TYPES OF SELECTION

Natural selection is that force which produces systematic heritable changes in a population from generation to generation, creating evolution. Thus it may become a directional phenomenon, producing changes in a definite direction, giving rise to new species.

Natural selection may be very fast or very slow depending upon the environmental demands and rate of genetic changes. American naturalists K. Mather & J.M. Theoday (1953) divided natural selection into 3 categories, viz., stabilizing or normalising selection, directional or balancing selection and disruptive selection.

1. Stabilising or Normalising selection or Centripetal selection: This type of natural selection operates in stable environmental conditions and in a short span of time, when species living in a particular environmental conditions are perfectly adapted to live in it. Thus individuals with extreme characters will be at a disadvantage as compared to the individuals having average characters and the latter would be favoured by natural selection. In is therefore a negative selection that weeds out continuously the less fit as well as more specialised genotypes from the population.

Examples: H.C. Bumpus (1899) observed 133 sparrows killed in a storm and found that those birds that were killed possessed abnormally long or short wings, away from the average. Oppossum, an American marsupial, has changed very little over the past 60 million years. Similarly, in the case of *Sphenodon*, not much change has taken place during the past 150 million years due to almost stable environment in New Zealand. M.N.Karn & L.S. Penrose (1951) studied the survival rate of human babies in London hospitals and found that most of the babies that survived after birth had an average weight of 7.5 pounds.

2. Directional or Balancing selection or Orthogenesis: This selection is always associated with environmental change, owing to which average characters become non-adaptive. Therefore, it favours individuals with non-average or extreme characters, which may prove useful in the changed environment. This is directional and progressive selection, which gives rise to new types from the original population, which have the ability to survive the change in the environment.

By keeping the gene from disappearing in heterozygous condition, natural selection provides a species with reserves upon which it may draw when condition changes. Species that have lots of heterozygotes and plenty of variations are the fittest ones in changing environments.

Examples: Evolution of horse is a good example of directional selection in which a small forest dwelling animal, *Hyracotherium*, had to undergo successive changes in its body when the environment changed from forest to grassland, giving rise to a tall, fast-running, grazing horse (see chapter 'Evolution of Horse'. Evolution of black form of industrial melanic moth (*Biston betularia*) from grey ones in England in 19thcentury is also directional selection. Gradual replacement of susceptible mosquitoes by the DDT resistant strains due to excessive use of insecticide is an example of directional artificial selection.

3. Disruptive or diversifying selection: This type of selection pushes some of the phenotypes away from the population average but at the same time maintains them in the population. Thus polymorphism appears and is maintained in the population. Uniformity of characters in young individuals and bimodal or trimodal diversity of characters in the adults is also considered to be due to disruptive selection. It enhances adaptability of a population. Megamutations may produce new types but they are not eliminated even when they are not advantageous.

Examples: White tigers and white leopards are common in the populations. The former must have given rise to Siberian tiger and the latter to snow leopard by migration. Similarly, origin of bird's wing from a reptilian foreleg must have occurred due to megamutation, but it may not have been an advantageous character in the formative stage but was still maintained in the population and became advantageous later. Polymorphism is very common in insects, such as butterflies, aphids and hoppers (winged and wingless forms), web-spinners and social insects. Polymorphism permits the species to exploit different types of ecological conditions by different forms. Widely distributed species, living in mosaic of environmental conditions, usually possess polymorphism.

K-selection and R-selection: These two categories are made based on the density of population and reproductive rate at which the natural selection operates.

<u>K-selection</u> operates in stable environmental conditions in which species live in saturated population densities. These populations show sigmoid growth curves and live near the carrying capacity. Selection favours those individuals that have enhanced competitive ability at high population densities near the carrying capacity. Such populations have slow growth rate and prevail in non-seasonal tropics.

<u>R-selection</u> operates on populations having rapid growth rate but low adaptiveness. They can rapidly exploit new environment, such as a burnt out forest or brief summer in mountains or in areas of uncertain environmental stress, e.g. storm, drought, fire etc. Such populations are good pioneers and can rapidly exploit a new environment with their high biotic potential and no selection pressure. They show J-shaped growth curves, as in the case of seasonal insects.

Natural selection in microorganisms

Microorganisms reproduce in three ways and natural selection may be different accordingly.

- **1.** In self-reproducing individuals: If the process of self-reproduction is perfect, there is no room for natural selection. But the process is never complete and mutants appear from time to time. If these mutants reproduce less efficiently, they are eliminated but if they reproduce more efficiently, they can maintain themselves side by side, causing diversification in the population. For example, protozoa reproducing by binary fission, Hydra by budding and coelenterates by strobilation.
- **2.** In self-fertilizing individuals: Hermaphrodite or parthenogenic individuals usually pass the same genotype to their offspring, which are called "pure races". Unless there are mutations, the genotype of each individual will remain unchanged. When several such races are exposed to natural selection, some of them are favoured while others are eliminated, which will alter the ratio accordingly. For example, flatworms, lower insects and other invertebrates reproduce by self-fertilization.
- **3.** In cross-fertilizing individuals: In cross-fertilising microorganisms no two individuals are alike genetically and every population possesses genes in different frequencies. Natural selection may increase the frequencies of some genes and decrease the frequency of others. Since new genotypes are constantly produced by cross-fertilisation, selection has an opportunity to exercise its effect. The character becomes heterozygous and dormant and survives for some generations, without being expressed and exposed to natural selection. During this period environment may change and the character may become advantageous. This also produces heterozygosity in the population.

VARIATIONS

In evolutionary terms, differences between closely related organisms are termed as variations. Thus differences between individuals of the same species, subspecies or race can be called variations and not differences between two genera, families or classes.

Only heritable changes have evolutionary significance, since they only make the population change from generation to generation as the evolution goes on. Variations can be of several types and can be classified in different ways based on the type of character taken into account.

- **1. Group variations:** When one population of a species differs from the other, it can be termed as group variation. For example, African population of man is black while European population is white. Insect populations show group variations even within a small range of distribution.
- **2. Individual variations:** These are differences among the individuals of the same population. They are very important in taxonomic studies, when extent of variation within a deme is taken into account for comparing and assigning the population to a taxon.

Variations can also be classified in the following 3 categories based on the type of character considered:

- **1. Meristic variations:** These are variations that can be counted in numbers. For example, man has 12 pairs of ribs but if some individual has 13 pairs of ribs, it will be called a meristic variation. Similarly some people possess 6 fingers instead of 5 due to trisomy, and a starfish may have 6 arms instead of the usual five.
- **2. Quantitative variations:** Variations that can be measured in size or weight, such as tall versus dwarf animal, heavy versus light body, long tail versus short tail etc.
- **3. Qualitative variations:** These include characters, which depict identification quality of an individual, e.g. presence or absence of spots, hairs, colour, stripes, specialized feathers, etc.

Based on the continuity of a character the variations can be classified into the following two categories:

- **1. Continuous variations (=Minus-plus variations):** Variations which fluctuate above or below the average, with intermediate stages also found. For example, in a population some individuals are larger, some smaller and some intermediate. In Indian population, some people have lighter skin, some darker and all kinds of intermediate shades are also found.
- **2. Discontinuous variations:** These variations deviate greatly from the average individuals. Major mutations and disruptive selection produce some individuals, which are distinct from the others. For example, white tiger, hornless calf and albino peacock or cow.

Based on the inheritance, variations can be classified into the following two types:

- **1. Somatic variations:** These are also called somatogenic variations, which are produced in the body due to the effect of environment. They are not heritable as they are not due to genetic changes, as for example, muscles of a wrestler, or weak individuals under starvation conditions.
- **2. Genetic variations:** They are germinal variations that occur in genes. They are blastogenic, heritable and produce phenotypic changes in the populations. If somatic variations persist for a longer time, they tend to become genetic and become important in evolution.

Some variations not classified in the above-mentioned ways are as follows:

1. Age variations: When young ones differ from the adults distinctly, as caterpillars differ from the adult butterfly or tadpole differ from frog, it is called age variation. These variations have adaptive value but not evolutionary significance, although they help in taxonomic identification.

- **2. Seasonal variations:** When animals change their appearances in different seasons, mainly as climatic adaptation, they are called seasonal variations, e.g. winter fur in temperate animals like snowshoe hare, whose fur becomes white in winter and brown in summer. Seasonal variations are commonly found in insects, like butterflies, grasshoppers, bugs etc.
- **3. Habitat variations:** In sedentary animals like sponges, corals, oysters as well as in plants, variations are produced due to local environmental influences of the particular habitat. Some of the mobile animals, namely grasshoppers, locusts and plant bugs also show habitat variations. Chameleon can change its colour according to the habitat.
- **4. Castes in social insects:** Division of labour in social insects, e.g. termites, honey bees, ants and wasps creates castes which have specialized organs to carry out a particular job in the colony. Therefore we can see different types of individuals moving about in the same population.
- **5. Polymorphism:** When different types of individuals occur in a single interbreeding population of a non-social animal, it is called polymorphism. It is very common among insects, like butterflies and beetles, which show dry and wet season forms.

SOURCES OF VARIATION

Somatic as well genetic variations can be produced in the following ways:

- **1. Environment:** Environmental factors, namely, heat cold, rain, drought, food etc. influence populations drastically and normally cause somatic variations within a short period. These variations are generally not heritable and disappear if environmental conditions revert back. If tadpoles are fed on thyroid extract, they quickly metamorphose into small frogs, without growing in size.
- **2. Endocrine glands:** Optimum activity and balance in the functioning of endocrine glands is very important for the normal growth of the body. Over or under functioning of pituitary, thyroid, adrenal etc. can produce variations in the body, which are again only somatic and not heritable. Such variations are also due to the environmental effects.
- **3. Blending inheritance:** Darwin laid emphasis on blending inheritance as a major source of variation in animals, without understanding its genetic mechanism. Characters of both the parents merge in the first generation of offspring, due to crossing over between homologous chromosomes in diplotene stage of meiosis. But the characters segregate in the subsequent generations according to Mendel's laws, but still the variations are produced.
- **4. Mutation:** Mutation is a change in the sequence of nitrogenous base pairs in DNA. For example, if AGC is a codon on DNA, its complementary codon on m-RNA will be UCG, which will code for the synthesis of amino acid **serine**. If a small mutation replaced Guanine with Adenine in the codon of DNA, the complementary codon in m-RNA will also change to UUG, which will now synthesize a different amino acid, **Leucine**. This is a point mutation that will alter the relevant character on the body. Similarly, point mutation produces sickle-cell anaemia in man, when codon CTT coding for glutamic acid is changed to CAT, which codes for valine.

Mutations can be produced by excessive environmental conditions or by radiation but most of the times they are caused naturally during the duplication of DNA, when new bases are synthesized. As these mutations are recessive, they remain hidden and do not express for a long time, and since they are genetic they play very important role in evolution.

Role of mutation in natural selection: Mutations may lead to formation of multiple alleles at a given locus. New alleles change the gene frequency in a population that upsets genetic equilibrium, causing microevolution.

In diploid organisms mutations are recessive and therefore remain hidden for a long time but keep spreading and accumulating in the population causing hybrid vigour (Heterosis) and variations, which help in natural selection.

In haploid organisms they affect the character immediately and expose it to natural selection.

Recombination of mutant genes takes place during crossing over, which makes the population heterozygous and much fitter when exposed to natural selection.

Due to the genetic drift, an advantageous mutation may be quickly fixed helping in natural selection or sometimes harmful mutations may be fixed, causing extinction of the population.

- **5. Chromosomal aberrations:** This involves breaking and rejoining of a segment of chromosome during the prophase of meiosis, by deletion, duplication, inversion or translocation.
- **1. <u>Deletion</u>**: When a small part of the chromosome breaks apart, generally during crossing over by the action of endonuclease and is lost. In man, a terminal deletion in chromosome 21 causes granulocytic leukemia and deletion of one arm of 5th chromosome causes Cri-du-chat syndrome in children. In *Drosophila*, deletion in X chromosome causes notched wings. Deletion causes abnormality in crossing over during pachytene stage of meiosis.
- **2.** <u>Duplication:</u> When one gene is represented more than once, if deleted portion of one chromosome gets attached with another chromosome. The zygote will have 3 doses of genes and crossing over will be unequal. Bar-eye in *Drosophila* arises due to duplication of a small section of X chromosome.
- **3.** <u>Inversion:</u> When a piece of chromosome breaks and joins at the same place after rotation, the sequence of genes is altered. It is most likely to occur in meiosis in germ cells if chromosomes form a loop. Chromosome breaks at centre and gets reattached after reversing. This will cause abnormal synopsis and crossing over. There is not loss or gain of genes but sometimes the effect may be due to new position of the genes.
- **4.** <u>Translocation:</u> This involves transfer of one gene block from one linkage group to another in non-homologous chromosomes. Most of the translocations do not produce any abnormality in carriers as deletion in one is balanced by the other. 50% of the offspring of carriers (heterozygotes) will be grossly abnormal. Translocations, like inversions, do not produce immediate effects but accumulate over long periods to introduce reproductive isolation in allopatric populations. In *Drosophila* 6 species have been produced by translocation from the ancestral *Drosophila virilis*, which has 6 pairs of chromosomes.
- **6. Aneuploidy:** When the entire chromosome is either lost or duplicated, it is called Aneuploidy. In *Drosophila* the gene for white eye is X chromosome. When two X chromosomes fail to separate during oogenesis (non-disjunction), female offspring with 3X chromosomes will be superfemales, which have low viability and are sterile, while some eggs will have no X chromosome at all. OY individuals do not survive because of the upset in gene balance.

In man non-disjunction in sex chromosomes influences secondary sexual characters. For example, trisomic XXX produces superfemales, while XXY causes Klinefelter's syndrome. Monosomic (2n-1) XO causes Turner's syndrome, while YO is non-viable. Down's syndrome or Mongolism is caused due to duplication of chromosome No. 21 and it causes mental retardation, malformed ears, no sexual

maturity and susceptible lungs. Aneuploidy causes abnormality in organisms but sometimes these abnormalities may prove to be useful in different environmental conditions.

- **7. Polyploidy:** When there is duplication of the entire haploid set (genome) of chromosomes, due to abnormal mitosis or meiosis, leading to triploid or tetraploid organisms, if diploid gametes are produced. Such offspring are normally sterile, but in plants owing to vegetative reproduction, they may be able to produce offspring. In horticulture, polyploidy is induced by treating them with Colchicine (obtained from the seeds of *Colchicum autumnale*) to obtain better fruits and flowers. Polyploidy is not successful in animals, except in some parthenogenetically reproducing animals, viz. shrimps, isopods, moths, beetles, flies etc.
- **8. Hybridization:** When isolating mechanisms between two species break down and they produce offsprings. Such offsprings are normally sterile but sometimes they can backcross with the parents to produce second generation of individuals (introgressive hybridization). For example, *Raphanobrassica* is produced by crossing *Raphanus* (Radish) and *Brassica* (Cabbage). Both have 18 chromosomes. Hybridization is a common mechanism that produces variation in invertebrates, particularly insects.

ISOLATION

Isolation, in evolutionary term, means segregation of different populations into smaller units by certain mechanism so as to prevent interbreeding among individuals.

1. Geographical isolation

When the populations are separated by a geographical barrier, such as river, sea, mountain, deserts and for aquatic animals land, they are physically prevented from interbreeding. Such populations are termed as **allopatric** and are forced to evolve independently and accumulate genetic differences. Geographical isolation may be different for different species. For example, a small stream may be an effective barrier for land insects and small mammals while for birds even mountain and oceans may not be barriers.

2. Reproductive isolation

It is the property of individuals that prevents interbreeding in populations that are actually **sympatric** (living in the same area).

Classification of reproductive isolating mechanisms

A. Premating mechanisms

They prevent interspecific crosses in sympatric populations.

- **1. Seasonal isolation:** Also called temporal isolation, in which potential mates do not come in contact with each other because of differences in breeding seasons of two species, e.g. different flowering seasons in plants. *Bufo americanus* breeds in early rainy season (May), while *Bufo fowleri* breeds in late rainy season (July) in USA.
- **2.** *Habitat isolation:* Also called Ecological isolation, in which also potential mates do not meet each other due to differences in habitats, requirements of food, space, climate etc. Potential mates live in different areas and therefore do not come in contact with one another. For example spawning grounds of riverine fishes are in different tributaries, which prevents interbreeding.

- **3. Ethological isolation:** It is a behavioural isolation, in which potential mates meet but cannot mate, due to differences in courtship displays or other specific signals that are necessary rituals before mating. The signals may be of the following three types, which stimulate the opposite sex for mating:
- (a) Visual stimuli: Feather displays and dancing in male birds is necessary to attract the female, e.g. peacocks, pheasants and birds of paradise. The colour and shape of the feathers as well as display pattern is so unique for each species that mating between two different species is not possible. Collection of the nest material and construction of the nest as by the weaverbird male is also a very specific display that cannot be imitated by the other species.
- **(b) Auditory stimuli:** Songbirds like cuckoos, mynas, nightingales, parakeets etc. use auditory signals to attract the opposite sex. Sometimes the singing goes on for several days before the pair can actually come together for mating. Auditory communication is used by a large number of animals, viz. frogs, toads, cicadas, gibbons, monkeys, jackals etc.
- **(c)** Chemical stimuli: This includes odour of the animals that attract the opposite sex for mating. For example scent of musk deer and musthing in elephants attract the females. In insects, particularly Lepidoptera, females produce highly specific pheromones that can be detected by the highly specialized antennae of males from a distance of about 2 kilometers.
- **4. Mechanical isolation:** In this case the above isolating mechanisms are not present and therefore mating is attempted but is not successful due to mechanical problems such as differences in the structure of genitalia. Dufour (1844) described "Lock and key mechanism" in the genitalia of insects. In the species of *Drosophila* the genitalia are so different that copulation is mechanically not possible.

B. Post-mating mechanisms

These reduce the success of interspecific crosses. In case premating mechanisms fail to prevent mating then several post-mating mechanisms prevent the success of mating and hybridization. There are 4 such mechanisms, which are given below:

- **1. Gamete mortality:** Mating and sperm transfer takes place but egg is not fertilized. In *Drosophila* vaginal wall swells killing spermatozoa should interspecific crosses take place. If mating takes place between *Bufo fowleri* and *Bufo valliceps*, sperms cannot penetrate the egg membrane of each other, leading to mortality of gametes.
- **2. Zygote mortality:** Egg is fertilized but the zygote dies. Eggs of many species of fishes may be present in the spawning grounds and some may be fertilized by the sperms of different species forming zygote but such zygotes fail to develop due to differences in chromosomes.
- **3.** Hybrid unviability: Zygote develops and hybrid is produced but is physically weak and inviable due to physiological disturbances in the body. It fails to survive for long and prematurely dies. Such cases have been recorded in different species of ducks.
- **4. Hybrid sterility:** Hybrid is viable, physically strong and physiologically sound but is sterile due to differences in chromosomes and different gene arrangements. Mule is a cross between male donkey and female horse and Hinny between female donkey and male horse and both are sterile, albeit physically strong.

Sometimes all isolating mechanisms break, leading to fertile hybrids, which are generally not reproductively isolated from the parents and can produce fertile offspring by Introgression (hybrids backcrossing with parents to produce fertile offspring). This will be instant speciation.

Significance of isolating mechanism

- Wasteful courtship is avoided. If isolating mechanisms are distinct and specific only individuals of the same species indulge in courtship.
- Isolating mechanism protects gene pool of a species and prevents hybridization.
- It prevents wastage of gametes and energy.
- A weak isolating mechanism leads to production of new species through hybridization.
- Absence of isolating mechanism leads to production of new species by instant speciation.
- Geographical isolation followed by reproductive isolation ultimately leads to production of new species.
- Isolating mechanisms protect the identity of a species, which all species fiercely guard.

SPECIATION

Speciation is the evolution of a new species from the pre-existing one by gradual modification. Since species are reproductively isolated populations, creation of a new species demands a mechanism that will produce reproductive isolation between two populations. Speciation can be classified into two categories as follows:

Convergent speciation: Two species that have not developed enough reproductive isolation but have maintained their independent existence owing to the geographical isolation can merge and produce a new species by hybridization should the geographical barrier separating them is removed. Sometimes migrations or accidental carriage by wind or storm can also make the two populations merge into one species. •

Divergent speciation: When two or more species are produced by splitting of a single species, either by migration or adaptive radiation. Gradually each population gives rise to an independent species, as happened in the case of Darwin's finches. When a population enters a new ecological zone evolution is generally quick to produce new species by adaptation to new environment.

Phyletic speciation: This is also called sequential evolution or transformation, in which a species changes gradually over a long period of time to become entirely different from the ancestor. Evolution of horse from *Hyracotherium* and elephant from *Moeritherium* are excellent examples of phyletic speciation. Darwin's theory is based on this concept of gradualism.

Quantum speciation: This involves sudden formation of a new species by rapid changes or saltation, caused by mega-mutation and disruptive selection, hybridization or polyploidy. When new areas are colonized, all niches are vacant that forces the isolating mechanism to set in rather rapidly to produce new types.

Based on the mode, habitat and geographical distribution, speciation can be of several types as follows:

1. Allopatric speciation: Also called **geographical speciation**. A physical barrier divides the population into smaller units, as happens during interglacial period when sea level rises and separates islands from the mainland. The separated populations on the islands evolve differently by constant genetic changes, translocations, inversions etc. They change into races, then subspecies and if time is long enough, into species.

Sometimes the populations can also be separated when they are accidentally carried into a new area (as Darwin's finches) or some individuals cross over the barriers like mountain, sea or river and never return back. Fourteen species of Darwin's finches found in various islands of Galapagos archipelago originated from a single population accidentally blown with storm from Ecuador in South America.

Reproductive isolation is produced by accumulation of genetic changes over long period of time. The above mechanism is traditional speciation and is termed as **Dichopatric speciation** but sometimes geographical barriers are not well defined and small populations do frequently wander out of the main range of distribution to the surrounding uninhabitable areas. Such peripheral isolates lose contact with the main population and establish themselves as new species. This kind of speciation is known as **Peripatric speciation**.

- **2. Parapatric speciation:** Described by Endler (1977), this type of speciation takes place in widely distributed species, having continuous distribution and no geographical barrier separating populations. Large populations are usually broken into clines, which have no effective geographical barrier between them but the distance and habitat differences themselves may form loose barriers. Such populations have overlapping boundaries which serve as **zones of hybridization** or **ecological escarpment**. Eleven species of land snail, *Partula*, on the island of Moorea in Society Island are known to have originated by parapatric speciation.
- **3. Stasipatric speciation:** This type of speciation was categorized by White (1968, 1978) and Key (1968). The new species arises sympatrically, first by chromosomal rearrangement within the geographical range of the parent species. The new population spreads within the range of parent species, spreading by parapatric distribution. White (1978) studied 7 species of Australian grasshopper (*Vandiemenella*) having parapatric distribution, with zones of hybridization 200-300 meters wide and believed that all species are chromosomally distinguished and that their differences arose sympatrically.
- **4. Sympatric speciation:** This type of speciation takes place in freely interbreeding populations which have no geographical isolation but sometimes host preferences may create pockets within the same area. Reproductive isolation is therefore produced by polyploidy or hybridization. Polyploidy is very common in plants. Approximately 47% of all angiosperms are polyploids. But it is rare in animals and has been reported in some asexually reproducing shrimps, isopods, bagworm moths, weevils and flies.

Hybridization normally produces sterile offspring but sometimes fertility is possible by introgressive hybridization (offspring backcrossing with the parents). Also if hybrids become polyploids, then they will have full complements of all chromosomes and therefore will be fertile and can create a new species instantly.

5. Quantum speciation: This is sudden emergence of new groups by saltation. This speciation is much more rapid and sudden, and produces new species or higher groups. In small, scattered populations or populations that have migrated to new area, genetic drift, rather than natural selection plays an important role in quickly changing the species. Sometimes chance events or mega mutations aid in quick speciation. Disruptive natural selection then makes the species distinct and diverse.

After mass extinction, surviving species find a relaxed natural selection, as most of the ecological niches are vacant. The species then split into small populations in new environmental pockets and slowly get diverged into new types.

EVOLUTION TYPES

Based on the degree of change and speed of evolution three stages in evolutionary process can be identified:

- 1) Origin of small evolutionary differences at sub-specific level.
- 2) Modifications in larger groups of animals, producing species and genera by adaptive radiation.
- **3)** Evolution of new types from their predecessors by large genetic changes, often producing families, orders, classes and phyla.

Microevolution

This is also called **Sequential evolution**, which involves a continuous and gradual change in an interbreeding population, usually giving rise to new subspecies and geographical races. Basic process involves changes in gene frequencies in a population from one generation to the next. Microevolution is produced by stabilizing or normalizing natural selections that operate in stable environmental conditions and in short time span.

<u>Examples:</u> Rowe has discovered several lines of descent in sea urchin, *Micraster*, where he found gradual change in characters from *M. corbovis* to that of *M. cor-anguinum*, mainly in the shape of the test, structure of oral opening and the form of ambulacra. The changes took place in a more or less stable environment. Similarly Fenton has described gradual replacement of one species by another in brachiopod, *Spirifer*.

Macroevolution

This may also be called **Adaptive radiation**, which includes evolutionary changes above the species level that may result in the production of new adaptive types through genetic divergence. The changes are on account of large gene mutations or macromutations and result in the establishment of new genera, families and orders. Macroevolution takes place in individuals that have entered a new environmental zone, which is free of competition. Darwin called such directional changes **Orthogenesis**.

<u>Examples</u>: Evolution of horse is a perfect example of macroevolution, in which there was an increase in the size of body and legs and in the enlargement of teeth. All body changes were related to life in open grasslands, fast running and feeding on harsh grasses, eventually leading to new adaptive types. Other examples of macroevolution are: adaptive radiation in Darwin's finches, divergence of reptiles and evolution of camel and elephant.

Megaevolution

This includes formation of new groups, classes or phyla due to evolution of new types from its predecessors by general adaptation. Megaevolutionary changes are rare and have occurred rarely in the evolutionary history. During megaevolution, organisms of the ancestral stalk attempt to enter a new and very different environmental zone where they face strong natural selection, for which they must possess certain pre-adaptations to enable them to survive in the new zone. Megaevolution is brought about by large genetic changes that are capable of producing different types and disruptive or divergent natural selection that makes the population occupy different types of environmental zones.

<u>Examples:</u> Amphibians were preadapted to live on land for short periods since as fish they already possessed lungs for air breathing and limbs to support body on land.

Origin of birds from reptiles included growth of feathers and sudden change in the fore limb to produce wing, which enabled them to invade air and then developed beak, sternal keel and loss of tail as post-adaptations.

Origin of mammals can be traced back from a series of fossil reptiles (Synapsida) of Triassic period. During evolution, a false palate was formed, teeth became thecodont, and limbs moved under the body for better locomotion. Emergence of bats (Order Chiroptera) from the primitive insectivores has been a sudden event in the beginning of Coenozoic era. Skeletons of early Eocene bats show fully developed wings, much like our modern day species possess. No transitional forms are known, suggesting that bats emerged by a megaevolutionary event. Megaevolution is always followed by micro- and macroevolution.

EVOLUTIONARY PATTERNS

There Are Six Important Patterns of Macroevolution:

- Mass Extinctions.
- Adaptive Radiation.
- Convergent Evolution.
- Coevolution.
- Punctuated Equilibrium.
- Developmental Gene Changes.

Punctuated equilibrium (also called punctuated equilibria) is a theory in evolutionary biology which proposes that once species appear in the fossil record the population will become stable, showing little evolutionary change for most of its geological history. This state of little or no morphological change is called stasis. When significant evolutionary change occurs, the theory proposes that it is generally restricted to rare and geologically rapid events of branching speciation called cladogenesis. Cladogenesis is the process by which a species splits into two distinct species, rather than one species gradually transforming into another.

ANAGENESIS – The Progressive Evolution

Series of fossils in various taxa suggest that phyletic lines begin as primitive types during evolution and end up at higher level through progressive evolution. Although lower forms may have been perfectly adapted to their specific habitats, higher forms show increased complexity of organs and adaptiveness achieved through consistent natural selection. Present day mammals possess much more complex body organization than their Cretaceous ancestors.

So, the single phylogenetic lineage in which a primitive ancestral species gradually acquires complexity and specialization in response to the environmental stimuli is called *Anagenesis*, whereas the branching of the lines of descent is known as *Cladogenesis*.

Natural Selection produces adaptations in relation to the existing conditions but such adaptations may prove disadvantageous in future and hence increase in the complexity and perfection of adaptations is a continuous biological process that leads a species to higher level. Anagenesis has the following characteristic features:

- Increased complexity of organs.
- Rationalisation of organs and structures in order to improve their functions.
- Increased complexity of central nervous system.

- Increased plasticity or flexibility of organs to allow greater variety of functions.
- Progress permitting further improvement when needed.
- Increased independence or resistance to environmental changes.
- Division of labour in body parts to enable more efficient functioning.

S.W. Williston (1852-1918) proposed that in organisms having serially repeated body parts there is a tendency of reduction in the number and increase in specialisation of these parts during Anagenesis. In arthropods, crustaceans possess almost 19 pairs of serially arranged appendages which are modified for various purposes, namely, food handling, walking and swimming. But in higher arthropods such as insects, these appendages undergo high degree of specialization to produce different types of mouth parts and reduction of legs into only three pairs.

Centralization of nervous system into brain rather than having segmental ganglia and increased complexity of this organ in molluscs and later in vertebrates is a typical anagenetic event. Improved and complex central nervous system gave the mammals an edge over reptiles in competition and in man it conferred the ability to change the environment.

In man, Anagenesis brought about increased complexity and rationalisation of brain in ape-like ancestors which were both arboreal and terrestrial and omnivorous in diet. Terrestrial habit and group selection promoted Anagenesis and complexity of brain conferred plasticity of hands, development of speech and social life.

Acquisition of homoeothermy in mammals and birds provided them with plasticity to explore areas from arctic region to deserts, which could not be conquered by their ancestors.

There is no general trend in Anagenesis. Natural selection produces patterns which determine line of evolution. Sometimes regressive development and simplification of unnecessary parts is a sign of progression and improved efficiency. For example, loss of limbs in snakes, limbless lizards and Apoda is progressive specialization in relation to their habitat. Anagenesis produces degeneration in organs of sessile and parasitic animals, but degeneration takes place only in those organs that are unnecessary for parasitic life.

Anagenetic Rates

A very rapid Anagenesis is termed **Tachytely**, while moderate speed of evolution in a lineage is called **Horotely**. A very slow rate of anagenesis which normally occurs in stable environmental conditions in isolated pockets is known as **Bradytely**. Evolutionary changes taking place per unit of time gives an idea how fast evolution has occurred in a lineage or in different comparable lineages.

CLADOGENESIS – The branching evolution

Splitting of a lineage into two or more branches during evolution is called cladogenesis. This is one of the most common modes of speciation in changing environment or in a mosaic of environmental conditions. Species tend to break into populations and try to adapt to different environmental conditions thus setting off branching of the ancestral taxon into lower ranked ones.

Tachyschizia

Rapid splitting of lineages, often due to invasion of new environment, or due to extinction of competitors, which makes new opportunities available to the population. Natural selection is relaxed in such situations and new types can be produced very fast, leading to adaptive radiation. A split in

the pseudosuchia lineage of the codont reptiles produced birds which invaded a new environment of flying in the air, while another branch of the codont reptiles gave rise to mammals.

Tachyschizia can also be seen in Darwin's finches which have all branched off from a single population that was blown off South American coast to the Galapagos Islands, where ecological niches were vacant and natural selection relaxed.

Horoschizia

This is moderate rate of splitting of phyletic lines under moderately changing environmental conditions when natural selection is not too harsh. Splitting takes place after long intervals.

Bradyschizia

A lineage persists without splitting for a long time and the evolution is slow, but a split can happen after a long gap and some branches may survive while the others become extinct. The rate of speciation can be measured as an average of several branching lineages, which would include both surviving and extinct ones.

Cladograms that show branching lineages are developed with the help of computers and compared with actual phylogenies to arrive at a realistic conclusion.

CONTINENTAL DRIFT

The theory that the present day position of continents is not permanent but the continents constantly drift and change positions, was first proposed by Alfred Wegener who from close studies of maps, discovered that coastlines of all continents fitted together like a jigsaw puzzle, suggesting that all continents in the past were placed together in a mass of supercontinent. Wegener believed that continents were made of light material called **Sial** (made of silica and aluminium) that floated over a heavier material **Sima** (made of silica and Magnesium) that makes ocean floors, like icebergs floating in ocean water.

Later, in 1937, A.L. Du Toit elaborated on this theory in his book, *On Wandering Continents*, which explained many of the puzzles of discontinuous distribution of animals. But it was much later in the late 1960s that detailed studies of ocean floors revealed that the earth's crust, which is made of hard rocks and soil, is only 30-60 km thick and is broken into several plates that float over the molten mass of the interior of earth that is constantly in circulation. The theory is now known as *plate tectonic theory* which postulates that the continental plates move at a very slow pace to change positions that can be measured in thousands of kilometres.

The innermost part of earth is called **Barysphere** or **core** or **nife** which is about 4,400 km in diameter, surrounding which is **Pyrosphere** or **mantle**, which is 2,500 km thick molten mass and like a wrapper is a thin **crust** or **Lithosphere** of only 30-60 km thickness that is made of rocks and soil and which supports life on its surface.

Continents move because the crust is broken into blocks or plates that float on the hot molten lava of mantle that keeps in circulation due to slow convection currents produced by the heat emanating from barysphere or core. Due to this heat the molten basalt rises upwards and spreads horizontally just under the crust and cools down. There are subduction zones where the crust sinks down and melts into the mantle due to the pressure of spreading sea floor. This process of spreading and sinking of the earth's crust makes the continental plates move.

During the Cambrian period major land masses occurred south of equator and Africa, South America, Australia, Antarctica and parts of Asia formed a single continental mass, Gondwanaland, that extended up to the South Pole but the position of continents was reverse of what it is today. There are evidences of major mountain building in North America and Europe and of glaciation during Devonian period, when much of Gondwanaland was covered with ice sheets. There was sharp decrease in the atmospheric CO₂ during this period perhaps because of invasion of land by plants. Invasion of land by plants attracted invertebrates and then vertebrates on land, pioneers among them must have been detrivores rather than plant feeders, such as springtails, millipedes and mites.

By Carboniferous period even the northern land masses started to move southwards to join Gondwanaland, forming a single supercontinent called **Pangaea** towards the end of this period. Most of the present day coal beds were formed when these forests were buried during this period (carboniferous means coal-bearing). High levels of atmospheric oxygen, low levels of CO₂ and abundance of food enabled invertebrates to diversify and become giants. Pangaea continued to exist till Permian when it again broke and started to drift apart.

During Permian, about 270 million years ago, a single large continent Pangaea started to split into two land masses, the northern **Laurasia** and southern **Gondwanaland**, separated by the sea of Tethys. The splitting perhaps caused what is known as the worst mass extinction in the history of evolution.

During Jurassic, the continental masses began to break up leading to the formation of Atlantic Ocean. Americas began to drift westward, Antarctica and Australia southwards and India towards the northeast.

North and South Americas were connected together by a narrow corridor, through which migrated reptiles and primitive mammals. Towards the end of Cretaceous some catastrophe struck the earth resulting in another mass extinction and extermination of the most powerful of all animals that ever existed – the dinosaurs.

During Eocene, North and South Americas got disconnected by the submergence of panama connection, isolating the South American continents from the others for a very long time. Almost at the same time North America also got disconnected from Europe for ever, although a filter bridge may have existed between the two continents for some time.

During Miocene Indian plate had moved sufficiently northwards to collide with the Eurasian plate, obliterating the **Sea of Tethys** and starting a process of mountain-building that continued well into the Pliocene. In the beginning, the rising Himalayas did not produce an effective barrier between the Palaearctic and Oriental Regions but they gradually rose to great heights of today and effectively checked the movement of animals between the two regions.

Sclater (1857) was the first one to give concepts of zoogeography and divided the continental masses into six realms based on his studies on the bird fauna under two Creatio or centres of Creation, namely, Palaeogeana (Old world) and Neogeana (New world).

The widely accepted modern classification of land masses into regions is given below which is based on Wallace (1876) and Darlington (1957).

1. Realm MEGAGEA

- a. Region PALEARCTIC (Europe, Russia, Mediterranean).
- b. NEARCTIC (North America up to the middle of Mexico).

- c. AFRICAN (=ETHIOPIAN) (Africa south of Sahara).
- c. ORIENTAL (Tropical Asia south of 30° latitude).

2. Realm NEOGEA

Region NEOTROPICAL (South America, tropical Mexico and Caribbean Islands).

3. Realm NOTOGEA

Region AUSTRALIAN (Australia, Tasmania, New Guinea and New Zealand).

FAUNA OF AFRICAN REGION

This region includes continental Africa south of Sahara desert. This is mainly a tropical region having evergreen forests and grasslands in the central and eastern parts. There is desert in the north.

Mammals. There are 38 families of mammals, out of which 12 are exclusive and the rest are shared with Neotropical and Oriental Regions.

Animals having worldwide distribution include shrews, rabbits, squirrels, cricetid mice, dogs, mired mice, cats and bovids, antelopes.

The exclusive animals include giraffes, hippopotamus, Aardvark or Cape anteater, rock hyrax, golden mole, elephant shrew, small deer-like water chevrotain, aye-aye, bushbabies and lemurs in Madagascar. There are 6 endemic families of rodents and 3 of insectivores.

There are no camels, bears and tigers in this region.

Animals shared with Oriental are lorises, monkeys, apes, pangolins, Cheetah, elephants and rhinoceros.

Shared with Palaearctic are dormice, jerboa, wild horses.

Aves. Bird fauna has affinities with Oriental Region. There are cuckoos, woodpeckers, hornbill, sunbirds, herons, orioles, birds of prey, storks, parrots, pigeons, fowls, pitta, guinea fowl, swallows and bee-eaters.

There are 6 exclusive families that include ostrich, secretary bird, hammer head that feed on frogs and fish, crested touracos, ground hornbill, mouse birds and helmet shrike. Honey guide feeds on honey bee larvae and guides honey collecting tribals to bee hives. Two species of oxpeckers, namely, yellow billed and red billed feed on ticks and other ectoparasites of rhinoceroses. The crocodile bird dares to enter the mouth of crocodiles to feed on leeches.

Reptiles. Crocodiles and turtles abound and few lizards belong to families Lacertidae and Agamidae. Iguanid horned lizards are absent. Spiny lizard of family Cordylidae is restricted to this region. *Chameleon* also occurs in the Oriental Region. Snakes include pythons, *Typhlops* and biting vipers. Crocodiles include, *Crocodylus noloticus, Osteolaemus* in West Africa and *Osteoblepharon* in Congo.

Amphibia. There are no urodeles but frogs and toads abound such as the African ridged frog and African shovel-nosed frog. Family Hylidae of tree frogs is absent, replaced by Polypedatidae. The flying frog is the African rhacophorid. Genera *Rana* and *Bufo* are absent. Phrynomerid tree frogs are endemic. *Xenopus* and aquatic clawed toads present. Limbless amphibians are present.

Fishes. Lung fishes have two species of *Protopterus* that live in the rivers and lakes of tropics. Chondrostei is represented by 10 species of Bichir (*Polypterus*). Electric eel of family Mormyridae has electric organs in tail. There are cat fishes, carps, characins and generally the fish fauna is diverse.

Fauna shows overwhelming similarity with the Oriental Region.

SUBREGIONS OF AFRICAN REGION

- **1. East African.** This includes tropical Africa and tropical Arabia. Fauna contains 145 families of vertebrates. There are rhinoceros, zebra, giraffe, cheetah, spotted hyena and lions.
- **2. West African.** Western Africa up to Congo includes forests. Fauna has 134 families of vertebrates that include, gorilla, chimpanzee, monkeys, baboons, flying squirrel.
- **3. South African.** Southern portion of Africa. Fauna contains 133 families of vertebrates. There are ostriches and secretary birds. Mammals include golden mole, elephant shrew, jumping mice, aardvark and naked mole rat that leads subterranean existence.
- **4. Malagasy.** Madagascar, Mauritius, Seychelles and neighbouring islands. Fauna has 86 families out of which 8 are endemic. There are aye-aye, lemurs and common tenrec. Helmet birds and cuckoo rollers and rough-tailed snakes are endemic. The flightless bird Dodo which was related to flightless pigeon became extinct in 1681 due to hunting by man and egg predation by dogs, pigs and monkeys.

FAUNA OF AUSTRALIAN REGION

This region includes Australia, Tasmania, New Guinea, New Zealand and islands east of Wallace's Line. New Guinea is tropical with rain forests. Eastern Australia is covered with lush green forests, Western Australia is desert and there are grasslands in the middle.

Mammals. Eight of the 9 families of marsupials are unique. There are 52 genera of 6 families of marsupials that are unique and are not found in the Neotropical Region. Marsupials show parallelism with their counterpart placentals in other parts of the world in their evolutionary modifications.

Placental mammals that were introduced by man or some of them immigrated themselves include rodents and bats, rabbits, foxes, rats, mice, dingo dogs, cats, pigs and murid mice.

Monotremes are represented by Ornythorhynchus and Echidna.

Birds. There are 58 families of birds out of which 44 are widely distributed. Species having wide range are trogons, hawks, kingfisher, cuckoos, parrots and pigeons.

Shared with Oriental are frogmouths, wood-swallows, flowerpeckers and megapods.

There are 10 families of endemic birds which include cassowary, emu, kiwi, lyrebird, bower birds, honey suckers, birds of paradise, magapods and cookabura or laughing jackass that feeds on lizards and snakes.

Birds not present are pheasants, finches, barbets and woodpeckers.

Reptiles. There are pythons, biting snakes, elepid coral snakes, geckos, skinks, agamid lizards, scale-footed lizard and Komodo Dragon, crocodiles and turtles. Chelyd turtles and snake-necked turtles possess strikingly long necks. *Sphenodon pounctatus* is found exclusively in New Zealand.

Amphibia. There are no tailed amphibians. Common toads are absent and frogs are few. Tree frogs belong to family Hyalidae which is also found in the New World and Palaearctic but absent in African

and Oriental Regions. The Australian Green Tree Frog secretes mosquito repellent compound from the skin glands. The Australian frogs, *Rheobatrachus silus* and *R. vitellinus* carry tadpoles in their stomachs. Some species of frogs are adapted to live in deserts, e.g. *Notaden, Neobatrachus*.

Fishes. Fresh water fishes are rare and belong to family Osteoglossidae. Lung fish is restricted to Burnett and Mary rivers in Queensland.

Fauna of this region is poor in freshwater fishes, Amphibia and reptiles. There is uniqueness of mammals and affinities exist with the Oriental and South American faunas.

SUBREGIONS OF AUSTRALIAN

- **1. Australo-Malayan.** Malayan Archipelago, Moluccas, Solomon Islands, New Guinea. Fauna includes 130 families of vertebrates. Birds are crowned pigeons, birds of paradise, honey eaters, cuckoos, bover birds, cassowaries. There are flyriver turtles, flying phalangers and tree frogs.
- **2. Australian.** Australia and Tasmania. There are 98 families of vertebrates and the region is home of monotremes and marsupials. Monotremes include short-nosed echidna, long-nosed echidna and duck-billed platypus. Marsupials include marsupial rat kangaroos, Tasmanian devil, koala, the horny possum, marsupial mole and rabbit-eared bandicoot. Tasmanian wolf became extinct on 1936. There are scrub birds, lyre birds, emus and plenty of cobras. Tailed amphibians are absent.
- **3. Polynesian.** Polynesia and the adjoining islands. Fauna is poor containing only 53 families. Tooth-billed pigeon is unique.
- **4. New Zealand.** New Zealand, Norfolk Island, Auckland and Campbell Island. Fauna includes murid bats, owl parrots, nester parrots, kiwi, *Sphenodon* and frog (*Liopelma*).

Flightless owl parrot or Kakapo feeds on leaves, shoots, berries, fruits and moss. The only carnivorous parrot called Kea was a vegetarian earlier but after introduction of sheep in New Zealand has learnt to cut sheep skin and feed on flesh.

Giant Moa that reached a height of 3 metres contained 22 species in New Zealand which became extinct all by 1600 AD.

FAUNA OF NEARCTIC REGION

This region includes the North American continent up to the middle of Mexico. Climate is temperate with an arctic edge. There are grasslands in the middle of the continent. Western part is arid with mountains and coniferous forests.

Mammals. There are 24 families of land mammals.

Endemic mammals include rodents, pocket mice, pocket gophers and mountain beavers. Pronghorns and Sewellel are endemic artiodactyls.

Palaearctic elements include beavers, moles, pikas and jumping mice.

Neotropical species that have crossed over to North America are marsupials such as opossum, shrew opossum, 9-banded armadillo and tree porcupine. There are some mammals of wide ranging distribution namely, shrews, rabbits, squirrels, mice, cats, bats, bears, deers and bovids.

Birds. There are 49 families of birds in this region out of which 39 are widely distributed.

Exclusive birds are: red cardinals, humming birds, tanagers and wild turkeys. Golden plover migrates from Europe.

Reptiles. There are turtles, non-poisonous garter snakes, rattle snakes, geckos, horned lizards, limbless lizard, horned toad and *Alligator mississipiensis*. Gila monster is exclusive to this region.

Amphibia. Urodeles include salamanders, hellbender, neotenic larva called axolotl, eel-like siren, the Congo eel and tiger salamanders. Newts include Smooth newt, great crested newt, banded newt, alpine newt, Bosca's newt. There are dusky salamanders, red-backed salamander and Jordan's salamander.

Anurans include American Bell toad, North American bull frog and Leopard frog found in grassy meadows. *Rana cascadae* and *Bufo boreas* inhabits Cascade Mountains of Oregon, USA. The desert spade-foot toad is adapted to the arid climate of northwestern America. Other toad species are: Oak toad, southwestern toad and the giant toad which is 20 cm long.

Fishes. There are many carps and perches. Holostei are endemic that include only two surviving ganoid fishes, one species of bowfin (*Amia calva*) found in American lakes and 7 species of garpike (*Lepidosteus*) found in American rivers. These fishes possess sharp teeth to seize and gulp prey with extraordinary swiftness. Paddlefish occurs in Mississippi river of America and represents Chondrostei. Another species of paddlefish occurs in China. These fishes have paddle-like snout that carries sensory organs for locating prey by detecting its electrical fields. Ameiurid catfishes, mooneyes and bass family with genera *Morone* and *Upiblema* are also endemic.

The fauna of Nearctic Region is rich in reptiles and is a complex of tropical and temperate animals.

SUBREGIONS OF NEARCTIC

Californian. Narrow strip between Sierra Nevada and Cascade Range. From Vancouver to British Columbia.

Fauna includes 86 families of vertebrates that include vampire and free-tailed bats.

Rocky Mountains. This includes dry mountainous region east of California.

Fauna contains 107 families of terrestrial vertebrates. There are pronghorns, mountain goat, American bison, prairie dogs and *Heloderma*.

Alleghany. This includes eastern region of USA.

The fauna includes opossum, starnosed mole, vampire bats, turkeys and mud eel.

Canadian. This sub region includes Canada, Greenland and Alaska. The fauna is poor and resembles Palaearctic region. There are reindeer, sheep, bisons, lemmings, polar beer, elk and arctic fox.

FAUNA OF NEOTROPICAL REGION

South America, most of Mexico, West Indies, Caribbean islands.

Mostly tropical but the southern part extends into temperate zone. Rain forests on the western side. Grasslands in the middle in Argentina. Andes Mountain on the western coast.

Mammals. There are 32 families of mammals of which 16 are unique.

Widely distributed animals are shrews, rabbits, squirrels, mice, dogs, bears, cats and deer.

Camels are represented by two species of *Llama*: *L. vicuna* and *L. guanaco*. Llama and Alpaca are domesticated breeds of these species. There are three species of tapirs of which one species also occurs in the Oriental Region.

Monkeys include: spider monkeys, squirrel monkeys, howlers, capuchin, marmosets.

Endemic mammals include, six-banded armadillo, two-toed sloth, 3-toed sloth, 3 species of anteaters, 11 endemic families of rodent Caviomorpha and five endemic families of bats that include disc-winged bats, furipterid bats and vampire bats, the last one is also a carrier of rabies.

Marsupials belong to the family Didelphidae that includes common opossum and water opossum and opossum rat. The common opossum has also spread to the Nearctic Region where it has adapted to varied climatic conditions.

There are no hedgehogs, moles, beavers, hyenas, bovids and horses in this region.

Aves. Almost 50% of the avian fauna is endemic and unique due to which South America is known as *The Bird Continent*. Out of 67 families of birds, 25 are endemic to the region. There are partridge-like tinamous, toucans that carry enormous beaks, trumpeters, hoatzin, cock of the rock, oil birds and several species of macaws, such as yellow macaw, Hahn's macaw, red bellied macaw and red and blue macaw. Quail is the only member of Galliformes here. Bee hummingbird found in Cuba measures only 6 cm and is the smallest bird.

Ostriches are represented by Rhea americana.

Common birds include herons, ibis, storks, ducks, hawks, owls, plover, cuckoos. There is scarcity of song birds.

Reptiles. There are plenty of snakes, iguanid lizards, Crocodiles, *Caiman* (alligator) and turtles. Xantusiid lizards are endemic. There are tree boas, anacondas, pit vipers and coral snakes. Mud turtles are shared with Africa and snake-neck turtles with Australia.

Amphibia. There are hylid tree frogs such as Brazilian tree frog *Hyla*, *Hylodes*, Cuban tree frog, Venezuelan tree frog that deters predators by foul odour and the poisonous *Phyllomedusa* found in Amazon.

The yellow frog is the largest and most toxic and its poison is used by Colombia tribes to poison their blowgun darts. The dart poison frog is also highly poisonous. Caecilians are represented by *Typhlonectes*. *Oedipus* is the only tailed amphibian found in South America.

Fishes. There are no carps and other fish fauna is endemic. There is electric eel, cat fishes and characin fish (Piranhas). Lung fishes are represented by *Lepidosiren paradoxa* found in Amazon River.

The fauna of Neotropical Region is rich in endemic families; almost 40 families are endemic out of 155 families of vertebrates. Other fauna is shared with Nearctic and other tropics.

SUBREGIONS OF NEOTROPICAL

Chilian. Western coast of South America, embracing summits of Andes, Peru and Bolivia. Fauna includes chinchilla, Llama, oil birds and Rhea.

Brazilian. Tropical forests up to Isthmus of Panama. Also open plains and pasture lands. Fauna includes New World Monkeys, vampire bats, tree porcupine, sloths, armadillo, opossum, tapirs, cavia, spiny mice.

Mexican. Mexico and northern lands of Isthmus of Panama and rocky mountains. Fauna includes mud terrapins, tapirs and Plethodontids.

Antilean or West Indies. Caribbean Islands except Tobago and Trinidad. Contains mountainous and rocky areas covered with forests. Fauna is poor and native mammals are absent.

FAUNA OF PALEARCTIC REGION

This region includes Europe, Russia up to pacific coast and Mediterranean up to Sahara. Climate is temperate and polar in the north. Eastern Asia is temperate with deciduous forests. In northern zone there are grasslands (steppe) and interior portion is arid.

Mammals. There are 33 families of land mammals. Animals of word-wide distribution which amounts to one-third of families are rabbits, mice, dog family, shrews, squirrels and cat family.

Animals that are restricted to the Old World include hedgehog, porcupine, civets, giant panda, hyena and pigs.

Four families are shared with Nearctic: beavers, jumping mice, flying squirrels, mole and four shared with African region.

Endemic mammals: mole rat and Camel, dormice.

African elements are wild horses, the prezevalski's horse is the only truly wild horse in the world.

Aves. There are 53 families of birds most of which are migratory. All birds have wide distribution and are shared with Nearctic, Oriental and African regions, e.g. pheasants, wrens, finches, warblers, sea birds, geese, birds of prey, cranes, terns, gulls etc.

Hedge sparrow is restricted to this region.

Reptiles. There is no endemic reptilian family. Lizard, *Sinisaurus*, and *Alligartor sinensis* are endemic in China. There are lizards, snakes and sand boa and emydine turtles.

Amphibia. There are common newts, crested newt, Spanish newt *and* alpine newt. The colourless *Proteus* is blind and lives in European caves. There are European salamanders and a species of giant salamander in Japan and China that attains a length of over 5 feet. Anurans are represented by frogs, toads, tree frogs. Male of the midwife toad, which is found in France and Italy carried eggs wrapped around his hind legs. Amphibians show affinities with Nearctic Region.

Fishes. Fish fauna also shows affinities with Nearctic. There is no endemic fish and carp is the dominant family. There are carps, salmon, pikes, perches, eels and *Petromyzon* that migrates from sea to the rivers to breed and the ammocoete larva, commonly known as sand sleeper lives in mud for several years in European rivers. Few species of toothless sturgeons immigrate from sea to the rivers of Japan and Russia for laying eggs which are harvested to prepare a delicacy called *caviar*.

The fauna is a mixture of Old World tropics and New World temperate.

SUBREGIONS OF PALAEARCTIC

European. Northern and central Europe. Black sea. The fauna hedgehog, shrew, mole and myogale (a mammal).

Mediterranean. Southern Europe. Arabian, Asia Minor, Afghanistan, Baluchistan and parts of Russia. Fauna includes civets, hyena, hyrax.

Siberian. Northern Asia north of Himalaya having extreme climatic conditions. Fauna includes yak, musk deer, mole, freshwater seal found in Baikal lake.

Manchurian. Mongolia, Japan, Korea, Manchuria, Tibet and northern China. The fauna contains Tibetan langur, giant panda, Chinese water deer, tufted deer.

FAUNA OF ORIENTAL REGION

This region includes Indian subcontinent, southern China south of 30° latitude, Malaya, Philippines and Indonesian islands up to Wallace's Line. There are rainforests in the east, high mountains in the north and the western part is arid. Along the south-western coast there is a forested low mountainous belt.

Mammals. There are 30 families of mammals out of which 5 are endemic that include *Cynocephalus*, which is called Calugo, a gliding mammal with furred membrane stretched between fore limb and hind limb. Tree shrews and arboreal tarsiers of Philippines are restricted primates. Spiny dormouse is arboreal rodent.

Twenty five percent of the fauna is shared with Africa that includes, old world monkeys, lorises, apes (Gibbon and Orang-Utan), pangolin or scaly anteater, bamboo rat, Elephant, *Rhinoceros unicornis* and a lion population in Gir forest.

Fauna shared with Palaearctic includes hedgehog, porcupine, civets, Lynx, hyenas, pigs, bear, red panda. Tapir found in Sumatra and Borneo is Neotropical element.

There are moles, tapirs, bears and deers which are absent in Africa.

Aves. Out of 66 families of birds 53 are eurytopic or widespread. Woodpeckers and barbets are widespread. There are also peacocks, argus pheasants, cattle egrets and jungle fowl.

Sunbirds, hornbills, parrots and cuckoos and shared with Africa.

Shared with Palaearctic are pheasants.

Exclusive birds are fairy blue bird which is found in Philippines where it follows troupes of monkeys to feed on insects disturbed by their movement. There are 4 genera and 14 species of leaf birds.

Whitehead's trogon is found in Indonesia and monkey-eating eagle is endangered species found in the dense forests of Philippines.

Reptiles. There are plenty of lizards, turtles, poisonous snakes, pythons and crocodiles. Lizards belong to Agamidae and Varanidae and include geckos, skinks, calotes, draco and chameleon. There are king cobras, common cobras, typhlops, xenopeltid snakes, uropeltid snakes and sea snakes.

Crocodiles include *Crocodylus porosus, C. palustris, Gavialis gangeticus. Tomistoma* is found in Sumatra and Borneo. *Alligator sinensis* is found in southern China.

Amphibia. Frogs and toads bound. Caecilians are represented by *Ichthyophis* and *Gegenophis* found in Indo-Malayan region. Tree frogs belong to family Polypedatidae and Hylidae family is absent. Flying frog, *Rhacophorus malabaricus* found in Western Ghats in India. Tailed Amphibia are few and found in northern Indo-china.

Fire-bellied toads are exclusive and extend to Palaearctic range.

Fishes. Fishes are dominated by carps and catfishes. Loaches, mullets and mud-eels are exclusive to this region. One species of the Chondrostean paddlefish *(Polyodon)* occurs in Yangtze River of China. Another species of this group occurs in American rivers.

Fauna shows similarity with the Ethiopian Region because of their proximity and similar environmental conditions.

SUBREGIONS OF ORIENTAL REGION

1. Indian. Indian subcontinent up to the foot of Himalaya and south up to Mysore. East and Western Ghats are tropical rain forests. There are rocky hills in the central part and desert in the north-west.

Fauna is varied. Tibetan Wild Ass found in Ladakh and Himachal Pradesh. Wild Ass found in Rann of Kutch. Golden Langur found in Assam. Indian Pangolin and great Indian Bustard.

2. Indo-Ceylonese. Sri Lanka and southern parts of India containing Tamil Nadu and Kerala.

Fauna includes lorises and elephants. Slender Loris, slow loris, lion-tailed monkey and giant squirrel.

3. Indo-Chinese. China south of 30° latitude, Burma and Thailand.

Fauna includes panda, gibbons, flying lemur, lynx, bear, Chinese pangolin, red panda, snow leopard and clouded leopard. Red-shanked douc langur is completely arboreal and endemic to Southeast Asia and Cat Ba Langur is endemic in Vietnam. There are Indo-Chinese warty pig and Javan warty pig, Sumatran and Annamite striped rabbits.

Crested Argus pheasant is endemic to Laos and Vietnam and possesses 70 inches long tail feathers, longest for any bird in the world.

Rhinoceros snake, the green, arboreal snake and green pricklenape lizard are endemic to Indo-china.

Whipping frog present.

4. Indo-Malayan. Malayan peninsula and islands of Malay Archipelago and Indonesia.

Fauna includes Orang-Utan, proboscis monkey, Malayan badger, Tupaia, gibbons, flying lemurs, tapirs and broad bills. *Rhinoceros sondaicus* is the lesser one-horned rhinoceros which is found in Java and *Rhinoceros unicornis* is found in India and Tarai regions of Nepal. Swamp deer.

MOLECULAR DRIVE

Molecular drive is a process through which mutations can proliferate within gene families (in process of homogenetization) and within the population (in process of fixation of mutations) through a number of mechanisms of nonreciprocal transfer of genetic information occurring on the chromosome or between different chromosomes. *Molecular drive* differs from *genetic drift* in that changes in the frequencies of the individual alleles that occur through its action are not random in their direction. If a certain population of genetically identical organisms is divided into several smaller populations, then *genetic drift* will lead to fixation of different alleles in each population. In contrast, the effect of *molecular drive* should lead to fixation of the same alleles in all populations. *Molecular drive* differs from selection in that the alleles that are fixed through its action need not favourably affect the phenotype of the organism and can thus have a zero or even negative impact on the *biological fitness* of the individual.

In *molecular drive*, one allele is replaced by another not because this is more advantageous for its bearer, but because, at the level of the DNA, it multiplies more effectively, either through a mechanism related to *replication* or through a mechanism related to *gene conversion*.

Molecular drive differs from *mutation bias* and *reparation drive* mainly in that it is responsible for the proliferation of certain mutations in the genome or in the gene pool of the population, but not for their repeated formation.

Molecular drive entails a number of mechanisms connected primarily with replication, recombination and repairing of nucleic acids. These mechanisms favour the formation and proliferation of certain sequential motifs in the gene pool of the population regardless of the degree to which the existence of these motifs is manifested in the phenotype of the organism and the degree to which it affects its biological fitness. The best-known processes active in the functioning of molecular drive include gene conversion, transposition, and also processes directly dependent on replication, i.e. uneven crossing-over and slipped-strand mispairing.

The existence of *molecular drive* is most clearly manifested in the **evolution of repetitive DNA segments** in closely related species. These segments are frequently located in the genome in a great many copies, of the order of hundreds of thousands. The individual copies are very similar and frequently completely identical. Simultaneously, *repetitive sequences* in closely related species are very different. It is difficult to explain this phenomenon without postulating the existence of a specific mechanism capable, following the speciation event – after the splitting off of a new species, of causing parallel differentiation in the repetitive DNA segments in all the loci of the genome. As the speciation process can hardly cause or affect the differentiation of repetitive genes, it is more reasonable to assume that this process occurs continuously in the gene pool of each species. *Speciation* division of the originally uniform gene pool into two gene pools alone only makes this visible, i.e. permits the repetitive sequences in the two gene pools to develop in different directions.

At the present time, it is mostly assumed that a random process of differentiation of repetitive genes occurs continuously in the gene pool of organisms and thus that mutations are accumulated in the individual copies of the repetitive gene. However, the process of **homogenization** of the individual copies also occurs simultaneously, i.e. a process in which the variants of the *repetitive genes* that are most successful from the standpoint of replication, transposition or gene conversion proliferate in the genome at the expense of other variants. In sexually reproducing organisms, the process of *homogenization* exceeds the boundaries of a single genome and the most successful variant of the repetitive sequence gradually proliferates in the whole gene pool. This is certainly a long-term process; however, it is relatively rapid compared to other evolutionary processes. New variants of *repetitive sequences* become fixed in a substantially shorter time than the interval separating two subsequent *speciation events* so that, when studying even closely related species, we find that different variants of the *repetitive sequence* became fixed in each of them. This fact can be utilized in molecular taxonomy – study of repetitive genes enables discrimination amongst representatives of even very closely related species