicate:

   a) Parallel evolution

   b) Convergent evolution

   c) Divergent evolution

   d) Natural evolution

6.1 THEORIES OF EVOLUTION

Many theories tried to explain the process of evolution, but the important theories that explain the scientific basis of organic evolution are Lamarckism, Darwinism, Mutation Theory and Synthetic Theory of Evolution.

6.1.1 Lamarckism

Jean Baptiste Pierre Antoine de Monet Lamarck (1744-1829) was a French naturalist, well known for his Theory of Evolution. Lamarck's Theory of Evolution was published in Philosophic Zoologique in 1809 as Lamarckism and as the Theory of Organic Evolution. It is popularly known as 'Inheritance of Acquired Characters'. It explains the origin of new species.

Fig. 1: Lamarck (1744-1829)

Source: https://en.wikipedia.org/wiki/Jean-Baptiste_Lamarck

Lamarck recognized two principal factors behind the evolution of living forms: the first being an inherent tendency of organic matter to reach new levels of complexity; the second being the modifying capacity of the environment. According to Lamarck, complex living organisms are formed from simple

living organisms. The environment does not remain constant, it changes. The changes in the environment provide new needs for the organisms. In response to the new needs, organisms develop new structures. Variations in organisms arise through the effects of use and disuse. The continuous use makes a structure greatly developed and disuse makes the structure atrophied. The new structures developed by the organisms in response to the environment are called acquired characters. These acquired characters are transmitted generation after generation and by this way a new species is produced (Lamarckism From Oe, n. d.).

Lamarck's theory has following assumptions and propositions:

6.1.1.1 Assumptions

- "Living organisms and their parts tend to increase in size continuously due to internal urge of life.
- New organs (characters) are developed in order to meet the needs of the new want and are maintained (acquired characters).
- The development of organs and their use are proportional to the activities of these organs. Use and disuse of organs result in variations.

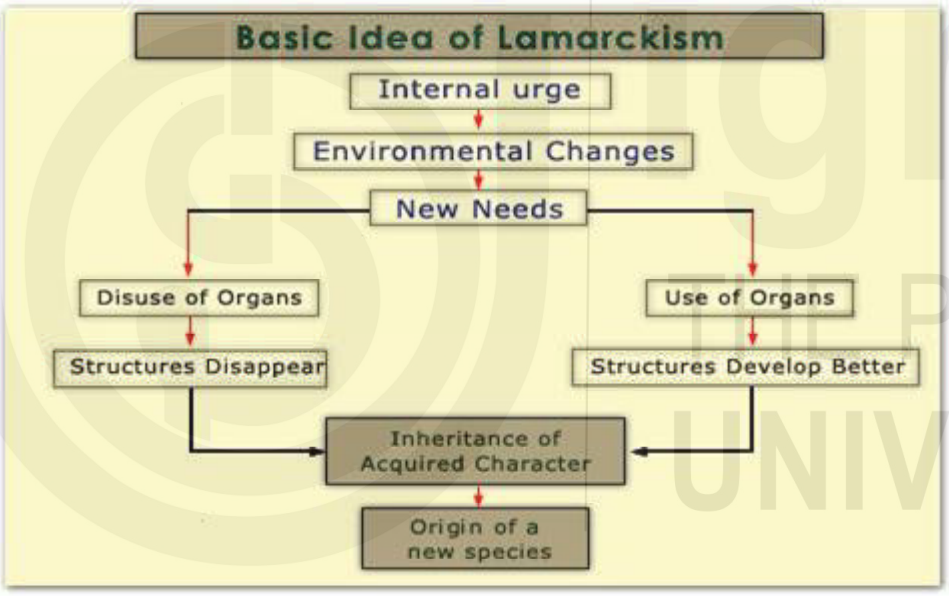

Fig. 2: Basic idea of Lamarckism

Source: https://www.tutorvista.com

- Every new character that has been acquired in the life of an individual is preserved and transmitted to the next generation by them (inheritance of acquired characters)" (Theories of Evolution, n. d.).

6.1.1.2 Propositions

- **Internal urge**: Living organisms and their parts tend to increase in size continuously due to internal forces of life. Lamarck thought that change of habits may initiate the formation of a new organ or may bring the modification of the existing organ or structure.
- **Inheritance of acquired characters: "**Environmental response leads to development of new adaptive characters in an organism through internal urge or through use and disuse of organs. Such characters

developed during the life time of an organism are called as acquired characters that are not found in its immediate ancestors. The new characters that have been acquired in the life time of an organism are preserved and transmitted to the next generation. In the offspring this modification become more and more pronounced if they are exposed to similar stress of the environment. Acquired characters are thus inherited leading to morphological and anatomical changes in a species." (Multi Language Document, n. d.).

- **New needs as a reaction to the environment**: New organs (characters) are the result of a new need. Lamarck believed that environment plays an important role in influencing the form of living organisms and their external and internal organs. The influence leads to change in their habits. The change results in unusual activity of an organ or structure. In case of animals migration from one area to another leads to change in the environment and introduces new needs and requirements. Lamarck demonstrated several cases where individuals of the same species, grown under different environmental conditions, exhibited marked differences.
- **Use and disuse:** The constant use of an organ increases its efficiency and size and leads to its better development. On the contrary if any organ is not used for a long time it leads to the reduction in efficiency and size of the organ and ultimately to its degeneration. In support of his theory, Lamarck cited the examples like long neck of giraffe and limbless in snakes to explain use and disuse of organs. Lamarck explained the long neck of giraffe for use of organs as follows: An original deer-like animal found the supply of trees and herbs inadequate, started to feed on the leaves of trees. In the process of reaching the leaves of higher branches the 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 as a result, the neck became longer along with their forelimbs.

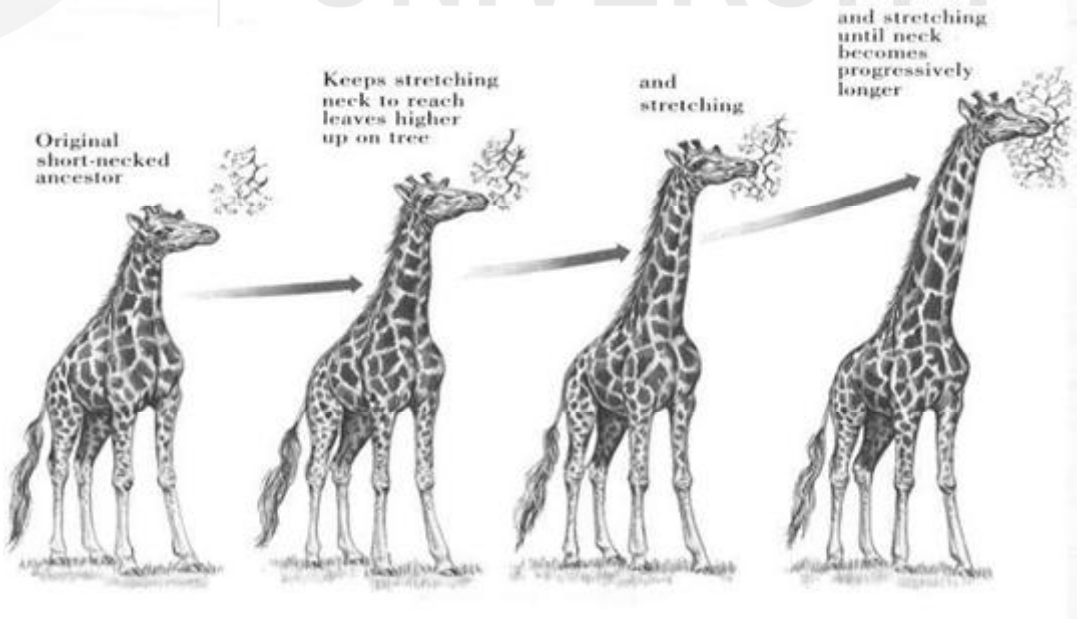

Fig. 3: Long neck of giraffe

Source: http://hawaiireedlab.com

An example for disuse of organs is limblessness in snake. The ancestors of snakes were the four limbed animals. In course time, the snakes adapted to burrowing habit. During this adaptation they gradually lost their limbs. Hence the present day snakes are without limbs.

6.1.1.3 Other examples of Lamarckism

- Development of webbed feet in aquatic birds, like duck is due to developing swimming habit. They are considered to have arisen from the terrestrial ancestors.
- Evolution of flightless birds from their flying ancestors. Flightlessness in kiwi is due to reduction of feathers and wings.
- Biceps in hands in blacksmiths which put their hands constant to heavy hammering.
- Presence of appendix post anal tail and trace of nictitating membrane in man.

6.1.1.4 Criticism of Lamarckism

Lamarckism was exposed to severe criticism as his principles of evolution met with much objection. One of the principles, inheritance of acquired characters has been much disputed. August Weismann (1890), a German biologist with his experiments on mice disproved the inheritance of acquired characters. He cut the tails of white mice for more than 20 generations and observed the length of the tail in the next generation. In all the 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 while the germplasm is in sex cells. The germplasm play an important role in heredity. Weismann established that the changes that took place in the somatic cells of an organism are not transmitted; only the changes that occur in the germplasm are transmitted. His proposition that the tendency to increase in size, has been noted in many forms but many times evolution shows reduction in size. Moreover, persons constantly busy in reading and writing and using their eyes more than others often develop impaired sight. Why do their eyes not become more efficient? Lamarck's proposition that new organs develop where the organisms feel their need also faced criticism. If the development of new organ or structure depends upon the desire then why man who has long desired to fly like birds has not developed the wings.

6.1.2 Neo-Lamarckism

Lamarckism is the first scientific assumption that recognised the "adaptation to the environment as a primary product of evolution". The followers of Lamarck like Cope, Spencer, Packard, Kammerer etc., tried to modify the Lamarckism and made it acceptable. This modified version of Lamarckism is called Neo-Lamarckism. These neo-Lamarckians considered that adaptations are universal. Organisms acquire the new structures due to their adaptations to changed environmental conditions that affect the somatic cells. The variations caused in somatic cells can be inherited in the next generation. The Neo-Lamarckians provided examples in favour of inheritance of acquired characters.

Proteus anguineus, an amphibian lives in caves where there is no light. Hence it is colourless and the eyes are rudimentary. Kammerer, one of the followers of Lamarck brought this animal to day light and observed that the animal gradually developed black skin and normal eyes. These somatic characters were inherited by the next generation.

Yet another experiment conducted by Griffth and Detleofsm on rats by placing them on rotating table for several months, noticed that even after the rotation stopped, the rats showed signs of dizziness and the offspring also exhibited dizziness.

Neo-Lamarckism does not give any importance to factors like internal vital force, appetency and use and disuse of organs. The theory stresses on the direct effect of changed environment on the organisms. It established that only those modifications are transferred to the next generation which influence germ cells or where somatic cells give rise to germ cells.

Lamarckism was incomplete in itself and unable to explain all the cases of evolutionary changes, but holds good to certain extent because the body characters of the organisms are not single attributes but the result of interaction of heritable factors (genes) and the environment conditions.

Check Your Progress 2

3) Lamarck's theory of evolution is popularly known as:

   a) Struggle for existence

   b) Inheritance of acquired characters

   c) Origin of new species

   d) Natural selection

4) Lamarck's theory of evolution was published in:

   a) Systema Natuare

   b) Origin of New Species

   c) Philosophic Zoologique

   d) The Descent of Man

5) Who conducted the experiment of removing tails of white mice for many generations to disprove the theory of Lamarck?

   a) Charles Darwin

   b) Herbert Spencer

   c) August Weismann

   d) J. B. S. Haldane

6.1.3 Darwinism

Charles Robert Darwin (1809-1882) was an English naturalist who was appointed as a Naturalist in 1831 upon a world survey-ship of British Government H.M.S. Beagle. During his voyage for five years (1831 to 1836)

he explored the fauna and flora of a number of continents and islands of which Galapagos Islands were the important one. The idea of evolution of new species by natural selection influenced him and based on his observations Darwin published a book titled 'Origin of Species by Natural Selection' in the year 1859.

Fig. 4: Charles Darwin (1809-1882)

Source: https://en.wikiquote.org/wiki/Charles_Darwin

Charles Darwin (1809-1882) was an evolutionary biologist. The evolutionary theory proposed by him is called 'Darwinism'. Darwin was much influenced by three publications namely

- the essay of T.R. Malthus, 1798, titled *"On the principles of populations"* which states that populations increase geometrically and the food sources increase arithmetically;
- the book written by Sir Charles Lyell 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) and
- the paper entitled *"On the tendency of varieties to depart from original types"* sent to him by Alfred Russel Wallace.

Darwin presented the summary of his theory in a joint paper titled, *'Origin of Species,* in 1858 to the Linnean society. Again in 1859, Darwin published his findings in detail in his book titled "The Origin of Species by Natural Selection" (Theories of Evolution, n. d.)**.**

Darwin's theory of natural selection is based on the following principles:

1) **Over Production**: This principle is also called prodigality of over production. Every organism tends to increase their population in a geometric ratio. The organisms produce more number of offspring than will be able to survive and reproduce. "The population of each species remains more or less constant because the offspring die in large number before they become reproductively active. The food and other sources do not increase in the same rate of population increase" (Theories of Evolution, n. d.).

2) **Variations**: Variation is the characteristic feature of all organisms. Variations may be harmful or useful. The useful variations are favourable and inherited to the next generation. Harmful variations make the organism unfit in the struggle for existence. Beneficial variations are favoured by the nature. Such variations become the raw material for evolution and make the organism fit in the struggle for existence and

thus the progeny has better chances of survival (Theories of Evolution, n. d.).

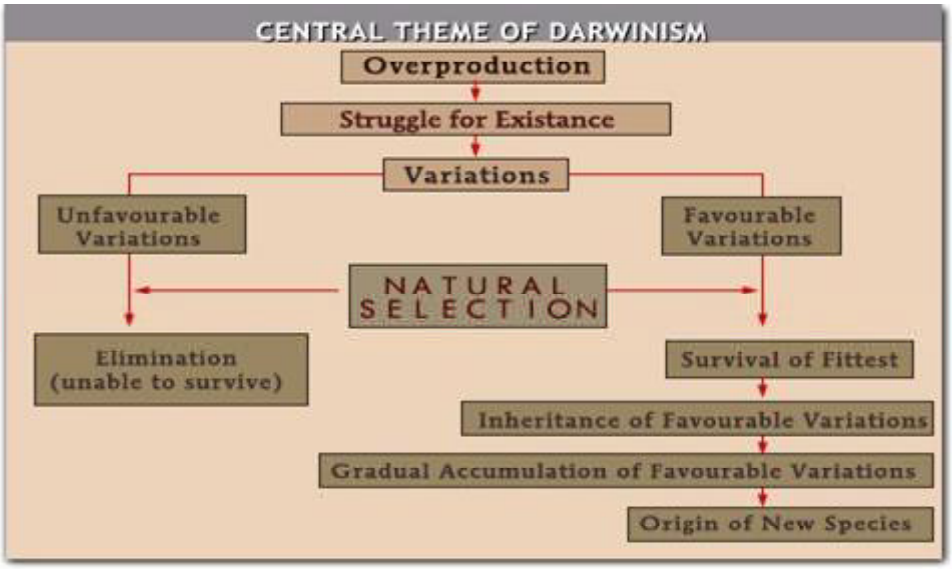

Fig. 5: Central Theme of Darwinism

Source: https://www.tutorvista.com

3) **Struggle for existence**: All organisms reproduce in geometric ratio, but the food and space are not increased correspondingly. The organism should face competition for survival. Darwin called it struggle for existence. The struggle is of three types:

- Intraspecific struggle;
- Interspecific struggle and
- Struggle with the environment.

Intraspecific struggle: It is the struggle found among the organisms of the same species. This struggle is for food and mating. It is the most severe check on the rate of reproduction.

Interspecific struggle: The struggle between individuals of different species is called interspecific struggle. The best example of interspecific struggle is for food.

Struggle with the environment: The struggle that the organisms have with the environment for survival is called environmental struggle. Living animals struggle with the environmental factors like food, cold waves, heat waves, earth quake etc.

4) **Natural selection or survival of the fittest**: The organisms with beneficial variations will survive and those with less fit and unfavourable variations will be eliminated. The organisms which are selected by nature are said to be the fittest. This idea of survival of the fittest was proposed by Herbert Spencer. Variations which are useful to the individual in a particular environment would increase that individual's ability to reproduce and leave fertile offspring.

Less favourable variations would be at disadvantage and organisms possessing them are reproductively less successful. Differential reproductive success exists among organisms. The concept of differential

reproductive success of various forms is more accurate. Over a period of time, the criterion for the success is the reproductive success. The organism that fails to reproduce cannot be represented in future generations however it may be fit in the struggle for existence (Theories of Evolution, n. d.).

5) **Origin of new species**: The over production of animals lead to struggle for existence. The animals survived with favourable variations are better adapted to the environment. All the modifications caused by variations and selected by nature are accumulated from generation to generation till a generation is produced that is more adapted and has more chances of survival (Theories of Evolution, n. d.). Thus a new species originates by gradual accumulation of favourable variations in a number of generations.

Darwin considered that a permanent racial change is the product of fluctuating variations. He also believed that evolution is a gradual, rather than a sudden, biological event. Thus, as per natural selection, new species are evolved due to cumulative effect of fluctuating variations.

6.1.3.1 Experimental Verification of Natural Selection – Industrial Melanism

"A classical example of natural selection in the wild is the case of peppered grey moth *Biston Betularia* which was abundant before industrial revolution all over England. These moths showed colouration with two phenotypes, grey and black. The black forms were more and grey forms were less in the industrial period particularly in the industrial cities like Birmingham. Biologists proposed this change in the population of peppered moth was due to the pollution caused by the industrial revolution. Prior to industrial revolution the grey moths succeeded to camouflage the light trunks of the trees. With the industrial revolution more soot was released due to the burning of coal. Tree barks became black. Grey moths were easily identified and were more predated by the birds. Grey moths decreased in number and dark moths increased in the population. Therefore natural selection favoured the melanic moths to reproduce more successfully. Natural selection of darker forms in response to industrial pollution is known as industrial melanism" Theories of Evolution, n. d.).

Check Your Progress 3

6) Who wrote the book "Origin of Species by Natural Selection"?

   a) Charles Darwin

   b) Jean-Baptiste Lamarck

   c) Alexander Oparin

   d) J. B. S. Haldane

7) T.R. Malthus wrote an essay on:

   a) Principles of Geology

   b) On the principles of populations

   c) On the tendency of varieties to depart from original types

   d) Theories of population

8) Natural selection of darker moths in response to industrial pollution is known as:

   a) Industrial pollution

   b) Industrial melanism

   c) Industrial selection

   d) Industrial revolution

6.1.4 The Mutation Theory

Hugo de Vries in the year 1900 proposed a new theory of evolution which is known as the Mutation Theory. This new theory did not consider natural selection as the principle force of evolution; rather it considered mutation as the main proponent of evolution. Mutations are called the spontaneous alteration of genes leading to changes in the organism and this in turn gives rise to new species. The new species originates suddenly and without any visible preparation.

The mutationists were of the opinion that most of the hereditary variables were discontinuous in nature and could be explained by the laws of Mendel. In this case, evolution would be effective if selection is operated on large mutations.

Contrary to the mutationists, the biometricians led by Karl Pearson, supported the view of Darwin and argued that the major cause of evolution was natural selection. They opined that selection acting on small differences was the primary mechanism for evolutionary change. After the acceptance of the Hardy-Weinberg equilibrium (1908), mathematical models began to be developed and a new field called "population genetics" emerged. This field was developed largely due to the efforts of scientists such as Th. Dobzhansky, R. A. Fisher, S. Wright and J.B.S. Haldane.

6.1.5 The Modern Synthetic Theory

As a result of emergence of population genetics, a framework developed for the integration of genetics into natural selection. This subsequently led to the demise of mutationism and the modern synthetic theory was conceived. By the middle of the 20th century, evolutionary biologists universally accepted this integration and the synthetic theory was widely adopted. In contrast to Weismann's and Wallace's Neo-Darwinian concept, the Synthetic Theory incorporated facts from fields such as genetics, systematics and paleontology. Hence, the term "Neo-Darwinian theory" should not be confused with the "Synthetic Theory" (or the phrase "Neo-Darwinian synthesis").

The basic tenets of the Synthetic Theory were Theodosius Dobzhansky (1900-1975), Ernst Mayr (born 1904), Julian Huxley (1887–1975), George G. Simpson (1902–1984), Bernhard Rensch (1900–1990) and G. Ledyard Stebbins (1906–2000).

The proponents of the Modern Synthetic Theory laid emphasis on the population and not on the individual levels. It was observed that natural populations exhibited considerable amount of genetic variation and that selection could act on these variations. Hence, the population had the necessary variability to explain evolutionary genetic change through time and space. Modern Synthetic Theory has considered following aspects:

- Mutation forms the base of the Modern Synthetic Theory. These occur in a random fashion and furnish the fuel for evolution by introducing genetic variability.
- Migration, founder effect, random genetic drift and hybridization are other factors.
- Synthetic theory is the concept of the "biological species" which has been proposed by Mayr in 1942.
- Speciation defined by Dobzhansky as a "step of the evolutionary process (at which) forms ... become incapable of interbreeding". Consequently a number of pre and post-mating isolation mechanisms have also been proposed.

Gradual evolution can be explained in terms of small genetic changes ("mutations") and recombination and the ordering of this genetic variation by natural selection. The observed evolutionary phenomena, particularly macro-evolutionary processes and speciation, can be explained in a manner that is consistent with the known genetic mechanisms.

Check Your Progress

9) Who proposed the theory of mutation?

   a) Hugo de Vries

   b) Ernst Mayr

   c) Julian Huxley

   d) Bernhard Rensch

10) Gradual evolution can be explained in terms of small genetic changes ("mutations") and recombination and the ordering of this genetic variation by natural selection. This statement defines:

   a) Neo Lamarckism

   b) Darwinism

   c) Mutation theory

   d) Modern synthetic theory

11) The concept of the "biological species" was proposed by:

   a) Ernst Mayr

   b) Theodosius Dobzhansky

   c) Julian Huxley

   d) Bernhard Rensch

6.2 SUMMARY

The term 'Evolution' refers to the development of more complex forms of life from simpler or earlier forms. To understand organic evolution various theories were put forth. But the important theories that explained the organic evolution are: Lamarckism, Darwinism, Mutation theory and Synthetic theory of Evolution. The Lamarckian theory mainly explained the Inheritance of Acquired Characters and Use and Disuse of Organs. The Darwinian Theory

consists of the principles such as, over production, struggle for existence and survival of the fittest. The Mutation Theory did not consider natural selection as the principle force of evolution; rather it considered mutation as the main proponent of evolution. The Synthetic Theory of Evolution is the combination of Darwinian natural selection and Mendelian genetics. Because of the developments in modern genetics, evolution can be studied as changes in gene frequencies between parents and offspring. Hence the Synthetic Theory can be studied with the help of mutation, natural selection and isolation.

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6.4 ANSWERS/HINTS TO CHECK YOUR PROGRESS

1. (a)
2. (b)
3. (b)
4. (c)
5. (c)
6. (a)
7. (b)
8. (b)
9. (a)
10. (c)
11. (a)

UNIT 7 BASIC CONCEPTS OF EVOLUTION*

Contents

Learning Objectives

After going through this unit, you would be able to understand the basic concepts of evolution, i.e.:

- speciation;
- irreversibility;
- parallelism and convergence;
- adaptive radiation; and
- extinction.

7.0 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. Let us first understand what evolution is as the present unit deals with basic concepts of evolution. All life on earth originated through common descent, from a last universal ancestor that lived approximately 3.5–3.8 billion years ago (Doolittle, 2000; Glansdorff et al., 2008). ‘‘Repeated formation of new species (speciation), change within species (anagenesis) and loss of species (extinction) throughout the evolutionary history of life on earth can be inferred from shared sets of morphological and biochemical traits, including shared DNA sequences. These shared traits are more similar among species that share a more recent

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common ancestor and can be used to reconstruct a biological "tree of life" based on evolutionary relationships (phylogenetics), using both existing species and the fossil record. Existing patterns of biodiversity have been shaped both by speciation and by extinction" (Evolution, n. d.). Although more than 99 percent of all species that ever lived on the planet are estimated to be extinct (Stearns & Stearns, 2000), there are currently 10–14 million species of life on earth (Miller & Spoolman, 2012).

According to Darwinian Theory of Evolution by Natural Selection organisms become progressively adapted to their environments by accumulating beneficial mutants, immediately strikes our mind. In fact when Darwin originated his theory in the mid 19th century, the mechanism of inheritance and the nature of heritable variations were unidentified; rather he slowly came to acknowledge the Lamarckian view that the inheritance of acquired traits did play some role in evolution. However, Darwin's Theory of Evolution by Natural Selection as a ground for evolution was accepted into other branches of biology. Huxley, Broca and Duckworth, recognized undoubtedly that, man's place in nature was amongst primates and held closest proximity to the great apes.

The study of human evolution advanced independently of human genetics owing largely due to the discrepancy in time. 20th century saw the rediscovery of Mendel's work, explaining the concepts and mechanism of inheritance; thus heralding the landmark Mendelian genetics. Modern Genetic Theory propagates that evolution is result of changes in gene (allele) frequencies between ancestral and descendent populations. Natural selection, mutation, genetic drift and migration are responsible for these changes. Despite the fact that evolution is result of changes in gene, it is practically not viable to measure directly the changes in gene frequencies. Hence, evolution is also essentially viewed as changes in the morphology of organisms through time; and the degree of morphological similarities and differences have always been part of evolutionary studies.

The understanding of human evolution continues and currently the Synthetic Theory of Evolution states that evolution paved way to the fact that functional adaptation of the diverse and variable forms of life, is through the continuous production of variation and the action of natural selection.

7.1 DEFINITION

Evolutionary processes give rise to diversity at every level of biological organisation, including the level of species, individual organisms and at the of molecular level (Hall and Hallgrímsson, 2008). Evolution was first used by Herbert Spencer (1852), an English philosopher, to denote the historical development of life. Evolution is change and the changes within the organism over a period of time is termed 'micro-evolution' whereas changes from one being to the other i.e. transformation, is termed as 'macro-evolution'. Evolution can be defined in numerous ways; there is 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 civilization or cultural evolution. Likewise 'organic evolution' is applied to the changes that have taken place in the living things, viz. plants and animals. Charles Darwin (1859) 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) while in 1951 Dobzhansky stated "evolution is the development of dissimilarities between the ancestral and the descendant population".

7.2 BASIC CONCEPTS OF EVOLUTION

Before mid 1800's it was presumed that the diversity of life on earth was due to God's grace and perfection and whatever we saw was God's creation that naturally remain unchanged; this thought lead to the belief that the basis of creation was its genesis only. Nevertheless evolutionary thought did evolve, as fossil discoveries showed that life had changed over time, few scientists considered that life had evolved with time and geological sciences provided evidence that earth was exceedingly old. It was pre-Darwin biologists who proposed mechanisms for evolution and finally Darwin and Wallace (1858; 1859) proposed a mechanism of evolution through their writings. There are various evolutionary principles like speciation, irreversibility, parallelism and convergence, adaptive radiation and extinction which we would be discussing.

7.3 SPECIATION

Speciation is the evolutionary process. Among diverse evolutionary principles, speciation by which new biological species arise plays the most important role**.** Orator F. Cook (1906) was the first to coin the term 'speciation' for the splitting of lineages. Mayr (1970) defined speciation as the creation of species. Speciation can also be defined as creation of two or more species from one. Did it strike you that the complete evolution depends on the origin of new populations from their ancestors? It gets very complicated to understand many of them in detail due to lack of sufficient resources because the origin is from their ancestors.

Let us first understand what is species? Species is one of the basic units of biological classification and a taxonomic rank that is often defined as a group of organisms capable of interbreeding and producing fertile offspring. Next, how does the speciation process occur? According to Mayr (1970), true speciation or multiplication of species may occur by the following agencies:

- *Instantaneous speciation* (through individuals) which could be genetical or cytological, in partially or wholly sexual species.
- *Gradual speciation* (through populations) which could be geographical speciation or sympatric speciation.

The course of speciation is achievable by four geographic modes in nature on the basis of the extent to which speciating populations are isolated from one another viz.

- allopatric,
- parapatric,
- sympatric and
- quantum speciation

A brief description of each is given below:

7.3.1 Allopatric Speciation

Allopatric *(*Greek word *allos* that means other + *patrâ* which means fatherland) speciation also referred to as geographic speciation is a common process by which new species arise. The population divides into two geographically isolated populations by a geographic barrier like a mountain range or river for terrestrial organisms, or a land mass for aquatic organisms depending upon the habitat of the animal. These isolated populations then experience genotypic and/or phenotypic deviation because of different selective pressures.

7.3.2 Parapatric Speciation

This mode of speciation is typified when a small population enters into entirely new habitat. But then there is only partial separation of the zones between these two diverging populations and the individuals of each species may come in contact or cross habitats from time to time, but reduced suitability of the heterozygote leads to selection for behaviors or mechanisms that avert their inter-breeding.

7.3.3 Sympatric Speciation

In sympatric speciation, two or more descendant species forms from a single ancestor and occupy the same geographical locality. In this sort of speciation even a small amount of gene flow tends to eradicate genetic differences between parts of a population. There are number of examples of sympatric speciation amongst the invertebrates, predominantly the insects that becomes dependent on diverse host plants in the same area.

7.3.4 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 fertilization organism”. This takes place through adaptive radiation by the discharge of genetic variability surrounded by ecologic islands. Quantum speciation is swift; requiring only few generations, in fact may consist of only one or few individuals. In quantum speciation, genetic drift plays a key role.

Check Your Progress 1

1) What do you understand by evolution?

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2) What is Speciation? Describe different mechanisms of speciation with suitable examples.

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7.4 IRREVERSIBILITY

Irreversibility is an important principle in the studies of primate evolution. Louis Dollo, a French born Belgian paleontologist proposed in 1893 the Principle of Irreversibility. Dollo's law of Irreversibility or Dollo's Law states that an organism is unable to return, even partially to a previous stage, already realized in the ranks of its ancestors. This means that a structure that changes its form in evolution will not revert to its earlier form. So once an animal has passed through a number of stages, a reversion, stage by stage, to the original ancestral condition does not occur. Flying reptiles can be taken as an illustration of this. After these reptiles became extinct, wings and adaptation to an airborne way of life occurred in two other distinct lineages – the birds and mammals.

7.5 PARALLELISM AND CONVERGENCE

Similar structures, similar adaptive relationships, or similar behaviors occurring in dissimilar groups of animals are consequential of similar evolutionary opportunities. The fundamental principle of evolutionary biology is that when there is a close similarity in the total morphological pattern of two organisms, there is a logically close phylogenetic relationship between them. Well, dilemma that erupts with this phenomenon of similarity is whether such similarities are examples of parallelism or convergence or whether they are proof of evolutionary affinity between the organisms. Parallelism and convergence imply that a close phylogenetic relationship does not exist.

- Parallelism is typically limited to the development of similar adaptive features in animals that are related, such as, animals belonging to the same order and also the parallel resemblances are, in all probability the recognition of a genetic potential that is present in the entire group. An example of this may occur when a species colonizes several new areas which are isolated from, but environmentally similar to each other. Similar selective pressures in these environments result in parallel evolution among the traits that confer.
- Convergence on the other hand is the development of similarities in adaptive relationships or structures in two animal species or major groups that are not closely related. The repeated evolution of flying is a typical example of convergent evolution, be it flying insects, birds and bats, all evolved the capacity of flight independently; so what we conclude that they have 'converged' on this useful trait. Let us understand this with an example. The eye of the octopus has the same complex structure as the human eye. However, substituting it for human eye study would be very wrong although the two species diverged at the time when animals had evolved into vertebrates and invertebrates.

It is herculean task to classify all cases of similarity as convergent or parallel due to complexity. Let us understand this. There are two types of photoreceptors in the vertebrate eye: rods and cones. Rods are highly sensitive and need very little light to function though have little power of discrimination; on the other side, 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 live in dim light such as

whales, cats and some fishes. The difficulty is, in which of these animals are the rods convergent and in which there is parallel development? Therefore, comes the perception of how we define parallel and convergent. As suggestive of the nomenclature, 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. The Old World Monkeys and New World Monkeys present an excellent example of parallelism between groups living today, since they appear to have evolved in parallel from a prosimian ancestor that most likely lived at least 35 million years ago. An example for convergent evolution is the 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 terms homologous and analogous are frequently used to portray particular structures in animals. Homologous structures are those that are related by evolutionary descent and divergence; e.g. the wing of a bat and the forelimb of a monkey are homologous – they are descendent from same ancestral structure, whereas, the wing of a bat and the wing of a butterfly are analogous. Though they may have similar functions and similar forms, but then 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.

7.6 ADAPTIVE RADIATION

In evolutionary biology, adaptive radiation is a process in which organisms diversify rapidly into a multitude of new forms, particularly when a change in the environment makes new resources available, creates new challenges and opens environmental niches (Larsen, 2011; Schulter, 2000). “Four features can be used to identify an adaptive radiation:

- Common ancestry of component species: specifically a recent ancestry. Note that this is not the same as a monophyly in which all descendants of a common ancestor are included.
- A phenotype-environment correlation: A significant association between environments and the morphological and physiological traits used to exploit those environments.
- Trait utility: The performance or fitness advantages of trait values in their corresponding environments.
- Rapid speciation: Presence of one or more bursts in the emergence of new species around the time that ecological and phenotypic divergence is underway.” (Adaptive Radiation, n. d.)

When there is a rapid increase in numbers and kinds of any evolving group of animals facilitated by environmental changes and utilizing a number of new places in the planetary living space because of adaptive radiation, it may result in the evolving group of animals be it at the level of a species, a genus and a super family. 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. Sometimes the descendants of a single species evolves to take advantage of many different environments and opportunities, now this rapid change in the external

environment may result in the formation of different animals to grow from a single ancestral form. The evolution of a trait that opens up many new possibilities may also give rise to adaptive radiation. Let us understand this principle of evolution 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 period of the Cenozoic Era, the earlier steady climates became unsettled as a result dinosaurs (a varied group of animals from taxonomic, morphological and ecological standpoints) became extinct as they did not adapt themselves to the new environment.

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Whereas the mammals evolved in many distinct lines e.g. the rodents specialized 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.

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Additionally, every mammalian order consecutively gave rise to sub lines that occupied new environments by acquiring new form of life. Many of today's mammals are distinctly different from their primitive common ancestors to the Paleocene epoch.

The spread of arboreal primates, the old world monkeys, into trees of the tropical forests is an example of an adaptive radiation. Adaptive radiation is said to have occurred when a group of organisms adapt into a planetary living space consequent to the changes in the group's relationship to environment, which naturally was not possible earlier. These altered relationships can be inferred from the lines of verification such as the morphology of the fossils and comparative studies of the living forms which are in all likelihood descendants of these fossils.

Besides, various orders and sub-orders of mammals have undergone more differentiation, dividing or 'radiating' into types adapted to different habitats. Hence, all the main groups of primates today embrace species with distinct dietary habits. Therefore, insect eating, seed eating, leaf eating and more or less omnivorous genera reappear in different branches of the primates as these branches diverge 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.

Darwin's finches are the famous example where adaptive radiation is seen. Patchy land is time and again a prime location for adaptive radiation to occur, is argued by the evolutionary biologists. The differences in geography all through disjointed landscapes are thought to promote such diversification in species. Darwin's finches also inhabit the patchy or fragmented land of the Galapagos Islands and are diversified into many different species which differ in ecology and morphology, specifically the size and shapes of their beaks.

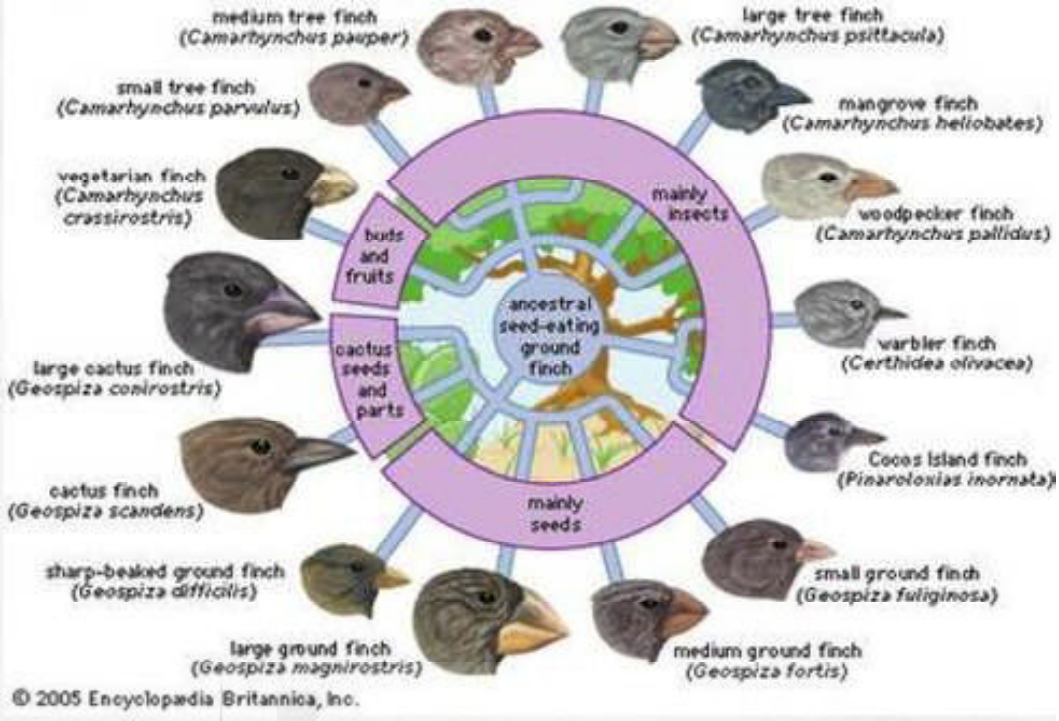

Fig. 1: Adaptive radiation in Galapagos finches

Source: https://www.britannica.com/science/speciation

It was adaptive radiation that paved way for the evolution of different beaks which facilitated the access to appropriate, different food and resources. Depending upon their beak would be their food e.g. those with short beaks are better adapted to eating seeds on the ground, those with thin, sharp beaks eat insects and those with long beaks use their beaks to probe for food inside cacti. Accordingly with such specializations in the beaks, seven or more species of finches are able to inhabit the same environments without competition or lack of resources killing several off. Consequently, these morphological differences in beak size and shape brought about by adaptive radiation allow the island diversification to continue.

7.7 EXTINCTION

Extinction is when an organism or of a group of organisms, that is, a species ceases to exist. It is through evolution that a new species is formed by the process of speciation. The relationship between animals and their ecological niches has been firmly established (Sahney et al., 2010). Extinction is the disappearance of an animal group, such as species, from the evolutionary record due to the death of the last individual of that species. It is not a bizarre occurrence, because species are produced by speciation when new organism evolve and increase when they find suitable ecological niche and when they are no longer able to cope with the new changing conditions, they disappear through extinction. Practically all animal and plant species that have lived on earth are now extinct and extinction appears to be the eventual destiny of all species. Hence, when there are no existing individuals to reproduce and carry on next generation extinction then becomes inevitable. The species also become functionally extinct when very few

individuals who are unable to reproduce that may be due to age, poor health, large distant or even lack of individuals of both the sexes, survive. The extinctions are constant all through the history of life, even if the rate of extinction elevates in occasional mass extinction events. Extinction of species may be due to the negative role of environmental selection in evolution wherein the species may develop a way of life such that a change in the environment is unable to support its survival or one species may become extinct when it is changed into another, resulting in species being a segment of a continuous, progressive evolutionary lineage. Therefore, the species of one time period in which this lineage exists is the ancestor of the subsequent species in the next time period and the ancestral species become extinct through the course by which it is transformed into its descendants. The early Pleistocene hominids, australopithecines are extinct; nevertheless it is probable 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 coupled with humanity's expansion across the globe over the past few thousand years. Human activities are now the crucial cause of the continuing extinction event; global warming may additionally hasten it in the future. The position of extinction in evolution is not very well understood and may depend on which type of extinction is considered. The foundation of the incessant "low-level" extinction events, which constitute the greater part of extinctions, may be the result of competition between species for limited resources. If one species can out-compete another, this could generate species selection, with the fitter species surviving and the other species driven to extinction. The sporadic mass extinctions are also important, but instead of acting as a selective force, they radically reduce diversity in a non-specific manner and promote bursts of rapid evolution and speciation in survivors.

7.7.1 Pseudoextinction

Extinction of a parent species where daughter species or subspecies are still alive is also called pseudoextinction. In other cases, species have produced no new variants, or none that are able to survive the parent species' extinction. 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 existing 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.

Check Your Progress 2

3) Write a short note on irreversibility, parallelism and convergence and adaptive radiation.

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4) What is extinction? Critically discuss this evolutionary process with examples.

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7.8 SUMMARY

Evolution simply means change. Organic evolution is the study of changes that have taken place in living things i.e., plants and animals. According to the progress of modern genetic theory, evolution is now considered as changes in gene (allele) frequencies between ancestral and decedent populations. But then it is practically unattainable task to measure directly the changes in gene frequencies. Hence, evolution is also essentially viewed as changes in the morphology of organisms through time. Analyses of degrees of morphological similarities and differences have always been focus of evolutionary studies. The origin of discontinuities between animal populations, that is speciation, is a foremost issue of biologists. After the foundation 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. While understanding the evolution, the basic concepts of evolution like speciation, irreversibility, parallelism and convergence, adaptive radiation and extinction are important.

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7.10 ANSWER/HINTS TO CHECK YOUR PROGRESS

1) Evolution, also known as descent with modification, is the change in heritable phenotype traits of biological populations over successive generations. (Refer to the section 7.1).

2) Speciation is the evolutionary process and whether genetic drift is a minor or major contributor to speciation is the subject matter of much ongoing debate. Among diverse evolutionary principles, speciation by which new biological species arise plays a most important role.

   There are two mechanism of speciation: Instantaneous speciation and Gradual speciation (Refer to the section 7.3).

3) Irreversibility

   Irreversibility is an important principle in the studies of primate evolution. Dollo's law of Irreversibility or Dollos Law states that an organism is unable to return, even partially, to a previous stage already realized in the ranks of its ancestors. This means that a structure that changes its form in evolution will not revert to its earlier form.

   Parallelism and Convergence

   Parallelism and convergence imply that a close phylogenetic relationship does not exist. Parallelism is typically limited to the development of similar adaptive features in animals that are related, such as animals belonging to the same order and also the parallel resemblances are in all probability the recognition of a genetic potential that is present

in the entire group. Convergence on the other hand is the development of similarities in adaptive relationships or structures in two animal species or major groups that are not closely related.

Adaptive Radiation

In evolutionary biology, adaptive radiation is a process in which organisms diversify rapidly into a multitude of new forms, particularly when a change in the environment makes new resources available, creates new challenges and opens environmental niches.

4) Extinction

Extinction is when an organism or of a group of organism that is species ceases to exist. It is through evolution that a new species is formed by the process of speciation. Extinction is the disappearance of an animal group, such as species, from the evolutionary record due to the death of the last individual of that species. (For further refer to section 7.7).

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