EVOLUTION

SPECIATION

Dr. Sithara K Urumbil
Assistant Professor in Botany
Little flower College, Guruvayur

Species Concept

- Species is a group of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups

General characteristics of species

- Species is a genetic unit consisting of a large gene pool shared by its members
- A species comprises genetically similar individuals which share a close common ancestry.
- The members of a species exhibit distinctive common features which are different from those of other species
- Each species is reproductively isolated from other species so that transient, intermediate, or intergrading forms are usually absent in between two species.
- Members of a species interbreed and produce fertile offspring

- Normally, members of different species do not interbreed and so natural inter specific hybrids are altogether absent or are very rare
- Each species interacts with its abiotic and biotic environments
- A species occupies a specific ecological niche which may not be occupied or utilized by another. So two species can never have the same niche
- Related species usually occupy separate but adjoining or nearby territories
- Every species evolve from a pre-existing ancestral species by acquiring heritable adaptive variations

1. Typological Species Concept:

- According to this concept, there are a number of diversities on the surface of the earth that exist as a limited number of universals or types. These types do not bear any relationship to each other. The universals or types are called species. Variation is considered as trifling and irrelevant phenomenon.
- This concept, was in the philosophies of Plato and Aristotle and was the species concept of Linnaeus and his followers.
- Species are static, immutable and ideal and the members of each species are only copies or representations of an ideal type.

2. Nominalistic Species Concept:

- According to this concept, only individuals exist but do not believe in the existence of species.
- Species are man's own creations and have no actual existence in nature. They are mental concept and nothing more. Therefore, such mental concept (i.e., species) of man has no value. This concept was popular in France in 18th century and still now is used among some botanists.

3.Morphological and taxonomic species concept

- According to it, species is a population, or a group of populations, morphologically different from other populations. Thus species are distinguished from each other on the basis of observed similarities and differences

4. Biological Species Concept:

- According to this concept, "**a species is a group of interbreeding natural population that is reproductively isolated from other such groups**".
- In biological species concept a species has three following properties.

A reproductive community

An ecological unit

Genetic unit

- Species forms a genetic unit in that it consists of a closed and protected gene pool which is prevented from genetic exchange with other species

Shortcomings of biological species concept

- Biological species concept holds good only for sexually reproducing organisms
- It does not take in to account the evolutionary history of sexuality starting from primitive ancestors of the distant past through a continuous evolutionary chain of a series of intermediate ancestors. Biological species concept does not consider this evolutionary continuity

- (i) Lack of information:
- Due to lack of proper information systematists face some problems when applied to some cases.
- (a) The morphological differences are observed due to sexual dimorphism, age differences and genetical polymorphism and individual variation can be unmasked through the study of life history and through the population analysis. The taxonomists mostly work on preserved museum specimens. So reproductive isolation is not verified in the preserved specimens. Again biological species concept is not applicable in fossil specimens.
- (b) The closely related two populations live in a continuous area but show preferences for different habitats. In this case, two populations fail to interbreed due to living in different habitats. So it is difficult to apply the biological species concept on these populations because these populations are either distinct species or failure of interbreeding due to living in different habitat.

5.Reproductive species concept

- The individuals of a species seek each other as potential mates for the purpose of reproduction and the members form a reproductive community.
- This is the concept that two organisms that are able to interbreed naturally and produce fertile offspring belong to the species. On the other hand, organisms that can interbreed, but almost always produce infertile hybrids, do not belong to the same species

6.Mate-recognition species concept

- A species, according to this concept, is a group of organisms that are known to recognise one another as potential mates. Just as the biological species concept, this also applies to sexually reproducing organisms

7. Ecological Species concept

- The members of a species differ each other for many features but all members together form a unit, interact as a unit with other species in any environment.
- Ecological species is a set of organisms similarly adapted to a particular set of environmental resources called niche.

8.Genetic species concept

- Species are recognised based on similarity of the DNA of individuals or populations.

9. Evolutionary Species Concept

- Not all taxonomists specially palaeontologists are not satisfied with the biological species concept. They preferred a definition of species which are related to the evolution.
- Simpson (1961) has proposed a definition with many modifications that is "**an evolutionary species is a lineage (an ancestral- descendant sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies**".

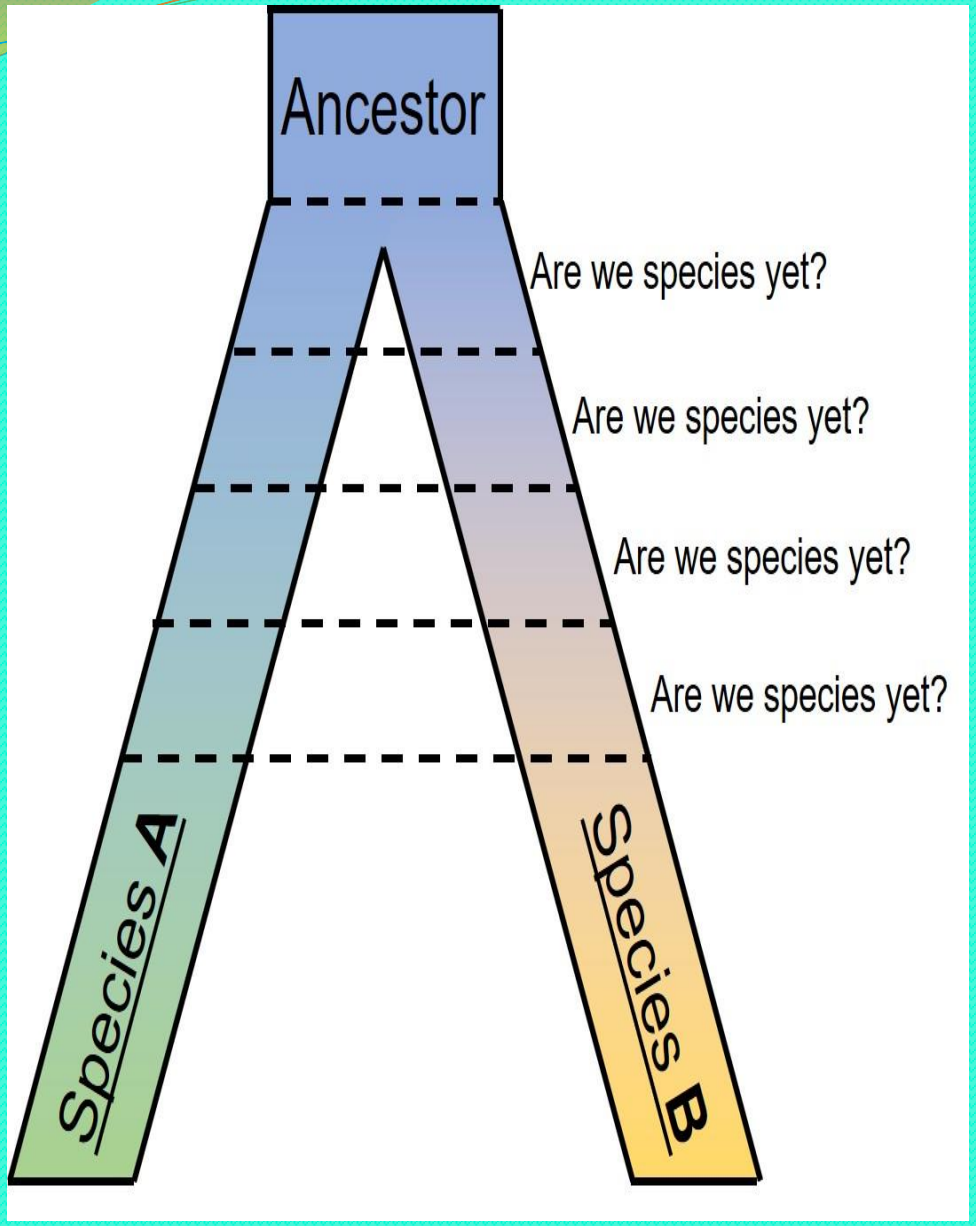
- **(vi) Monotypic species:**
- When a genus includes a single species but does not include any subspecies, e.g., Vampyroteuthis, a vampire squid which is a single monotypic genus and also contains a single species, V. infernalis (monotypic species).
- **(vii) Polytypic species:**
- When a species contains two or more subspecies, it is called polytypic species. Examples are tiger, Panthera tigris which has several subspecies; such as—(i) Indian tiger, Panthera tigris tigris, (ii) the Chinese tiger, P. t. amoyensis, (iii) the Siberian tiger, P. t. altaica, (iv) the Javan tiger, P. t. sondaica, etc.

Types of Species:

- **Various types of species are recognised, of which the followings are:**
- **(i) Allopatric species (Gk. allos = other, patris = native land):**
- The two or more related species that have disjunct geographical ranges are called allopatric species. Examples of such species are Indian lion (Panthera leo persica) and African lion (Panthera leo leo).
- **(ii) Sympatric species (Gk. syn = with, together):**
- Two or more species are said to be sympatric when their geographical distributions overlap, though they may segregate into different ecological niche. Examples of this type are the fig-frog (Rana grylio) and the gopher frog (R. areolata). The former is extremely aquatic, while the latter species is restricted to the margins of swampy areas.
- **(iii) Parapatric species:**
- These are the species which have the geographical ranges with a very narrow region of overlap. Example of this type is the flightless Australian grasshoppers, Moraba scurra and M. viatica.

Speciation

- **Speciation**, the formation of new and distinct species in the course of evolution. Speciation involves the splitting of a single evolutionary lineage into two or more genetically independent lineages.
- Speciation is the process of formation of a new genetically independent group of organisms, called species, through the course of evolution.
- The process of splitting of genetically homogenous population into two or more populations that undergo genetic differentiation and eventual reproductive isolation is called speciation.



- The entire course of evolution depends upon the origin of new populations (species) that have greater adaptive efficiency than their ancestors.
- Speciation occurs in two ways.
- Transformation of old species into new species over time.
- Splitting of a single species into several, that is the multiplication of species.

Speciation Causes

- Speciation occurs as a result of several factors which are:
- **Natural selection**
- As explained by Charles Darwin, different individuals in a species might develop specific distinct characteristics which are advantageous and affect the genetic makeup of the individual.
- Under such conditions, these characteristics will be conserved, and over time, new species might be formed.
- However, in this case, the essential aspect of this factor is that speciation occurs only when a single species splits into several species resulting in the multiplication of species.

- **Genetic drift**
- Genetic drift is the change in the allele frequencies in a population as a result of “sampling error” while selecting the alleles for the next generation from the gene pool of the current population.
- It has been, however, argued that genetic drift doesn’t result in speciation and just results in evolution, that is, change from one species to another, which cannot be considered speciation.

- **Migration**
- When a certain number of species from a population migrate from one geographical region to another, the species might accumulate characteristics which are different from that of the original population.
- Migration usually results in geographical isolation and ultimately leads to speciation.

- **Chromosomal Mutations**
- Chromosomal mutations have the potential to serve as (or contribute to) isolating mechanisms, and the locking up and protection of a particularly favorable gene complement through a chromosomal mutation.
- These mutations, when preserved from one generation to another, might result in the formation of new species.

- **Natural causes**
- Sometimes, natural events imposed by the environment like a river or a mountain range might cause the separation of what once a continuous population is divided into two or smaller populations.
- These events result in geographical isolation of the incipient species followed by reproductive isolation leading to speciation.

- **Reduction of gene flow**
- Speciation might also occur in the absence of some extrinsic physical barriers.
- There might be a reduced gene flow over a broad geographical range where individuals in the far east would have zero chance of mating with individuals in the far western end of the range.
- In addition, if there are some selective mechanisms like genetic drift at the opposite ends of the range, the gene frequencies would be altered, and speciation would be ensured.

Speciation process (how does speciation occur?)

- The process of speciation begins with the isolation of subpopulation of a species which could either occur through physical isolation (allotropic speciation) or genetic isolation (sympatric speciation).
- Once the population is separated, a gradual accumulation of small genetic changes results in a subpopulation of a species that eventually accumulate so many changes that the subpopulations become different species.

- Over time, the subpopulation now becomes genetically independent and will continue to diverge by mutation, selection, and genetic drift.
- The genetic differentiation might cause a slight change in the mating dance or even a small change in the shape of the male genitalia or some changes in the habitat or feeding habits of the subpopulation, which results in reproductive isolation.
- Eventually, the genetic differentiation between the subpopulation becomes so high that the formation of hybrids between them would be physiologically, developmentally, or behaviourally impossible even if the modes of the separation were abolished.

Types of speciation

- The classification of the modes or types of speciation is based on how much the geographical separation of the original population contributes to the reduced gene flow and ultimately, the formation of new species.
- The types of speciation are:
- Phyletic speciation
- Quantum speciation
- Gradual speciation

Phyletic speciation

- **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. ·

Moeritherium

Quantum speciation

- This involves sudden formation of a new species by rapid changes or **saltation,** caused by megamutation 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.

Gradual speciation

- Gradual accumulation of many minute genetic variations over a long period of time under the influence of natural selection leads to gradual speciation
- Interruption of gene flow between populations due to reproductive isolation
- Genetic diversity in populations
- Operation of selection and genetic drift on populations

Methods of speciation

- **Allopatric Speciation**
- **Sympatric Speciation**
- **Peripatric speciation**
- **Parapatric speciation**

Allopatric Speciation

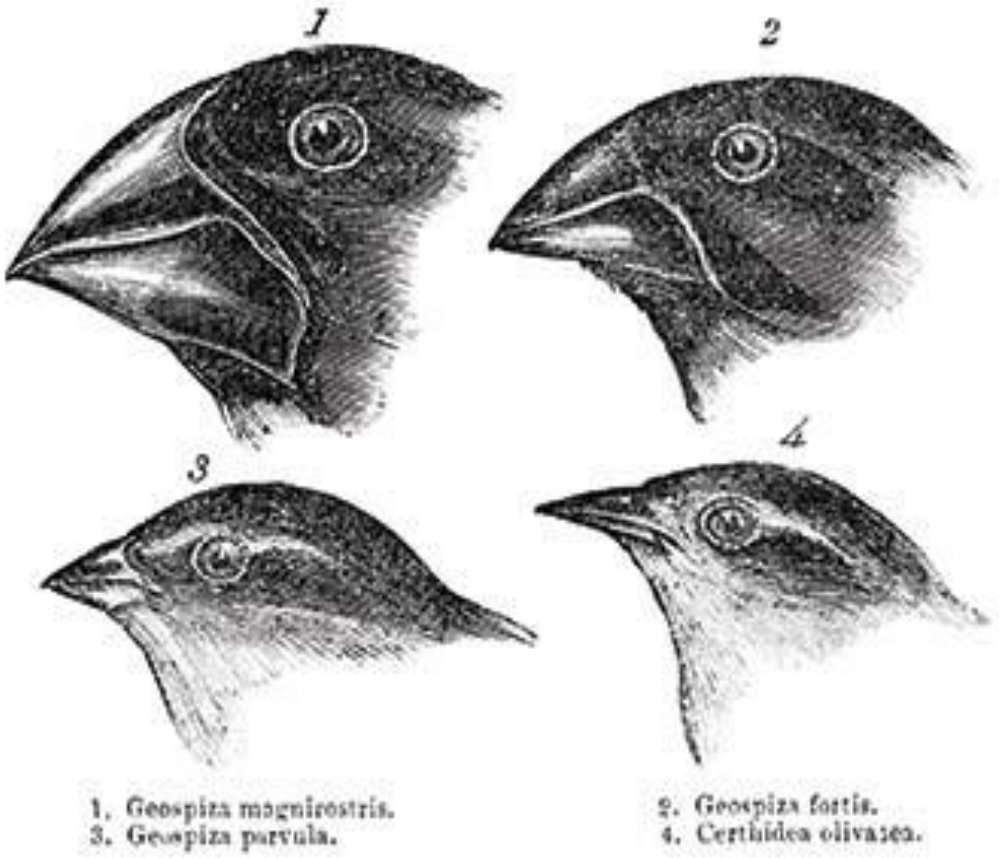
- Allopatric speciation is the mode of speciation in which the original population is divided into two by a barrier resulting in reproductive isolation.
- It is based on the concept that new species arise when some physical geographic barrier divides the large population of a species into two or more small populations.
- The individuals of these isolated populations cannot interbreed because of their physical isolation.

- Physical isolation might occur either due to physical barriers like vast expanses of ocean, high mountains, glaciers, deep river valleys, wide rivers or deserts, or a considerable distance due to a larger geographical range.
- Each isolated population starts to adapt to their separated environments while accumulating differences and evolving independently into new species.
- Allopatric speciation can occur even in cases in which the barrier allows some individuals to cross the barrier to mate with the members of the other groups.
- For speciation even to be considered “allopatric,” gene flow between the soon-to-be species must be significantly reduced—but it doesn’t have to be entirely reduced to zero.

- **Examples of Allopatric speciation**
- The classic example of allopatric speciation is that of Darwin's finches. The divergent populations of finches inhabiting the Galapagos Islands were observed to have differences in features such as body size, colour, and beak length or shape.

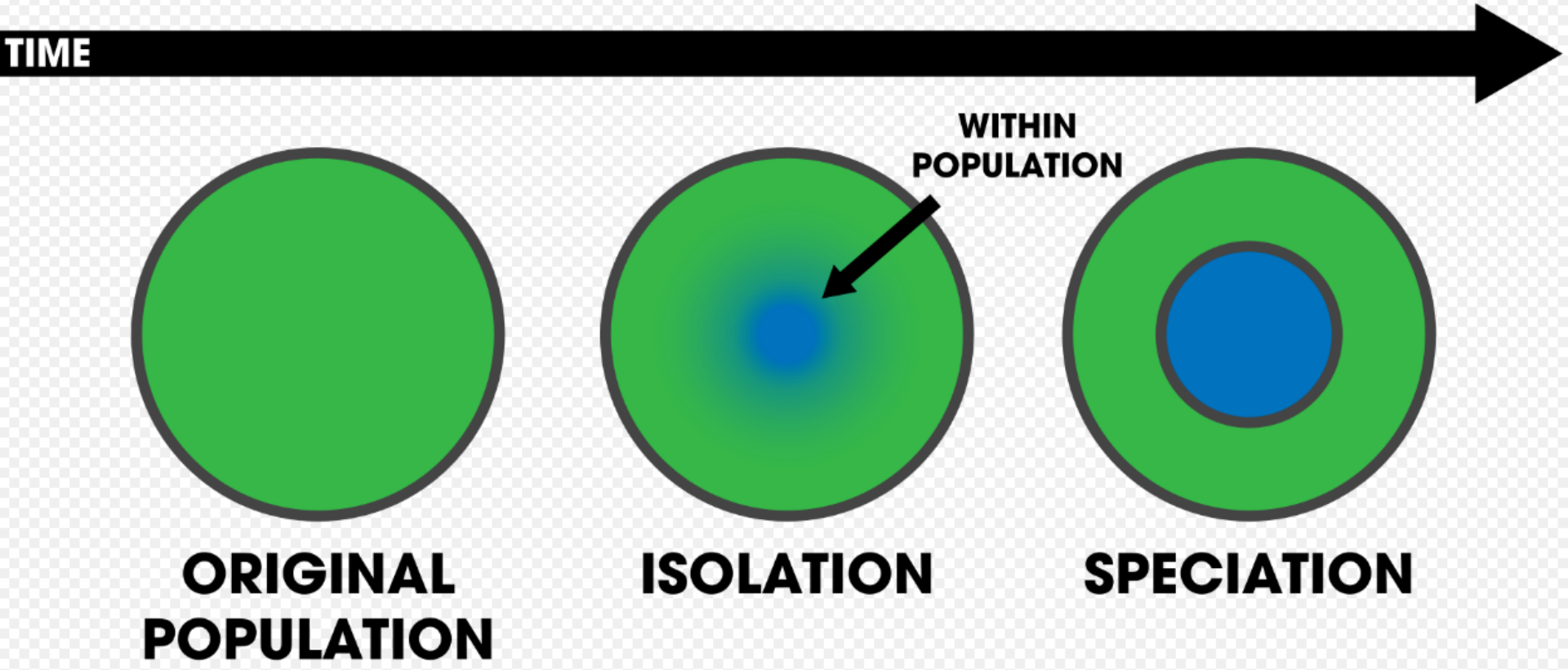
Speciation

definition, causes, process, types, examples



Sympatric Speciation

- Sympatric speciation is the process of the formation of new species from an original population that are not geographically isolated.
- It is based on the establishment of new populations of a species in different ecological niches and the reproductive isolation of founders of the new population from the individuals of the source population.



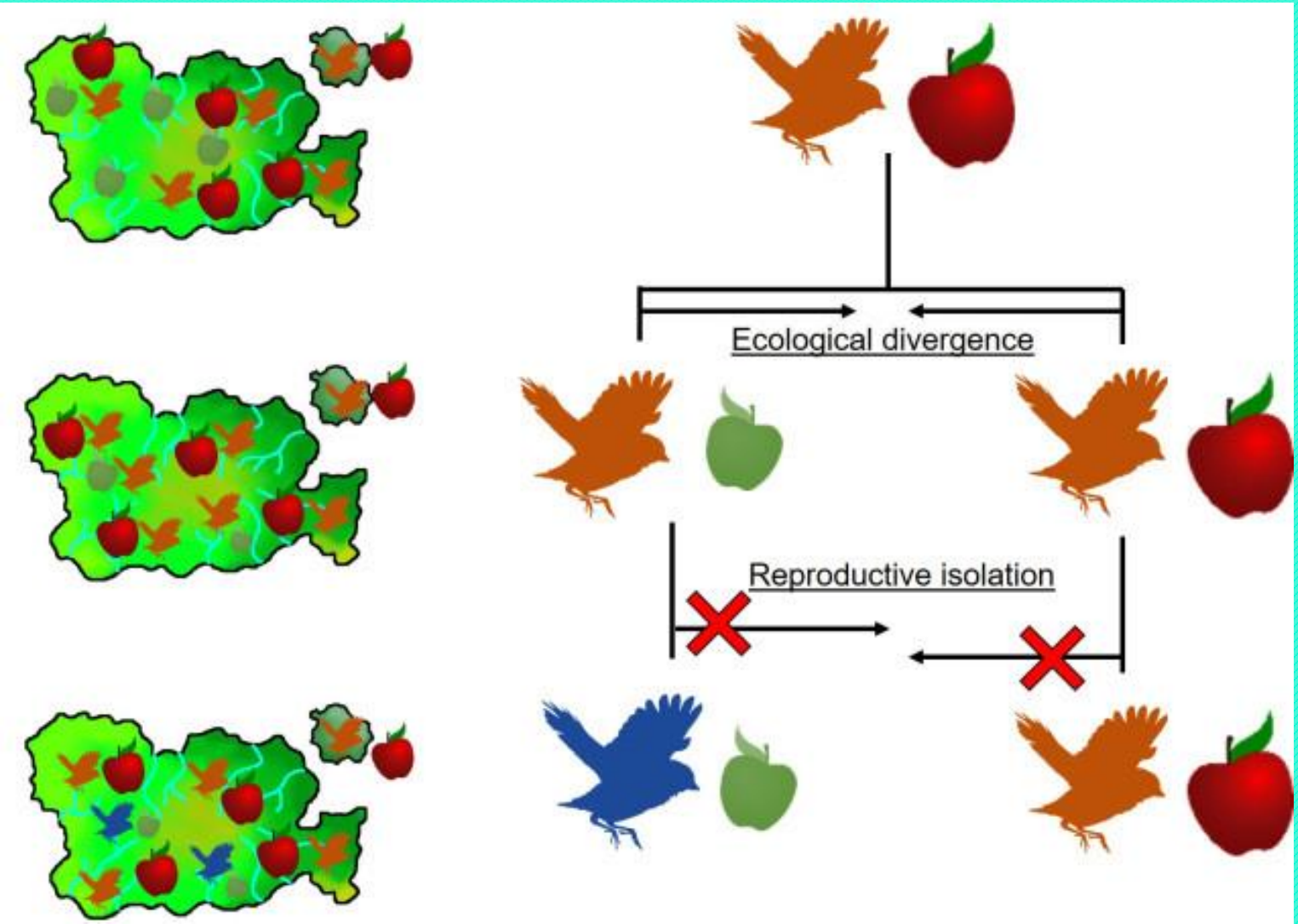
Gene flow between daughter and parental population during sympatric speciation is postulated to be inhibited by intrinsic factors, such as chromosomal changes and non-random mating.

Exploiting a new niche might automatically reduce gene flow with individuals exploiting a different niche.

- This mode of speciation is common in herbivore insects when they begin feeding and mating on a new plant or when a new plant is introduced within the geographical range of the species.
- The gene flow is then reduced between the species that specialize in a particular plant which might ultimately lead to the formation of new species.
- The selection resulting in specialization needs to be really strong for the population to diverge.
- Thus, sympatric speciation is a sporadic event in multicellular organisms or randomly mating populations.

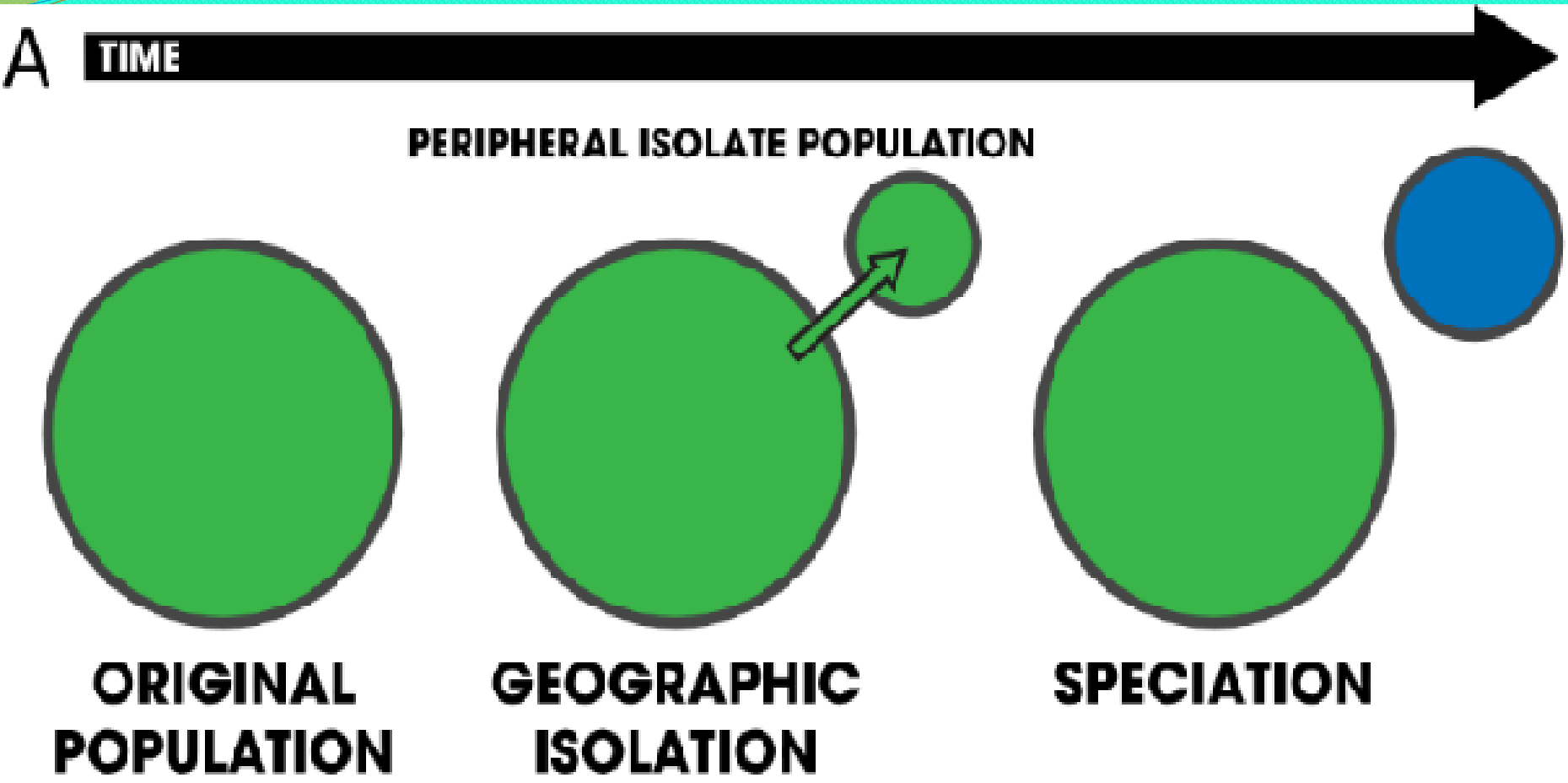
- Say we have a tropical island, which is occupied by one bird species. This bird prefers to eat the large native fruit of the island, although there is another fruit tree which produces smaller fruits. However, there's only so much space and eventually there are too many birds for the number of large fruit trees available. So, some birds are pushed to eat the smaller fruit, and adapt to a different diet, changing physiology over time to better acquire their new food and obtain nutrients. This shift in ecological niche causes the two populations to become genetically separated as small-fruit-eating-birds interact more with other small-fruit-eating-birds than large-fruit-eating-birds.

- Over time, these divergences in genetics and ecology causes the two populations to form reproductively isolated species despite occupying the same island.



Peripatric Speciation

- Peripatric speciation is a special condition of allopatric speciation which occurs when the size of the isolated subpopulation is small.
- In this case, in addition to geographic separation, genetic drift also plays an important as genetic drift acts more quickly in small populations.
- The small isolated subpopulation might carry some rare genes which upon reaching the new geographical region become fixed over the course of a few generations as a result of genetic drift.

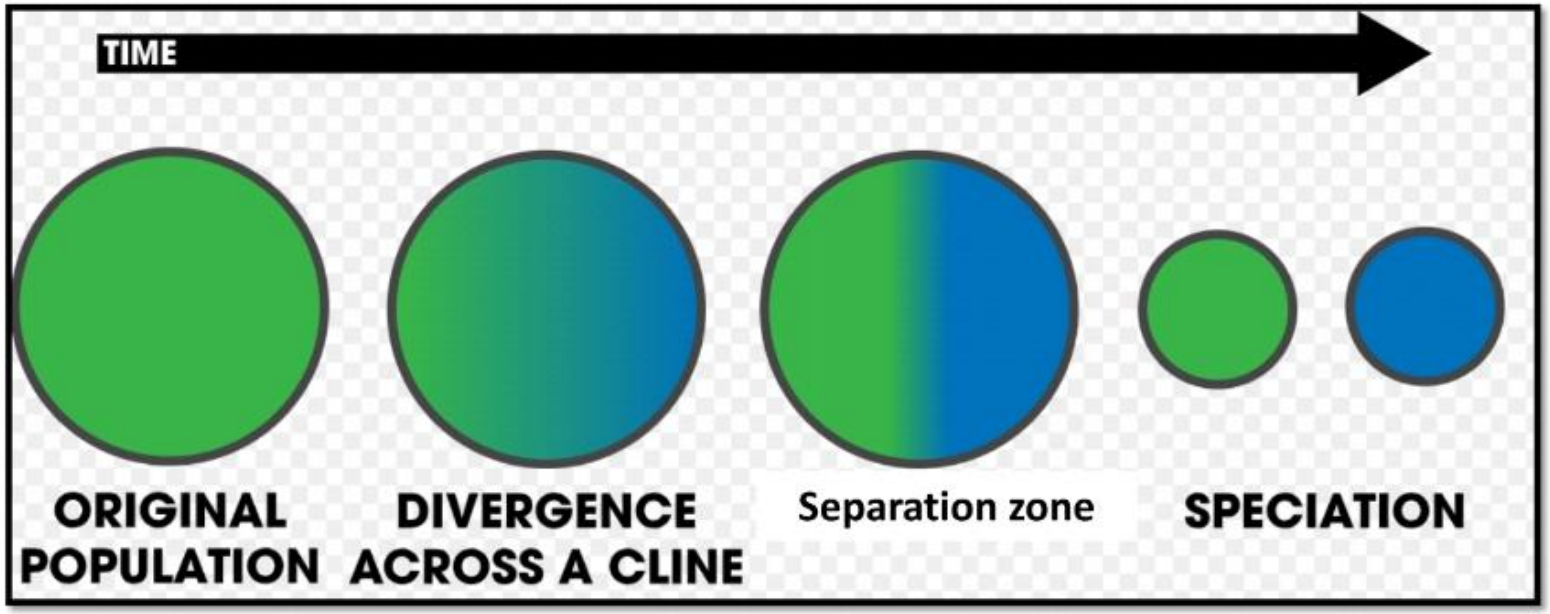

A
TIME
PERIPHERAL ISOLATE POPULATION
ORIGINAL POPULATION
GEOGRAPHIC ISOLATION
SPECIATION

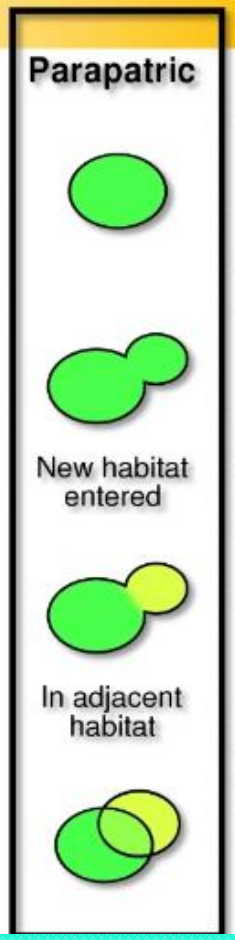
- As a result, the entire population of the new region ends up having these rare genes.
- Over time, new genetic characters, as well as natural selection, cause the survival of individuals which are better suited to the climate and food of the new region.
- Finally, under the influence of all these factors, new species are formed.
- However, it is very difficult to explain what role genetic drift played in the divergence of the two populations, which makes gathering evidence to support or refute this mode very challenging.

Parapatric Speciation

- Parapatric speciation is a mode of speciation in which there is no extrinsic barrier between the population but, the large geographic range of the population causes the individuals to mate with the neighbouring individuals than with the individuals in a different part of the geographical range.
- In this case, the population is continuous, but the population doesn't mate randomly.
- Here, the genetic variation occurs as a result of reduced gene flow within the population and varying selection pressures across the population's range.

Parapatric Speciation





- This occurs in population which is distributed over a large geographical range. Thus, the individuals in the far west region cannot mate with the individuals in the far east region.
- Through a few generations, new species might be formed within the existing population.

- **Examples of Parapatric speciation**
- The grass species *Anthoxanthum odoratum* where some species living near the mine have become tolerant to heavy metals; however, other plants that don't live around the mines are not tolerant.
- But because the plants are close together, they could fertilize each other and result in a new species.

Thank You

This class prepared for

Fifth Semester BSc Botany Students

Little Flower College, Guruvayur

Affiliated to University of Calicut

Next Class:

Isolation