SPECIATION

Speciation : Multiplication of Species in Space

Speciation simply means formation of new species. The term is applied to the process in which one species divides into two or more reproductively isolated lineages. Speciation requires some form of reproductive isolation which may be either pre zygotic or post zygotic. Evolutionary theory suggests that once two populations or taxa are reproductively isolated then they should start to diverge genetically.

Patterns of Speciation

By examining the fossil record, evolutionary biologists have found two different patterns of speciation – **anagenesis** and **cladogenesis**.

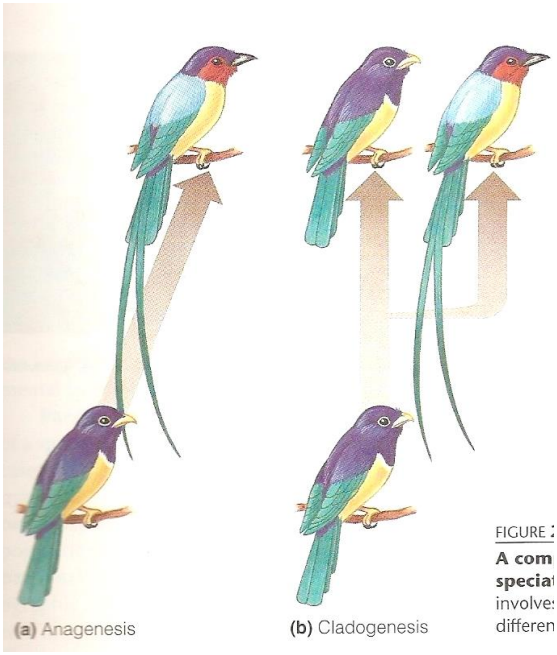


Fig 1. Showing the two common modes of speciation

1. **Anagenesis** (Greek, 'ana' meaning 'up' and 'genesis' meaning 'origin')**:**

- When a single species is transformed into a different species over the course of many generations, is **called anagenesis**.

- During this process, the characteristics of the species change due to both neutral evolutionary forces and adaptive forces promoted by natural selection.

- As a result of natural selection, the new species may be better adapted to survive in its original environment, or the environment may have changed so that the new species is better adapted to the new surroundings.

2. **Cladogenesis** (Greek, 'clados' meaning 'branch' and 'genesis' meaning 'origin'):

- When a single species is divided into two or more species over the course of many generations, is **called cladogenesis**. This is the most common from of speciation.
- Although cladogenesis is usually thought of as a branching process, it commonly occurs as a budding process in which a single species divides into the original species plus a new species with different characteristics that prevent it from interbreeding with the original one.

Basis of Speciation (How do new species evolved?)

A new species arises when members of a population are isolated from other members so long that changes in their genetic makeup prevent them from producing fertile offspring if they get together again. Speciation requires some form of reproductive isolation which may be pre zygotic or post zygotic. Chromosomal rearrangement may be the first step in speciation. For e.g., four species of Drosophila (*D. melanogaster, D. ananassae, D. pseudoobscura and D. willistoni*) have apparently evolved from a common type (*D. subscura*) through chromosome fusions and a major inversion.

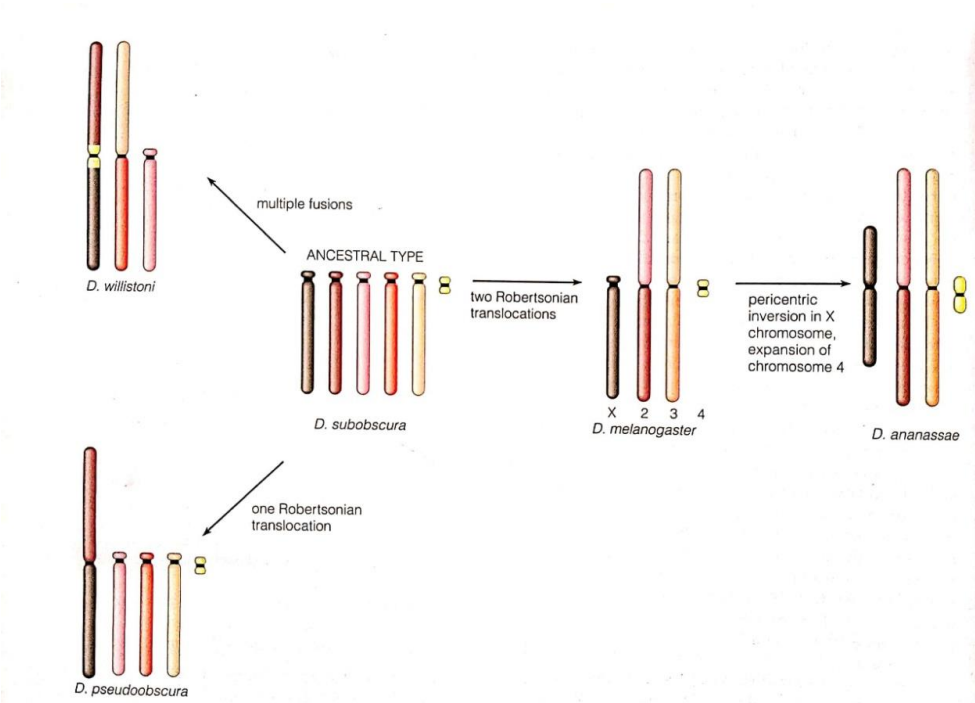
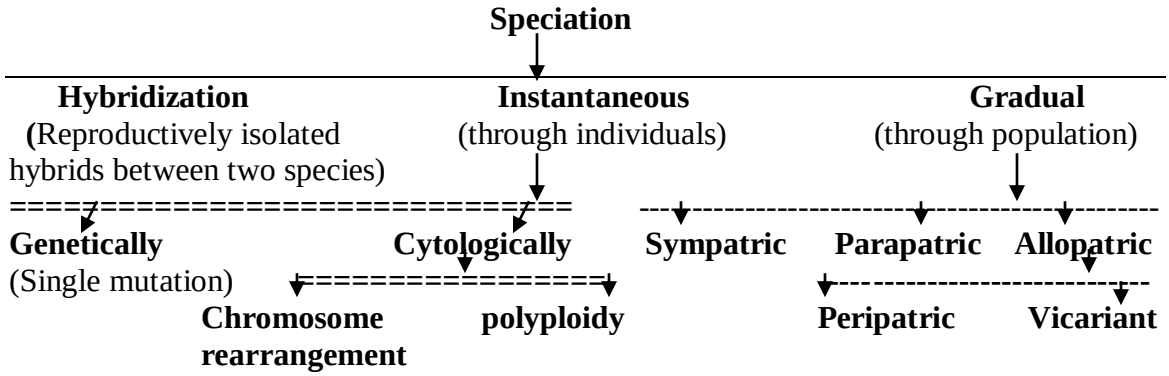


Fig 2. Possible pattern of speciation from ancestral stock of Drosophila subobscura due to chromosomal rearrangement.

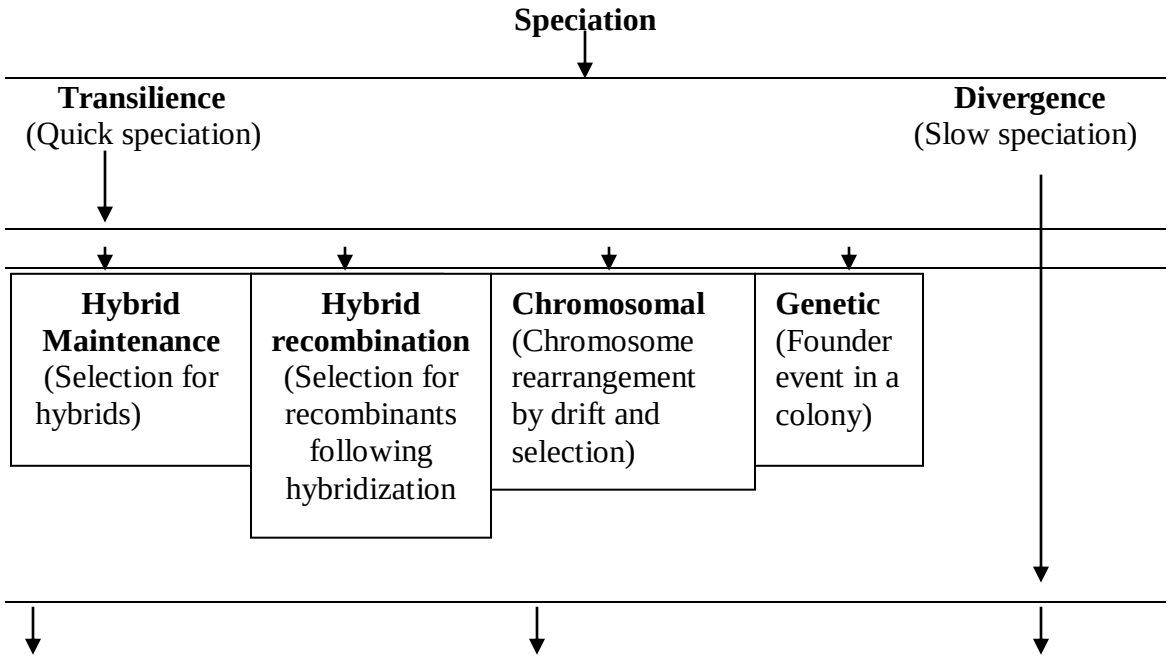
a. Genetic differentiation between species.
b. Genetic processes and adaptation.
c. Accumulation of major gene and quantitative trait loci (QTLs) differences.
d. Ecological differences / shifts.

Modes of Speciation in Sexual Organisms

A. After Myer (1963):



B. After Templeton (1982):



Habitat
(Divergent selection without isolation by distance)

Clinal
(selection on a cline with isolation by distance)

Adaptive
(erection of an extrinsic barriers followed by diver-gent microevolution)

Remark:

Different authors presented different potential modes of speciation. The divergence of one species into two or more discrete species is the most common form of speciation. Myer (1973) classified into two broad classes – instantaneous speciation and gradual speciation.

I. **Instantaneous speciation**: It is an an individual phenomenon.
II. **Gradual speciation**: It is a populational phenomenon.
   A. Allopatric – a). Vacariant, b). Peripatric
   B. Parapatric
   C. Sympatric.

Instantaneous speciation	Gradual speciation
It is an individual phenomenon.	It is a populational phenomenon
It is a rare or as an exceptional phenomenon.	It is a true speciation.
It occurs through simple gene mutation or major chromosomal mutation.	It occurs through gradual divergence of populations until they have reached the level of specific distinctness.
It is production of one individual that is reproductively isolated from parent species.	It is the production of new population by reproductive isolation.

- **Depending on the geographic locations of the evolving population(s), gradual speciation is categorized as allopatric, parapatric and sympatric.**

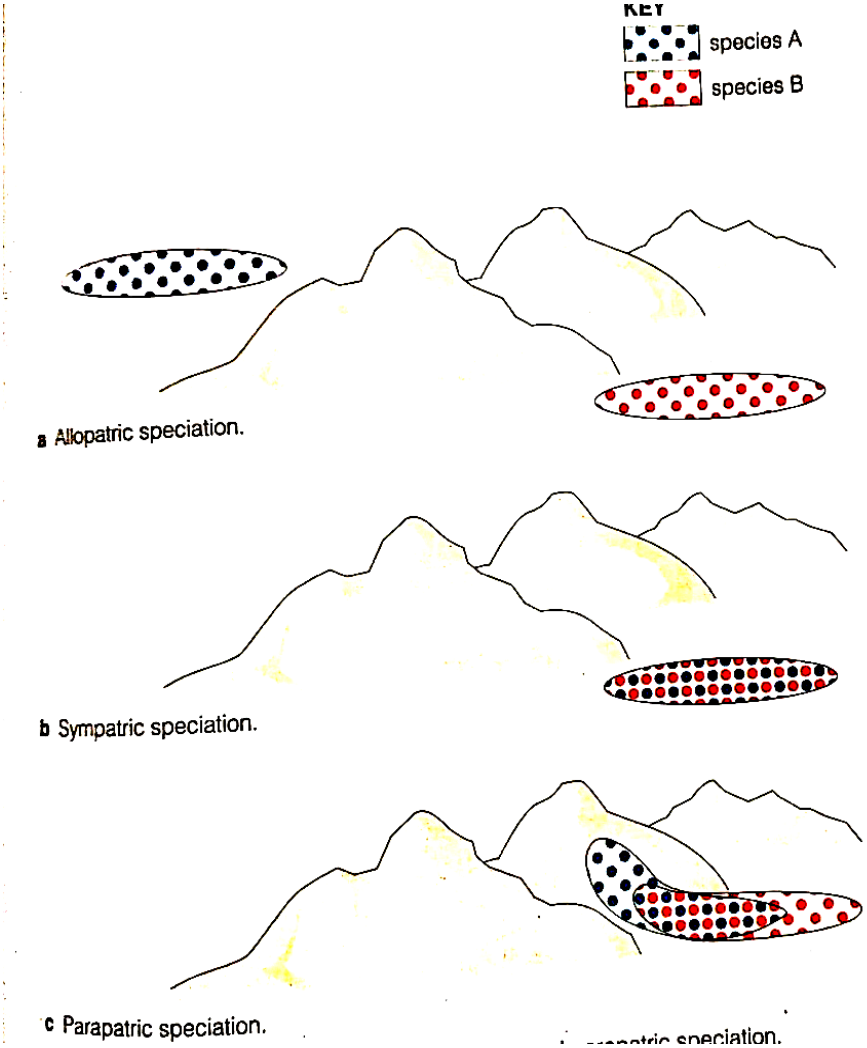


Fig 3. Showing the comparison of allopatric, sympatric and parapatric speciation.

1. **<u>Allopatric Speciation</u>** (Greek, '*allos*', "other", and Latin '*patria*', "homeland"):

   - When members of a species become geographically separated from the other members by an extrinsic barriers, physical barriers (such as topography, water or land) or unfavorable habitat, it results in the formation of separate species due to reproductive isolation and the process is **called allopatric speciation**.

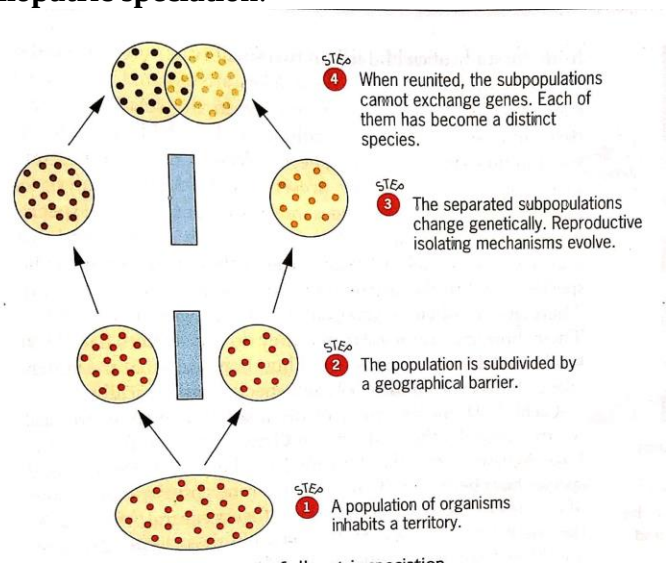
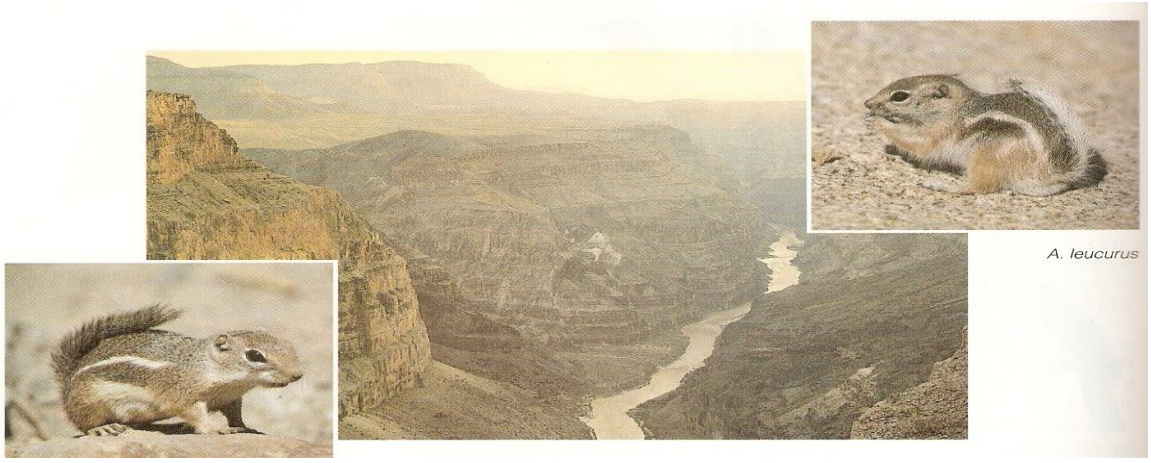


Fig 4. The process of allopatric speciation

   - It occurs in two phases: **<u>geographic isolation</u>** and **<u>reproductive isolation</u>**.
   - <u>Geographic isolation</u> occurs when different groups of the same population become physically isolated from one another for long periods by the **<u>by geological processes</u>** **(**such as a extrinsic. Physical barrier such as topography, water or land or mountain range, stream, lake or road, volcanic eruption or earthquake). For example, a mountain range may emerge and split a species that occupies the low land regions. Similarly a creeping glacier may divide a population.

     Two species of antelope squirrels occupy opposite rims of the Grand Canyon. On the south rim is Harris's antelope squirrel (*Ammospermophilus harrisi*), while a closely related white tailed antelope squirrel (*Ammospermophilus leucurus*) is found on the north rim. Presumbly, these two species evolved from a common species that existed before the canyon was formed. Overtime, the accumulation of genetic changes in the two populations led to the formation of two morphologically distinct species. Interestingly, birds that can easily fly across the canyon have not diverged into different species on the opposite rims.



A. harrisi

Fig 5. An example of allopatric speciation of two closely related species of antelope squirrel that occupy opposite rims of the Grand Canyon

- While the second phase of allopatric speciation is reproductive isolation occurs when mutation and natural selection operate independently in the gene pools of two geographically isolated populations. If this divergence process continues long enough, members of isolated populations of a sexually reproducing species may become so different in genetic makeup that when they get together again, they cannot produce live, fertile offspring. Then one species has become two.

- Allopatric speciation can occur **via founder effect** , which is thought to be more rapid and frequent than allopatric speciation caused by geological events. For eg., a storm may force a small group of birds from the mainland to a distant island. In this case, migration between the island and mainland populations is a very infrequent event. In a reality short period of time, the founding population on the island may evolve into a new species. First, genetic drift may quickly lead to random fixation of certain alleles and elimination of the other alleles from the population. Another factor is natural selection. The environment on an island may differ significantly from the mainland environment.

- **Kinds of allopatric speciation:**

1. **Vacariant Speciation:**

   - ✓ It occurs when two rather widespread populations are divided either by emergence of an extrinsic barrier, or the extinction of intervening populations, or migration into a separate region.
   - ✓ One such example is the emergence of the Isthmus of Panama during the Pliocene. It divided many marine organisms into

Pacific and Caribbean populations, some of which have diverged into distinct species (Knowlton *et al.*, 1993).

- ✓ Vacariant speciation is supposed to occur by the operation of natural selection and perhaps by genetic drift, in both the populations separately and perhaps, to a greater extent in one than the other.

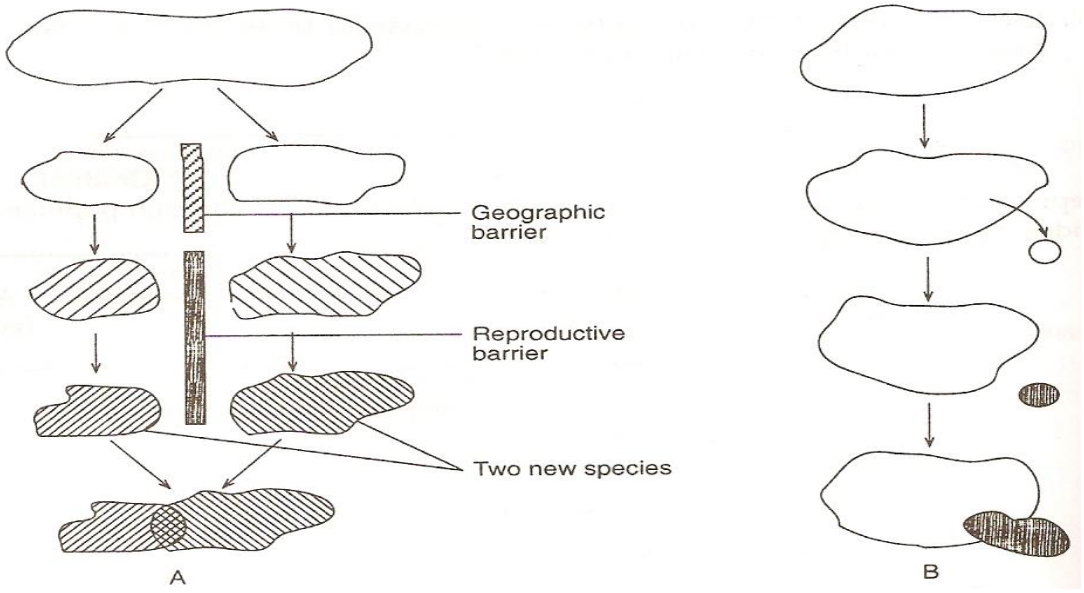


Fig 6. Diagram showing the successive stages in two kinds of allopatric speciation: A. Vacariant speciation & B. Peripatric speciation

2. Peripatric Speciation:

- ✓ It occurs when a colony that is derived from a much widespread parent population diverges and acquires reproductive isolation. Sometimes it is called founder-effect speciation.
- ✓ According to Myer (1954, 63), Templeton (1980) and others, this process is thought to as speciation due to a shift, initiated by genetic drift and followed by natural selection between adaptive peaks.
- ✓ It has been seen in many birds and animals that isolated populations with restricted distributions often are highly divergent, even though ecological environment appears similar to that of the parent.
- ✓ An example of founder-effect speciation is the robin, *Petrocia multicolour*. The bright plumage of the male is quite contrasting with the duller plumage of the female throughout eastern Australia. But among the various Melanesian islands present nearby, the male robins have ‘female’ coloration on some, while the females have ‘male’ coloration on others.

2. **Parapatric Speciation:** (Greek *'para'*, "beside"and Latin *'patria'*, "homeland")

- Parapatric speciation occurs when members of a species are separated only partially or when a species is very sedentary. In these cases, the geographic separation is not complete. Populations may be isolated at the extremes of the range but overlap and interbreed in intermediate areas of it.
- Prior to parapatric speciation, the zones where two populations can interbreed are known as **hybrid zones**. For speciation to occur, the amount of gene flow within the hybrid zones must become very limited and result in reproductive isolation.
- For example, a mountain range may divide a species into two populations, but with breaks in the range where two groups are connected physically. In these zones of contact, the members of two populations can interbreed, although this tends to occur infrequently.
- Likewise, parapatric speciation may occur among very sedentary species even though no geographic isolation exists. Certain organisms are so sedentary that 100 to 1000 meters may be sufficient to limit the interbreeding between neighboring groups.
- Parapetric speciation is exemplified by the old world mole rat, *Spalox ehrenbergi* which have 04 chromosomal subspecies in and around Israel. Plants, terrestrial snails, rodents, grasshoppers, lizards, and many flightless insects may speciate in a parapatric manner.

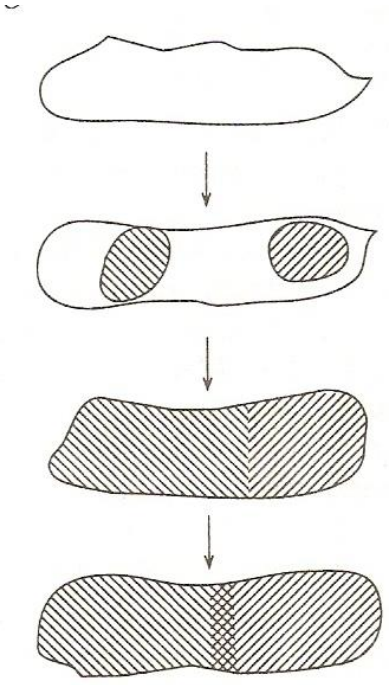
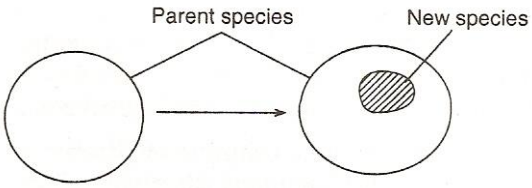


Fig 7. Showing successive stages on parapatric speciation

3. **Sympatric Speciation:** (Greek *'sym'*, "together" and Latin *'patria'*, "homeland")

Sympatric speciation occurs when members of a species living close together in same habitat within the same range are unable to interbreed because of a mutation or subtle behavioral changes. It is the evolution of reproductive isolation within a randomly mating population and two populations inhabit the same place. Diversifying selection can lead in sympatric speciation. Sympatric speciation in which genetic differences develop gradually resulting in reproductive isolation within members of an initially randomly mating population.



Process:

It is based on two successive events – (i) establishment of new populations of a species in different ecological niches but within the normal reaching range of parental population and (ii) establishment of reproductive isolation between the individuals of new population from those of parental population. Ecological factors are primary and geographical isolation is the secondary cause for such speciation. The process can be summarized as follows-

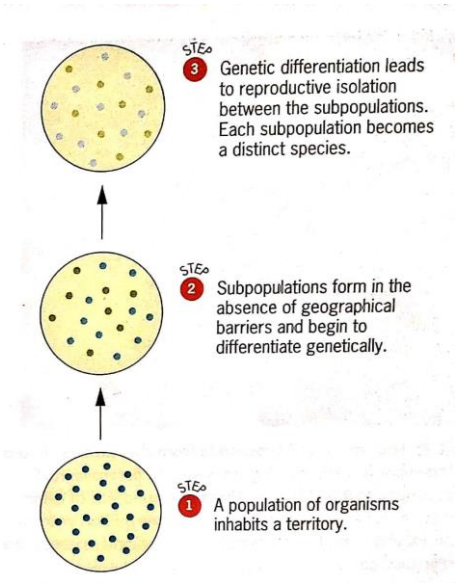
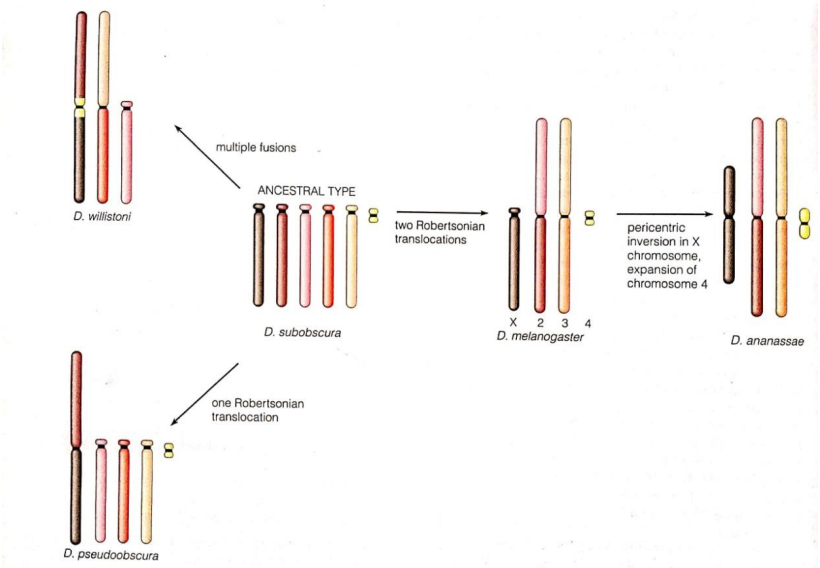


Fig 8. ***The process of sympatric speciation***

Example:

1. The apple maggot fly, *Rhagoletis pomonela*, shows genetic differences due to habitat isolation and is undergoing the process of sympatric speciation.

2. Development of *Drosophila melanogaster, D. pseudoobscura, D. persimilis and D. williostoni* from ancestral *Drosophila virilis* due to chromosomal rearrangement and translocation



Distinction Between Allopatric, Sympatric & Parapatric Speciation

Allopatric Speciation	Sympatric Speciation	Parapatric speciation
1. It is the **most common form** of speciation.	1. It is a **less common form** of speciation.	1. It is a **rapid form** of speciation.
2. Geographic isolation is **must and essential** requirements for such speciation.	**2. No** need of **geographic isolation**.	2. Incomplete geographic isolation.
3. Most frequently found in **animal population.**	3. Most frequently found in **plant population**.	3. Most commonly found in old world mole rat.
4. Geographic isolation can lead to reproductive isolation, divergence and **allopatric speciation.**	**4. Mutation, disruptive selection or subtle behavioral changes can lead to** reproductive isolation and **sympatric speciation.**	4. Parapatric speciation occurs when members of a species are separated only partially or when a species is very sedentary.
5. Complete reproductive isolation occurs.	**5. Complete reproductive isolation occurs.**	5. **Partial reproductive isolation occurs.**
5. Allopatric species occupy areas separated by time or space, so they do not come into physical contact with each other and **have no opportunity to interbreed.**	5. Sympatric species occupy the same area at the same time, so **they have an opportunity to interbreed.**	5. In these cases, populations may be isolated at the extremes of the range but overlap and **interbreed in intermediate areas of it.**