Organic Evolution

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Introduction

Since antiquity humans have been observing a great variety of living organisms on the earth .

Figure : Representatives of various domains (a) Bacteria (b) Archea –Thermophiles (c) Eukarya Plantae and Animalia (d)

Source: http://cnx.org/content/m44388/latest/Figure_01_02_17abcd.png

The very basic question that comes in our minds is – Why is there so much of biodiversity on the earth? And further, who has created all of this? Different people have attempted to answer such questions related to biodiversity. One group of people (religious group) searched the answers of these questions in realms of various religious texts and proclaimed all biodiversity to be created by a supernatural power, the God. Apart from this, there is another group of people (scientific group), which on the basis of various systematic investigations has suggested that present day organisms are the outcome of a long and continuous series of changes called **organic evolution**. The vast biodiversity that we see now on our planet, is the result of same evolutionary process.

Organic evolution

From physico-chemical state point of view, life is an **open system**, which maintains its ordered structure and performs its functions by obtaining the building blocks and energy from its surroundings. For that, it requires an ordered and sequential functioning of its various components, each having a definite structure. One of the characteristic features of a living system is **reproduction** that is possible only when it has a self-building mechanism and a system of information storage and transfer (genetic material). The living system functions properly, only when it is in harmony with its environment. However, the environment always has a tendency to change. Therefore, in order to maintain harmony a living system must change with its changing environment by bringing suitable changes in its various structural components. The suitable changes in the structure of a living system can only be incorporated permanently through the changes in its genetic material. All the living organisms show this ability to change and adapt according to changed conditions. This inbuilt capability of living organisms to adjust and change according to changing environmental conditions is known as organic evolution or simply evolution, which ultimately transforms them into new living forms over a long period. The evolution is a continuous, gradual and an orderly process that always remains in action, and is responsible for fixing the genetic changes in the hereditary material of a **population**.

Theories of organic evolution

In order to explain evolution, a number of theories have been proposed. Some of the important theories are following.

1. **Theory of special creation or divine origin:** This is the most primitive theory and refutes the concept of evolution. According to this theory all living forms present on the earth were specially created once and for all by a supernatural power. Since all these organisms are of divine origin, they are permanent and non-changeable entities that exist in the same form in which they were created initially. Many of the religious faiths are based on this concept, for instance, Christianity believes that present world was created about 4000 B.C. and to be more precise, on 23rd of

October, 4004 B.C. at 9:00 AM on Sunday as pronounced by Archbishop James Ussher in 17th century. Similarly, Hindu mythology says that Brahama, the God of creation, has created all the living organisms.

2. **Idealistic Concept:** Plato (428-348 B.C.) suggested that all observable things are imperfect representations of an ideal unseen world. According to this concept, initially there was a world of ideals (most perfect living forms) and any change in these ideals resulted into disharmonies (less perfect living forms). This concept was based on generalization of things and any variation to it was considered as an illusion.

3. **Scale of nature concept:** Aristotle (384-322 B.C.) extended the philosophy of Plato and arranged different living forms in the progressive fashion from most imperfect (simple) to most perfect (complex).

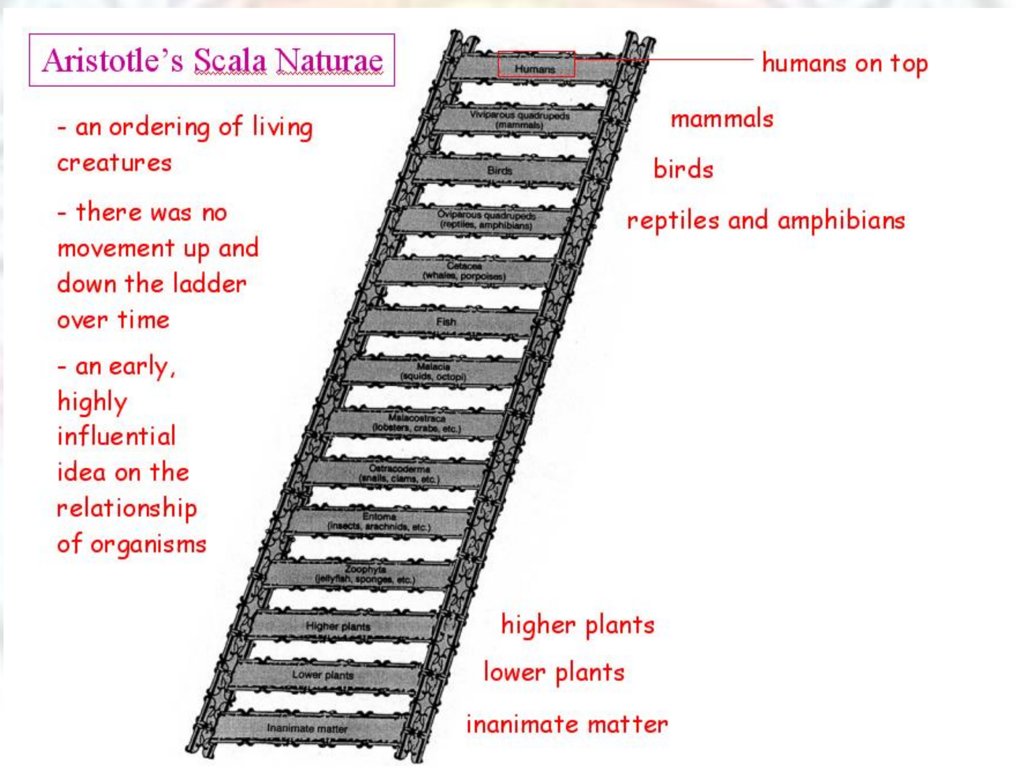

Figure: Scale of nature, a progressive arrangement of organisms (simple to complex).
Source: http://biology200.gsu.edu/houghton/2107%20%2713/Figures/General/Aristotle.jpg

4. **Catastrophism:** George Cuvier (1769-1832), in order to explain sharp discontinuities observed in **fossils**, proposed that fossils, which appear in different strata of sedimentary rocks, are the remnants of life destroyed by various catastrophes. Each catastrophe is followed by recreation of a new life by God.

5. **Gradualism:** James Hutton and Charles Lyell (1795) proposed that unlike the Biblical view, the earth is older than few thousand years. Since its inception, the earth has undergone numerous geological and climate changes that occurred slowly but continuously over geological time scale. These changes not only changed the earth but also the life and therefore, life has evolved gradually along with the evolution of earth. This theory is widely accepted and has two schools – Lamarckism and Darwinism, on the basis of mechanism of evolution as given below.
6. **Theory of inheritance of acquired characters:** Jean Baptiste de Lamarck (1809) in his book "Philosophie Zoologique" proposed this theory and that is why it is also called Lamarckism.

Figure : Jean-Baptiste de Monet Chevalier de Lamarck
Source: http://commons.wikimedia.org/wiki/File:Jean-Baptiste_de_Lamarck.jpg

According to this, living organisms evolved gradually through evolution involving two mechanisms.

(i) **Principle of use and disuse:** In response to the environment, different organisms in their lifetimes use some organs frequently and continuously in comparison to others. The frequently and continuously used organs consequently become more developed whereas unused or little used organs become weak and finally disappear. In other words, environment induces changes in living organisms.

(ii) **Inheritance of acquired characters:** Offspring inherit the characters acquired by their parents in their lifetimes provided that acquired modifications are common to both of the parents or at least to the maternal parent.Individuals in a population adapt themselves in response to changing environment and transmit these adaptations to their progeny. With passage of time, accumulation of variations takes place in organisms and this lead to the transformation of a species into a new species. In support of this theory, Lamarck took help of fossil records and said that evolution of present day longneck giraffe took place from short-neck forms. Because, reduced ground vegetation forced the ancestors to stretch their short necks in efforts to feed on the leaves of tall trees. Similarly, legless snakes were evolved from legged ancestors so that they could move or crawl through thick vegetation. However, this theory has been criticized for supporting the transfer of environment mediated somatic changes to progeny from parents. Weismann amputated the tail of mice continuously for 22 generations and even after the offspring had a tail as long as in the original parents. He established that changes occurring in the germplasm are heritable whereas those occurring in somatic cells are non-heritable. Since in response to change in environment, somatic cells are the ones that acquire new changes thus, remain non-inheritable.

7. **Theory of natural selection:** In 1831, Charles Darwin a fresh pass out from Cambridge University on the recommendation of his Professor of Botany (Reverend John Henslow), got an unpaid post of naturalist aboard HMS Beagle, a ship commissioned by the British Admiralty for a surveying expedition around poorly known stretches of the South American Coastline. This ship sailed in different parts of globe for five years and during this period Darwin studied the geography, flora and fauna of these regions. The observations made and the specimens collected by him especially from Argentine pampas and Galapagos Islands, paved the way for Darwin to understand the process of evolution. On his return to England in 1836, he kept working on the concept of evolution for 22 years and during this period he came across a book "An essay on the principles of population" written by Thomas Malthus (1798) in which, it was postulated that reproductive capacity of mankind exceeds the food supply available to an expanding human population. As a result, humans compete among themselves for the necessities of life leading to misery, war, famine and conscious control of reproduction these in turn regulate the population. Inspired by his views, Darwin applied the same in development of the concept of evolution. Meanwhile, another British naturalist, Alfred Russel Wallace, also independently conceived the idea of evolution similar to Darwin's idea on the basis of his explorations and collections in South America and the East Indies (South East Asia). In June of 1858, Wallace sent Darwin an essay entitled "On the tendencies of varieties to depart indefinitely from the original type". On receiving this essay, Darwin found the views expressed by Wallace remarkably, similar to his own. Rather than competing with each other to be the first to publish, Darwin and Wallace agreed to read their papers jointly before Linnaean Society of London on July 1, 1858.

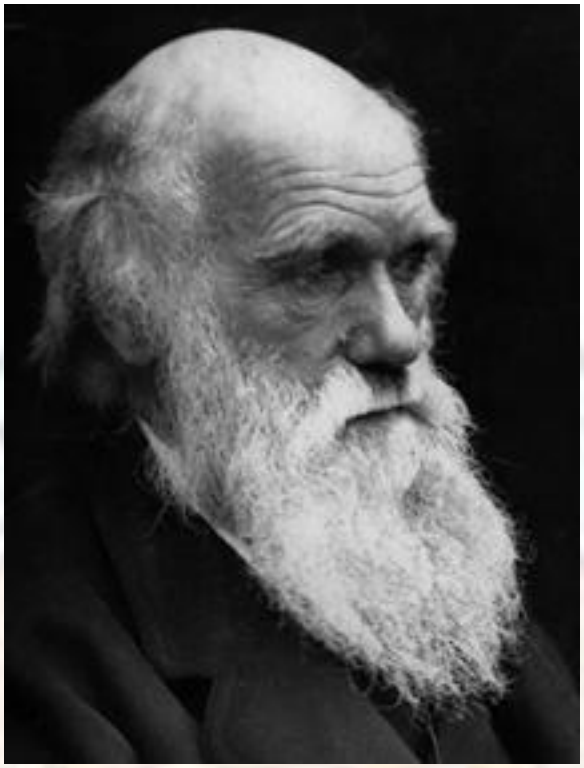

Figure : Charles Darwin

Source: http://commons.wikimedia.org/wiki/File%3ADarwin_Profile.JPG

Figure : Alfred Russel Wallace

Source: http://commons.wikimedia.org/wiki/File:Alfred_Russel_Wallace.jpg

Subsequently, in 1859, Darwin published his famous book "On the origin of species by means of natural selection or the preservation of favoured races in the struggle for life" in which, he elaborated the theory of natural selection. According to this theory, new species originate from their ancestral ones by gradual accumulation of adaptations over a very long period of time and adaptations are acquired because of natural selection. This theory is mainly based on three important observations and two conclusions derived logically from these, which are following.

1. **Tendency of overproduction:** All living organisms have high rate of reproduction and if, all the newborn of one particular species happen to survive and reproduce there would hardly be any space left for others to live. Thus, this will lead to overpopulation as population increases in exponential manner (1,2,4,8,16,32----). For example, a female Salmon fish produces around 28 million eggs at one spawning; a tropical orchid plant may form over 1 million seeds in a year. Similarly, considering the elephant, which is one of the slowest breeders having a breeding life from 30 to 90 years. It bears on an average 6 young ones in a life span of 100 years. If all these young ones survive and breed at the same rate then about 19 million elephants will be produced within a period of 750 years.
2. **Stability of population size:** Second important observation made by Darwin was that though the reproduction rate of a species remains high, the actual size of population of that species remains relatively constant over long period of time under a fairly stable environment.
3. **Variations:** Darwin's third observation was that individuals in a population are not all alike but differ from one another minutely with respect to different characters. All these differences constitute variations or polymorphism in a population.

Above observations and their interpretation led Darwin made two deductions.

1. **Struggle for existence:** On the basis of first and second observation, Darwin concluded that not all individuals that were born in any generation could survive. He explained this in terms of struggle for existence, which means that although organisms tend to overproduce but, in nature the resources required by living organisms for their survival, especially food and space, are limited. Because of this limitation of resources only limited individuals will be able to utilize those available resources and rest will be deprived and therefore, will ultimately be eliminated. In order to grab available resources, the individuals in a population compete amongst themselves (intra specific competition), with individuals of other species (inter specific competition) and with adverse environment as well. These different types of

competitions lead to a struggle for survival or existence and keep the number of individuals of a population in a particular range that can be sustained by the available resources.

2. **Survival of fittest:** Individuals of a population show polymorphism among themselves with respect to different characters. These variations could be both heritable and non-heritable. Because of variations, the different individuals in a population exhibit different performances with respect to various traits in a prevailing environment. For example, if different individuals in a plant species posses different heights, the taller plants will be at an advantage in getting more sunlight and pollinators due to extra exposure to these factors. Therefore, in the absence of a predator preferring the taller plants, tallness of plants will make them more competitive over dwarf ones; so more chances of survival of taller ones. During the struggle for existence in a given environment, heritable variations helping the individuals in grabbing the resources are selected over those which are not helpful. The individuals with favoured variations will survive and be able to produce their offspring inheriting the selected variations. This phenomenon was termed as survival of the fittest by Herbert Spencer, which Darwin considered equivalent to natural selection. Thus, natural selection is a condition prevailing at a given time that is responsible for differential abilities of individuals to survive and reproduce. Consequently, only the selected individuals with high rate of survival and reproduction are allowed to perpetuate and therefore the genes they carry will pass on to next generation. Gradually but continuously this changes the genetic composition of population over time, which is nothing but evolution. Since the direction of natural selection is usually not fixed but variable and it is a continuous and a slow process. So with every change in the environment, preference of individuals and therefore, the genes for selection also change causing accumulation of changes in genetic composition of populations. As a result of gradual accumulation of vast changes in the population, it may become totally different, a new species different from its ancestral population.

Evidences for natural selection

The process of evolution is very slow but continuous, and takes thousands to millions of years in bringing distinguishable changes in a large population. This makes the process of gathering evidences in support of evolution, a difficult task. However, biologists have come across a number of situations in nature where favourable changes have spread through a population in a comparatively short span of time, suggesting the progress of evolutionary process.

Industrial Melanism: One of the most spectacular examples of evolutionary changes witnessed by several scientists, particularly E. B. Ford and H. B. D. Kettlewell during mid of 20th century has been the post-industrialization emergence and predominance of dark coloured moths in the industrial areas of England and Germany. During pre-industrial time, in early 1800s, the light-coloured variety of peppered moth (*Biston betularia*) was dominant at Manchester in England as it could evade predators (insect eating birds) by camouflaging on bright-coloured-lichen covered trunks of oak trees. On the other hand, dark form of peppered moth was at disadvantage as it could not evade the predators due to its prominence in such a background and therefore, comprised less than 1 percent of population in 1848. However, after industrialization of Manchester area, in 1898, dark form became dominant and comprised 95 percent of population because, sooty-black oak trunk had become protective to dark variety of moth. This dramatic change in colouration of moths has been termed as industrial melanism. This suggests that any change in direction of envrionmental factor, for instance, industrialization in this particular case, results in drastic changes in the composition of a population and thus substantiates natural selection.

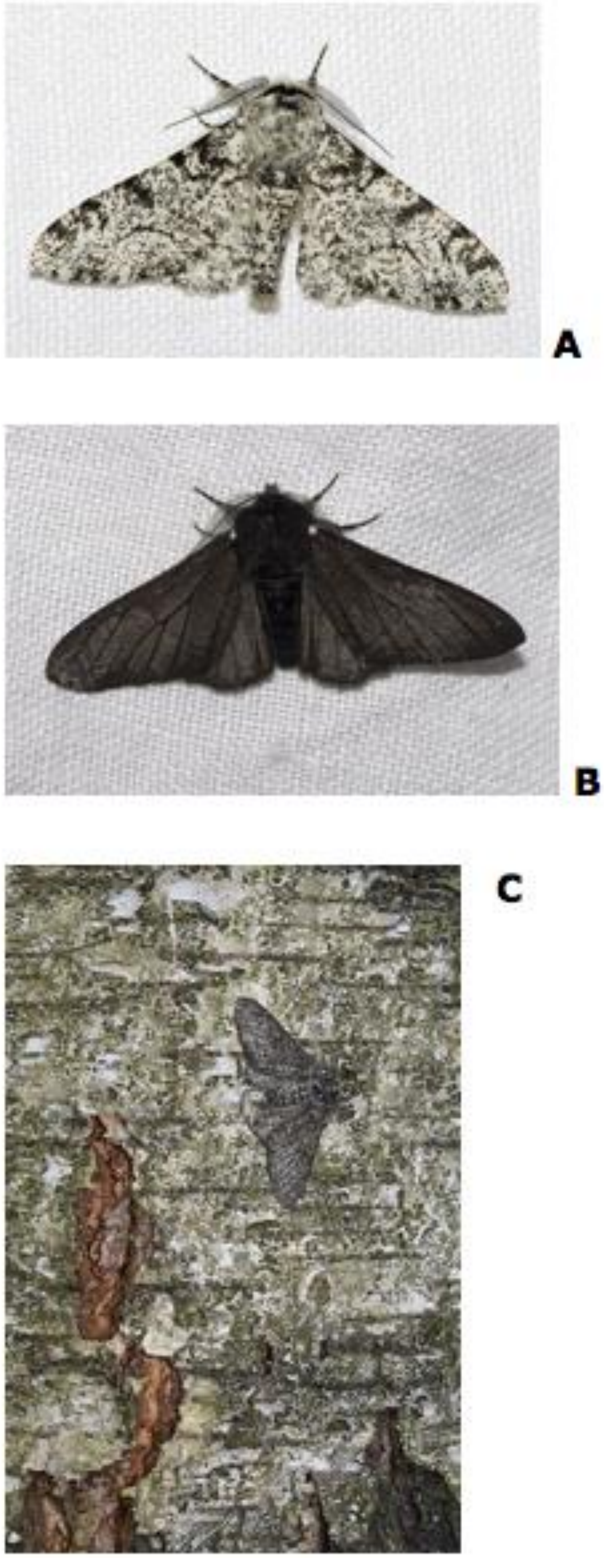
A
B
C

Figure : *Biston betularia* (Peppered moth) a) light coloured form (http://commons.wikimedia.org/wiki/File:Biston.betularia.7200.jpg) b) dark coloured form (http://commons.wikimedia.org/wiki/File:Biston.betularia.f.carbonaria.7209.jpg) and (c) dark coloured form on bark of birch (*Betula pendula*) tree (http://commons.wikimedia.org/wiki/File:Biston_betularia_20110529_103331_8099.JPG)

Changes in Guppy population in response to differential predation: John Endler and David Reznick studied wild populations of a small fresh water fish – Guppy (*Poecilia reticulata*), in different pools in the Arpio river on the Caribbean Island, Trinidad.

Figure : Guppy fish

Source: http://commons.wikimedia.org/wiki/File:Guppy-male.jpg

In one of the pools containing a small predator, killifish, which preys mainly on juvenile Guppies, it was observed that the average size of Guppies was large as they took longer time to reach sexual maturity. On the other hand, another pool containing a large predator, pike-cichlid that preys predominantly on large and sexually mature Guppies, had small sized Guppies attaining sexual maturity at younger age. In order to study natural selection, Endler and Reznick introduced a sample of Guppy population from the pool containing pike-cichlid to a new pool that contained killifish but no prior existence of Guppy population. For 11 years, they compared the age and size at sexual maturity of transplanted Guppy sub-population with the original population, and concluded that average size and the age of attaining sexual maturity increased in transplanted Guppy sub-population because, change in predator favoured large size as it helped in evading predation (natural selection).

Resistance against metal toxicity: Unlike animals, plants face more environmental stress due to their immobility. An interesting observation, related to natural selection in favour of metal tolerance, was made in algae. Aquatic plants cause a lot of economic problems for ship owners as such organisms have tendency to attach and grow on the bottom of ships that adds to the cost of scraping, extra consumption of fuel and loss of ship's earning during the time of scraping. To overcome this problem antifouling paint, which contains toxic compounds of copper, was developed and its application stopped the attachment of aquatic organisms. However, some species of brown alga- *Ectocarpus* sp. continued to grow on the hulls even after antifouling treatment.

Figure : The bottom of the sea hulls a number of marine species tolerant to copper are found these include the *Ectocarpus siliculosus* a common brown marine alga.
Source:http://www.serc.si.edu/labs/marine_invasions/feature_story/198035_1957571304175_1389511209_2325383_7149739_n%282%29.jpg
,http://commons.wikimedia.org/wiki/File:Ectocarpus_siliculosus_Crouan_(2).jpg

Therefore, the ships still needed to be scraped. Samples of *Ectocarpus silculosus* taken from the bottom of ship were shown to be tolerant to the concentration of copper ten times of what *E. silculosus* growing on a normal rocky shore could tolerate. So, within a brief period of time, the effect of antifouling paints has been reduced by the rapid selection of *Ectocarpus* sp. that can survive in the high local concentration of copper metal.

Lecture: Adaptive evolution- Natural Selection

Source: http://oyc.yale.edu/ecology-and-evolutionary-biology/eeb-122/lecture-3 (CC-BY-SA)

8. Neo-Darwinism

Darwin through his theory of natural selection postulated two important things related to evolution – first, evolution is a permanent process and all organisms have descended with modifications from a common ancestor and second, the natural selection is the primary mechanism of evolution. First postulate, as far as concerned, is now settled and biologists now consider it as one of the facts of the evolution. However, second postulate has still been open for discussion and time-to-time several objections have been raised about the mechanism of evolution. One of the major flaws of Darwin's theory was its inability to explain - how did the heritable variations required for natural selection appear? And, how did organisms transmit these variations to their offspring? Advent of Mendel's work on inheritance was initially thought to be contradictory to Darwin's theory of evolution as it proposed the particulate nature of inheritance instead of blending nature believed at that time. Darwin considered continuous variations to be the raw material for natural selection to act upon unlike discontinuous variations, which followed Mendel's pattern of inheritance. However, later on, continuous variations were also found to be following mendelian pattern of inheritance which are controlled by multiple genes that act in cumulative fashion. These discoveries and further advancement in population genetics helped reconcile Darwin's and Mendel's ideas and led to a new concept called Neo-Darwinism. Neo-Darwinism is also called the **Modern Synthesis** because it synthesizes or brings together classical Darwinism with modern genetic theory. It is based on work done by R. A. Fisher, J. B. S. Haldane, Theodosius Dobzhansky, Sewall Wright, Ernst Mayr, George Gaylord Simpson and G. Ledyard Stebbins. According to this theory evolution is an ongoing process in which genetic variations are introduced in populations at random by mutation and recombination. Populations evolve over time through changes in their gene frequencies brought about by number of causal agents such as random genetic drift, gene flow and especially natural selection. The accumulation of gene frequency differences, which takes place often gradually, eventually leads to more diversification among populations in geographically different localities. When gene exchange between racial groups can no longer occur because of reproductive barriers, separate species become established. The major tenets regarding the mechanism of evolution of Modern Synthesis are following:

1. Characters in living organisms are inherited as discrete entities called genes. Characters may be discontinuous (regulated by single gene) and continuous (regulated by multiple gene). More than one alternative forms of a gene are called alleles; sum total of these in a population constitute gene pool.
2. Populations contain heritable variations that generate at random. Different populations differ from one another on the basis of quantity and quality of variation (gene pools) present in them. Populations evolve with change in their gene pools.
3. Numbers of mechanisms of which natural selection is prominent one can bring changes in gene pools of populations. Because of activation of these mechanisms some of the variations are favoured over others. This causes differential abilities of survival and reproduction among individuals in a population at a given time, which consequently leads to evolution of population.
4. Under the influence of natural selection and other similar mechanisms diversification of populations take place due to gradual accumulation of small changes in their gene pools. This consequently divides a particular population into number of subpopulations. With passage of time subpopulations become reproductively isolated and stop inbreeding amongst themselves. This process is called speciation, which leads to origin of new species.

The modern theory of the mechanism of evolution differs from Darwinism in three important respects:

1. It recognizes several mechanisms of evolution including natural selection.
2. It recognizes that genes are responsible for inheritance of characteristics. Variations within a population are due to the presence of multiple alleles of genes.
3. It postulates that speciation is (usually) due to the gradual accumulation of small genetic changes. This is equivalent to saying that macroevolution (evolution

at or above species level) is simply a lot of microevolution (evolution at population level)

In other words, the Modern Synthesis or Neo-Darwinism is a theory about how evolution works at the level of genes, phenotypes, and populations whereas Darwinism was concerned mainly with organisms, speciation and individuals.

Population- the basic unit of organic evolution

As per Neo-Darwinism, evolution is a property of populations because it is the population rather than the individual that evolves over a time. Natural selection acts on the individuals but the effect is seen in changes in population. However, individuals due to their short life span cannot evolve but merely ensure continuity of changes to a population through offspring and therefore contributing to the evolution of the population.

A population is not a mere assemblage of individuals, but is a group of individuals which have coevolved and are capable of interbreeding and producing fertile progeny.

Figure : Black-tailed Godwit (wading birds) population.

Source: http://commons.wikimedia.org/wiki/File:Black_Tailed_Godwits_(5333964703).jpg

During evolution, the populations change genetically. The accumulation of genetic changes in a population, over a very long period of time, results into a new population and subsequently into a new species.

Like an individual, a population also has a genetic constitution, which is represented by its **gene pool**. The gene pool of a population is different from the genome of an individual belonging to it as genome of an individual depending on its ploidy level, can carry only few copies of a **gene** (alleles). For instance, a diploid organism can have only two alleles of a gene at any time. Whereas, the population to which that organism belongs, may have more than two alleles. The gene pool of a population is expressed in terms of frequencies of different alleles present.

Hardy-Weinberg Law

Regarding the allelic frequencies of different genes in a population, a very important observation was made independently by an English mathematician G. H. Hardy and a German physician W. Weinberg in 1908, which is now known as Hardy and Weinberg Law. This law states that the frequencies of all the alleles of a particular gene in an ideal population remains constant from generation to generation provided no any evolutionary force is acting on such population and individuals comprising such a large population have equal opportunities of producing offspring. Thus in a large and stable population, each allele has a constant frequency or proportion and sum total of all the allelic frequencies of a particular gene makes 1 or 100 percent.

Mathematically it is written as

$p + q = 1$

Where, p and q are the frequencies of a dominant allele and a recessive allele respectively, in a population.

If the organisms constituting the population are diploid, then the allelic frequencies will be

$(p + q)2 = p2 + q2 + 2pq = 1$

Therefore according to this law, each population has a unique genetic composition in terms of its gene pool and allelic frequencies of different genes, which differs from others. Further, the amount of variation present in a population does not change in an ideal population. When the genetic composition of a population changes it causes the evolution of the population. The Hardy- Weinberg law is based on an entirely theoretical population because the set of assumptions under which this law holds true can scarcely be fulfilled in any natural population. However, an understanding of Hardy-Weinberg law is helpful in recognizing the forces responsible for bringing evolutionary changes in a population. These forces are:

Genetic drift: One of the requirements of applicability of Hardy-Weinberg equilibrium is, a large sized population, because, the chances of repeated mating between two individuals increases as the size of population decreases. Therefore, the probability of fluctuation in genetic composition, in terms of gene frequency, also becomes greater. The phenomenon of any sudden fluctuation in allelic frequencies of a population purly by chance is known as genetic drift. Alleles may get lost or get completely fixed irrespective of the selective value. Sewall Wright gave the theory of genetic drift in 1930s and therefore, this phenomenon is also called as Sewall Wright effect. Due to restricted size of the breeding population, the gene pool of the new generation may not always be the true representation of the gene pool of parental population. In nature the population size may get reduced by number of means but two important means are given below.

(i) **Bottleneck effect:** Sometimes a population comprising of a large number of individuals, on exposure to a natural/unnatural calamity is reduced to a small population.

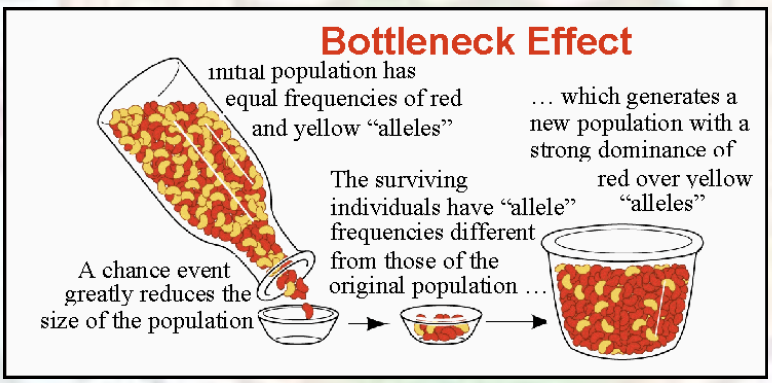

Figure : Bottleneck effect, an original population is reduced to small population due to sudden disastrous conditions (bottlenecking event) that may change the genetic constitution of new surviving population.

Source: http://1.bp.blogspot.com/-CJVZqejNip8/UTEj5yq4fxI/AAAAAAAAAjs/JBko30F6H_Q/s1600/bottleneckeffect.gif

The gene pool of such reduced population may not represent the original one, as the chances of over-representation of certain alleles and elimination of some other alleles becomes very high because of such disasters. The new population that arises as a result of interbreeding amongst leftover individuals will be genetically different from original population. Stebbins termed this phenomenon as bottleneck effect. For example, the population size of northern elephant seal in California (USA) reduced drastically to just around 20 individuals because of over hunting in 1890.

Figure : Northern Elephant Seal

Source:http://commons.wikimedia.org/wiki/File:Northern_Elephant_Seal,_San_Simeon2.jpg

In order to protect this species from getting extinct it's hunting was banned and over a period of time, the population of northern elephant seal increased to around 30000. However, the genetic diversity of the population was reduced since it involved the matings with only a few able males. This made the population susceptible to diseases etc.

(ii) **Founder effect:** Sometimes, a small group of individuals belonging to a large population invades a new territory either accidentally (by chance) or due to forced emigration. The first settlers called founders, which start a new population, have a very limited gene pool that may differ from the gene pool of the population from which they moved. Therefore, the resulting population will represent the gene pool of founders rather than the gene pool of population to which founders originally belonged.

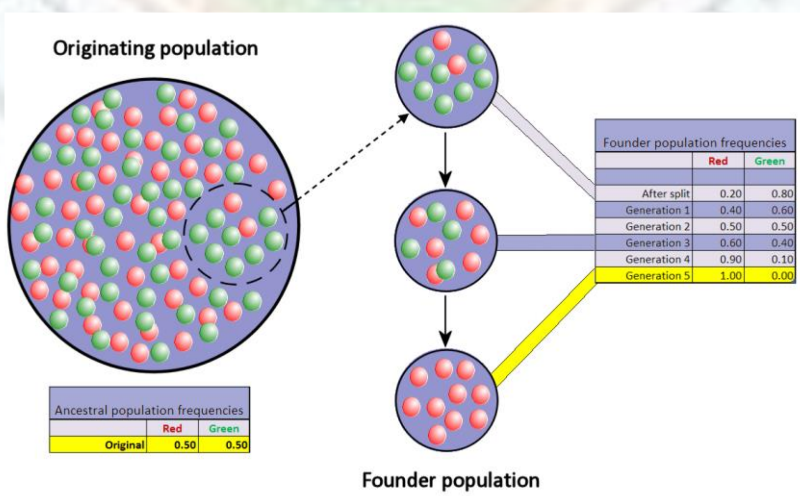

Figure : Founder effect, very small poulation differring genetically from original population colonize new habitate and evolves into a new population (founder population).

Source:http://upload.wikimedia.org/wikipedia/commons/d/d6/Founder_effect_with_drift.jpg
Moreover, the founders population being small in size, becomes prone to change in allelic frequencies as due to the process of random genetic drift some alleles may get completely lost, while other alleles may get completely fixed. In addition some of the alleles, which were disadvantageous in the environment of original population may become favourable in the new environment and hence favoured by natural selection. For example, the Collared Dove (*Streptopelia decaocto*) was confined to Danube but it extended its territorial range to Holland in 1947, to Belgium in 1952 and has now become a common bird throughout Western Europe and the British Isles.

Figure : *Streptopelia decaocto* (Collared Dove)
Source: http://commons.wikimedia.org/wiki/File:Streptopelia_decaocto_1280126_cr.jpg
The rapid spread of this species into previously uncolonized areas did not happen merely by chance but according to Mayr, who gave the concept of founder effect in 1956, this could have been possible only through genetic changes in the gene pool that provided a greater tolerance to lower temperatures and so enabled the colonists to survive. The founder effect is commonly observed in religious isolates of Human population who emigrated and settled in new places, for example, the Dunkers in the United States, are descendents of the old German Baptist Brethren who came to U.S.A. in early eighteenth century. This community has remained genetically isolated from other communities, due to its rigid marriage customs. Dunker community was compared with surrounding heterogeneous American population and the population in western Germany, from which the Dunker sect has emigrated three centuries ago, on the basis of frequencies of certain traits like blood group

types. The frequencies of many of these traits have been found to be strikingly different in the Dunker community from those of the general United States and West German populations.

Gene Flow: The genetic composition of a population may change by introduction of new alleles from other populations. The process is called gene flow. The natural populations are generally open and are found in a state of flux where migration of individuals is quite common. When immigrant individuals posses allele frequencies different from those of recipient population, redistribution of allelic frequencies takes place and a new equilibrium is set.

Mutation: Sudden inheritable changes that take place in the genetic material of any living organism are called mutation.

Figure : Mutations of coat colour in pet Rose-ringed Parakeets (*Psittacula krameri*)
Source: http://commons.wikimedia.org/wiki/File:Psittacula_krameri_-colour_mutations_-pets-8a.jpg

When change involves one or few nucleotides such mutations are called point mutation and when change occurs due to addition or deletion or change in orientation of a sequence of nucleotides, such mutations are called chromosomal mutations. Most of the mutations are found to be harmful to organism in which they occur and therefore in absence of any fixative mechanism such as heterozygosity harmful mutations are lost in same generation in which they are induced. In contrast, if mutations are either beneficial or neutral, such mutations may pass on from generation to generation in a population. This causes the accumulation of mutations and changes the gene pool of the population by altering the allelic frequency. Although mutation is the only mechanism known which is responsible for the introduction of new alleles in a population, mutation alone cannot change allele frequencies because of low rate of spontaneous mutations.

Selected Mating: When individuals in a population preferentially choose mates having specific traits and hence genotypes. This may result in non-random mixing of gametes as only selected genotypes get chance to reproduce. Consequently, this may lead to change in the allelic frequencies and therefore, change in the genetic composition of populations.

Natural selection: Because of their genetic differences, individuals in a population when exposed to a particular environment, under the influence of natural selection, show differential rates of survival and reproduction. Natural selection reduces the proportion of individuals having low relative finesses in populations. On the other hand, it increases the chances of gene- contribution by individuals with high survival rates to gene pool of populations. Natural selection is considered to be most important factor causing substantial changes in gene frequencies in populations. Majority of traits being under polygenic control are quantitative in their expression. When gradients measured of such a quantitative trait present in an original and a stable population are plotted against the number of individuals exhibiting the phenotype, a bell-shaped curve known as a normal frequency distribution curve is obtained. Any change in the shape of this normal frequency distribution curve is considered as an influence of some evolutionary force .

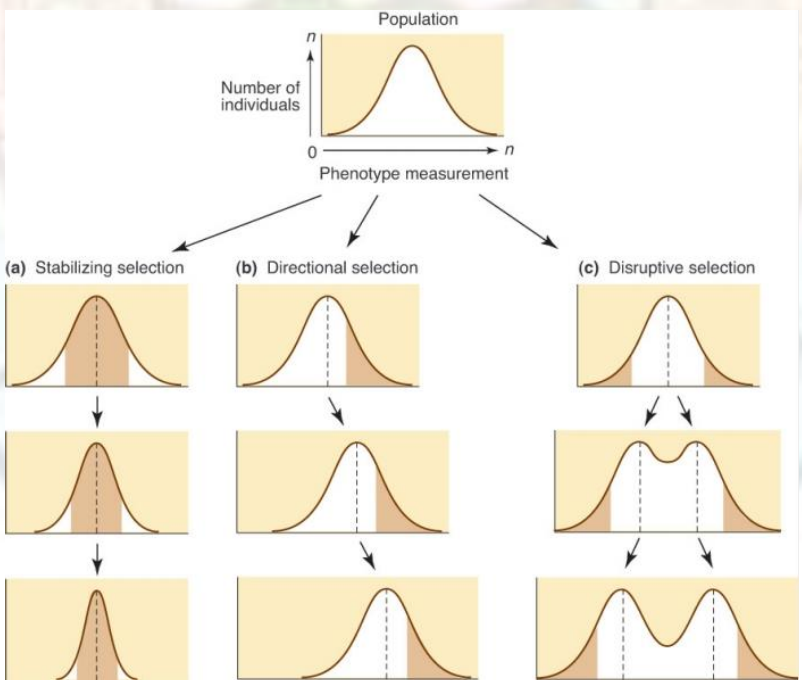

Figure: Frequency distribution curve of an ideal population and its exposure to various types of natural selection. The horizontal axis of each bell-shaped curve indicates measurements of a quantitative character and vertical axis indicates number of individuals possessing such measurement. Dashed lines indicate mean value and shaded areas represent the individuals selected as parents of next generation.

Source: http://i.imgur.com/ITk8J.jpg

On the basis of its net impact on a population, the natural selection can mainly be of three types.

1. **Directional selection:** In this, natural selection favours the individuals possessing one of the extreme phenotypes in a population. As a result, normal distribution curve is skewed in the direction of favoured phenotype due to shift in the mean value and phenotype initially occurring at one of ends of the distribution curve moves towards central region . Directional selection operates when environment is changed in one particular direction and favours the accumulation of those phenotypes that increase fitness of population in changed environment, and eliminates the unsuited ones. For example, the spread of resistance in bacteria and insects against antibiotics and insecticides respectively, can be explained on the basis of directional selection. Exposure of these organisms to toxic chemicals causes the death of sensitive ones and survival of few resistant ones. The resistant individuals quickly form a resistant population because of their short generation time. In one of the studies, a survey of mosquito (*Anopheles gambiae*) in the villages of Nigeria was conducted before **DDT** spray. It showed 0.4 to 6% of mosquitoes to be heterozygous for DDT resistant gene. However, after DDT spray, 90% of the mosquito populations were found homozygous for DDT resistant gene.
2. **Disruptive selection:** In this type, natural selection favours the individuals with extreme phenotypes located at both ends of normal distribution curve over the expense of individuals with intermediate phenotypes. It occurs when a population is subjected to divergent or cyclically changing environment that makes a variety of genotypes amongst a population most suited. This natural selection is also known as diversifying selection, because of formation of more than one peak of phenotypes adapted to different environmental conditions. Many small animals either live in a green background or a brown background as this provides camouflage to individuals in comparison to intermediate colour. European Swallowtail Butterfly (*Papilio macaon*) pupate either on green leaf or brown stem so, only two distinct pupa colours – green and brown are found without any intermediate colour.
3. **Stabilizing selection:** This type of selection favours the individuals expressing intermediate phenotype in middle of normal distribution curve and excludes those

with rare phenotypes. This happens when the environment remains relatively stable or unchanged on geological time scale. As a result the fitness of population reduces and population becomes homogeneous as selection discards the mutations . The birth weight of human babies is a good example describing stabilizing selection in action. In one of the studies at University College Hospital (U.K.), Karn and Penrose (1951) reported a direct relationship between the optimal birth weight (7.1 pounds) and optimum birth weight of 7.3 pounds at which infant mortality was lowest. Newborn infants less than 5.5 pounds and more than 10 pounds had highest mortality rate suggesting that natural selection favours mean birth weight.

Summary

Organic evolution is the process of gradual accumulation of genetic changes in populations of organisms through time that lead to transformation of species into new ones. It is an orderly and a continuous process, and is the cause of biodiversity observed on the earth. There are many theories of organic evolution of those gradualism theory is widely accepted. This theory considers organic evolution as a very slow and continuous process. Under the concept of gradualism on the basis of mechanism of evolution, there are two schools namely, Lamarckism and Darwinism. Lamarckism believes that due to change in environment, the living organisms in order to adjust according to changed environment, bring changes in themselves. Such acquired characters (variations) lead to origin of new species. In contrast to this, Darwinism believes that population always carry variations and any change in environment make some of these variations favourable. The favourable variations are selected by the environment (natural selection) and are passed to next generation. The gradual accumulation of those over a very long time results into origin of new species. The basic unit of evolution is population. Different populations have different gene pools and any change in the composition of gene pool of a population causes the introduction of variation in that particular population. As per Hardy- Weinberg Law the genetic composition of populations remain stable under ideal conditions. However, natural populations are always under the process of evolution. The gene pool of populations is affected by number of factors such as genetic drift, gene flow, mutation, selected mating and natural selection. Any sudden fluctuation in allelic frequencies of a population is called genetic drift, which occurs when a large population is reduced to small in number due to some disaster, Bottleneck effect, or due to emigration of a subpopulation to new territory, founder effect. The populations also change genetically when new genes are introduced from other population (gene flow) or they develop their own at random (mutation).

Similarly, selective interbreeding also changes the gene pool of populations over the generations. Amongst various factors responsible for evolution of populations, natural selection is most important as it results in differential capacities of survival and reproduction of genetically differing individuals in a population. Depending upon the types of individual being favoured by natural selection, it could be directional selection (if some extreme character is under selection), disruptive selection (if more than one extreme characters are under selection) and stabilizing selection (if most common character is under selection).

Glossary

Allele: an alternative form of a gene, different alleles of a gene occupy the same locus on homologous chromosomes.

DDT: dichloro diphenyl trichloroethane, a manmade insecticide.

Fossil : remnants of living organisms that died long ago.

Gene: a part of hereditary material that is the basic unit of inheritance and encodes some specific function.

Gene pool: Sum total of genes present in a population at a given time.

Genome: Sum total of genes present in an organism.

Open system:a system exchanging energy with its surroundings.

Population:a localized group of interbreeding individuals that Produce fertile offspring.

Reproduction:ability of living organisms to make their own copies.

Exercise/ Practice

Q1. Define the followings.

a) Organic evolution

b) Natural selection

c) Population

d) Gene pool

e) Genetic drift

f) Mutation

g) Speciation

h) Variations

i) Hardy-Weinberg Law

Q2. Write short notes on following concepts of organic evolution.

a) Lamarckism

b) Darwinism

c) Neo-Darwinism

d) Gradualism

e) Catastrophism

Q3. Differentiate between the following.

a) Lamarckism and Darwinism

b) Darwinism and Neo-Darwinism

c) Gene pool and Genome

d) Bottleneck effect and Founder effect

e) Disruptive selection and Stabilizing evolution

Q4. What are the salient features of Lamarckism? Critically examine this concept in the light of modern biology.

Q5. What is law of inheritance of acquired characters? How does it explain the elongation of neck in giraffe?

Q6. What is Darwin's concept of evolution? Discuss the observations made and deductions drawn by him, which helped in building this concept.

Q7. What is Neo-Darwinism? On what points does it differ from Darwinism?

Q8. Name the factors responsible for affecting the gene pool of populations. Write the significance of mutation in relation to variation present in a population.

Q9. Write a short note on the importance of Hardy-Weinberg Law in understanding the evolution of populations.

Q10. Write a short essay on natural selection and its major types.

Q11. Discuss some of evidences studied by you in support of natural selection.

Further Knowledge hunt

Search scientific literature and try to find out about following.

a) Deme

b) Neo-Lamarckism

c) Punctualism

d) Mechanism of speciation

References/ Bibliography/ Further Reading

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Links

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