Evolution - Evidences of Evolution - Part 3

Objectives

After going through this module the learner will be able to:

- Understand the concept of evolution
- Explain the importance of Lamarck's theory of evolution
- Differentiate between Lamarck's and Darwin's theory of evolution
- Discuss the theory of saltation as proposed by Hugo de Vries
- Comprehend adaptive radiation
- Compare convergent evolution and divergent evolution

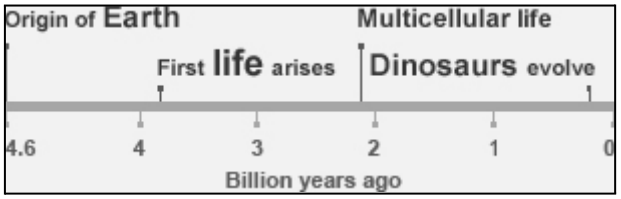
Content Outline

Introduction

The word evolution tells us how single celled organisms have given rise to multicellular forms. It tells us about the evolution of dinosaurs , the monkeys, apes and humans. Today, we know that all species have a common ancestor. But, how did the scientists come to this conclusion? What made the earlier scientist look for a common origin among different species? In this section we will try to answer some of these questions and understand the evolutionary process.

Life on Earth

The history of life on Earth began about 3.8 billion years ago. Life began with prokaryotic single celled organisms such as bacteria. Multicellular organisms evolved over a billion years later. Our own species *Homo sapiens,* evolved only 200,000 years ago. So humans have been around for only 0.004% of the Earth's history. Evolutionary Biology tells us how these simple prokaryotic cells have given rise to complex multicellular organisms.



Understanding Evolution

What is evolution? Let us understand this concept. Continuous and orderly changes taking place in nature is what is called evolution. Hence, we can say that evolution is any change in the physical (non-living) or biological world through time. According to this, we can have:

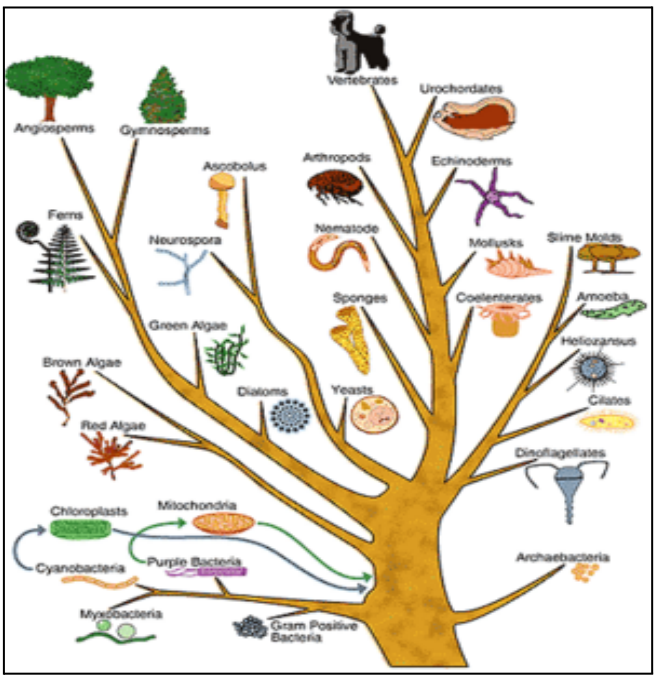
- Evolution of universe(stars and planets)=Cosmic evolution or Stellar evolution
- Chemical evolution i.e. evolution taking place at molecular level
- Erosion of land, rising of mountains etc. i.e. through time are examples of physical evolution
- Evolution taking place at the level of living objects is what is called Biological evolution.

Here we shall only be discussing biological evolution or bio-evolution.

Darwin has defined evolution as "Descent with modification". It was Ernst Mayr who introduced the term evolutionary biology or bio-evolution. Bio-evolution may be defined as "modification of organisms by which a primitive simple form of organism gets gradually modified through descent and transformed into a highly complex and organized present day organism". According to the concept of biological evolution, all life forms on earth share a common ancestor.

However, evolution is a slow and gradual process. These modifications get accumulated through successive generations over millions of years. Thus, the mechanism of evolution cannot be experimented within the short life span of any organism. There is no experimental

evidence to explain the mechanism of evolution; it can be studied on the basis of observed facts and theoretical concepts.



Lamrack's Theory of Evolution

Jean Baptist Lamarck, a French naturalist and former professor of zoology in Paris published his theory of organic evolution in the book entitled *philosophique zoologigue* which later became well known as Lamarckism in 1809.

Lamarck's theory was based on four theoretical postulates. These are:

- Inner urge of organisms
- Environmental change and new needs
- Use and disuse of organs/acquisition of new characters
- Inheritance of acquired characters

Jean Baptist Lamarck (1744-1829)

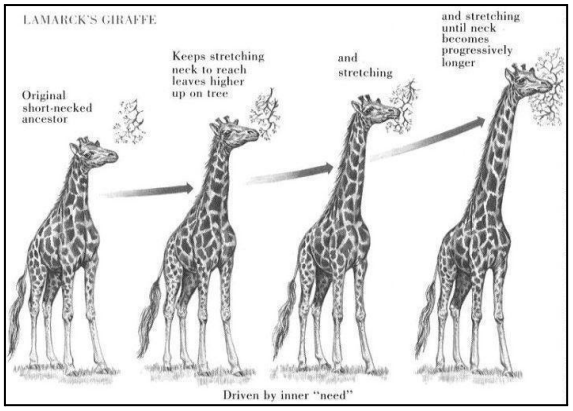
- **Inner urge of organisms:** Usually plants and animals tend to grow and increase in size. According to Lamarck this increase in size in form and structure is due to an inner urge or internal force of life.
- **Environmental change and new needs:** Lamarck studied the relationship between living organisms and the environment and came to the conclusion that:
    - Environment is always in a state of change
    - The change in environment results in a new habitat
    - This new habitat exerts a great influence on the organism. It brings about new needs in the living organisms so that they are better adapted to survive in the changed environment
    - Thus, change in environment brings about the development of new characters which results in structural modifications and behavioral change in the organism.

  Organisms develop adaptive features to cope with the new environment.
- **Use and disuse of organs:** Lamarck was of the view that the organs of the body which are more frequently used have the tendency to grow and develop efficiently, whereas the organs which are less used in the changed environment are reduced or become vestigial.
- **Inheritance of acquired character:** Environmental change and the response of living organisms to this change leads to development of new adaptive characters in an organism. Such characters developed during the lifetime of an organism are called acquired **characters.** They are not found in its immediate ancestor. According to Lamarck, these acquired characters are passed on to the next generation leading to morphological, anatomical and physiological changes in a species.

Lamarck cited some examples in various groups of animals in support of his theories.

- **Lengthening of forelimb and long necks of giraffe**

  According to Lamarck the ancestors of giraffes had short forelimbs and short necks. They grazed on the grass. The climate of this area gradually changed and the rich green vegetation of the area was replaced by a few tall trees.



Source: http://www.bio.miami.edu/ecosummer/lectures/lec_evolution.html

Due to the scarcity of grass, the ancestors of present day giraffes stretched their neck and forelimbs to obtain food/vegetation from the tall trees. Continuous stretching of the neck and forelimbs to reach higher branches of the trees resulted in the elongation of the neck and forelimbs. This was passed on to the next generation. In the next generation too the giraffe faced the same problem and further stretched their neck and forelimbs to get their food. The present day giraffe is the result of several generations.

Another example studied by Lamarck was of the flightless birds. According to Lamarck, the flightless birds like Kiwi of New Zealand, Emu from Australia and Ostrich from Africa have all descended from flying birds. Once settled in their habitat, they had plenty of food and no enemies. They did not feel the need to fly. In due course of time in subsequent generations they lost the ability to fly and because of the disuse of the wings, the wings got degenerated.

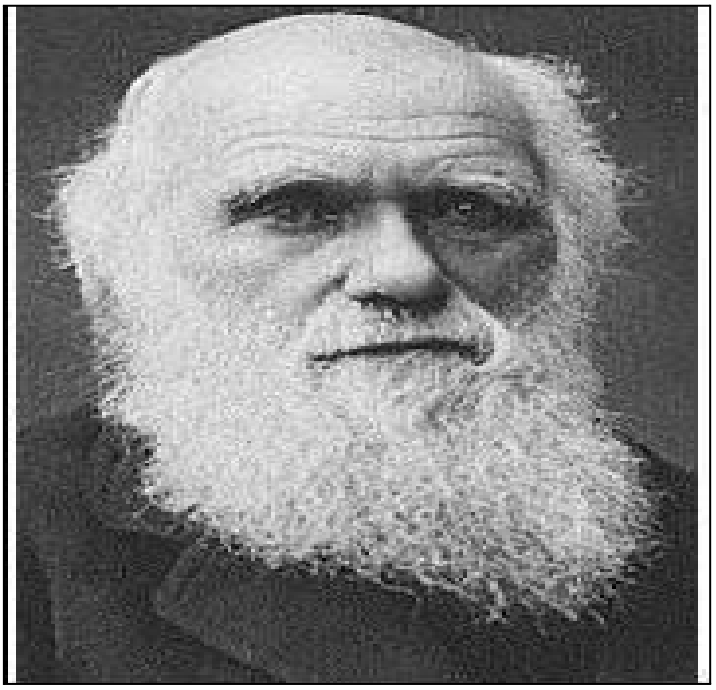
Similarly moles have reduced eyes because they live in burrows.Lamarck cited many more such examples to prove his theory. However, Lamarck did not give any examples of plants in support of his theory.

Criticism of Lamarck's Theory

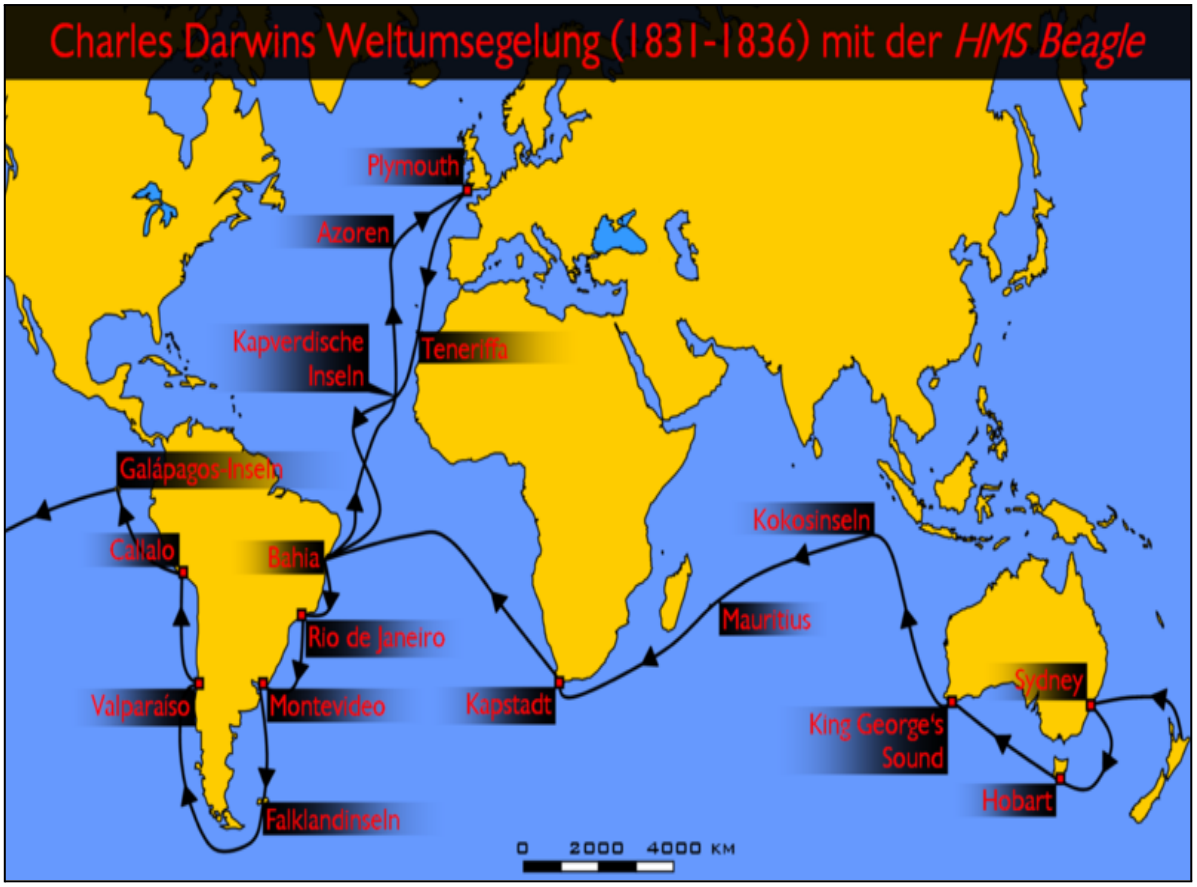
Weisman (1904) rejected Lamarck's use and disuse theory by introducing germ plasm theory. He cut off the tails of rats for about 22 generations and allowed them to breed but never did he observe a rat without a tail in any generation. According to Weisman only the characters which influence the germ cells are passed on to the next generation. Any changes taking place in the somatic cells are not passed on to the next generation (mutilations or wounds of parents due to an accident are not passed on to the next generation). This was known as the "theory of germplasm".

Darwin's Theory of Evolution

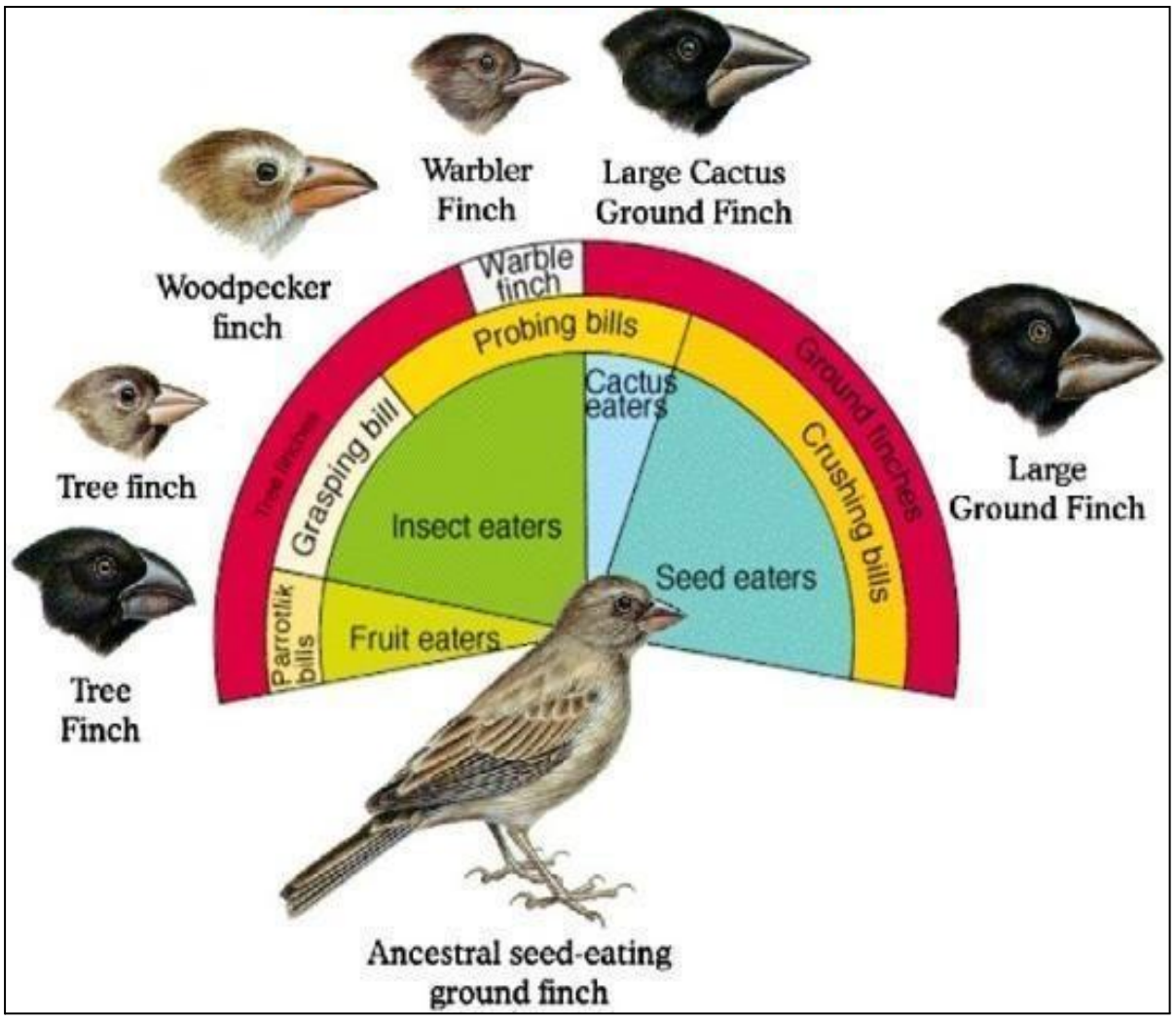
Charles Darwin, a naturalist was born in England (1809-1882) and is known for his theory of natural selection. Darwin in 1831 got an opportunity to travel by HMS Beagle around the world. This voyage around the world lasted for five years (1831-1836) and during this period the ship visited many places of the world like South-East Asia, some of the islands of the Atlantic ocean, coast of South America, Southern tip of Africa and some islands of South Pacific.



Charles Robert Darwin (1809-1882)



During his voyage Charles Darwin carefully studied the geology of these islands, their flora and fauna. He observed that different islands which were widely separated from each other but had similar climate and topography had different flora and fauna. The flora and fauna of nearby islands was related, however, they differed amongst themselves and from the plants and animals found on the mainland. When HMS Beagle sailed to Galápagos Islands about 600 miles away from the west coast of South America, he came across various plants and animals which were different on each island. He observed that the Galápagos Islands had various species of birds which were not found in any other part of the world, though similar ones existed on the west coast of South America. He observed 13 different kinds of birds, each species occupying a different island and slightly different from one island to another. The difference was in their beak size and shape. He also noted that the different types of beaks were associated with the type of food they had. These birds also differed from the birds of the mainland of South America. Today, these birds are popularly known as Darwin's finches.



Source: Class 12 CBSE Books/ Pradeep's Elementary Biology for Class 12

According to Darwin, these finches found on the Galápagos Island had migrated from the mainland of South America. The ancestral forms then adapted themselves to the environmental conditions of the different islands and diversified into different species.

Later in 1838 Darwin was inspired by the work of Thomas Malthus “Principles of population”.Malthus said that the rate of reproduction in plants and animals is very high. If unchecked, the rate of population takes place in geometric progression. But, the food supply increases in arithmetic ratio. So, there is competition for food. This concept of competition among the living organisms for their survival inspired Darwin and was the basis of Theory of Natural Selection.

Thomas Robert Malthus

Darwin's concept of Natural Selection is based on five postulates:

- Overproduction
- Competition
- Variation
- Natural Selection and Survival of the fittest
- Speciation

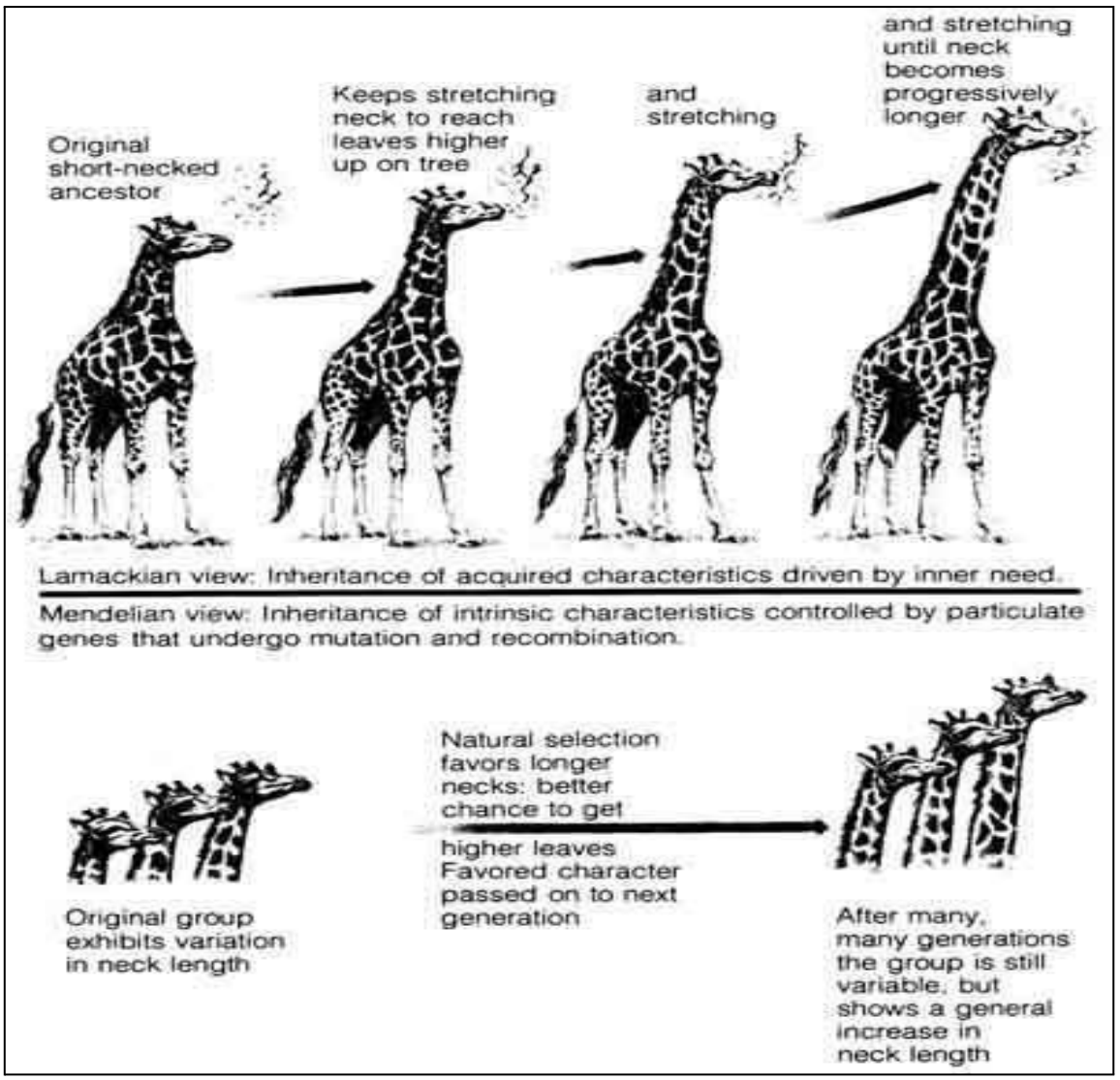
- **Overproduction:** All living organisms reproduce in a geometric progression for the perpetuation of their species. The number of offspring produced is much more than the available food and space and if not checked will soon exhaust the available space and food. For example: elephants which are the slowest breeders start breeding at the age of 30 and during its life-time of 90 years produces only 6 offspring. If all the offspring were to survive then a single pair of elephants would produce about nineteen millions of descendants in 750 years. Similarly, a single evening primrose plant produces an average of 1,18,000 seeds.

- **Competition:** Darwin observed that space and food more or less remains constant**.** Thus, overpopulation results in a struggle for existence. The struggle for existence can be:
    - Intraspecific: Competition among the individuals of the same species or closely related species.
    - Interspecific: Struggle between organisms of different species living together for food, shelter and breeding places.

- Environmental struggle: Struggle against physical factors like excess of moisture or drought, extreme temperatures (heat or cold), shortage or absence of shelter and space, shortage of food and water, earthquake, volcanic eruption etc.

- **Variation**: Competitions among organisms compel them to change and adapt themselves according to the prevailing conditions. Thus, no two individuals are alike. Even the progeny of the same parents are not alike. These differences are known as variation. Darwin observed that variation exists in living organisms, however small these variations may be. All the variations however are not significant from the evolution point of view. Some variations become advantageous in the struggle for survival and are passed onto the next generation. These are heritable variations. Some variations are harmful and are not passed on to the next generation. These variations finally lead to the extermination of the species. Variation is the key factor in evolution. Without variations evolution cannot take place.

- **Natural selection and Survival of the fittest**: In the struggle for existence, organisms with variations which are better adapted to the existing and changing environmental conditions will survive. The unfit or the less fit organisms will perish in this struggle for existence. Thus, nature selects only those individuals which have more favorable variations to adapt themselves to the environment. Organisms with the most beneficial variations are more likely to survive and reproduce.
- **Origin of species**: Useful variations are passed on to the next generation. These variations accumulate in the individuals of a species. However, our environment is not stable and is always changing and this leads to further changes and appearance of new adaptations in the organisms. As natural selection continues these organisms after several generations become quite different from their ancestors resulting in the origin of new species.



Let us now once again study the example of giraffes from Darwin's point of view. According to him, the whole population of giraffes is considered with variable neck sizes. Those with the long necks will be able to reach higher tree branches and thus have access to more food. This gives them more energy and thus a slight advantage in reproduction, meaning that in the subsequent generations they will produce more offspring with longer necks. These long necked giraffes will outcompete the shorter-necked ones over many generations. According to Darwin this is how the long necked giraffe had evolved.

Criticism of Darwinism

- Darwin talked about survival of the fittest but could not explain arrival of the fittest.
- He could not explain the origin of variation.

- He emphasized on small and cumulative variations. He said that these variations were directional.
- Natural selection is not the only cause of the origin of new species.
- He could not explain the inheritance of non-useful variations.

Alfred Russel Wallace

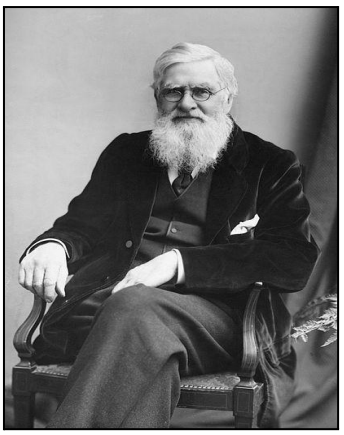
During the same time as Darwin, there was another scientist, Alfred Russel Wallace who too was inspired by the essay on "Principle of population" written by Thomas Malthus. He observed many different species in Asia and the Amazon River basin in South America. He wondered how and why different species were living in different places. Why is it that only some individuals only succeed in reproducing and not others?

In order to get answers to his questions he studied the various species of Malay Archipelago and came to the same conclusion as Darwin. The difference between the work of these two scientists was that Darwin thought evolution was driven by competition between individuals while Wallace believed that the environment was the driving force. He said that species change over time so that they can fit into the new environment.

Hugo de Vries Theory of Saltation

Darwin described the occurrence of variations but could not explain the origin of variation. As stated earlier, he had emphasized on small and cumulative variations. It was Hugo de Vries who said that variations, the key factor for evolution, are sudden and large. He called these as mutations or saltations.

He found the sudden appearance of seven new varieties of Evening Primrose in his garden. He observed that these characters originated suddenly and were heritable. He called these individuals of Evening Primrose with new characters as mutants and the characters as saltatory mutations (single step large mutations).

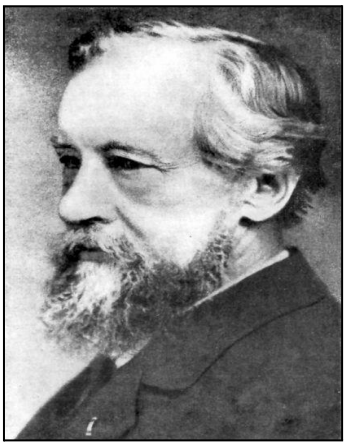


Alfred Russel Wallace (1823-1913)

According to Hugo de Vries:

- Mutations are sudden, large heritable changes.
- Mutations are random and can occur in all directions
- They may be useful or harmful. When subjected to natural selection, the beneficial mutations are favored by nature and selected while the harmful ones are eliminated (death of the mutants).

He said that different mutations can appear in different members of the same species thus giving rise to many new related species. Mutations though rare are of common occurrence.



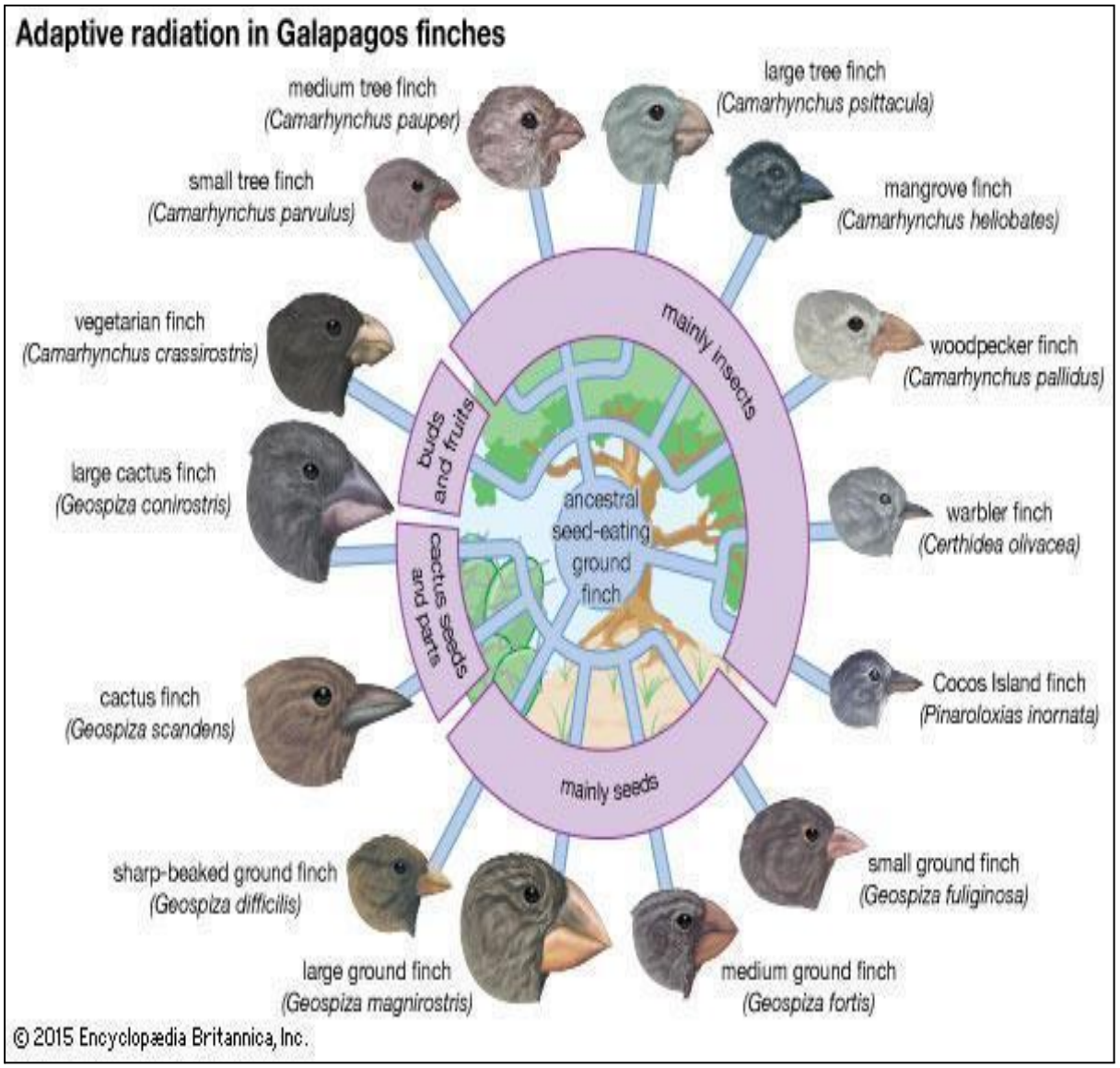
Hugo de Vries (1848-1935)

Adaptive Radiation

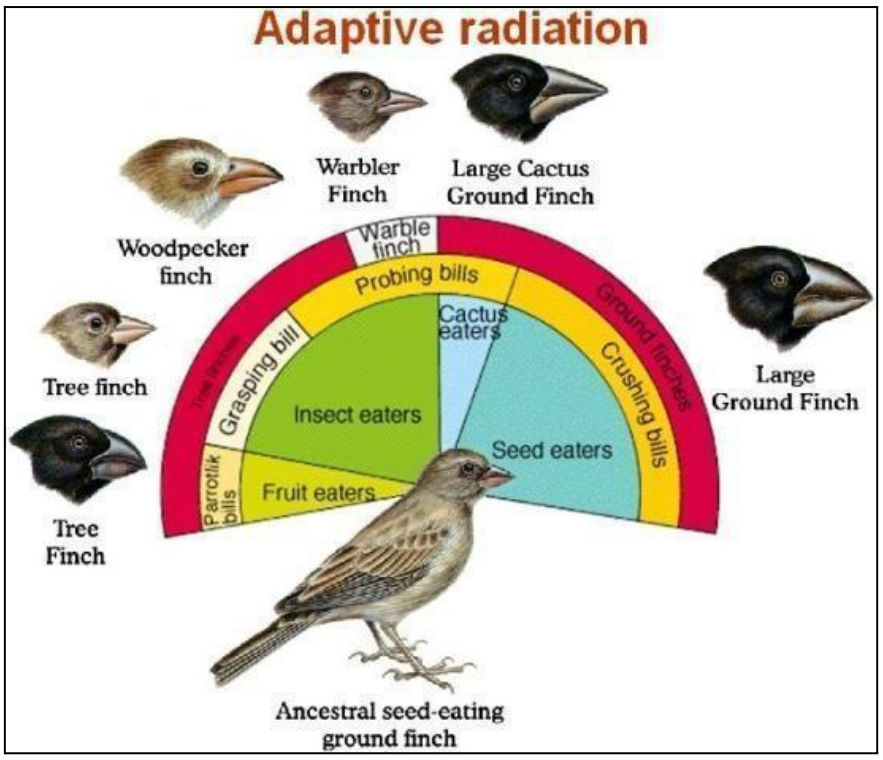
In section 6.3.3 we have said that the different finches on the Galápagos Island had migrated from the mainland of South America. The ancestral forms then adapted themselves to the different niches and habitats, the environmental conditions of the different islands and evolved into different species. These species differed from each other in beak size and shape

depending upon the type of food. Some had stout, straight but long beak (woodpecker finches-insectivorous), some had short, thick parrot-like beak to feed on the leaves, buds and fruits (vegetarian tree finches), while some others had long, decurved beak with a split tongue to feed on the pulp of the cactus plant (Cactus ground finches). Thus, from the original seed eating birds many other forms with altered beaks and different feeding habits arose.

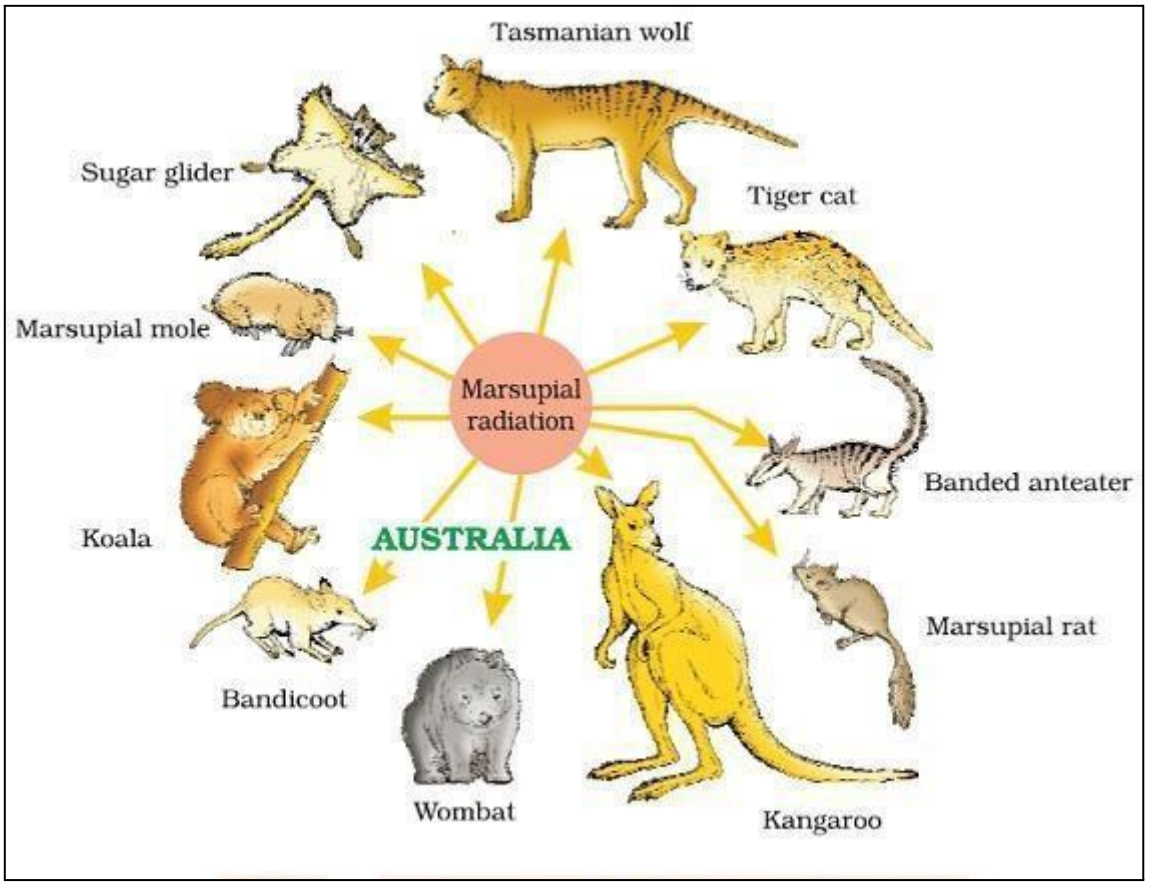
What can we conclude from this? Well, the finches have evolved in response to the selective pressures of the environment and have adapted themselves to the environment in different ways.



Source: https://www.britannica.com/science/adaptive-radiation



Source: Class 12 CBSE Books/ Pradeep's Elementary Biology for Class 12



Source: NCERT BOOK

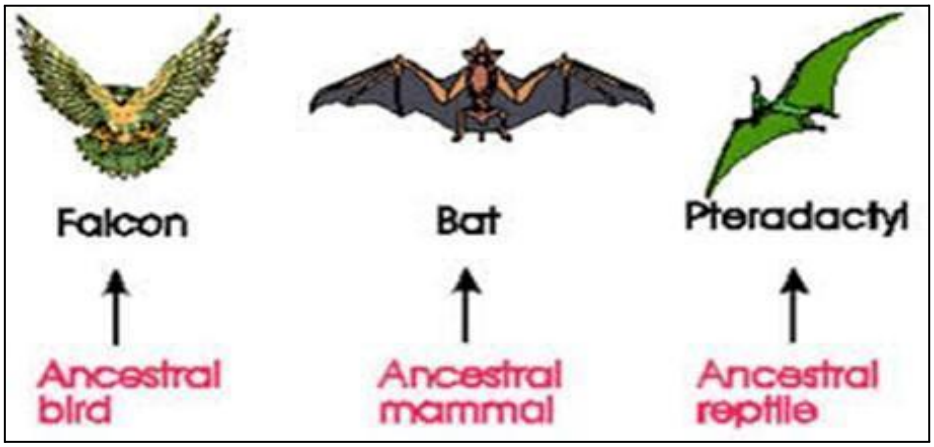
Let us study the above given figure of various marsupials found in Australia. As you can see in the figure, a number of marsupials all different from each other evolved from a common ancestral stock but all within the Australian continent. Each one of them got adapted to the new habitat. Their structure of limbs, tails and appearance as a whole got adapted to the new habitat which was very much different from the ancestral stock.

Surely, now, the significance of adaptive radiation in evolution must be clear to you. We can say that adaptive radiation is a process in which organisms diversify from the ancestral stock into many new forms when there is a change in environment with new environmental niches, new challenges and new resources.

In the two above given examples (adaptive radiation in finches and marsupial radiation) we found that the organisms of the same group (or closely related groups) appear very different when found in different habitats. The same structure (beaks in Darwin's finches and limbs and tails in marsupials) developed along different directions due to adaptations to different needs. This is called divergent evolution.

Divergent evolution can lead to speciation.

Conversely, two distinct species with different ancestors when subjected to the same environmental pressures require similar structural alterations in order to adapt themselves to the environment. The two different unrelated species occupy a similar environment. This is known as convergent evolution.



Source: http://slideplayer.com/slide/3843683/

In the example given above the ancestors of all three organisms namely Falcon, Bat and Pterodactyl are different. However, in all of them the forelimbs are modified into wings as

they share a similar environment. Anatomically also the structure of wings differ in the three groups. Thus, totally different groups have one common feature, development of wings for flight.

Convergent evolution in Marsupial and Placental mammals. In the figure given below one can see that the placental mammals (eutherian mammals) are similar to the corresponding Australian marsupials e.g. the placental moles are similar to marsupial moles, placental lemurs are similar to spotted cuscus, placental wolf corresponds to Tasmanian wolf and so on. This similarity between the placental mammals and marsupials could be because of convergent evolution. How do we come to this conclusion? Let us understand. Australia which is the home of marsupials separated from the mainland of Asia about 50 million years ago. At the time when Australia was a part of Asia, the eutherian mammals were not much evolved and the land was inhabited by marsupials. After the separation of the Australian continent, eutherian mammals now got the opportunity to evolve into various forms as they faced less competition from the marsupials. Marsupials soon disappeared from the mainland of Asia. However, the marsupials on the Australian continent did not face any competition from the eutherians and continued to develop into various forms in the next 50 million years. Both the placental eutherian mammals and the marsupials faced similar selective pressures of the environment. Their resemblance is only a superficial one. Thus the marsupial and placental mammal are examples of convergent evolution.

Summary

- Life began with prokaryotic single celled organisms such as bacteria.
- Organic evolution is the formation of new species from the pre-existing ones through modification.
- Bio-evolution is the modification of organisms by which a primitive simple form of organism gets gradually modified into a highly complex and organized present day organism.
- Lamarck is famous for his theory of use and disuse of organs and theory of inheritance of acquired characters.
- Theory of germplasm was proposed by Weisman according to which only the variations that appear in the germplasm are passed onto the next generation.

- Darwin was inspired by T.R. Malthus paper “an essay on population”. It gave him an idea of high reproductive rates of plants and animals and limited resources.
- According to Darwin new species evolve over a long period of time through accumulation of small variations.
- Nature selects only those individuals which have more favorable variations to adapt themselves to the environment.
- Hugo de Vries gave the concept of mutation or saltation.
- Mutations are sudden, large heritable changes.
- Mutations may be useful or harmful.
- When subjected to natural selection, the beneficial mutations are favored by nature and selected while the harmful ones are eliminated (death of the mutants).
- Adaptive radiation is a process in which organisms diversify from the ancestral stock into many new forms when there is a change in environment.
- Convergent evolution is the formation of similar structures or traits by unrelated groups of organisms.
- Divergent evolution is the formation of different structures from a common ancestral stock.