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Allopatric, Sympatric and Stasipatric Modes of Speciation

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Abstract:**Species means kind and it is Latin word. Species is a basic unit and also considered as basic category of classification which has been defined in different manners under different concepts of species. Under biological species concept, a species is defined as a group of potentially or actually interbreeding natural populations which are reproductively isolated from other such groups. During the process of speciation, new species are created and the term speciation was coined by Cook in 1906. The basic processes of speciation are anagenesis and cladogenesis which are distinct ways by which new species are created. During anagenesis, one species is transformed into another in due course of time. So it is a phyletic change during the course of geological time and old species is transformed into a new species. Thus, one exists at a time. Cladogenesis (true speciation)- during this process of speciation there is origin of new species of organisms through splitting of the pre-existing species. Speciation (cladogenesis) is one of the main ways by which living organisms adapt in order to exploit the diversity of environments available to them. Theoretically, three main sets of variables are involved during the process of speciation: (i) Genetic variability generated by mutations and recombination in evolving population, (ii) origin of genetically based isolating mechanisms and (iii) geographic components ranging from complete (allopatry) to absent (sympatry). Based on these three variables, there are three different modes of speciation which lead to the creation of new species which are: Allopatric (ii) sympatric and (iii) stasipatric modes of speciation which are briefly described in this article with suitable examples.**

Index Terms:**Speciation, modes of speciation, sympatric, allopatric and stasipatric, examples.**

I. INTRODUCTION

Species means kind and it is Latin word. Species is a basic unit and also considered as basic category of binomial classification which has been defined in different manners under different concepts of species. Under biological species concept, a species is defined as a group of potentially or actually interbreeding natural populations which are reproductively isolated from other such groups. The term speciation was coined by Cook in 1906. Basically there are two main ways by which new species are created: anagenesis and cladogenesis. During anagenesis, one species is transformed into another species and thus it is a phylertic change during the course of geological time. In cladogenesis which is true speciation, a new species originates through the splitting of preexisting ones. Speciation (cladogenesis) is one of the main ways by which living organisms adapt in order to exploit the diversity of environments available to them. Speciation is ultimately an adaptive process that involves establishment of intrinsic barriers to gene flow between closely related populations by development of reproductive isolating mechanisms (Bush, 1975). To a considerable extent, a study of speciation is a study of genetics and evolution of reproductive isolating mechanisms. It has been remarked that reproductive isolating mechanisms are prerequisite for speciation (Singh, 2014). Sawamura (1999) has also remarked that based on biological species concept, the question how new species evolve should be substituted by a more answerable question how reproductive isolating mechanisms are established between populations". Speciation has also been discussed by Coyne and Orr (2004).

Theoretically, three main sets of variables are involved during the process of speciation: (i) genetic variability generated by mutations and recombination in evolving populations, (ii) origin of genetically based isolating mechanisms and (iii) geographic components ranging from complete (allopatry) to absent (sympatry). White (1978) has discussed different modes of speciation based on the above three factors. Among the different modes of speciation discussed by White (1978), three are basically important: allopatric, sympatric and stasipatric.. In this article, allopatric, sympatric and stasipatric modes of speciation are briefly described with suitable examples.

II. ALLOPATRIC MODE OF SPECIATION

When different species or populations occur in different geographical areas and are isolated by different factors such as mountains/oceans/forests are said to be allopatric species or

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populations. The allopatric mode of speciation is very important way of the origin of new species which has also been called as geographic speciation (White, 1978). Basically, allopatric or geographic speciation is based on geographic component and it has been considered as an important mode of speciation which is supported by a large number of examples (Mayr, 1966; White, 1978). This mode of speciation is divided into two types: Dichopatric or dumbbell model and peripatric speciation. There is difference between these two types of allopatric mode of speciation. In dichopatric, genetic drift, founder effect or population bottleneck do not play any role because one population is divided into two subpopulations by geographical barrier which are considerably large in size. In peripatric mode of allopatric speciation, genetic drift/founder effect/population bottleneck play an important role because the new population which is separated from the original population is of small size. In small population, the role of genetic drift is important (Figure 1).

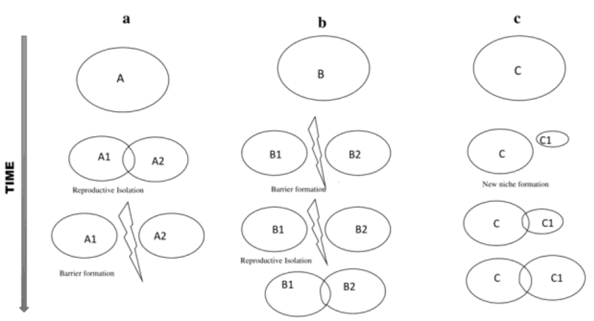

Figure 1.Schematic representation of (a) Sympatric, (b) Allopatric without a narrow population bottleneck and (c) Allopatric with a narrow population bottleneck (peripatric/founder effect) modes of speciation modified from Bush (1975) and Savage (1963). The geographical component and development and perfection of reproductive isolating mechanisms are important for the origin of species (Singh, 2021).

In dichopatric or dumbbell model, a population of a species splits into two subpopulations by geographical or ecological barriers and the subpopulations are of considerably large size characterized by absence of contact zone and gene flow. During the long course of time, both the subpopulations which are allopatric in distribution evolve independently and undergo the process of microevolutionary changes due to the action of mutation, recombination, natural selection, random genetic drift, migration etc. This leads to accumulation of microevolutionary changes during the course of evolutionary process. As they are geographically isolated, gene flow between them is completely prevented and they become genetically different in the course of time. Which leads to the development of genetically based reproductive isolating mechanisms and these two allopatric populations acquire the status of two independent species and are said to be two allopatric species. In case the geographical barrier between the allopatric species is removed, they become two sympatric species but they do not interbreed because they had already developed reproductive isolating mechanisms which allow them to remain two independent species maintaining their own gene pools due to prevention of interbreeding. Interestingly, two allopatric species originating through dichopatric (dumbbell) mode of speciation become sympatric species because of developing zone of contact resulting from removal of geographic barrier. There is an interesting example of this dichopatric mode of speciation (allopatric) reported in Hawaiian species of *Drosophila*. White (1978) has mentioned an example in which the population of Hawaiian species of Drosophila existing at low elevation had been split into two becoming separate species by the separation of two islands Molokai from Maui due to rise in sea level. The clear cut cases of geographic or allopatric speciation has occurred on archipelagos. An interesting example of allopatric speciation is given from archipelago i.e. evolution of Darwin's finches on Galapagos Islands situated about 500 miles west of the coast of South America. Geospizidae has several species which are found on these islands and their evolution on these islands has been explained by allopatric mode of speciation. Currently 13 species of this family are recognized which are found on these islands. Only one species is confined to single island. Genus Geospiza (ground finches) has six species. Species of the geospizid finches differed from island to island (Moorehead, 1969). There are a number of endemic subspecies which are distinguished by beak size and shape and by colouration which are confined to single islands. Certhidea olivacea, the only species of its genus, is present on all 16 islands and has eight subspecies, five of which are localized to single islands. However, the widespread species Geospiza fortis found on twelve islands and C. fuliginosa found on 13 islands do not seem to be differentiated into subspecies. Interestingly, all Geospizidae except Certhidea have a considerable similarity in the patterns of allozymes and karyotypes (White, 1978). These species and subspecies occupy varied ecological niches and have diverse diets on different islands extending evidence for allopatric mode of speciation. In Figure 1, different types of modes of speciation are depicted.

In allopatric mode of speciation, there is another kind of speciation which is known as peripatric mode of speciation which is characterized by narrow population bottleneck. During this process, a small number of individuals (in extreme cases a single gravid female) migrate from the parental population to a new area and evolve into a new species in the long course of time. Due to the effects of population bottleneck/founder effect/random genetic drift / flush crash cycles it becomes genetically different from the original population. It has been argued that rate of evolution is faster in these populations because of the action of random genetic drift leading to genetic differences. Thus, peripatric mode of speciation differs from dichopatric mode of speciation although both come under allopatric mode of speciation (geographic speciation). Carson (1971) has explained speciation in the Hawaiian species of *Drosophila* on the basis of peripatric mode of speciation which involves random genetic drift/founder principle/population bottle neck/flush-crash cycles in the populations. In laboratory populations of Drosophila, the effects of founder principle on the origin of sexual isolation has been demonstrated (Nanda & Singh, 2011) which extends evidence for peripatric mode of speciation.

III. Sympatric mode of speciation

Sympatric mode of speciation has been explained by Bush (1975) and White (1978). In this mode of speciation, a new species originates from the segment of original population as a result of instantaneous origin of reproductive isolation. The most important aspect is instantaneous origin of reproductive isolation which leads to the creation of new species in the same geographical area. Since both old and new species remain in the same geographical area and maintain their integrity due reproductive isolation which prevents gene flow between them, they are called as sympatric species. Thus reproductive isolation becomes prerequisite for speciation. In due course of time when these two sympatric species move to other areas they become allopatric species. So the most important factor is the instantaneous origin of certain kinds of reproductive isolating mechanisms within the same geographical area between original and new population. It is depicted in Figure 1. There are very good examples of sympatric speciation in host specific plant feeders and host specific parasites, Bush (1975) studied speciation in fruit flies of the family Tephritidae occurring in USA and reported that hawthorn race gave rise to apple race sympatrically which belongs to Rhagoletis pomonella. This is a very good example of sympatric mode of speciation because one race has given rise to another race sympatrically which are reproductively isolated by allochronic isolation (breeding time is different). Polyploidy which results from the change in the number of chromosomes (whole sets of chromosomes are involved) also play role in speciation which is basically chromosomal model of instantaneous speciation which also comes under sympatric mode of speciation and it is more common in plants than animals. A number of plant species have originated as a result of change in the number of chromosomes caused due to polyploidy. An interesting example is given here which demonstrates that how a new species was created by making hybridization between two species and then doubling of chromosomes in hybrids caused the production of fertile hybrids resulting in the origin of new species with different chromosome number. Karpechenko (1927) has shown that a new species Raphanobrassica which was tetraploid has arisen by union of two unreduced diploid gametes derived from a sterile diploid hybrid between Raphanus sativum (radish) and Brassica oleracea ((cabbage). The new species was having four sets of chromosomes (tetraploid) : two sets of radish and two sets of cabbage. But it was not useful because it had roots like cabbage and leaves like radish.

IV. Stasipatric mode of speciation

It is also basically chromosomal model of speciation when clearly allopatric mode is not reasonable. It has been explained in detail by White (1978) with suitable examples. In certain animals, where vagility is low and there is similarity in karyotypic constitutions, the stasipatric model is suggested. A new species is generated within the geographical range of a widespread species and the daughter species is characterized by new chromosomal rearrangements which play an important role in speciation by reducing the adaptive fitness (fecundity or viability) of the heterozygous individuals. The new species may extend its range at the expense of parental species maintaining a narrow parapatric zone of contact in the peripheral area of their distribution in which hybridization leads to the production of such individuals which have lowered Darwinian fitness. The suitable examples supporting this stasipatric mode of speciation are provided by White (1978). He has given an interesting example of Australian morabine grasshoppers of the genus Vandiemenella having seven species which differ in their karyotypic constitutions. These insects are wingless with low vagility which feed on shrubs of the family Compositae. V. viatica has been considered as ancestral species There is occurrence of duplication, deletions, fusions, translocations and pericentric inversions There is variation in chromosome constitutions such as 17 chromosomes, 19 chromosomes, XO, XY, and translocation. There is another example i.e. Australian stick insects occurring from Brisbane to Adeleide having ten cytological races which have primarily parapatric distribution with overlapping zones. In these cases, chromosomal fusions have also been reported which leads to the change in karyotypic constitution. A metacentric V shaped chromosome in one species may be represented by two acrocentric rod shaped chromosomes in the other. Thus, different species may differ in their karyotypic constitution.

V. Concluding Remarks

Speciation is most important aspect of evolution. Dobzhansky remarked that “Nothing in biology makes a sense except in the light of evolution”. On the other hand, Mayr is of the opinion that speciation is a key problem of evolution and it is remarkable how many problems of evolution cannot be completely understood until speciation is understood. It has also been remarked that reproductive isolating mechanisms are prerequisite for the process of speciation. It is also emphasized that under biological species concept the question should be asked how reproductive isolating mechanisms are established instead of asking how new species evolve. Thus the role of reproductive isolating mechanisms are important for the creation of new species. There are different modes of speciation based on generation of genetic variability, origin and establishment of reproductive isolating mechanisms and the geographical factors. Considering all the different modes of speciation, the allopatric mode which is also known as geographic isolation is considered as the most important mode of speciation (Mayr, 1966).

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