2

Theories of Evolution (Cont.) : Lamarckism

LAMARCK

Jean Baptiste Pierre Antoine de Monet Lamarck (1744-1829) was a French naturalist, well-known for his theory of evolution. In 1778, **Lamarck** published his work in *'Flore Francaise'*. In this book he developed **Dichotomous Key** that helped in the identification of species. In 1781, he wrote *'Dictionnaire de Botanique'* and *'Illustrations De Generes'*. These contained the account on the wonderful plant life of Mediterranean Sea. In 1801 and 1802, **Lamarck** submitted two important papers on evolution under the name of *Systeme des Animaure Sans Vertebras* and *Recharches Surl Organisation des Corps vivans*. In 1809, **Lamarck** elaborated his doctrine of evolution in his masterpiece *'Philosophie Zoologique'*. In spite of his impaired sight, **Lamarck** wrote *'Histoire Naturelle de Animaure Sans Vertebrates'*. **Lamarck** became blind in his later years and died in great poverty in Paris on December 18, 1829.

Lamarck's name is inseparably linked with the theory of evolution. But he had attributed to biology in a number of other ways. He introduced the word **'Biology'** to emphasize the kinship between living beings (*i.e.*, plants and animals). He also provided detailed investigations of fossils and living invertebrates. He introduced the words **invertebrates** and **vertebrates** and emphasized distinction between them. Moreover, **Lamarck** arranged all living creatures of past (fossil animals) and present (living ones) in one broad line or 'staircase' leading uphill to the primates and the highest being man. The sequence of arranged animals in the presumptive staircase of Lamarck is the same as is followed today.

LAMARCKISM

(Theory of Inheritance of Acquired Characters)

This theory was proposed by French biologist, **Jean Baptiste de Lamarck** in 1809. It was published in *'Philosophie Zoologique'* in the year 1809. It is popularly known as *'The Inheritance of Acquired Characters in Organisms'*.

Definition

Lamarckism or theory of inheritance of acquired characters can be defined as *'The changes in structure or function of any organ acquired during the life-time of an*

individual in response to changes in the surrounding environment are inherited by its offsprings and keep on adding up over a period of time'. These changes lead to the origin of new species.

Postulates of Lamarckism or Inheritance of Acquired Characters

Lamarckism is based on three factors or postulates :

1. New Needs : Changes in the environment create new needs in living organisms so that these are better adapted or more suited to the changed environment. The organisms have to put in special efforts for the fulfilment of the new needs. These efforts lead to a change in the habits or behaviour. The new need results in the formulation of new organ or a part in the body. If the need continues that organ or part continues to grow.

2. Acquisition of New Characters : New characters are acquired by the living beings in two ways :

(a) **By use and disuse** : The new habits involve **greater use of certain organs** to meet the new need, and **disuse** or **lesser use** of certain other organs in changed conditions. The continuous use of an organ or organs keeps them functional and makes them stronger, larger and more efficient. Continuous disuse of an organ or organs leads to gradual reduction in their size and to their final disappearance.

Vestigial organs are examples of such non-functional organs in the modern forms. These were in the functional form in the ancestors. Thus by differential use and disuse of various body parts, an organism would change to some extent and acquire some characters and modify some others.

The changes acquired or accumulated in an organism during its life time by the use and disuse of organs or by the influence of the environment are called **acquired characters.**

(b) **Effect of environment** : Changes in temperature, light, medium, food, etc., influence the functioning and behaviour of living beings and introduce changes in their structure. Thus organisms acquire certain new characters due to direct or indirect influence of environment.

3. Inheritance of Acquired Characters : The characters acquired by an organism during its life time are inherited to the next generation. In every generation some new characters were acquired or the older ones keep on increasing or improving. As a result, after a number of generations, the species gets modified into a new one.

Evidences in Favour of Lamarckism

1. Evolution of Long Neck in Giraffe : According to **Lamarck,** Giraffes have evolved from some deer-like ancestors who had short neck and forelimbs and grazed on grass. As the climate of this area gradually became arid and this changed into a desert, its rich vegetation was gradually replaced by a few high trees. Thus leaves of these high trees was the only food available to the ancestors of giraffe. For obtaining their food from the tall trees, they had to continuously stretch their neck and forelegs. The continuous stretching of neck to reach the tree leaves, resulted in gradual elongation of neck and forelimbs. The increase was transmitted to the members of next generation, in which further elongation occurred due to similar efforts. This in due course of time resulted in the present day long neck of giraffe.

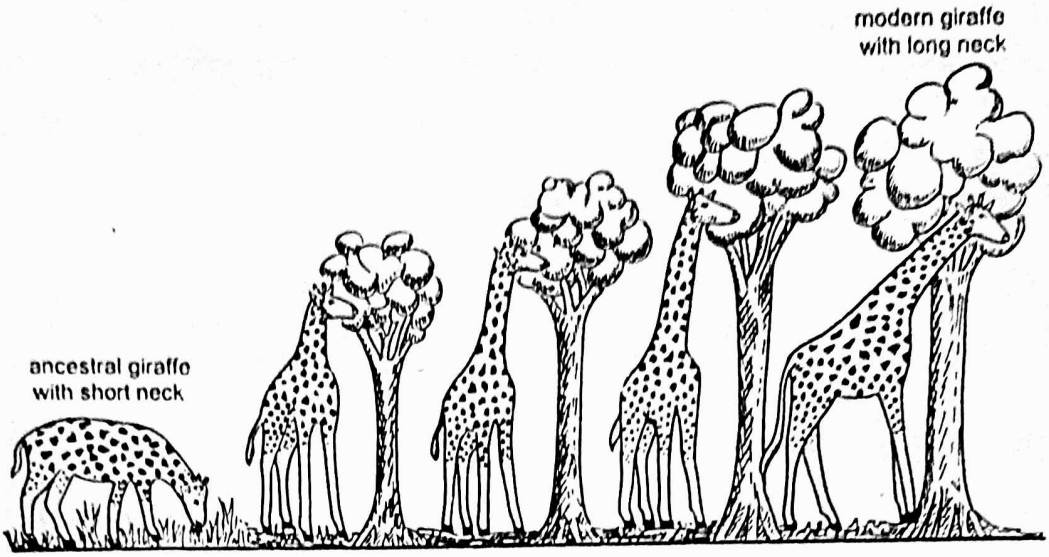


Fig. 1. Evolution of long neck in giraffe according to Lamarck. **A.** Ancestor with short neck able to eat grass; **B.** Neck lengthens a little by stretching in an effort to reach leaves; **C.** Offspring with slightly longer neck; **D.** Offspring lengthens neck further by stretching as leaves from lower branches are consumed; **E.** Very long neck after a number of generations.

2. Evolution of Snakes : According to **Lamarck,** the ancestors of snakes were limbed and lizard-like. They lived in thick jungles. Out of fear of mammals, who were more powerful, the snake's ancestors started creeping on jungle floor and living in narrow crevices or burrows. For creeping among the vegetation or burrowing in the narrow crevices, they stretched their body, which gradually became elongated. The legs which were of no use but proved to be a hindrance in creeping and burrowing gradually disappeared.

3. Evolution of Aquatic Birds : Aquatic birds like ducks, swans and geese, etc., have arisen from terrestrial ancestor by developing web between the toes for wading in water (adaptation to aquatic mode of life : **continuous use**). Web developed because the ancestral forms had to spread their toes and stretch the skin between them to rest on water. Reduction in the size of wings due to their continuous disuse.

4. Evolution of Horse and Deer : Ancestors of modern horse lived in soft ground in jungles. When they were replaced by dry grassy plains, the horses and deer had to graze on hard grass and to walk on dry land. These changes in habit were accompanied by changes in the molars and premolars, reduction in the number of digits and lengthening of the legs. The foot posture gradually changed to unguligrade which was suited for swift running over hard ground.

5. Some Other Examples :

(a) Clasping birds through constant perching on the twigs or branches of the trees have developed sharp and curved digits.

(b) Eyes are reduced in moles because they live underground.

(c) Muscles of pinna are reduced in mass but are well developed and functional in rabbit, dog, elephant, etc., because they live in jungles and use their pinna to collect sound waves from the surroundings.

(d) Biceps muscles in the right arm of blacksmith are more developed because of the continuous use of this arm.

(e) **Flightless birds** (Kiwi of New Zealand; Ostrich from Africa and Emu from Australia) are believed to have descended from flying birds. When they first

reached New Zealand, they were able to fly. On settling there, they did not find any need to fly, as there were no enemies on land and there was plenty of food. In due course of time, they lost their ability to fly and accordingly wings got degenerated. The evolutionary theory of **Lamarck** was warmly supported by **Etienna Geoffroy** (1772-1844), Professor of Geology at the Faculty of Sciences at Paris.

Criticism of Lamarckism

Lamarckian theory was exposed to severe criticism and **Lamarck** had to defend it throughout his life. It failed to meet the tests of observations. Even our day to day observations indicate its futility. **Cuvier** and **Weismann** were the great critics of Lamarckism. Some objections which even Lamarck could not answer are as follows :

1. The **tendency to increase in size,** has been noted in many forms, but many times evolution shows reduction in size. For example, in angiosperms, the trees are primitive and shurbs, herbs and grasses have evolved later and are more advanced. Moreover, persons constantly busy in reading and writing and using their eyes more than others, often develop impaired sight.
2. The **new organs develop where the organisms feel their need** is also not true. If the development of new organ or structure depends upon the desire why man who has long desired to fly like birds has not developed the wings.
3. The **reaction to the environment,** may have some weightage. Organisms do react to the environment but environment causes temporary changes in their organisation and these changes can not be inherited to the offsprings. Similarly, it could not be understood that how use or disuse of an organ will produce a change in its size and how this change will be inherited to the offsprings.
4. Experiments have discarded the law of **inheritance of acquired characteristics.** For example, if any of the parent becomes blind or deaf or lame before producing the offsprings, they do not produce blind, deaf or lame offsprings. Mutilations and wounds of parents do not appear in the offsprings. Small feet in Chinese women, piercing of nose and ears in Indian women and circumcision of penis in Jews and Muslims are age old customs, yet these have no hereditary effect. The strong muscles of a wrestler are not inherited by his children.
5. **August Weismann (1904),** in his famous experiment, cut off the tails of rats for about 80 generations, but tailless offsprings were never born.
6. **Pavlov,** a Russian physiologist, trained mice to come to food on hearing the bell. But training was not inherited.
7. **'Theory of continuity of germplasm'** proposed by **Weismann** (1892) and **Mendel's laws of inheritance** were hard blow to Lamarck's theory of inheritance of acquired characters. According to germplasm theory, each organism has two types of cells :
   (a) **Germ cells,** which pass on their hereditary material to next generation and are found in gonads.
   (b) **Somatic cells,** which form the body and do not pass their hereditary material to the offsprings.

The environment and use and disuse of organs affect somatic cells only. This means acquired characters are restricted to somatic cells alone and do not influence germ cells.

As such these can not be inherited. Lamarck's theory of evolution is now considered as an erroneous assumption.

NEO-LAMARCKISM

According to Neo-Lamarckians mainly **T. H. Morgan** and **Cope,** the acquired characters which become incorporated in the germplasm are heritable and accumulate generation after generation resulting in the origin of new forms or new species.

Experiments in Support of Inheritance of Acquired Characters : The following examples support Neo-Lamarckism :

1. **Bonner** carried out numerous transplantation experiments within native and unnatural environments and found that variations produced were inherited to their future generations.
2. The white mice which were reared at a high temperature (20°–30°C), were found to develop a longer body, a long tail and longer hindlimbs. This character was found to be transmitted to the offsprings generation after generation.
3. **Tower** exposed some potato beetles to abnormal conditions of temperature and humidity at a stage when their reproductive organs were developing. The offsprings of these beetles showed colour variations and these were passed on to offsprings.
4. **Brown-Scquared** described that certain diseases like exophthalmia, haematoma and dry gangrene are caused by injuries in the restiform body of the brain and are inherited to the offsprings.
5. **McDougall** trained rats to follow certain 'escape routes' from a tank of water and the training was given for about 45–50 generations. It was found that there was a decrease in number of errors made in learning the problem generation after generation.
6. Cells exposed to X-rays or treated with certain chemical (like colchicine, mustard gas, etc.) cause changes in chromosome structure **(chromosomal aberrations).**

Neo-Lamarckian Explanation : Neo-Lamarckians explain the above observations as follows :

1. Formation of Germ Cells from Somatic Cells : In case of asexual reproduction and vegetative propagation, the germ cells are derived from the somatic cells. These have chromosomes and genes, similar to the parent. For example, plants raised from tubers, stem cutting or from leaf buds or underground stem inherit genes and chromosomes of the parent plant. **Driesch** raised complete embryo from a part of egg or from isolated early blastomeres.

2. Effect of Environment on Germ Cells through Somatic Cells : Heslop Harrison demonstrated that a pale variety of moth, *Selonia bilunaria*, when fed on manganese coated food, a melanic variety of moth is produced. This breeds true to its colour showing permanent change in the genotype and phenotype of offsprings. He also observed a melanic variety of this moth in areas where food plants were infected with manganese salts from the industrial smoke. The influence of manganese is through somatic cells on to the germ cells.

3. Direct Effect of Environment on Germ Cells : Tower exposed young ones of potato beetle to abnormal conditions of temperature and humidity. The heat treatment did not produce any somatic changes in the beetles themselves, but their offsprings

showed marked colour changes in the next generation. These changes were passed on to the succeeding generations.

Muller demonstrated the role of X-rays in producing heritable variations in *Drosophila* by changes in the chromosome structure. **C. Auerback** in collaboration with **Robinson** and **Carr** produced heritable changes in *Drosophila* by using certain chemical mutagen like mustard gas. Thus, Neo-Lamarckism proves that :

1. Germ cells are influenced by the environmental changes.
2. Germ cells may carry acquired or somatic variations to the offsprings **(Harrison's experiment)**.
3. Germ cells may be affected directly by the environmental factors **(Tower's experiment)**.
4. Somatic characters are the result of interaction between genes and environment. It means environment does affect the gene expression.

Conclusion

The criticism and the experiments in support of theory of acquired characters are not convincing and satisfactory. The main theories in support of this theory are **'Mneme theory of Semon** and **Centro-epigenesis theory of Rignano.**

Semon holds that the functional activity of an organism leaves a permanent record of itself in the form of **engramme.** These engrammes become inheritable when continued for a long period but fail to inherit in case of short duration. It is now established that only these characters which affect germplasm are inherited while the characters that affect somatic cells are not transmitted to their offsprings.

STUDY QUESTIONS

1. Write an essay on Lamarckism.
2. Describe the theory of inheritance of acquired characters.
3. Discuss briefly Lamarckism and give its present position.
4. Write what you know about Lamarck and his work.
5. What are the salient features of the Lamarckism concept of evolution ? Critically examine this concept in the light of modern biology.
6. Give an account of Lamarck's theory of Organic Evolution.
7. Explain the occurrence of vestigial organs on the basis of Lamarckism. Which law of Lamarckism is applied for this explanation ?
8. What is the law of inheritance of acquired characters? How does it explain the elongation of neck in giraffe?
9. List the main factors on which Lamarck based his theory of biological evolution.
10. Give Weismann's theory of germplasm. What light does it throw on Lamarckism?

3

Theories of Evolution (Cont.) : Darwinism

The author of "The Origin of Species", **Charles Darwin** was born on February 12, 1809 at Shrewsbury in England. **Charles Lyell** (1797-1875), a geologist was the person who influenced **Darwin** the most. He was Darwin's senior by 12 years. Instead of supporting the theory of catastrophism, **Lyell** produced evidence in support of Hutton's early theory of uniformitarianism. According to **Lyell,** the slow, steady and cumulative effect of natural forces has produced continuous change in the course of earth's history. But this process is very slow and is not visible in one's lifetime, though it has been going on for a long time and will continue to occur in future.

The Voyage on Beagle

In 1831, **Darwin** got an opportunity to travel by **H. M. S. Beagle** for a voyage of world exploration, planned by British Admiralty. The voyage lasted for five years. During this period (1831-36), the ship visited some of the islands of Atlantic Ocean, many points on the coast of South America and some islands of South Pacific. During his voyage **Darwin** carefully noted the flora, fauna and geology of many little islands and collected numerous living and fossil specimens. Later, Beagle sailed to the **Galapagos Islands**, about 600 miles away from the west coast of America. Here **Darwin** found a living laboratory of evolution. He observed great variations among the organisms that lived on these islands and exhibited radiations and modifications in form. He came across giant tortoises of huge size, recognizably different on each island. The common birds of Galapagos islands, the finches, were markedly different from the finches of main land. The closely related species of finches had beaks of different shapes and sizes, and adapted for feeding on completely different diets. **Darwin** also found that fossils of Galapagos islands were most similar to living species of South America.

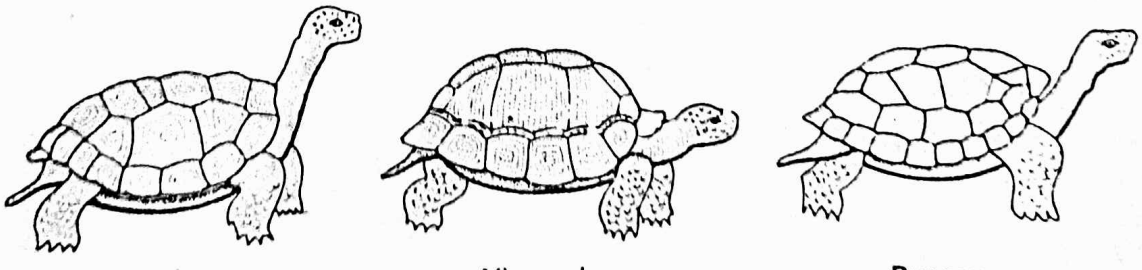


Fig. 1. Three species of tortoises of Galapagos Islands.

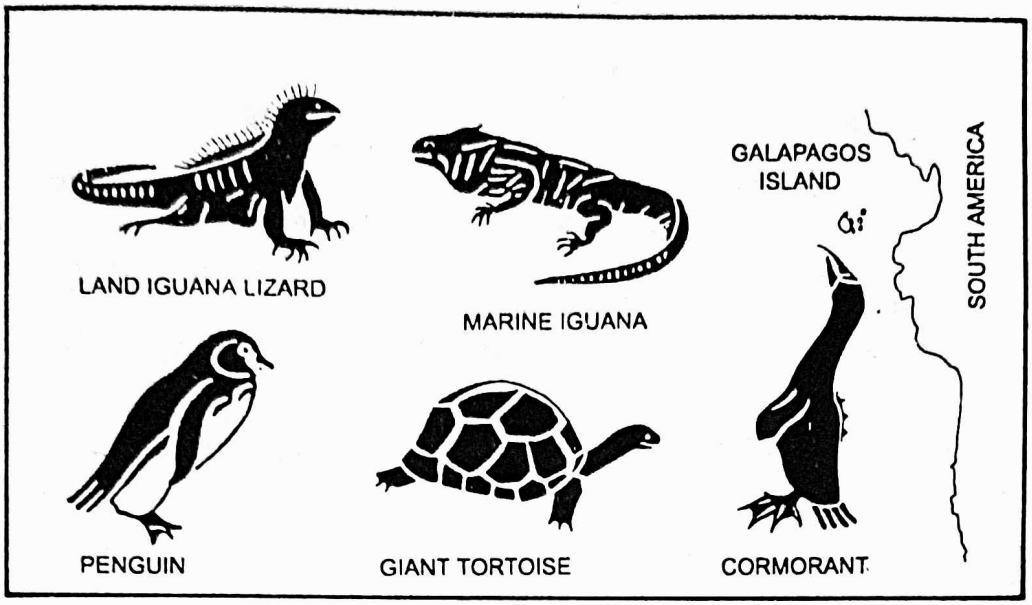


Fig. 2. Various animals such as Land Iguana lizard, Marine Iguana, Penguin, Giant tortoise and Cormorant found on Galapagos islands.

THE THEORY OF EVOLUTION

In 1838, **Darwin** went through an essay on 'The principles of Populations,' by **R. Malthus,** who explained that the rate of reproduction was such that animal population increases many times more rapidly than the available food supply. The food supply increases in arithmetic ratio but the population increases in geometric ratio. This leads to competition. The concept of competition among the living beings for their survival offered the basis of the theory of Natural Selection. **Darwin** also studied variations in the breeds of domestic pigeons and cultivated plants and found that these differ from the wild varieties.

With the above observations, **Darwin** framed a reasonable theory of evolution. When **Darwin** was busy in giving shape to his findings, he received manuscript on *'The Tendency of Variations to depart from Original Type'* from **Alfred Russel Wallace,** in Malaya Archipelago, who had taken observations almost identical to **Darwin**. The paper contained complete details of the theory of *'Origin of Species by means of Natural Selection'*.

In 1858, **Charles Darwin** and **Alfred Wallace** presented a paper to the **Linnaean Society of London** in which they used the term **'evolution'** to describe the progressive changes in successive generations of living organisms. The theory of evolution helps to explain the following two things :

1. The similarities between related organisms are due to their descent from a common ancestor, and
2. The differences between them being the result of variation inherited from one generation to the next.

The theory of evolution by natural selection announced jointly by **Darwin** and **Wallace** in 1858, made little impact on the world of science. Finally, in 1859, **Darwin** published his observations and conclusions under the name **'Origin of Species'.**

DARWINISM

(Origin of Species by Natural Selection or Theory of Natural Selection)

Darwinism is the term coined for the explanation offered by **Charles Darwin** (1809-1882) for the origin of species by Natural Selection. Darwinism does not exactly mean what evolution is, but it explains how evolution might have occurred in nature. This explanation has been beautifully elaborated by **Darwin** in his book entitled **"The Origin of Species by Natural Selection".** An English biologist, **Alfred Russel Wallace,** (1823-1913) also arrived on the same conclusion independently.

Theory of Natural Selection was announced on June 30th, 1858 by **Charles Darwin** and **Alfred Russel Wallace.** Darwin's theory was based on following observations :

1. Study of animals and plants in South America, Galapagos islands and other islands.
2. Observations on animal distribution and relationship between living and extinct animals.
3. Analysis of data from **'Malthus's Essay on Human Population'.**
4. Controlled breeding and artificial selection in domestic animals and plants for obtaining better varieties since remote past.

BASIC POSTULATES OF DARWINISM

Darwin's theory of natural selection is based upon the following five fundamental propositions :

1. Overproduction

All living beings have an inherent tendency to produce offsprings of their own kind in large number for the perpetuation of their race. This is called **geometric increase.** The number of their offsprings is much more than can be supported by a particular environment and can possibly survive. For example :

(a) A *Paramecium* divides three times in 48 hours. If all its offsprings survive and multiply, in five years the mass of paramecia will be equal to ten thousand times the mass of earth.

(b) A **codfish** produces over a million eggs in a year. If all the eggs develop into fishes, the whole Atlantic Ocean will be full of cods in five years.

(c) **Oyster** lays about 1,14,000,000 eggs in a single spawn. If all the eggs develop and young ones survived, after five generations, there would be more oysters than the estimated number of electrons in the visible universe.

(d) **Elephant** which is the slowest breeder, starts breeding at the age of 30 years and during its life time of 90 years produces only six offsprings. If all the young ones survive, a single pair of elephants would produce 1,90,000 elephants in 750 years.

(e) A rabbit produces about 6 young ones in a litter (at one time) and four litters per year and the young ones start reproducing at the age of 6 months.

(f) A single evening primrose plant produces average 1,18,000 seeds while a fern produces few million spores.

Regardless of the rate of reproduction of a species, its number remains roughly constant under a fairly stable environment. For example, in the life history of *Fasciola*

(liver fluke), the adult fluke produces thousands of eggs per year which escape out of the host faeces. Further development of eggs is possible only if these get suitable environment. The miracidium larvae hatching out of the eggs can survive in water only for a short period. Their further development is possible only if they get the secondary host, snail (*Limnea* or *Planorbis*), and are able to reach the pulmonary sac. During their development inside snail body, they have all the chances of being exterminated along with snail which forms food of large number of carnivorous animals. Finally, the cercaria larvae coming out of the snail body are exposed to their enemies (like insects, crustaceans and others). Their metamorphosis into the adult is possible only when they are eaten up by the sheep. As a result only few of the thousands of eggs reach up to the adult stage.

2. Struggle for Existence

According to **Darwin** individuals multiply in geometric ratio whereas space and food remain almost constant. There is three-fold struggle to ensure living, to obtain maximum amount of food and suitable shelter. The three-fold struggle operates at following levels :

1. Intraspecific Struggle : The intraspecific struggle is the competition among the individuals of the same species or in closely related forms to gain the upper hand. This type of struggle is very severe, because the need and approach of all the competing organisms is precisely the same. Example of intraspecific struggle is offered by the young trees in a forest. Their seedlings spring up in clusters. Some of them die soon from lack of sufficient soil, moisture or food. But many of them are able to grow and their tall branches begin to mingle and shut out light and air.

2. Interspecific Struggle : It is struggle between the organisms of different species living together. Individuals of one species compete with those of other species for similar requirements, *i.e.*, food, shelter and breeding places. For example, **Arnold** observed an everlasting struggle for food and described it **'Each slew a slayer and in turn was slain'.** A lizard feeds on ants and is preyed upon by snakes and kites feed on both.

3. Struggle with the Environment or Inanimate Nature : It is the struggle of living forms against extreme heat or cold, against excess of moisture or drought, against lightening, storms, earthquakes and volcanic eruptions or shortage of food, water and oxygen, lack of light, presence of predators, absence or shortage of shelter and space, etc. For example, in North Central State of America, a severe winter with late snow cuts off food supplies and causes extermination of quails.

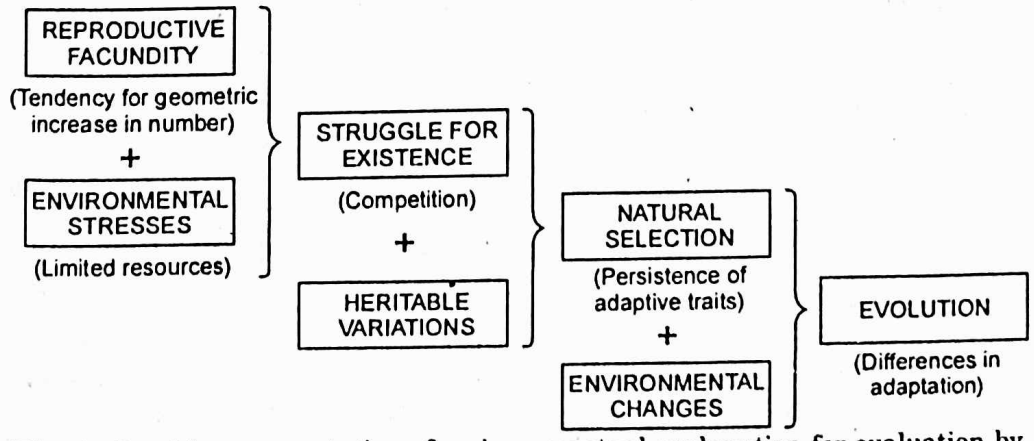


Fig. 3. Graphic representation of main conceptual explanation for evaluation by natural selection given by Darwin.

3. Variations and Heredity

The everlasting competition among the organisms has compelled them to change according to the conditions so that they can utilize the natural resources and can survive successfully. Therefore, it is difficult to find out any of the two individuals alike. Even the progeny of the same parents are not exactly alike in all respects. These differences are known as **variations.** Without variation changes could not occur and there will be no possibility of evolution to occur. But all the variations are not significant from evolutionary point of view. Some of them are changes caused temporarily in some of the organisms and are not inherited to the offsprings. But certain variations are such which once appeared in the parent generation, continue to appear in the progeny generation after generation. These variations are now known as **heritable variations** and form raw material for evolution. The dual or biparental heritage, mechanism of cell division at the time of gamete formation (*i.e.*, meiosis), effect of X-rays or other radiations and other atmospheric changes which produce changes either in the genes or the chromosomes of the germplasm are responsible for producing variations.

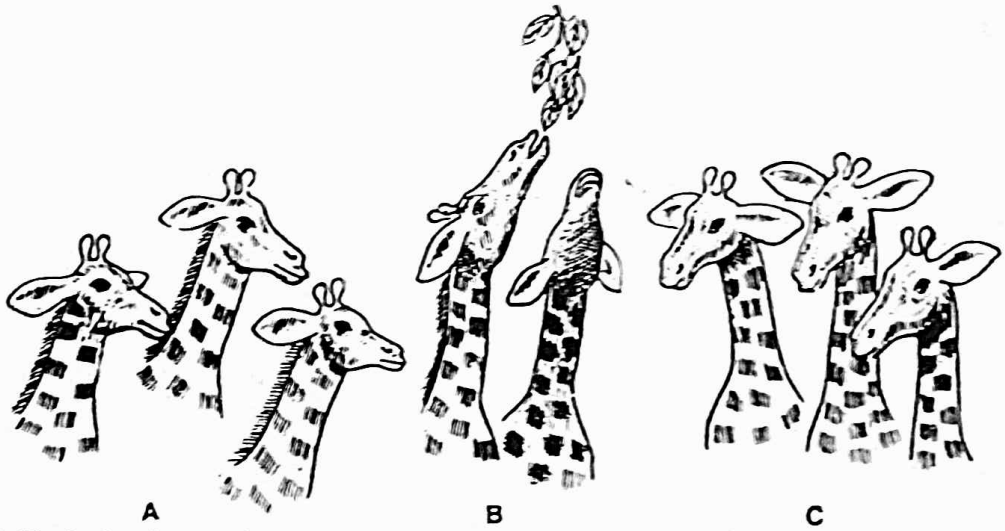


Fig. 4. Variation in population of giraffe and natural selection favouring the long neck-giraffe.

Variations may be harmful, neutral or useful. Harmful variations will make its possessor unfit in the struggle for existence and will lead to their extermination. For example, a change leading to chlorophyll deficiency in a plant will result in lower area of photosynthesis and weakening of plant. These will naturally be weeded out. On the other hand, individuals possessing useful variations will be more successful in the struggle for existence. For example, development of thick exoskeleton in terrestrial organisms protects them against water loss. These animals are better suited to terrestrial life than those with soft skin, having a danger of dessication.

4. Survival of the Fittest or Natural Selection

During the struggle for existence only those individuals could survive which exhibit such variations that are proved to be more beneficial in facing the hardships and rigours of environment or which change to adapt them to the changing conditions. Those individuals or races which can not tolerate these hardships stand no chance in the struggle for existence and are routed out. In Darwin's words the nature appears saying, ***"Thou art weighed in the balance of nature and art found wanting."***

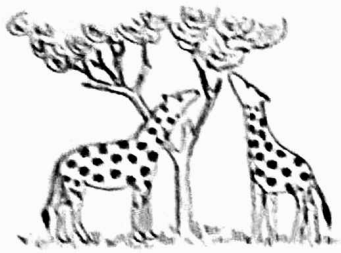
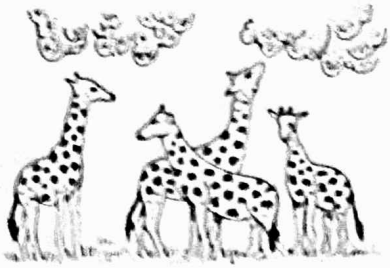
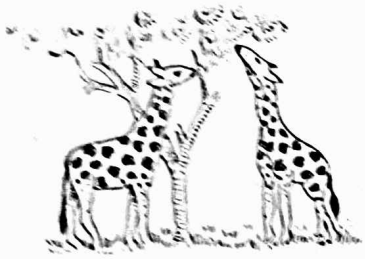
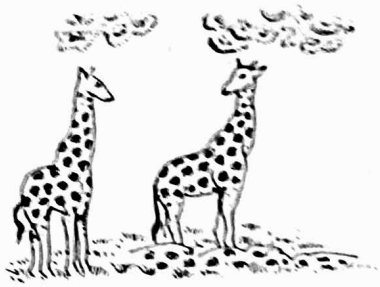
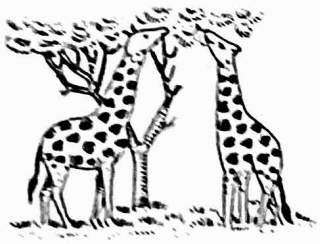
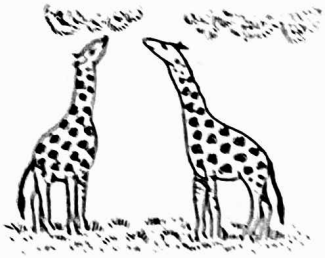
Lamack's Explanation	Darwin's Explanation
	
I. Ancestral giraffes all had short necks, which were subjected to stretching to enable the giraffes to reach the foliage of trees.	I. Ancestral giraffes had necks of varied length. The variations were hereditary.
	
II. Stretching resulted in comparatively longer necks in the offsprings. These were also stretched frequently for obtaining leafy food from trees.	II. Long necked giraffes were found to be more suitable for obtaining foliage from the trees. Therefore, competition and natural selection led to the survival of long necked individuals.
	
III. The continued stretching of neck resulted in the modern long necked giraffes.	III. Only long necked giraffes survived.

Fig. 5. A comparison of Lamarck's and Darwin's theories as illustrated by the evolution of long neck in giraffe.

Darwin illustrated survival of the fittest by taking example of Lamarck's giraffe. According to **Darwin,** giraffe exhibited great variations in the length of their neck and legs. Since grass was scarce on the land they had to eat the leaves of tall trees.

Naturally, giraffes with long neck and longer legs had advantage over those with shorter legs and necks, because they could get food more easily and had better chances of survival. These forms fed and reproduced and became abundant. On the contrary giraffes with short necks starved and gradually became extinct.

5. Origin of Species

From above observations **Darwin** made certain conclusions and summarised them under the heading ***"Origin of Species by Natural Selection"*** as follows :

As a result of struggle for existence, variability and inheritance, the successive generations tend to become better adapted to their environment. These adaptations are preserved and accumulated in the individuals of the species and ultimately lead to the origin of new species from the old ones. The environment is ever changing and it leads to further changes and the appearance of new adaptations in the organisms. As natural selection continues, the latter descendants after several generations become markedly distinct from their ancestors. Further more, certain members of a population with one group of variations may become adapted to environmental changes in one way, while others with a different set of variations may become adapted in a different way. As a result two or more species may arise from a single ancestral species.

Origin of new species by natural selection as envisaged by **Darwin** can be summed in the from of the following Wallace's chart.

TABLE 1 : WALLACE'S CHART

	Facts	Inference
A.	1. Rapid multiplication 2. Limited space for shelter 3. Stability of populations	**Struggle for existence**
B.	1. Struggle for existence 2. Variations and heredity	**Survival of the fittest and natural selection**
C.	1. Survival of the fittest 2. Continued changes (adaptations)	**Origin of new species**

Evidences in Support of Darwinism

Darwin's theory of natural selection is today recognised as the main factor in the evolution of organisms. Following evidences support Darwin's theory of natural selection :

1. Artificial Selection : There is a close parallelism between natural selection and artificial selection. By controlled breeding and natural selection for several generations, many new varieties of plants and new species, races or breeds of domestic animals have been developed. New races of dogs, horses, pigeons, poultry, sheep, pigs, goats, etc., have been developed by man by artificial selection. If man can produce new varieties in a short time, nature with more time and vast resources can easily produce new species by selection.

2. Mimicry and Protective Colouration : Mimicry and protective colouration as seen in certain animals can be achieved only by gradual changes occurring side by side both in the model and mimic occupying the same area.

3. Correlation between Position of Nectaries in Flowers and Length of Proboscis of Pollinating Insects : This relation between two different organisms can evolve gradually and can be explained by natural selection.

Criticism of Darwinism or Objections to Darwin's Theory of Natural Selection

Darwin's theory was so reasonable and well documented that most biologists soon accepted it. But it was attacked by certain clergymen and certain scientists such as **Sir Richard Owen** and **Adam Sedgwick** :

1. Darwin's theory stresses upon small fluctuating variations, which are to a large extent nonheritable and can play no part in the process of evolution.
2. It does not explain the effect of use and disuse and the presence of vestigial organs.
3. He did not differentiate between somatic and germinal variations and considered all variations as heritable.
4. Many of the differences between the species are not of adaptive value but are simply incidental effects of genes. How and why are these preserved, accumulated and inherited?
5. Why are the inherited characteristics not diluted when the organisms possessing them breed with others without them?
6. Darwinism explains the survival of the fittest but not the arrival of fittest.
7. Natural selection does not account for the beginning of organ or how an organ can be useful in initial stages.
8. It does not explain overspecialisation of particular structure, which in some cases has led to the extinction of its possessors like antlers of extinct Irish deer and large special tusks of Jefferson mammoth.
9. It could not tell whether instincts are acquired and modified through natural selection or not.
10. Natural selection does not explain the origin and development of coordinated sets of structures and co-adaptation, whose effectiveness depends upon perfection. Adaptations such as electric organs of fishes, mimicry in *Kallima* butterfly, etc., can not be explained by Natural Selection.
11. **Darwin** proposed **'artificial selection'** for improving races of domestic plants and animals but these could never lead to permanent specific variations.
12. Natural selection does not explain the evolution of terrestrial animals from aquatic forms.
13. Specific objection was raised to the theory of **sexual selection** proposed by **Darwin.** The theory involves passivity on the part of male and an active choice on the part of female for a more beautiful, attractive and more powerful male.

SUPPLEMENTARY THEORIES OF DARWIN

Darwin proposed three **additional theories** to explain certain objections against theory of Natural Selection. These are :

1. Theory of Sexual Selection

In some animal species, males differ from females of the same species in their morphology. Their males possess certain specialised characters for attracting the mate for reproduction. These are called **secondary sexual characters** such as :

(a) brilliantly coloured feathers of peacock,

(b) antlers in male deer,

(c) beautiful and brightly coloured bands on the body of tiger,

(d) mane in lions,
(e) moustache and beard in man,
(f) nuptial pads of frogs,
(g) vocal sacs in male frogs,
(h) brood pouch in sea horse,
(i) scent glands in male mammals, and
(j) musical notes produced by male birds and certain insects.

Darwin proposed sexual selection theory to explain the occurrence of these characters. Because females select the male partner for mating, so males have developed various characters to attract females. It suggested that males which are provided with attractive characters are selected by female for mating. There is competition among males to get the females. This competition leads to struggle or fight among the males of certain species.

Salient Features of Theory of Sexual Selection

1. In almost all species males are more numerous than females. This gives an opportunity to female for selecting the male.
2. Males are more attractive in most mammals and birds.
3. Males are provided with brilliant colours, conspicuous ornamentation, pleasing behaviour, mating dances, melodious songs and sounds. Females lack such features.
4. There is competition, quarrel and fight among males for the possession of females.
5. Sexual selection operates only on one sex (*i.e.*, male) of the species, but natural selection operates equally on both the sexes.
6. Sexual selection is associated with reproduction while natural selection is concerned with the survival of the individual.

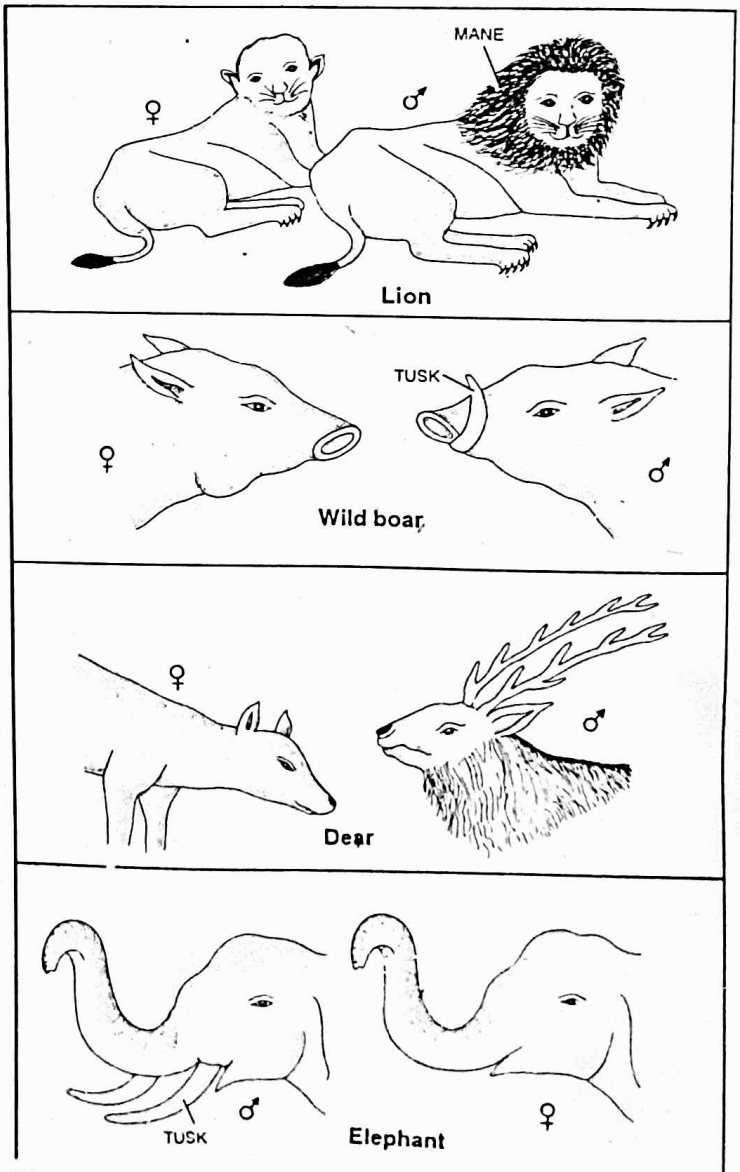


Fig. 6. Secondary sexual characters in males of some of the mammalian groups.

2. Theory of Artificial Selection

Artificial selection means selection exercised by man to select the plants and animals with desirable characters with features of economic interest. For example, production of large number of eggs by hen or production of large quantity of milk by cows and buffaloes or crops with good yield are features of human interest.

The artificial selection involves selection of organisms from the existing stock or by interbreeding or cross breeding different varieties and then selecting the best hybrid. Cross breeding and selection have helped in the origin of a number of new varieties in crops, vegetables, pigeons, dogs, poultry, horses, cows, buffaloes, etc.

3. Darwin's Theory of Pangenesis

To explain the inheritance of characteristics from parents to the offsprings, **Darwin** proposed the **"Theory of Pangenesis"**, which is now totally discarded. The theory can be briefed in following points :

1. All the somatic cells of the body produce minute particles, the **pangenes** or **gemmules** which are carried away by the blood stream and are accumulated in the germ cells.
2. Each gamete or germ cell represents a minute replica of the parent's body and is capable of developing into the adult with minutest details.
3. Each pangene or gemmule in the developing individual regulates the development of the organ from which it originated from the parent.
4. Gemmules are produced continuously at all stages of development.
5. Sometimes certain gemmules might lie dormant for several generations and then develop. This results in the appearance of characteristics in the offsprings which were present in their ancestors (atavism) and are not seen in the parents.

Therefore, according to this theory every somatic cell produces gemmules and the actual germ cells are the sites of collection of gemmules coming from different somatic cells. The theory is of historical importance only, since the detailed structure of sperm and ovum has been studied and the entire process of their formation is clearly evident.

4. The Experimental Support to Theory of Natural Selection

Darwin's theory of natural selection was accepted because of its direct approach and practical nature. The staunch supporters of Darwinism were **Wallace, Thomas Henry Huxley, Ernst Haeckel, August Weismann, I. B. S. Haldane, Sewall Wright, H. J. Muller, T. Dobzhanskey, Kettlewell, Herbert Spencer** and **Mendel.**

Many biologists carried out experiments to provide support to **Darwinism.** These supporters of **Darwinism** are known as **Neo-Darwinians.** They introduced a number of new facts to make the idea of natural selection more conceivable. Some of the experiments conducted in this series are as follows :

1. Weldor's Experiments with the Shore-Crabs of Plymouth Sound : **Weldon** in his experiments with shore-crabs placed a large break near the mouth of **Plymouth Sound river.** This slowed the rate of flow of river water and China-clay deposition increased. This caused the death of numerous crabs. The survivors had a slightly narrow frontum and there was a progressive narrowing of the frontum in succeeding generations. This shows that natural selection operates upon minute fluctuating variations and under changed environmental conditions it favoured narrow frontum in crabs resulting in their survival and perpetuation.

2. Cesnola's Experiments with Mantis : The role of natural selection was illustrated by **Cesnola** in *Mantis religiosa* by fixing them on plants. Those having colour markings harmonious with the plants survived, whereas all others were eaten up by the birds.

3. Polution's and Sander's Experiments with Butterfly Pupae : The survival value of protective colouration was also exhibited by Polution's experiment. The numerous pupae of butterflies with different colours were placed under conditions which favoured protective colouration. Some of them were also kept in non-harmonious background. The protective colouration was found to have a survival value.

4. Davenport's Experiment with Chicken : Chickens with black-white, barred and checkered colour pattern were left in the field. It was found that the chickens with plain colours were killed by hawks while those with barred and checkered colour pattern were spared because they were inconspicuous from the surroundings.

5. Industrial Melanism in Peppered Moth : Industrial melanism was studied by **R. A. Fisher, E. B. Ford** and **H. B. O. Kettlewell.** Their study was based on peppered moth, *Biston betularia*. The original population of this moth had mottled grey wings that blended perfectly with lichen-covered tree-trunks in Great Britain. Until 1848, these **nonmelanic forms** nicely blended with the surrounding and were protected from the predatory birds. With dramatic rise of industrialisation in Europe (specially Manchester), the atmosphere became sooty and tree trunks became dark in colour due to the absence of lichens. One black moth appeared in Manchester in 1845. This is called **carbonaria** or **melanic form.** In 1848, this black variety of moth formed 10% of the moth population, but by 1898 it formed 99% of the total moth population.

Genetic studies show that melanism is produced by a **single dominant gene** and it follows typical Mendelian inheritance. The change in the gene, genotype and phenotype frequencies is found to be correlated with the spread of industry and change in the surroundings. This can be explained as follows :

The grey or light coloured moths in soot-covered area were easily located by predators and preyed upon. The black coloured moths matched and camouflaged with the soot-covered surroundings and were able to escape from their predators. Thus natural selection operated and favoured the black moths.

To prove that natural selection was the cause of changed gene frequency, **Kettlewell** bred large stocks of the nonmelanic and melanic varieties of peppered moth. These were marked and released in two areas :

(a) The nonpolluted rural area of Dorset, and

(b) The highly polluted area of Birmingham.

He filmed insectivorous birds feeding in the two localities and also recaptured the surviving marked moths. The results of one such experiment are given in table below :

TABLE 2. NATURAL SELECTION OF PEPPERED MOTH IN TWO LOCALITIES

(FROM MARSHALL 1978)

Place	Nonmelanic	Melanic
1. **Dorset 1955 (Unpolluted)**		
1. Released	496	473
2. Recaptured	62	30
2. **Birmingham 1953 (Polluted)**		
1. Released	137	447
2. Recaptured	18	123
3. % of recaptured	13·1	27·5

Industrial melanism, therefore, presents an excellent example of natural selection. This has been observed in a wide variety of moths (about 70 species in Great Britain and about 100 species in USA) in addition to peppered moth.

6. Resistance to DDT : In agriculture and also in houses DDT or some other insecticide is sprayed to control insect pests. But none of the insecticides brings about 100% death of any insect species. Some individuals are resistant to insecticides and are able to survive. The resistance to DDT is a character controlled by genes. This gene was present in the population of the species but in the absence of DDT has no selective value. On DDT spraying, the forms with DDT resistance gene were able to survive while others died. Thus insect population with DDT resistant gene evolved due to selective advantage against insecticide.

NEO-DARWINISM OR MODERN SYNTHETIC THEORY

In the last 25 years, a number of new facts have been added to the knowledge of evolution and the theory of Natural Selection has been reanalysed in the light of genetics, Mendelism, population genetics and biological species concept. This has given rise to 'Modern Synthetic Theory'.

The modern theory of Origin of Species or Evolution is known as **Modern Synthetic Theory of Evolution** or **Neo-Darwinism.** It is the merger of Darwinian selection, and genetic theory. This concept evolved after a book published by **Julian Huxley** (1942) entitled ***'Evolution : The Modern Synthesis',*. Theodosius Dobzhansky** reviewed the Darwinian concept of evolution by Natural Selection in Mendelian populations. In his book ***'Genetics and Origin of Species'*** (1937), he presented the chromosomal studies of *Drosophila* populations and interrelation among its different species. **E. B. Bobcock** provided botanical support to the 'Neo-Darwinian theory' by studying plant genus *Crepis*. **Stebbins** (1950) provided an account of ***'Variation and Evolution in Plants'*. Rensch** (1947, 1960) showed that phenomena of microevolution were adequate to explain macroevolution. **Mayr** (1963) established that modern synthetic theory is applicable to animals too. It presents a combination of mutations, variations, heredity, isolation and natural selection. According to **Modern Synthetic Theory,** origin of species can be explained on the basis of :

1. Genetic variability in population,
2. Significance of genetic variability,
3. Natural selection, and
4. Isolation.

1. Genetic Variability in Populations

Population is a group of individuals of a species living in a given geographical area and freely interbreeding in nature. The total gene contents of all the individuals of a population is called **gene pool.** The members of a population share the same gene pool and interbreed with one another more preferentially than with the members of neighbouring sister populations. Thus they have a **'free gene flow'.** Changes in the gene pool of a population diversify it from other sister populations of a species.

A. Causes of Genetic Variations (At Individual Level)

Genetic variations, *i.e.*, changes in the genes of gametes, introduce genotypic differences in the individuals of a population. Genotype variations are essential for evolution. These are introduced at two levels :

1. Gene Mutations : Gene mutations refer to changes in the chemical and structural composition of genes. These changes may occur by the rearrangement of nitrogenous bases present in a specific DNA molecule or the addition or deletion of one or more nucleotides in a DNA segment. These changes are also called **point mutations.**

1. Gene mutations occur at random. These are nonspecific and nondirectional. These may produce drastic changes or may remain insignificant.
2. Most gene mutations are recessive to normal gene but dominant mutations also arise. Recessive mutations are able to express only in homozygous state.
3. Most gene mutations are **delcterious** or **harmful,** but not all. A few may prove to be beneficial. The harmful mutations are eliminated by natural selection, whereas beneficial ones are preserved in the gene pool of the population.
4. Usually one gene mutates in every 2,000 gametes. Some genes mutate several times, whereas some genes do not mutate at all or mutate rarely. Some genes may mutate back to normal. This is called **reverse mutation.**
5. Mutation rate is influenced by changes in the external or internal environment of the organisms.
6. Mutations occur naturally but may be artificially induced by several mutagenic agents, such as :
   (a) **radiations** (X-rays, UV-rays or infra-red rays),
   (b) **chemicals** (nitrous acid, mustard gas, colchicine, peroxides, phenol, certain organic compounds, etc.), and
   (c) **high temperature.**
7. Mutations introduced artificially are called **induced mutations.**

2. Mendelian Recombination of Genes : It refers to the reshuffling or mixing of genes in sexually reproducing organisms resulting in new combinations of parental genes in the offsprings. It occurs in the following ways :

(a) **By fertilisation** : In sexual reproduction genes from two different parents (male and female) come together by the union of male and female gametes (*i.e.*, **fertilisation**). So the offsprings receive equal number of genes from each parent.

(b) **By meiosis** : Meiosis, at the time of gamete formation, leads to random assortment of maternal and paternal chromosomes in the gametes.

(c) **By crossing over** : Crossing over and exchange of chromosome-segments between maternal and paternal chromosomes during meiosis results in new combinations of maternal and paternal genes.

All these changes result in the new combinations of dominant and recessive genes introducing changes in the genotype and phenotype of the individuals.

B. Causes of Genetic Variations (At Population Level)

At population level genetic variations are introduced by :

1. **Chromosomal Mutations or Chromosomal Aberrations *i.e.*, Change in the Structure of Chromosomes :**
   (a) **Changes in Number of Genes :**
      (i) ***Deletion or deficiency*** : loss of one or more genes.
      (ii) ***Duplication*** : addition of one or more genes.

(b) **Changes in the Arrangement of Genes :**

(i) ***Inversion*** : rotation of a block of genes in a chromosome at 180°.

(ii) ***Translocation*** : exchange of parts between non-homologous chromosomes.

2. **Change in the Number of Chromosomes** (Heteroploidy)

(a) **Change Involving Entire Sets :**

(i) ***Haploidy*** : having only one set of chromosomes, *i.e.*, n-chromosomes.

(ii) ***Polyploidy*** : each set of chromosomes is represented more than twice Triploidy – 3n, Tetraploidy – 4n, Pentaploidy – 5n

(b) **Changes Involving the Number of Chromosomes in One Set of Chromosomes (Aneuploidy) :**

(i) ***Monosomic*** : loss of one chromosome from one set, *i.e.*, $2n-1$

(ii) ***Polysomic*** : addition of one or more chromosomes to one set : $2n+1$ or $2n+2$

(iii) ***Nullisomic*** : loss of both the chromosomes of a pair : $2n-2$

3. **Hybridisation** is the intermingling of genes of two populations of a species or between individuals of two species which are otherwise separated. This can occur either by migration or by artificial cross breeding by man. The hybrids share genetic material from two different species. For example :

(a) *Mule* is a hybrid of horse and donkey,

(b) *Raphanobrassica* is a hybrid of *Raphanus* (radish) and *Brassica* (cabbage).

(c) *Pomato* is a hybrid of potato and tomato.

All the above factors produce genetic variations.

2. Significance of Genetic Variability or Adaptation

The success in survival and reproduction depends on the characteristics of the individuals. Organisms with certain characters or combination of certain characters (*i.e.*, certain genotypes) may prove to be more successfully adapted than other genotypes. For example, a rice variety from central India, *Oryza nivara*, was found to be resistant to grassy stunt virus infection and survived, whereas other varieties of rice crop were all destroyed due to infection in early 1930s. Similarly, during servere drought, plants and animals which can efficiently minimize the loss of water and maximize water absorption have better chances of survival. It means adaptations play a major role in survival. In the struggle for existence, only those organisms manage to survive that are well adapted to the environment. In other words natural selection selects and favours the multiplication of those genetic variations which are of adaptive value to the organism or to the population by encouraging survival and reproduction of individuals with such gene combinations.

3. Natural Selection

Natural selection includes all those kinetic forces introduced by physical and biotic factors, which determine how and in what direction an organism is going to change. Natural selection plays no favouritism, but is obvious that the organisms which are more suited for the environmental conditions will survive overpowering the force of competition and produce more offsprings. Thus the natural selection is a creative process which uses the variations and mutations as the raw materials from which better adapted

individuals with more chances of survival are obtained. How natural selection acts in nature can be examplified as follows :

In any physical environment at a given time a certain proportion of individuals in the population carry normal genes while others represent the mutants, which have mutant genes combined in such a manner that the individuals carrying them differ from normal parents. If the gene pool of that population achieves stability *i.e.*, there are no more changes in the genotype of individuals of the population, it will exhibit following conditions :

(a) mutational equilibrium,
(b) random mating,
(c) equal chances for all genotypes to live and reproduce.

But a population is never stable and constant. The changes occur due to gene mutations, chromosomal rearrangement and recombination of genes. Due to unequal opportunity of mating and inadequate chances of survival in every case, the individuals with changes of survival value survive and perpetuate introducing more offsprings to the population. Thus natural selection operates through differential reproduction and competitive reproductive success always exerts a selective influence. As a result certain mutational changes or variations establish themselves in the line. This process is known as **non-random reproduction** or **differential reproduction.**

4. Genetic Drifts

In small populations, natural selection has less role to play in fixing a gene or a gene combination. In small populations gene frequencies fluctuate purely by chance. This sudden drift of change in gene frequency to one or other side is called **genetic drift.** This was proposed by **Sewall Wright** and is also called **Sewall Wright effect.** According to this concept, a mutation arising in a small population is either fixed or lost just by chance irrespective of its adaptive value. The fixation or loss of a mutation is due to tendency of populations to become homozygous. For this reason, in small populations sometimes unfavourable characters are also fixed. Individuals homozygous for deleterious gene die deleting the harmful genes from population's gene pool.

Thus, when a small population gets isolated from the bulk of large population, it becomes more genetically diversified because of fluctuation and fixation of some characters and loss of others in small isolated population.

5. Isolation

Isolation or segregation of individuals of a species into several populations or groups under psychic, physiological or geographical factors is considered to be one of the most important factors responsible for evolution.

Geographical isolation includes physical barriers like mountains, rivers, oceans and long distances, which prevent interbreeding between related forms. Physiological barriers help in maintaining the individuality of the species, because these isolations do not permit interbreeding among the individuals of different species. All these lead to reproductive isolation.

6. Origin of New Species

The populations of a species, when present in different environments and are separated by some above mentioned barrier, accumulate different mutations independently and become morphologically and genetically so different that they become reproductively isolated and form new species.

Differences between Darwinism and Neo-Darwinism

Darwin's basic theory of natural selection remains the same. However, Neo Darwinism is an enhanced and advanced version of Darwinism which explains all those aspects of natural selection which Darwin's theory could not. The essential points of Neo Darwinism are :

1. Unit of evolution is a population and not species, because species are subdivided into local populations.
2. During evolution, it is the gene pool of the population that evolves and not the individuals.
3. According to Neo Darwinism, the differential reproduction of genotypes and genes is responsible for evolution and not the mortality or survival of the individuals. It means natural selection is differential reproduction of genotypes and genes.
4. Differences among individuals result from accumulation of mutations in population and recombination of genes due to independent assortment, crossing over and fertilisation. The reasons for variations in individuals of a species were not known to **Darwin**.
5. Darwinism emphasised on struggle for existence, whereas Neo Darwinism has also recognised the importance of chance factor in evolution.

NEUTRAL THEORY OF EVOLUTION

Investigations at the molecular level, at which finer distinctions can be made between genetic make ups, have led to the controversial **'Neutral Theory of Evolution. Kimura** proposed this theory and suggested that speciation is not due to selection of advantageous genotypes but elimination of deleterious alleles and random selection of neutral alleles.

It emphasised that mutations are of neutral or nearly neutral value and genetic drift is responsible for divergence. It means all mutations are alike in adaptive value. It is only chance or random drift which delineates a novel collection of mutants into a group, divergent from the parental population.

Kimura's neutral theory has received support from data collected by **Jukes** and **King.** They found a large number of **'hidden mutations'** or 'silent nucleotide substitutions' in proteins of closely related species that are not retained in the population for any especial advantage.

Kimura's neutral theory was based on the following observations :

1. There is a far greater rate of mutations in regions of coding and non-coding DNA that contribute to change in function as compared to the rate of mutations in regions of DNA for functional area of proteins.
2. Rate of neutral mutations is constant. For example, rate of amino acid substitution in a particular protein is almost identical in species closely related as well as widely divergent.
3. The number of substitutions in α-chain of haemoglobin in mouse, horse and man is about the same.
4. The amino acid substitution in the above cases was random in kind as well in position.
5. Many important proteins are polymorphic, but carry out the same function.

STUDY QUESTIONS

1. Describe briefly Darwin's theory of natural selection. Explain how our ideas about natural selection have changed since then (Neo-Darwinism)?
2. Discuss Darwin's theory of 'Natural Selection' in the light of recent studies.
3. Discuss theory of natural selection. What is the criticism against this theory? What do you understand by Neo-Darwinism?
4. Write an essay on Darwin's concept of organic evolution.
5. Give an account of Darwin's theory of natural selection.
6. What do you understand by organic evolution? Explain clearly Darwin's theory of organic evolution.
7. Write an essay on Darwin's theory of natural selection and origin of species.
8. Write a short essay on "Natural Selection".
9. Explain Darwin's theory of natural selection with a note on its present status.
10. Write an essay on Darwinism.
11. Give a critical account of Darwin's theory of Natural Selection.
12. Where does Darwinism stand in modern concept of evolution?
13. How Darwin arrived at the theory of Natural Selection?
14. Write an essay on Neo-Darwinism.
15. Explain Darwin's theory of Natural Selection and Origin of Species.
16. Give an account of Darwin's theory of evolution. Discuss the theory in the light of modern researches.
17. What is the modern concept of organic evolution?
18. Neo-Darwinian school has given a new status to the Darwinian concept of "Natural Selection". Explain.
19. Describe briefly Lamarckism and Darwinism.
    (a) Explain briefly the essential points of the evolutionary theories of :
        (i) Lamarck, (ii) Darwin and (iii) Wallace
    (b) How could the evolution of giraffes from short-necked ancestor be explained in terms of each of these two theories.
    (c) Mention the weakness of each theory.