1. Details of Module and its structure

Module Detail	
Subject Name	Biology
Course Name	Biology 03 (Class XII, Semester - 1)
Module Name/Title	Evolution - Evidences of Evolution – Part 4
Module Id	lebo_10704
Pre-requisites	"Where did all these lifeforms came from?", "How living organisms developed from inanimate matter and how such a vast variety of lifeform developed on earth? What were the ideal conditions in which simple organic molecules gave birth to the first forms of life?
Objectives	After going through this module the learner will be able to: • Understand selection • Explain the importance of artificial selection • List the different types of natural selection • Differentiate between stabilizing selection, directional selection and disruptive selection with examples • Discuss the role of natural selection in evolution
Keywords	Selection, artificial selection, natural selection, stabilizing selection, directional selection, disruptive selection

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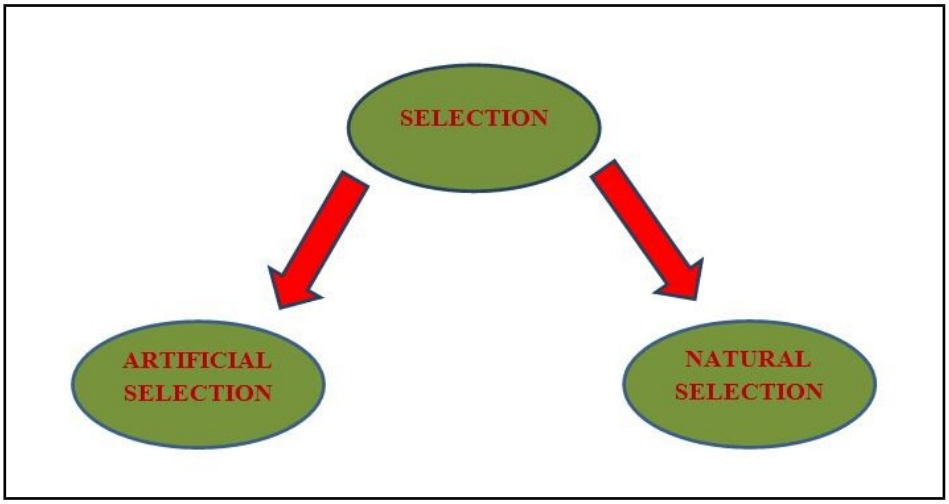
1. Introduction:

Our natural world is so beautiful but at the same time very complex. It consists of a large variety of flora and fauna—some simple and some complex. Being so close to nature, many questions about this beautiful world must have come to your mind, like why are no two individuals alike? How has life originated? How did the things come to be the way they are? It was Herbert Spencer who coined the word evolution to explain the continuous and orderly changes in nature. Darwin later defined evolution as “Descent with modification”. It was Darwin only who explained the concept of natural selection as the primary force behind the descent with modification. Natural selection favours individuals that contribute more offspring to the next generation. According to Darwin, it is natural selection that can alter the frequency distribution of heritable traits in different ways depending on the type of phenotypes which are being favoured.

2. Selection:

Selection is a process in which the environmental factors or genetic makeup of the organisms decide which organisms would adapt themselves better than the others. Selection occurs only when the individuals of a population have diverse characteristics. It will not occur if there are no variations or when they are selectively neutral. One must also understand that selection may not always be **positive selection**. It can also be **negative selection.** Negative selection decreases the occurrence of traits that reduces the individual’s capacity to reproduce, whereas, the **positive selection** increases the occurrence of adaptive traits. However, selection does not always suggest that only the

advantageous traits or allele will occur in a population. There are chances that selection can cause some deleterious traits or allele to occur universally in members of a species.

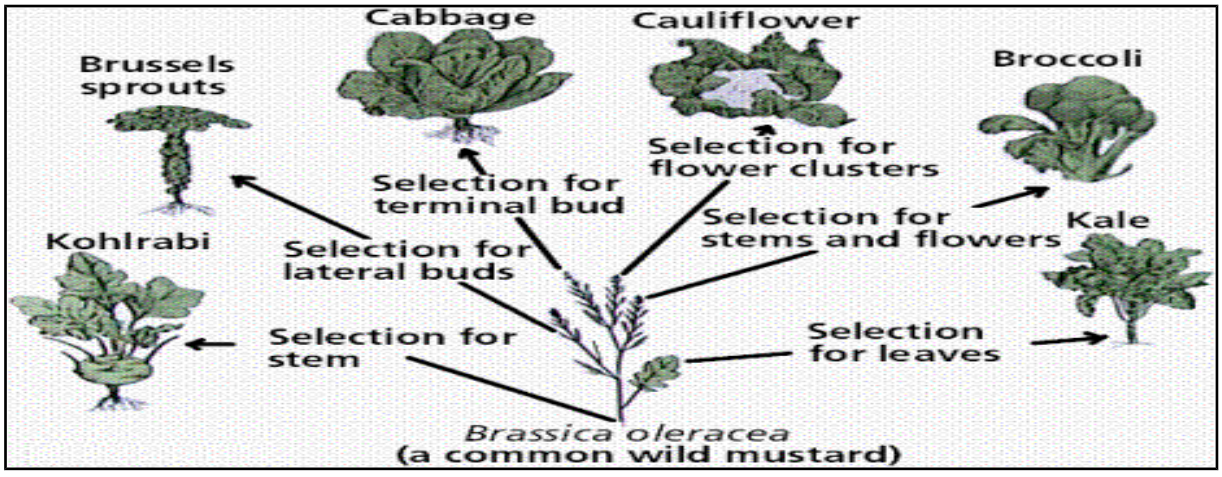


Selection whether natural or artificial, may be defined as differential contribution of the allele of the gene to the gene pool of the population in the next generation.

2.1. Artificial selection:

Artificial selection is also known as **Selective breeding**. Basically, it is the breeding of animals and plants for desirable trait. A plant or animal with desired trait/traits are artificially cross bred with organisms with similar trait/traits, resulting in an offspring with a higher potential of the specific desired trait/traits. This cycle can be repeated with the offspring until the specific desired trait/traits is achieved.

In the fig. given below, different vegetables were cultivated from wild mustard by artificially selecting certain traits.



2.2. Natural selection:

Natural selection is a process that results in the adaptation of organisms to its environment. Individuals with certain characteristics have a greater survival or reproductive rate than other individuals in a population. They pass on these inheritable genetic characteristics to their offspring finally leading to evolutionary changes. Thus, natural selection is the fundamental operating mechanism of evolution. Let us study the classical example of peppered moth to understand natural selection in nature. The peppered moth, *Biston betularia* occurs widely in England. It is a nocturnal moth and during the day it rests on the trunk or branches of the trees where it is vulnerable to attack by insectivorous birds. It occurs in two polymorphic forms:

1. Grey form which is lightly coloured
2. Melanic form with black wings and body which is called as **carbonica form**

The moths satisfy the conditions necessary for natural selection to take place:

- ❖ They reproduce
- ❖ There is variation in their color patterns
- ❖ Their color pattern is inherited
- ❖ The different forms can adapt themselves to the environment differently

In the late eighteenth century and early nineteenth century, there was industrial revolution in England. Until this time only light colored moths were found in large numbers in England. The grey moth camouflaged well with the background of lichen covered barks of the trees. This helped them to escape from the predatory birds.The melanic form on the other hand was conspicuous against a background of grey bark and thus could be easily picked up by the birds. Thus, the melanic form (carbonica form) were very few in number. The industrial revolution in England produced a lot of soot over the English countryside. The sooty smoke killed the lichens growing on the trees. A lot of soot was deposited on the trees and the background environment of the peppered moth changed drastically. The tree trunks and branches turned black with soot. Now the melanic form camouflaged well with their surroundings and escaped predation by the birds. Their number increased rapidly in these industrial areas. The pale/grey colored moths became easy victim to the predatory birds and their population drastically decreased. The frequency of carbonica form increased from 1% to 99% during 50 generations from 1848-1898 in the industrial areas thus

showing that melanic form had the selective advantage. Natural selection allowed them to survive and increase in number thus changing the moth population towards one direction i.e. melanic form.

The Fig. below shows the original and melanic forms of the Peppered moth.

In Fig. 1. both moths are on light colored tree branches and it is the melanic form which is without camouflage.

In Fig. 2. both moths are on dark colored tree branches and it is the light coloured/grey form which is without camouflage.

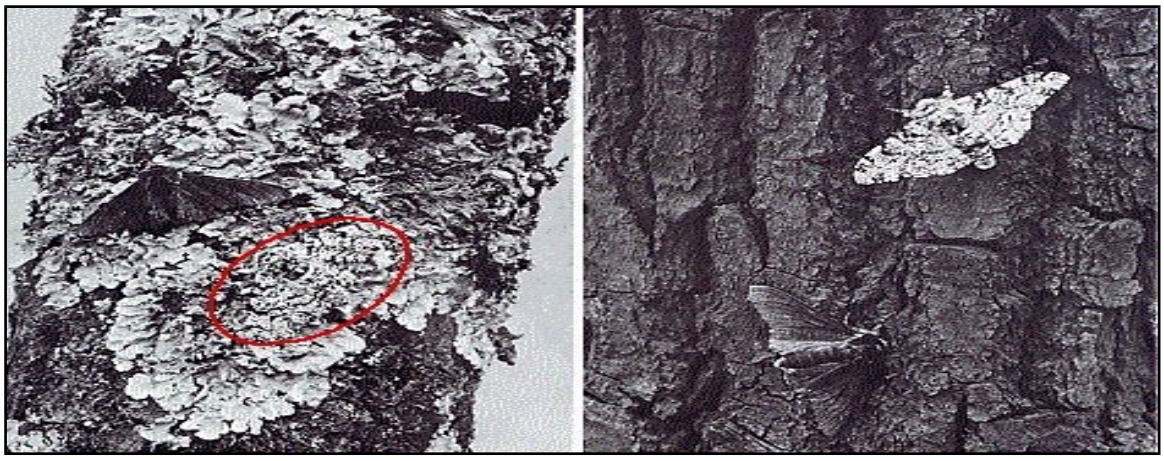


Fig. 1 Fig. 2

- The two varieties of the peppered moth differ by only a single gene. The gene for dark colour is dominant to light colour.
- The dominant mutant gene was initially disadvantageous and was maintained at an extremely low frequency
- As a result of industrialisation, the mutant gene was favoured by natural selection. It became abundant in the population of peppered moths in comparatively short period of time.

Now, here the environmental factor that has selected the melanic variety against the wild type (grey/light moth) is the bird predation. The natural selection has operated in the direction of eliminating gene for light colour and a gradual increase of gene for dark color.

In non- polluted or non-industrial areas of England and in Northern Scotland, the recessive variety remains more abundant showing role of selection. The reason for the increase in the number of melanic form of peppered moth was studied by E.B. Ford and H.B.D. Kettlewell.

Another good example to explain natural selection in nature is: Resistance to pesticides (DDT) in insects:

Mosquitoes are known to be the vectors of diseases like malaria and dengue. During the early times DDT was successfully used as an insecticide for controlling the mosquitoes. The mosquito population then, was more DDT-sensitive but less DDT-resistant. Or in other words, DDT-sensitive mosquitoes were dominant over DDT-resistant mosquitoes. But when DDT was used as an insecticide on a large scale, DDT-resistant mosquitoes had a competitive advantage over the DDT-sensitive mosquitoes. The DDT-resistant mosquitoes became more and more numerous. Over a period of time, the entire population of mosquitoes became DDT-resistant. A similar observation was recorded with some new insecticides. Thus, according to principle of Natural Selection, chemical insecticides would remain useful only for a limited time.

2.3 Types of natural selection:

Natural selection is responsible both for maintaining the constancy of species and for changing them. Based upon different organism-environment relationships, different kind of natural selection have been recognised:

- stabilizing selection/ normalizing/ normal selection
- directional selection/progressive selection
- disruptive selection/diversifying selection

2.3.a. Stabilizing selection:

Stabilizing selection is the most common mode of selection in nature. It is a negative sort of selection that eliminates out the less fit or more specialized phenotypes and favours the average or intermediate phenotypes in sexually reproducing organisms. Stabilizing selection operates only when the environment remains stable for a long period of time. Variations that are brought about by mutation, gene flow, segregation and recombination in a stable environment (constant environment with no change) are thus eliminated. The gene pool of a population is genetically constant in such an environment.

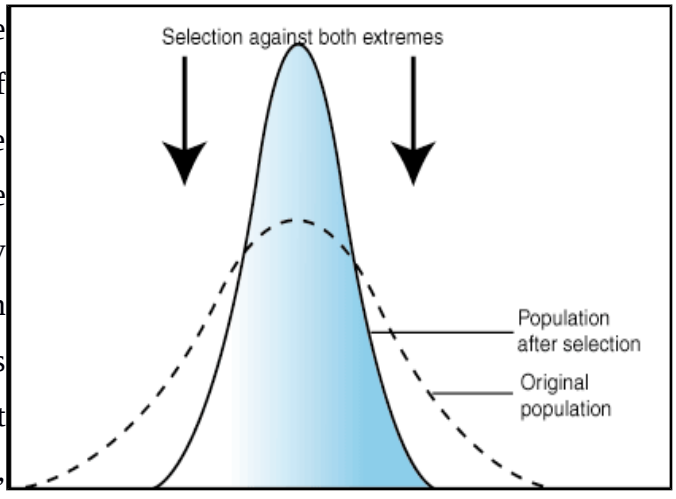


Figure shows the effect of **stabilizing selection** on trait distribution

For example, plant height might be acted upon by stabilizing selection. A plant that is too short may not be able to compete with other plants for sunlight and will be eliminated. Extremely tall plants may be more susceptible to wind damage and they would be eliminated. Selection pressures select and maintain plants of medium height. **The number of plants of medium height will increase while the number of short and tall plants will decrease.**

Another well known example of the stabilizing selection was studied by H. C. Bumpus in 1899. He observed that about 136 sparrows were injured or killed in a severe sleet storm in Rhode Island. He found that the birds that were killed by the storm had abnormally long or short wings as compared to average winged birds. Only 72 birds survived. The majority of the birds that survived possessed normal wings and normal body proportion, which were close to the mean value. This indicated that individuals very much different from the average tend to be eliminated during catastrophic events while the average were able to survive.

So what are the important features of stabilizing selection:

- It operates in constant or unchanging environment.
- Stabilizing selection leads to the population becoming more homogenous. It reduces variance of characteristics.
- It maintains the genetic constancy of species over generations.
- It favours average or normal individuals and eliminates overspecialised as well as less specialised or less adapted individuals.
- It checks accumulation of mutations in the gene pool of population. Mutations might lower the fitness of species in unchanging environment.

Can you now reason out why this type of selection is called stabilizing selection or normalizing selection? Absolutely right!!!!As this selection is maintaining a constancy in the gene pool of the population, it is called **stabilizing selection**. It favours the normal individuals and eliminates the specialized individuals and hence is also called **normalizing selection**.

However, one should remember that Stabilizing selection operates rarely because the environment is constantly changing and is seldom constant.

2.3.b. Directional selection or progressive selection:

Directional selection brings about a progressive or unidirectional change in the genetic composition of a population. It occurs when the environment is progressively changing in a particular direction and thus produces a regular change within a population in one direction with respect to certain characteristics. The environment that changes continuously imposes upon living organisms the need

to change in order to adapt to the continuously changing environment. The selection operating under these circumstances is called **Directional Selection**. The individuals develop adaptations in response to the environmental change and tend to survive and produce more off-springs. Individuals which cannot adapt to the environmental change are eliminated. It favours the phenotype which is non-average or extreme. It is progressive selection which removes more individuals from one end of the normal and adds towards the other end and thereby alters the mean value of the trait in the population in one direction. Thus, the mean moves in one direction generation after generation.

Consider the example of giraffe necks: there was a selection pressure against short necks, since individuals with short necks could not reach leaves on the higher branches of the trees to feed. As a result, the distribution of neck length shifted to favour individuals with long necks.

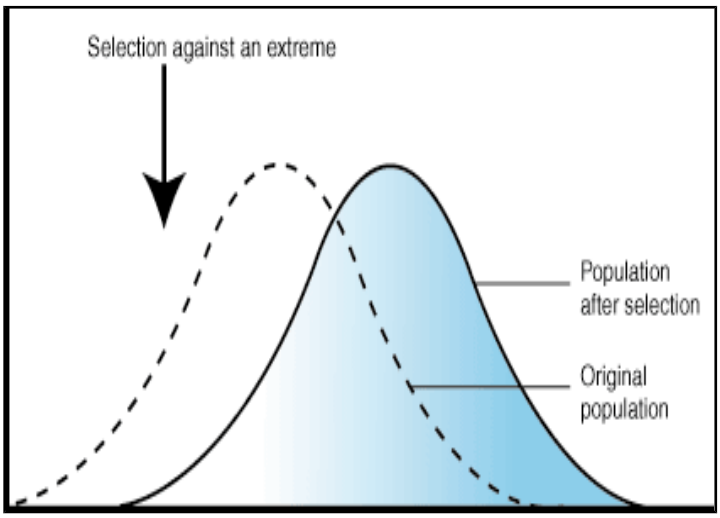


Figure shows the effect of **directional selection** on trait distribution

Directional selection operates under two different sets of conditions:

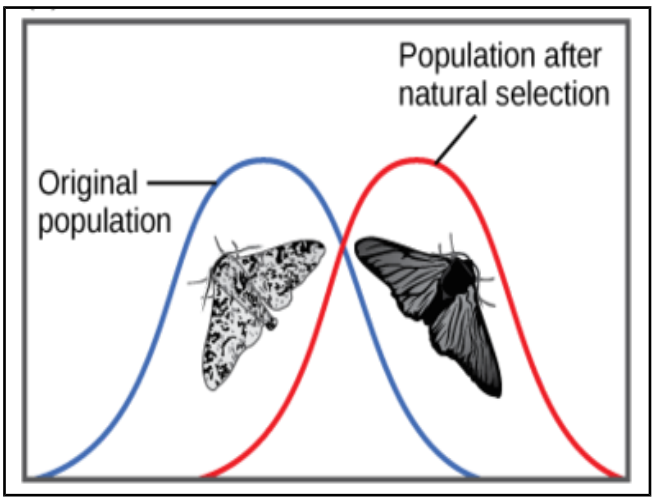
1. In a population subjected to a progressive or directional change in the environment. For example: Biston betularia
2. In a population which was migrating into a new territory having progressively altered environmental conditions. For example: At the end of ice- age many species migrated northward into the regions which were left bare by the retreating glaciers. These must have been subjected to increasing cold, and an increased cycle of difference between short days and long nights of winter and the long days and short nights of summer. Only those populations capable of adaptive responses would have been able to migrate and survive.

In both the cases, directional selection tends to reduce variance in the population.

Important features of directional selection:

- Directional selection occurs during or after the environmental change.
- The gene frequency of a particular gene changes in one direction over a fairly long period.
- Directional selection favours the accumulation of mutations that would increase the fitness of the species in the changing environment.
- It favours the specialized individuals and eliminates the normal individuals.
- It produces a regular change in population in one direction in respect to certain adaptive characteristics i.e. it brings about progressive evolution.

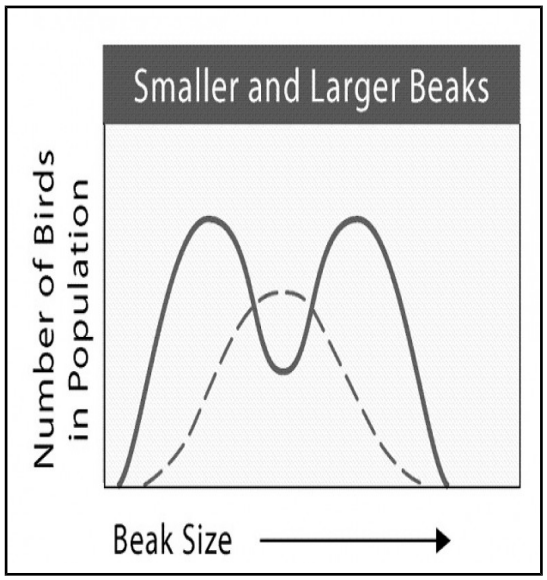
A good **example** is the rise in frequency of the melanic form of *Biston betularia* because of a sudden change in environment viz., industrial soot (refer 6.4.2)



The grey moth camouflaged well with the background of lichen covered barks of the trees. The industrial revolution in England produced a lot of soot over the English countryside. The sooty smoke killed the lichens growing on the trees. The tree trunks and branches turned black with soot. Melanic form camouflaged well with their surroundings and escaped predation by the birds. The frequency of carbonica form increased from 1% to 99% during 50 generations from 1848-1898 in the industrial areas showing that melanic form had the selective advantage. Natural selection allowed them to survive and increase in number thus changing the moth population towards one direction i.e. melanic form.

2.3.c. Disruptive selection or diversifying selection:

Disruptive selection can be explained once again with the help of the example of *Biston betularia* (refer 6.4.2). In industrial areas, the peppered moths almost all were of dark in colour. However, these same moths were very light in colour in rural areas. Very few medium coloured moths were seen in either location. The lighter coloured moths escaped from their predators in the rural areas by camouflaging with the light colored surroundings. The dark colored moths were easily seen by predators in rural areas and were eaten. The opposite happened in the industrial areas. The medium coloured moths were easily seen by the predators and eaten in both locations. Thus, very few medium colored moths were left after disruptive selection. Thus, it is clear from this example that in



disruptive selection, individuals with extreme variation of traits are favoured over the individuals with intermediate traits.

Beak size of Darwin's finches is another example to explain disruptive selection.

From the graph it is evident that birds with large sized beaks and small sized beaks are preferred over birds with medium sized beaks. Birds with beak of average size were least preferred and their number gradually decreased. What must have really happened was that there were seeds of two types viz. soft seeds and hard seeds. There were no medium sized seeds. Birds with short beaks could feed easily on soft seeds while those with large beaks could easily crack hard seeds and feed on them. Finches whose beaks were of average size (neither long nor short) were not able to use either kind of seeds effectively and thus failed to survive.

Important characteristics of disruptive selection:

- Disruptive selection occurs in a population that occupy areas with different types of resources.
- It occurs in a heterogenous environment when more than one environmental factors are operating against the same phenotype.
- It indicates that the extreme values have the highest fitness and the intermediate or mean values are relatively disadvantageous.
- Disruptive selection is important in maintaining and increasing variation within natural populations.
- This type of selection promotes genetic diversity because in every generation the most extreme individuals survive.
- This is the only type of natural selection which increases variance within the population.

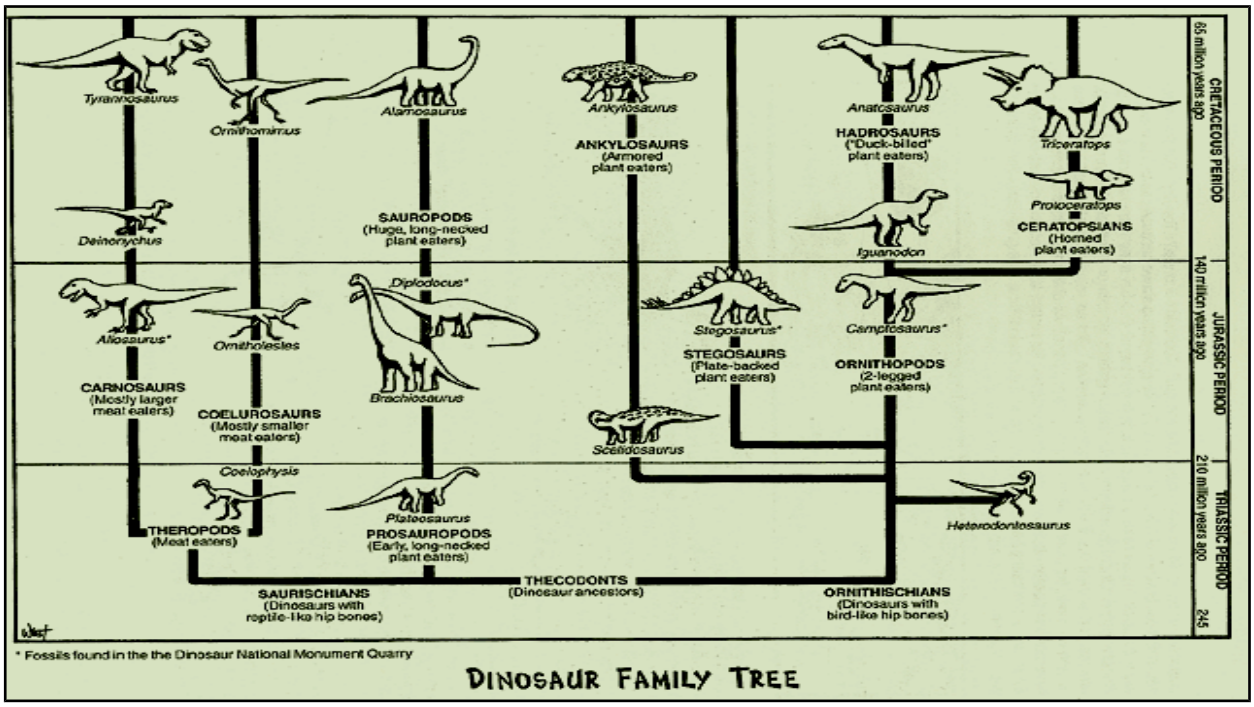
Disruptive selection is the rarest of the three types of natural selection.

2.4 Role of natural selection in evolution: Effect of natural selection as an evolutionary factor:

- Under new conditions harmful characters will be eliminated by selection
- Beneficial characters are intensified and modified
- Characters which are neither harmful nor beneficial are not modified and persist through heredity

According to Darwin and his followers, repeated and intensive selection leads to a slow but steady modifications of the form and functions of the species, through successive generations=a modification always toward adaptation, toward fitness. **Natural selection is the essential idea in Darwinism.**

For a long time it was thought that evolution was a simple linear progression, with humans at the top of the ladder. However, this view is no longer accepted. We now understand that evolution proceeds in a branching pattern, with species on one branch giving rise to other branches and so on. Evolution proceeds as changes (mutations) occur in the genetic code of an organism. These mutations are selected by the environment in which the organism exists. Many of these mutational changes may be harmful to the organism, and may lead to the death of the organism before the harmful genes are passed on to its offspring. Occasionally, however, a gene combination may arise that actually improves the adaptation of the organism to its particular environment and these genes are more likely to be passed on to the next generation. Thus, by the process of natural selection all life forms have branched. The great diversity of dinosaurs was able to evolve because of this natural selection only.



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2.4.a. Natural selection explains both evolution and adaptation:

Natural selection produces evolution when the environment changes; it will also produce evolutionary change in a constant environment if a new form arises that is better than the current form of species. When the environment of the peppered moth changed, so that the background where the moths settled was dark rather than light coloured, the population of moths changed in form (from light colored to dark colored moth) over time. In other words, the moth population evolved. In addition to producing evolutionary change, natural selection can also cause a population to remain constant. If the environment is constant and no superior form arises in the population, natural selection will keep the population the way it is. Natural selection can, therefore, explain both evolutionary change and the absence of change.

Natural selection can also explain adaptation. The camouflage of the peppered moth is the example of adaptation. The colour pattern of the moth, against the appropriate background, makes it less visible and less likely to be eaten by the birds. The moth's survival is therefore increased. When the environment changed, the form of the adaptation needed in it changed as well. In industrial regions, the grey peppered coloration was no longer adaptive. The action of natural selection to increase the frequency of melanic moths resulted in the moths becoming adapted to the environment. Over time, natural selection generates adaptation.

Thus, the theory of natural selection explains both evolution and adaptation.

3. Summary:

- Selection is a process in which the environmental factors or genetic makeup of the organisms decide which organisms would adapt themselves better than the others.
- Selection occurs only when the individuals of a population have diverse characteristics.
- Selection can either be positive selection or negative selection.
- Selection can be of two types viz. artificial selection (man-made) and natural selection.
- Artificial selection is the breeding of animals and plants for desirable trait.
- Natural selection is a process that results in the adaptation of organisms to its environment.

- Based upon different organism-environment relationships, three types of natural selection have been recognised: stabilizing selection, directional selection and disruptive selection.
- Stabilizing selection favours average or normal individuals and eliminates overspecialised as well as less specialised or less adapted individuals.
- Directional selection brings about a progressive or unidirectional change in the genetic composition of a population. It occurs when the environment is progressively changing.
- Directional selection tends to reduce variance in the population.
- In disruptive selection, individuals with extreme variation of traits are favoured over the individuals with intermediate traits.
- Disruptive selection is important in maintaining and increasing variation within natural populations.
- Natural selection explains both evolution and adaptation.
- Natural selection is the fundamental operating mechanism of evolution.