CHAPTER 3

SELECTION AND SPECIATION

(Hours: 1L + 3T)

CHAPTER 3: SELECTION AND SPECIATION

3.1 Selection

3.2 Speciation

UPS 2	PSPM 2
3 MCQ	6 MARKS

LEARNING OUTCOMES

3.1 Selection

a) State the types of selection (C1); - **LECTURE**
   i. Natural selection
   ii. Artificial selection

b) Define natural selection. (C1) - **LECTURE**

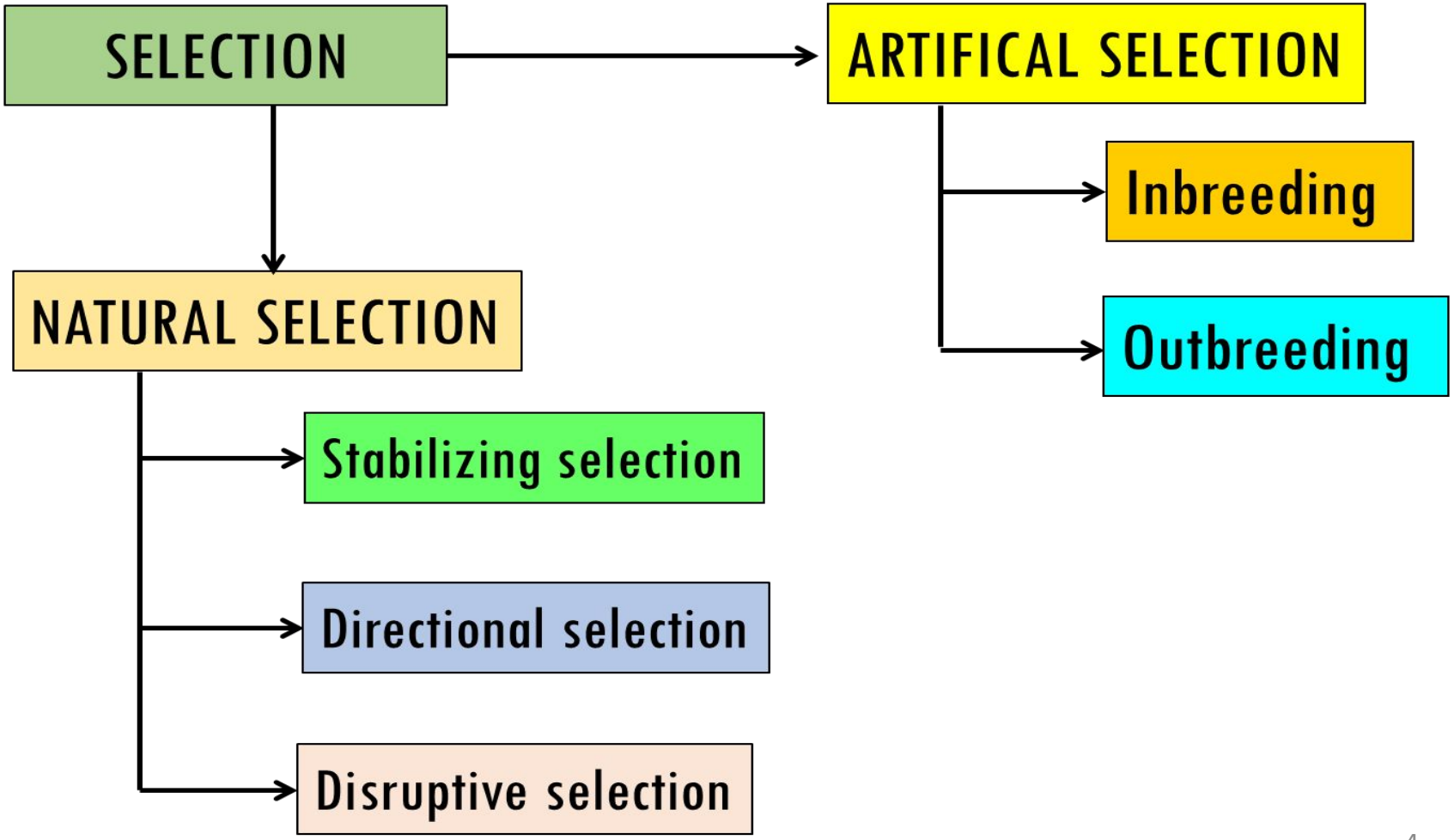
c) State three types of natural selection (C1): - **LECTURE**
   i. Stabilizing selection
   ii. Disruptive selection
   iii. Directional selection

d) Analyze stabilizing selection, disruptive selection and directional selection with examples. (C4) - **TUTORIAL**

e) Define artificial selection. (C1) - **LECTURE**

f) Describe inbreeding and outbreeding. (C2) - **LECTURE**

Selection

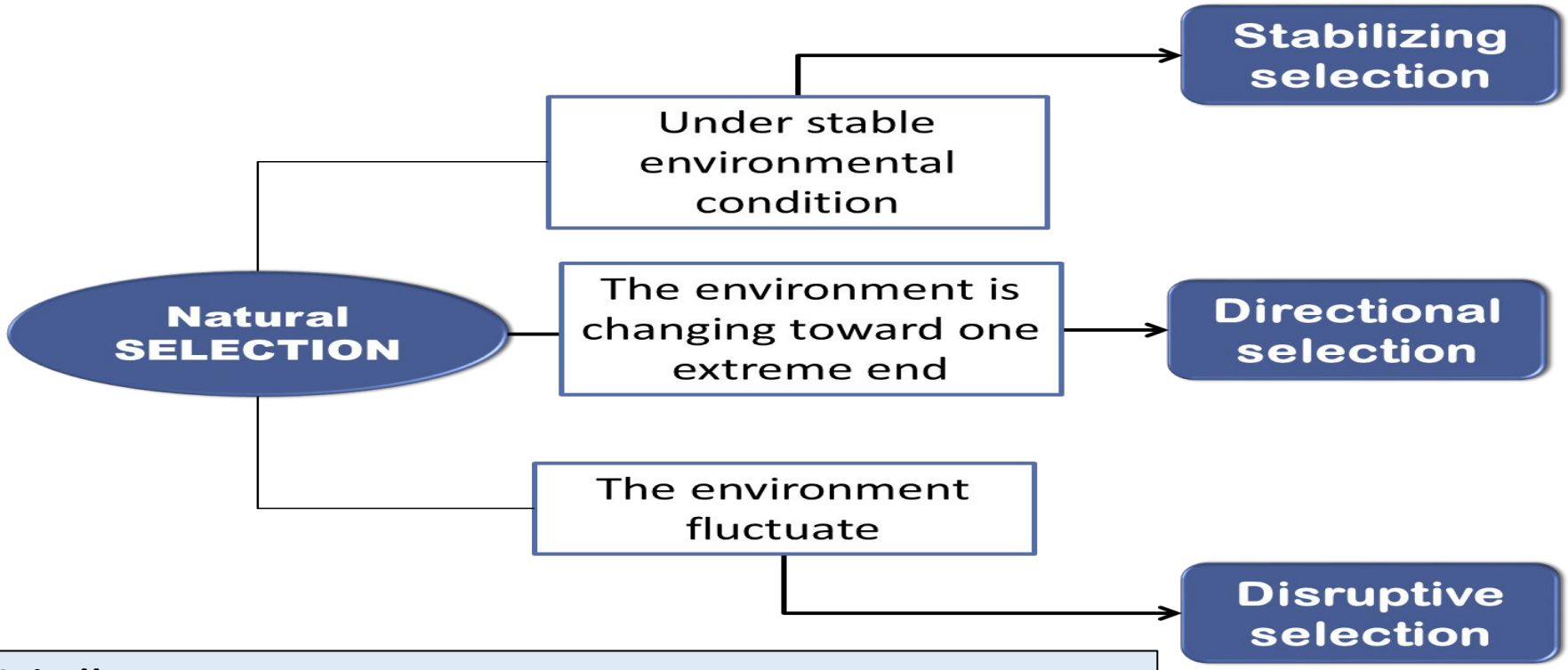

SELECTION
ARTIFICAL SELECTION
Inbreeding
Outbreeding
NATURAL SELECTION
Stabilizing selection
Directional selection
Disruptive selection

Natural Selection

- **Definition:** Natural selection is a process in which individuals with certain heritable traits survive and reproduce more successfully than other individuals due to those traits.

- Natural selection involves **environmental factor as selecting agent**

Natural Selection



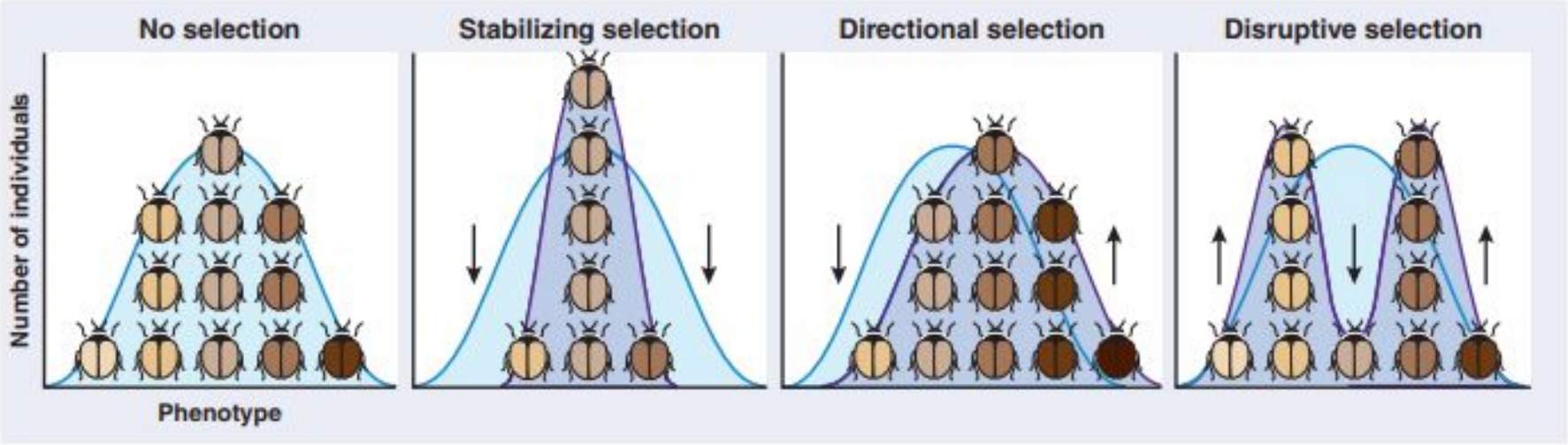
LKC tips!!

Must include term 'selection' after word stabilizing, disruptive or directional

Take note spelling for: Disruptive (√) Distruptive (x) Destructive (x)

: Stabilizing (√) Stabalizing (x)
: Directional (√) Direction (x)

Natural Selection



(a) A character that is under polygenic control (in this example, wing colors in a hypothetical population of beetles) exhibits a normal distribution of phenotypes in the absence of selection.

(b) As a result of stabilizing selection, which trims off extreme phenotypes, variation about the mean is reduced.

(c) Directional selection shifts the curve in one direction, changing the average value of the character.

(d) Disruptive selection, which trims off intermediate phenotypes, results in two or more peaks.

Figure 1

Stabilizing Selection

Definition:

Natural selection in which **intermediate phenotypes survive/reproduce more successfully than extreme phenotypes**

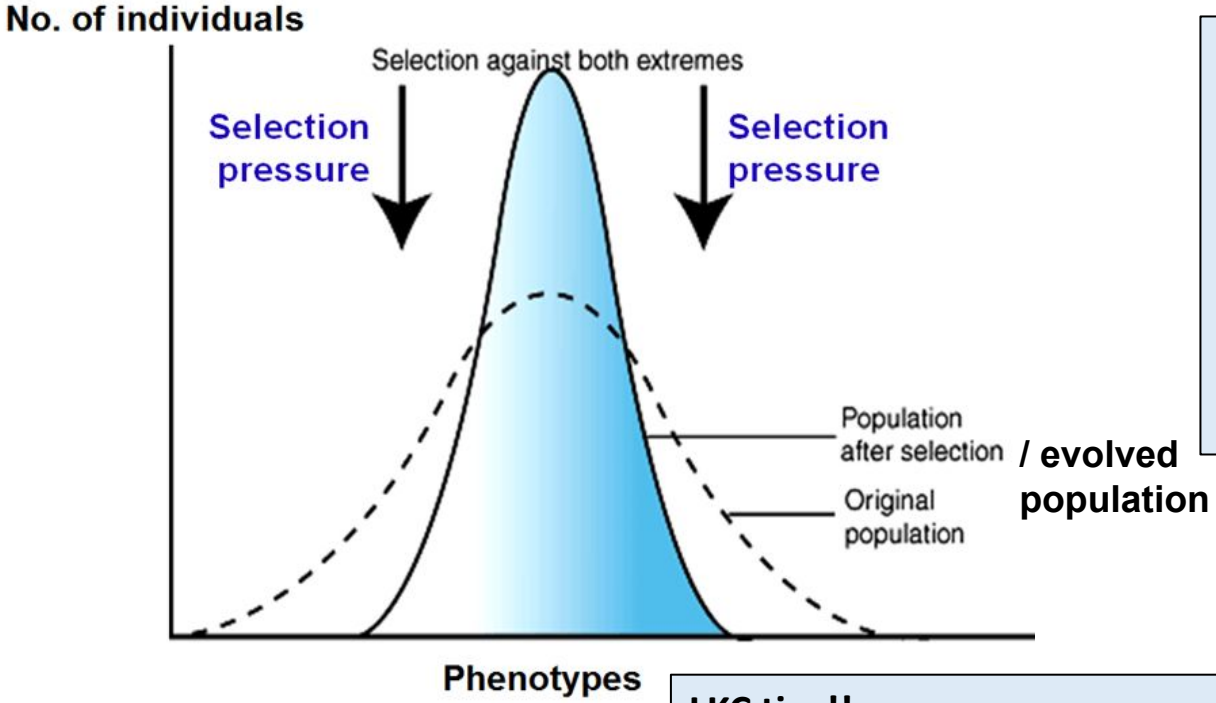
- **Favors intermediate phenotype**.
  - Intermediate phenotypes have higher chance to survive/reproduce successfully
- **Acts against both extreme phenotypes**
  - Individuals with extreme phenotypes are less likely to survive/reproduce
- Occurs **when environmental condition are stable**

LKC tips!!

Must use term 'phenotype' : Favors intermediate phenotype and ….. (√)

Stabilizing Selection

- The frequency curve narrows near the mean
- Stabilizing selection **reduce genetic variation**



/ evolved population

Figure 2

LKC tips!! Must draw the curve correctly with labels:

-Axis (**y-axis** – number of individual,

x-axis – phenotype)

-Arrow (label selection pressure)

-Curve with labels (original population and population after selection)

LKC tips!!

-Reduce genetic variation (√) , Reduce genetic variability (√)

Reduce gene variation (x) , Reduce variation (x)

Stabilizing Selection

- Example: **Birth weight of human babies**
  - Babies birth weight in the range of 3-4 kg has higher survival rate
  - Babies with lower birth weight suffer higher rates of mortality
  - Babies with higher birth weight show a slight increase in mortality.

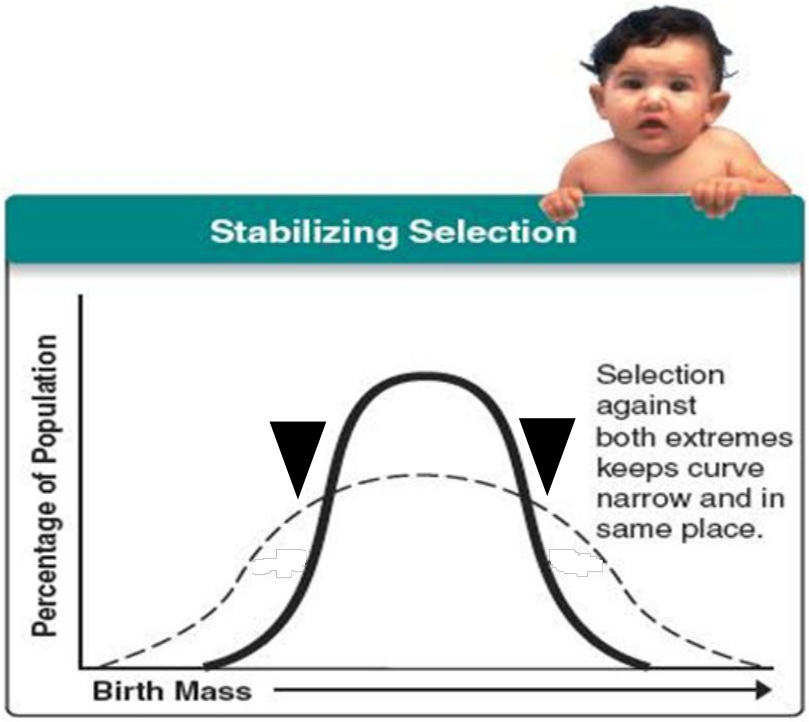


Figure 3

Directional Selection

Definition: Natural selection in which **individuals at one of the extreme phenotype survive/reproduce more successfully than other individuals.**

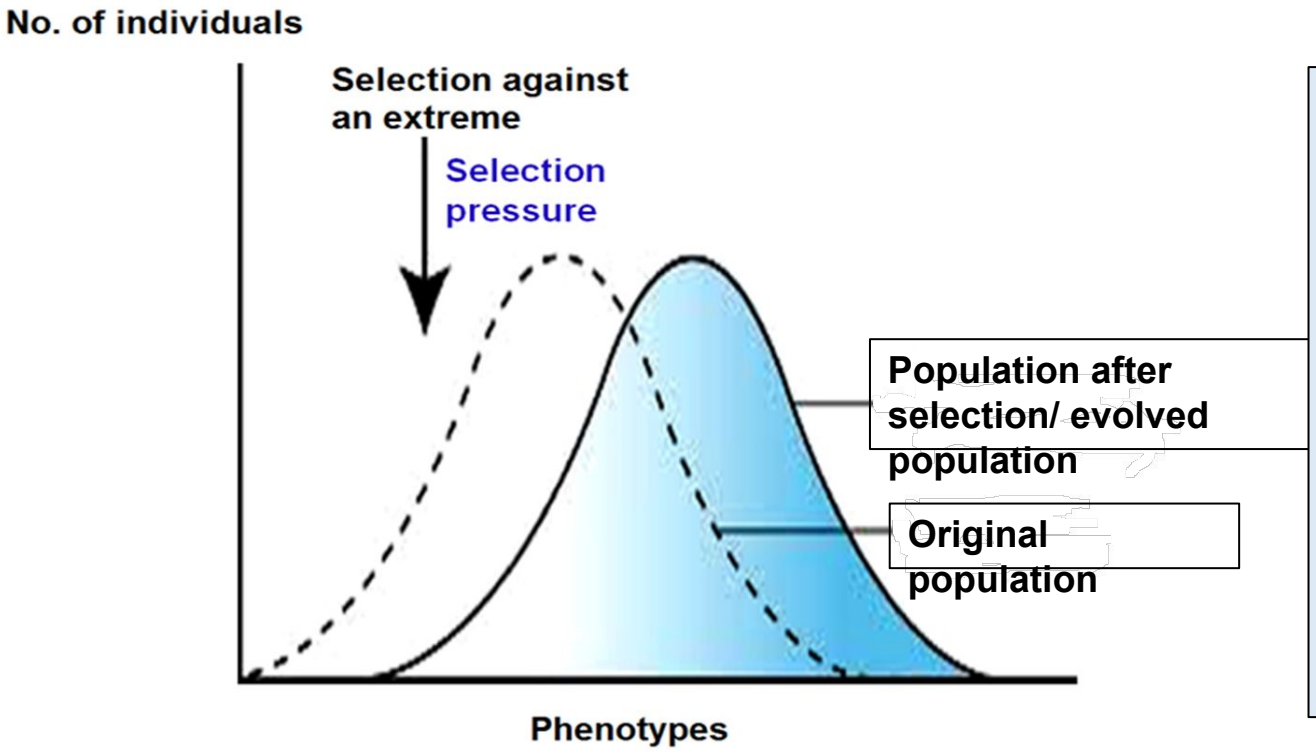
- **Favors one extreme phenotype**
  - One favored extreme phenotypes have higher chance to survive/reproduce successfully
- **Act against the other extreme phenotype**
  - The other extreme phenotype are less likely to survive/reproduce
- Occurs when **environmental condition is changing towards one extreme end**

LKC tips!!

Must use term 'phenotype' : Favors one extreme phenotype and ….. (√)

Directional Selection

- Shift the frequency curve towards the favoured phenotype / in one direction
- Directional selection **reduce genetic variation**



LKC tips!! Must draw the curve correctly with labels:

-Axis (**y-axis** – number of individual,

x-axis – phenotype)

-Arrow (label selection pressure)

-Correct arrow position (at one extreme phenotype)

-Curve with labels (original population and population after selection)

Figure 4

Directional Selection

- Example: **Industrial melanism of peppered moth (*Biston betularia*).**
- The dark/black peppered moth is selected to survive (in comparison to the light coloured form) and increase in numbers as the area becomes more industrialized & polluted.



Figure 5



Figure 6

LKC tips!!

Must underline scientific name if handwritten: Biston betularia (√)

Disruptive Selection

Definition: Natural selection in which **individuals on both extreme phenotypes survive/reproduce more successfully than individuals with intermediate phenotype.**

- **Favor both extreme phenotypes**
  - Both extreme phenotypes have higher chance to survive/reproduce successfully
- **Act against intermediate phenotypes**.
  - Intermediate phenotype are less likely to survive/reproduce
- Occurs when environmental condition are varied
- Disruptive selection **increase genetic variation**

LKC tips!!
Must include the word "**both**" when referring to both extreme phenotypes.

Must use term 'phenotype' : Favors both extreme phenotypes and ….. (√)

Disruptive Selection

- This selection causes **splitting of a population into 2 distinct phenotypes**, resulting in 2 or more peaks in frequency curve
- Disruptive selection **increase genetic variation**

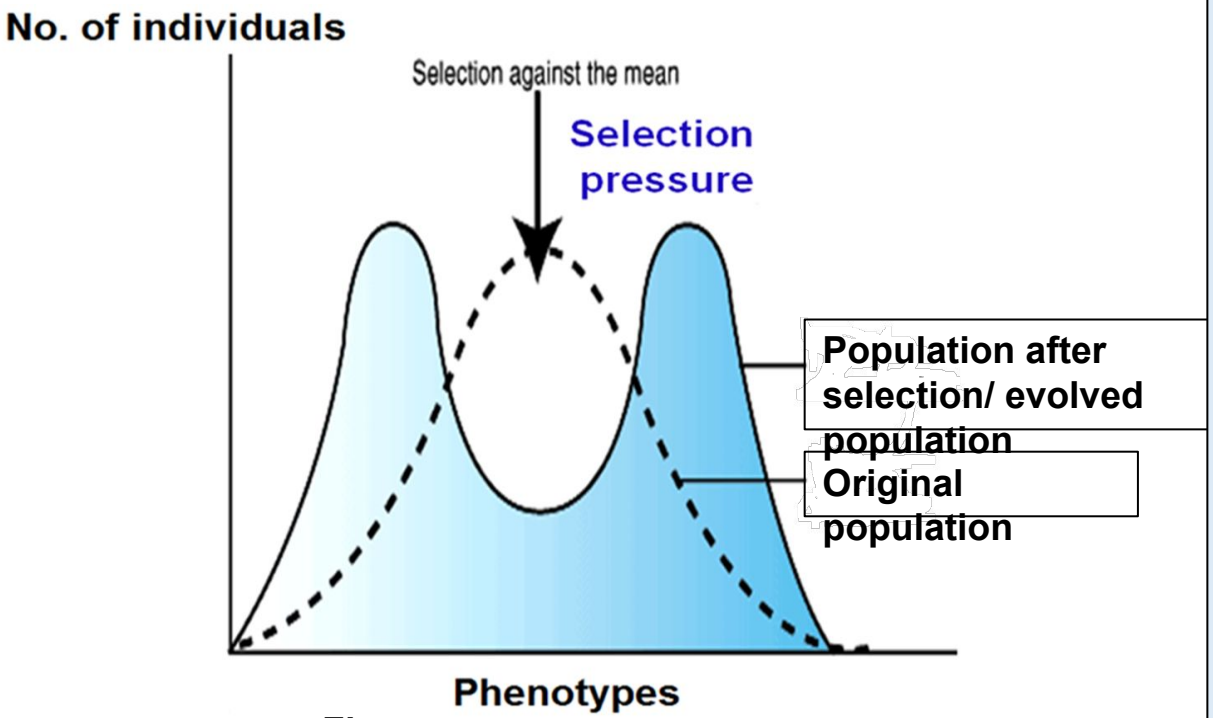


Figure 7

LKC tips!! Must draw the curve correctly with labels:

-Axis (**y-axis** – number of individual,

x-axis – phenotype)

-Arrow (label selection pressure)

-Curve with labels (original population and population after selection)
-Starting point for both curve must touch 0
-Original population: Bell shape, begin and end point of curve must touch X-axis
-Population after selection: The groove for intermediate phenotype should not touch X-axis, and a clear groove shown.

Disruptive Selection

- Example: **Beak sizes of (black-bellied) seed cracker finches in Cameroon / Darwin's Galapagos finches**
  - Birds with small beak feed mainly on soft seeds
  - Birds with large beak mainly feed on hard seeds.
  - Birds with intermediate-sized beak are relatively inefficient at cracking both types of seeds; thus have lower survival rate.



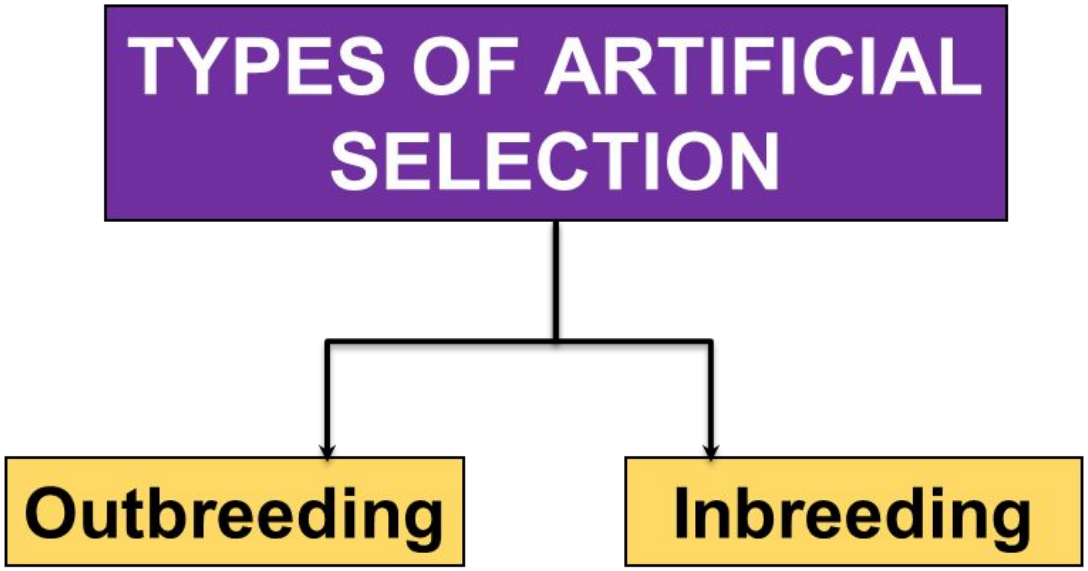
Figure 8

Artificial Selection

Definition : **The selective breeding of domesticated plants and animals to obtain the desirable traits**. *(Campbell Biology,2021,G3)*

- **Selecting agent : Humans intervention.**
- This leads to changes in allele and genotype frequencies in populations.
- Mainly practiced in agriculture to produce new varieties of organism (livestock & crop plants).
- Selected varieties are useful to human for a specific purpose
- The process is known as **selective breeding**.

Artificial Selection





Artificial Selection: Inbreeding

- **Definition:** Selective mating between **closely related organisms** within the same population.
- **Benefits:**
  1. Ensures the retention of advantageous traits
  2. Produces uniform offspring with predictable traits
- **Effect of prolonged inbreeding :**
  1. Reduce fertility
  2. Reduce genetic variation
  3. Increase the number of homozygosity (increase genetic disorders)
  4. Less adapted to changing environments

Artificial Selection: Inbreeding

Inbreeding in cattle

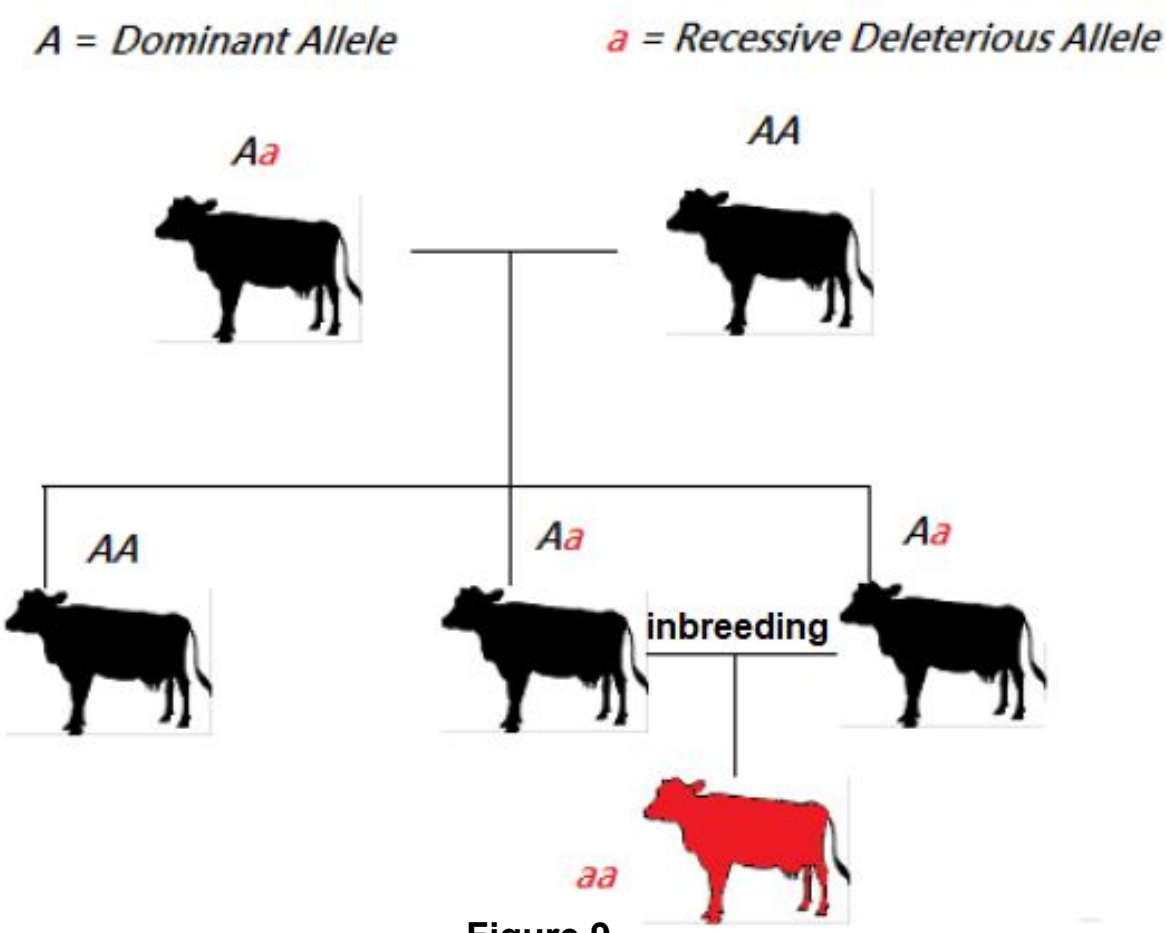


Figure 9

Artificial Selection: Outbreeding

- **Definition:** Mating between **unrelated / distantly related individuals of a species or individuals from different population / subspecies** to produce offspring known as hybrids.
- **Benefits :**
  1. Increase hybrid vigour or heterosis (hybrid with good or high quality i.e: increased fruit size, resistance to disease)
  2. Increase genetic variation
  3. Increase heterozygosity
  4. Better adapted to changing environments

Artificial Selection: Outbreeding



Hereford



Aberdeen Angus

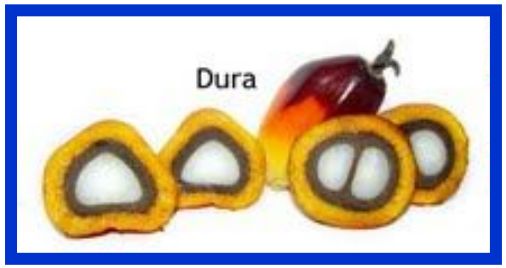


Hereford X Aberdeen Angus

Hereford x Aberdeen Angus produce better quality meat

Artificial Selection: Outbreeding

- Eg: Oil palm (*Elaeis guineensis*) has 2 varieties:



Dura

- *Thin mesocarp*
- *Thick shell*
- *Low oil content*

X



Tenera

- *Thick mesocarp*
- *Thin shell*
- *High oil content*



Pisifera

- *Thick mesocarp*
- *Has no shell*
- *Unproductive sometimes female is sterile*

Figure 10

LEARNING OUTCOMES

3.2 Speciation

a) Define biological species concept (C1) - **LECTURE**

b) Describe modes of speciation: sympatric and allopatric (C2) - **LECTURE**

c) State the processes that lead to speciation (C1) - **LECTURE**

d) Explain the processes that lead to speciation (C3): - **TUTORIAL**

   i. Reproductive isolation
   ii. Genetic drift
   iii. Hybridization
   iv. Adaptive radiation

Introduction

- Biological species concept is based on the potential to interbreed, **NOT** on physical similarity



Figure 11

Similarity between different species
Sturnella magna (left) and *Sturnella neglecta* (right) have similar appearance but are considered as different species because their behavior prevent them from interbreed.



Figure 12

Diversity within a species
All humans belong to a species (*Homo sapiens)*, due to our capacity to interbreed successfully

Species

Definition :

Members/individuals of a population/group of populations have the potential to interbreed and produce viable, fertile offspring in nature.

(Campbell 12th edition (2021) , G-31)

Speciation

- **Definition :** A process of **forming new species from pre-existing species through evolution.**
- Populations of the same species evolve to become so different that they can no longer breed with one another to produce fertile offspring (reproductive isolation is established).
- Gene flow is prevented between the new species.

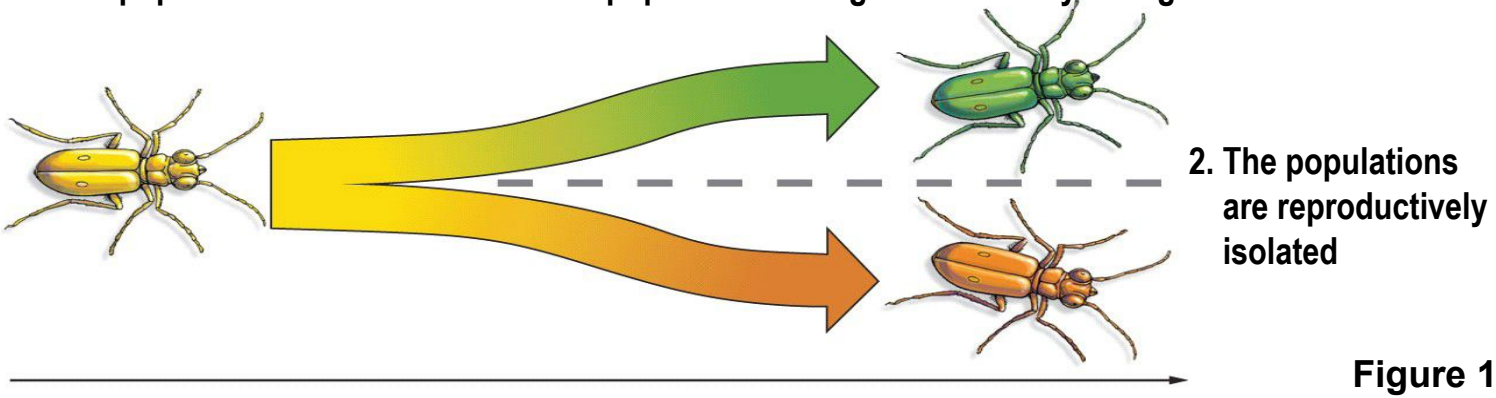


Figure 13

How do new species originate from previously existing species?

- Over time, populations of a single species connected by gene flow can split/diverge genetically, giving rise to a new species

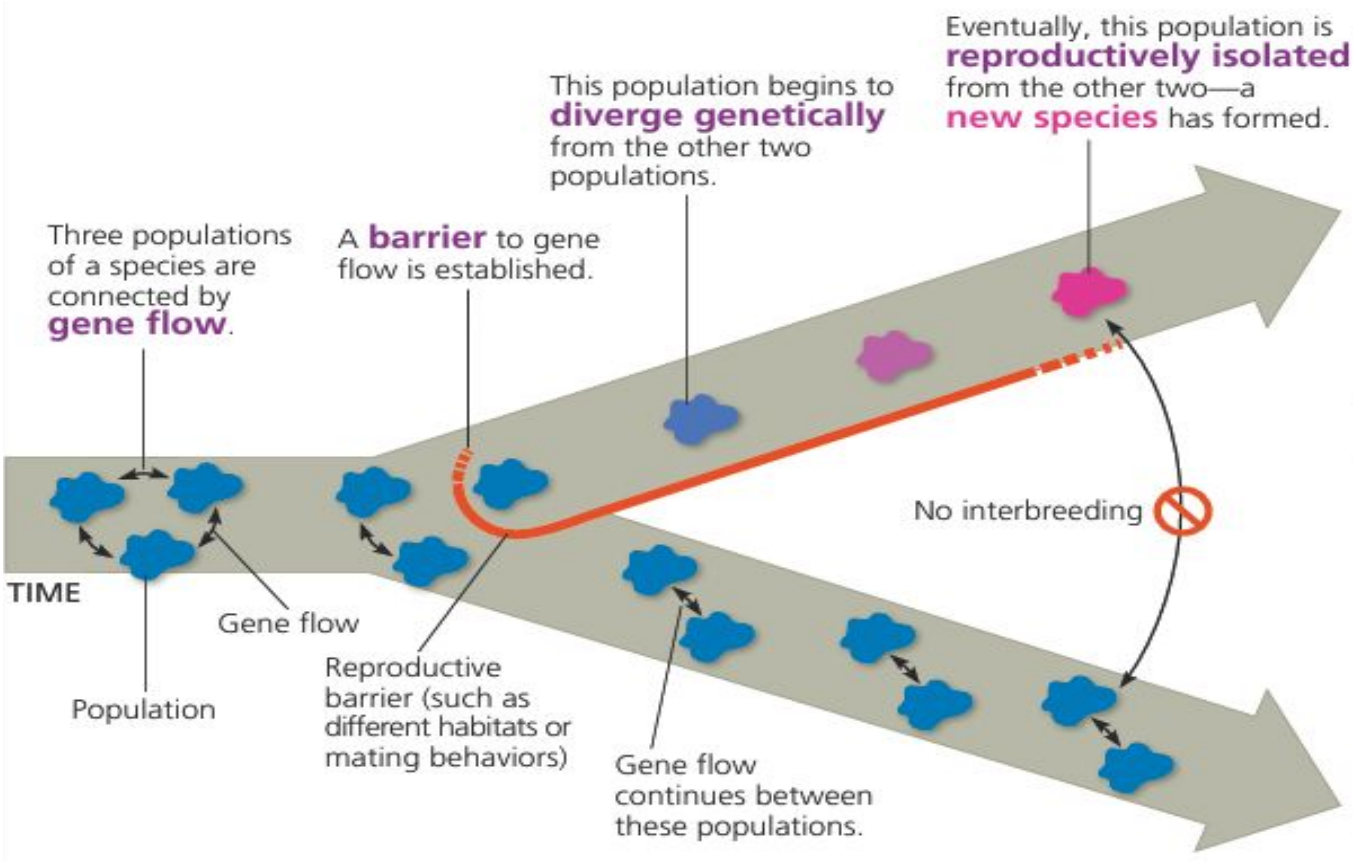


Figure 14

How do new species originate from previously existing species?

- Speciation occur when the allele frequency change and leads to genotype and phenotype divergence due to adaptation to new environment.
- This leads to evolution.
- If the two subpopulations meet and tries to mate again, but unable to mate, the **two subpopulations are reproductively isolated, so new species is formed**.
- But if the two subpopulations tries to mate and produce fertile offspring, no speciation occur, but variety of phenotypes are produced.

Mode of speciation

Two modes of speciation :

1. Sympatric speciation
2. Allopatric speciation

LKC Tips!!

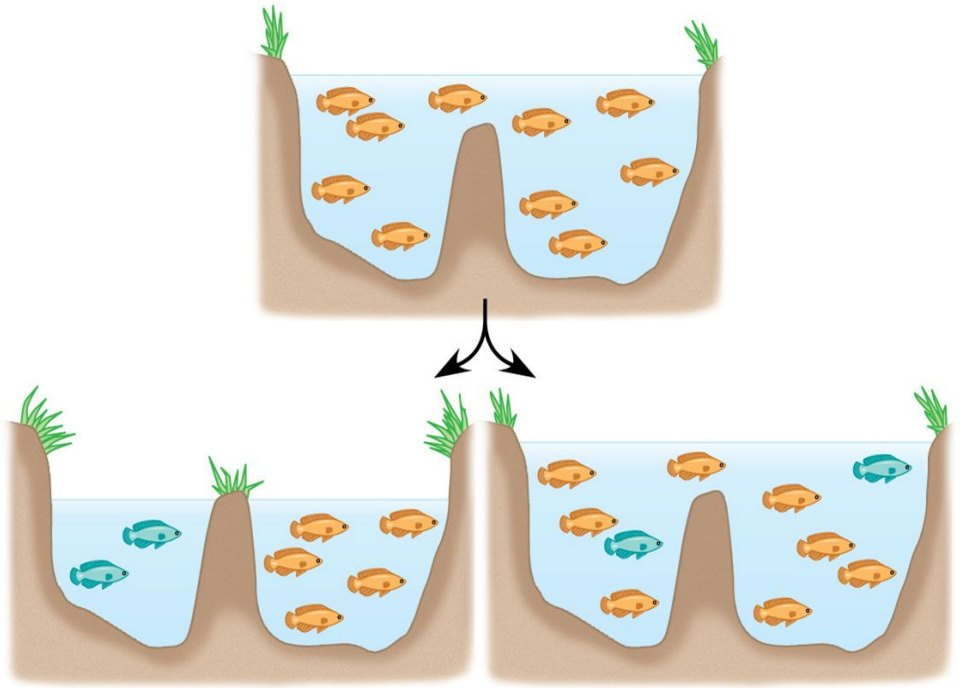
-Modes of speciation occur in the population and not to the species directly

-But these modes will contribute to the formation of a new species

-Take note spelling for: Sympatric (√)

Sympatic (x) symphatic (x)

- Must know when to use term selection, speciation and isolation



(a) Allopatric speciation. **(b) Sympatric speciation.**

Figure 15

Sympatric speciation

Definition: **Formation of new species that live in the same geographical area**

- A small population becomes a new species without geographical isolation
- Result from the new ecological niches

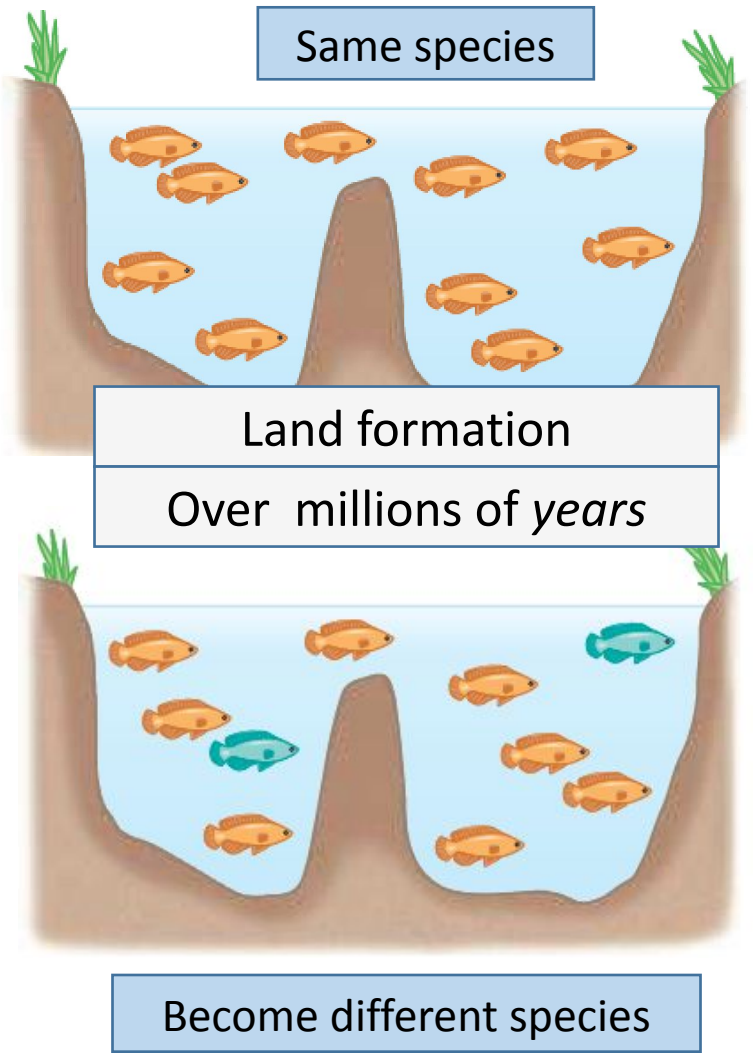


Figure 16

Sympatric speciation

- They can co-exist as separate species within the same geographical area.
- Gene flow / interbreeding between individual is reduced / prevented by factors such as:
  i. Polyploidy
  ii. Habitat differentiation
  iii. Sexual selection

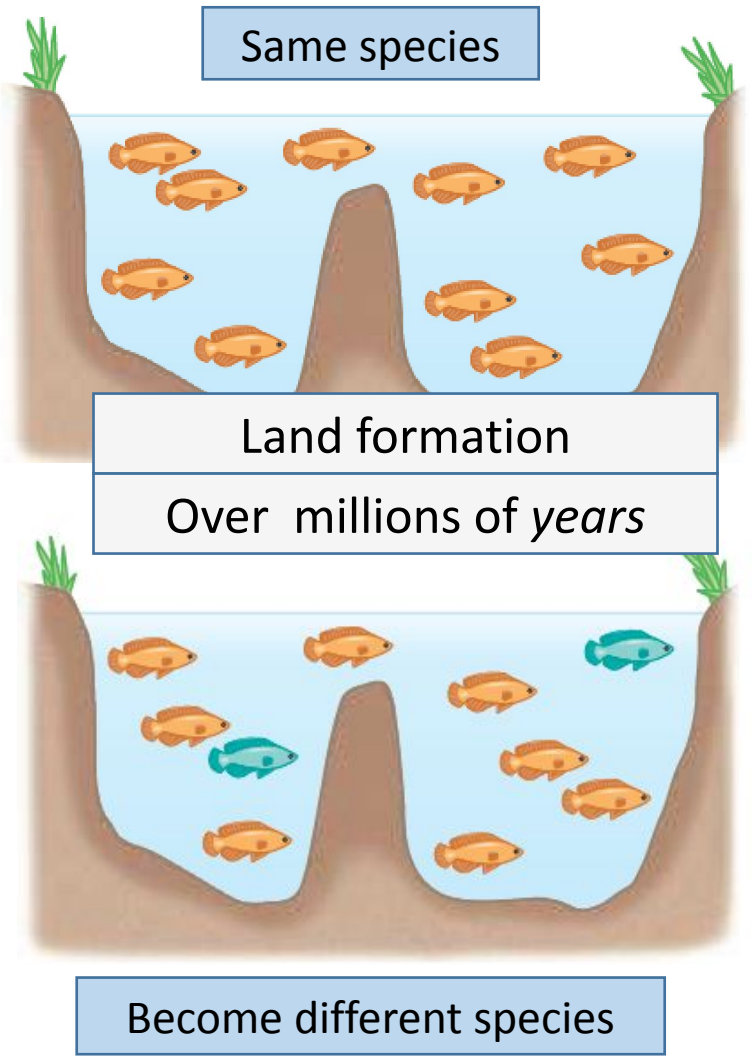


Figure 18

i. Polyploidy

- A species may originate from mutation during cell division that result in extra sets of chromosomes
- Example : **allopolyploid speciation in *Tragopogon* sp.**

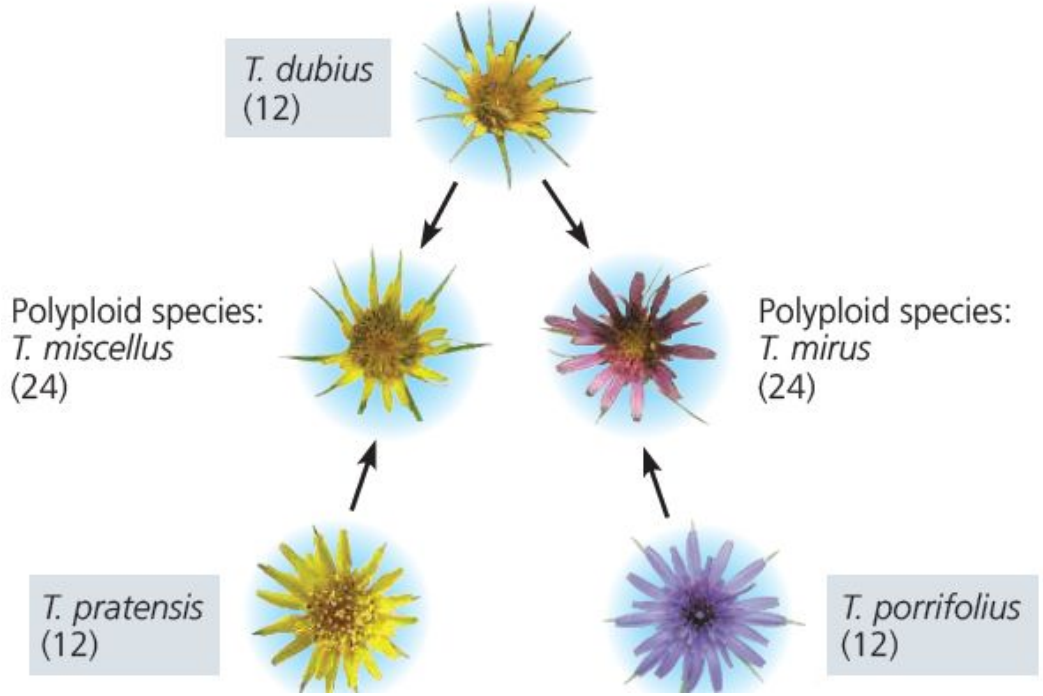


Figure 17

ii. Habitat differentiation

- Example : **Apple maggot flies.**
- 200 years ago, the ancestors of apple maggot flies laid their eggs only on hawthorns
- But today, these flies lay eggs on hawthorns (which are native to America) and domestic apples (which were introduced to America by immigrants).
- Females generally choose to lay their eggs on the type of fruit they grew up in, and males tend to look for mates on the type of fruit they grew up in.

ii. Habitat differentiation

- Hawthorn flies usually mate with other hawthorn flies and apple flies mate with other apple flies.
- Gene flow between the population that mate on different types of fruit is reduced.
- Results in two different species of apple maggot flies.



Apple maggot fly
(*Rhagoletis pomonella*)



Feeds & mates on hawthorns and apples

Figure 18

iii. Sexual selection

- Example: **Cichlid fish at East Africa's Lake Victoria**
- 200 closely-related cichlid fishes arose from the same ancestor.
- Females select males based on their appearance
- Based on coloration of males; blue-tinged back and red-tinged back
- The two groups may lost the ability to interbreed, becomes reproductively isolated due to female mating choice

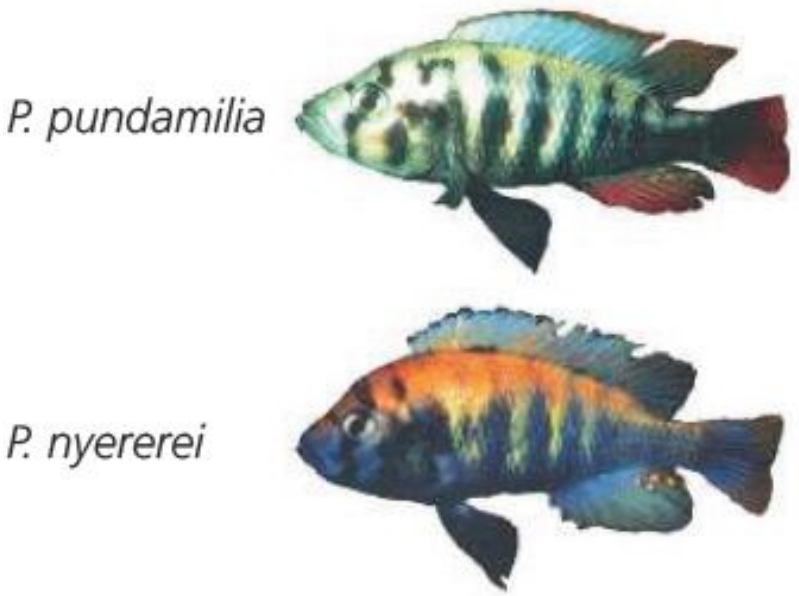


Figure 19

Allopatric speciation

Definition: **Formation of new species that occurs in populations that are geographically isolated / separated**

- A population splits into two subpopulations due to the presence of geographical barrier.
- Gene flow / interbreeding from one population to another is prevented.
- Isolated subpopulation undergoes genotypic/phenotypic divergence over a long period of time.
- Due to selective pressure or adaption to new environment.

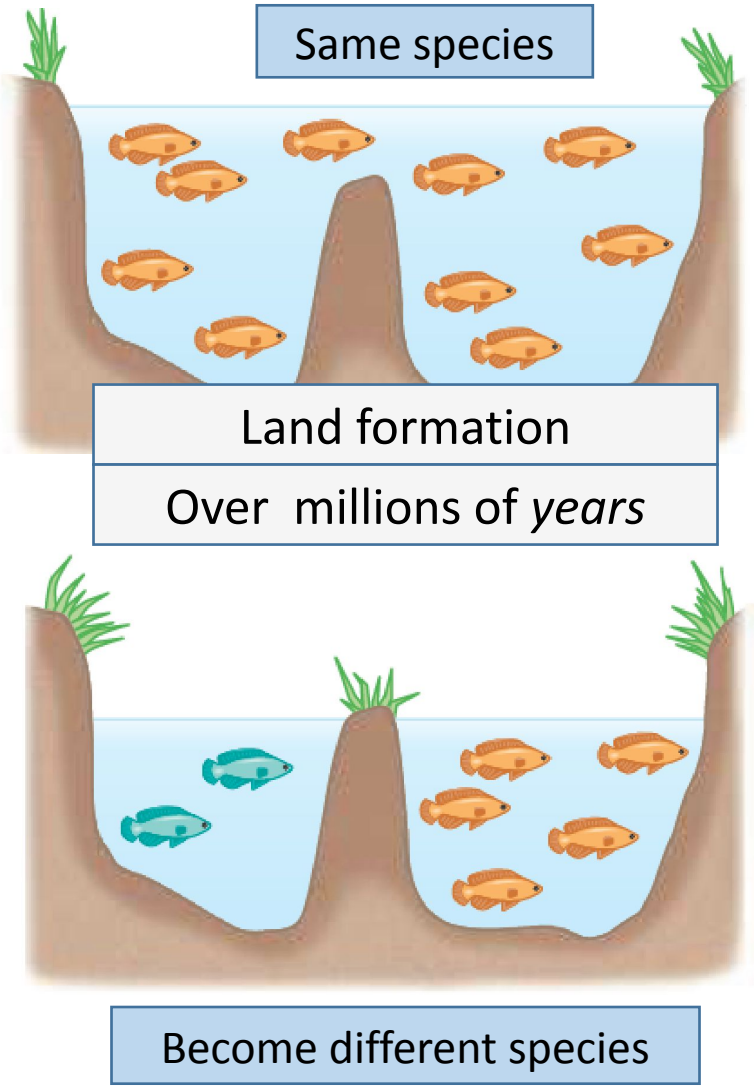


Figure 20

Allopatric speciation

- Lead to the changes in allele and genotype frequencies.
- Prolonged separation of sub-populations may **cause them to become genetically isolated (cannot interbreed) even if brought together, thus; reproductive isolation established**.
- In this way new species may form.

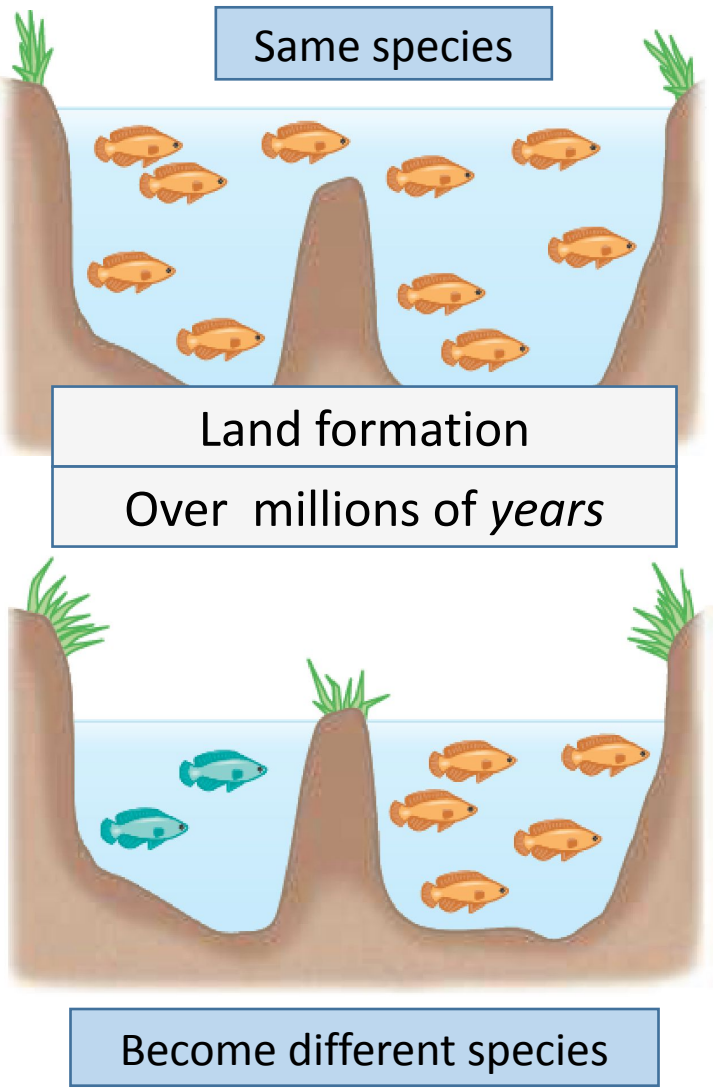


Figure 20

Allopatric speciation

- Examples of geographical barrier:
  - River shifting their courses
  - Mountain ranges forming
  - Land bridges forming
  - Large lakes reduce into several smaller lakes
  - Small population migrates or dispersed and colonizes a new area away from original species

 *The definition of **barrier** depends on the ability of a population to disperse. E.g: a canyon may create a barrier for small rodents, but not birds, coyotes or pollen*

Geographical barrier → no gene flow → genetic isolation/divergence → reproductive isolation → formation of new species

Allopatric speciation

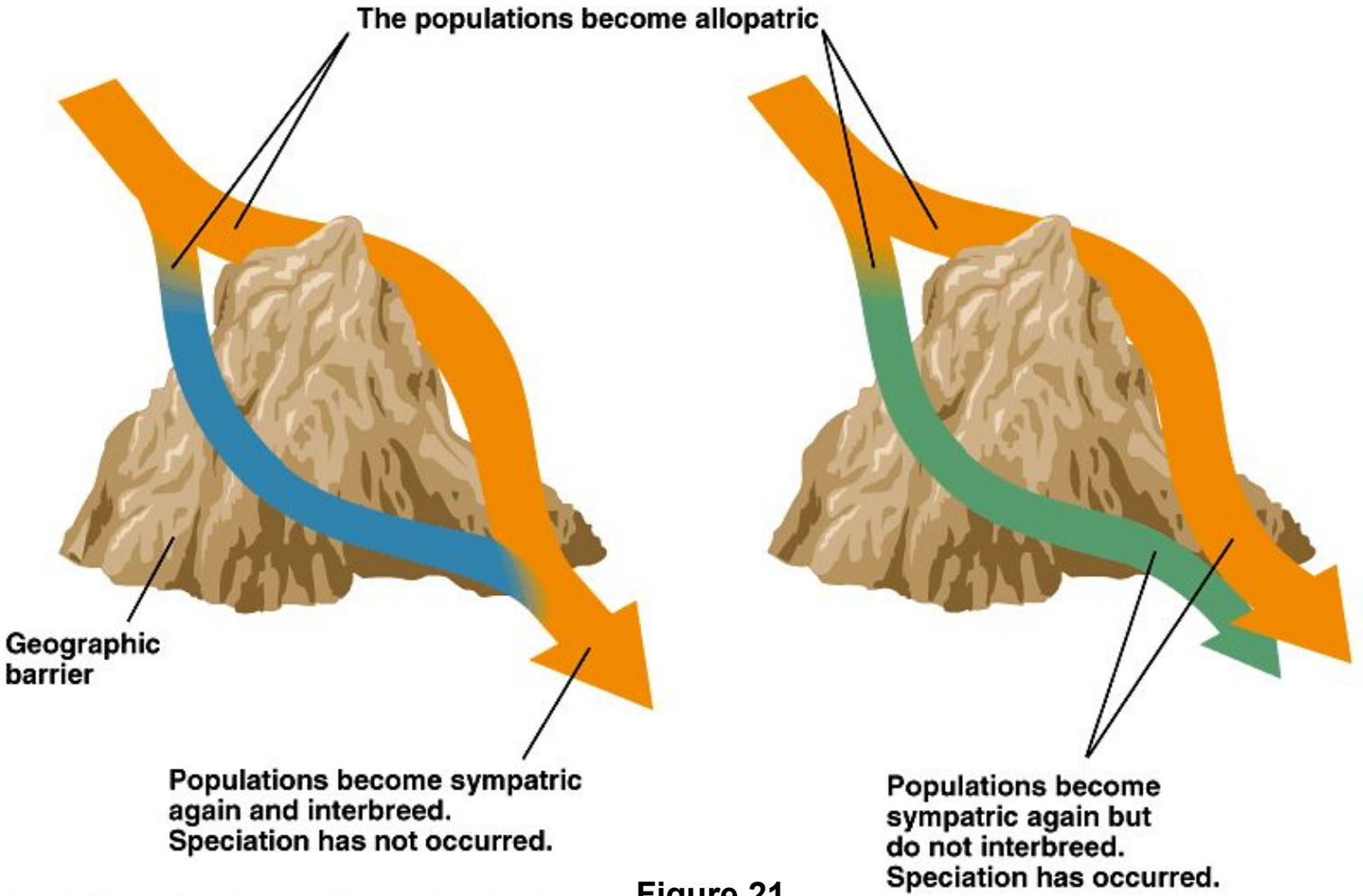


Figure 21

Allopatric speciation



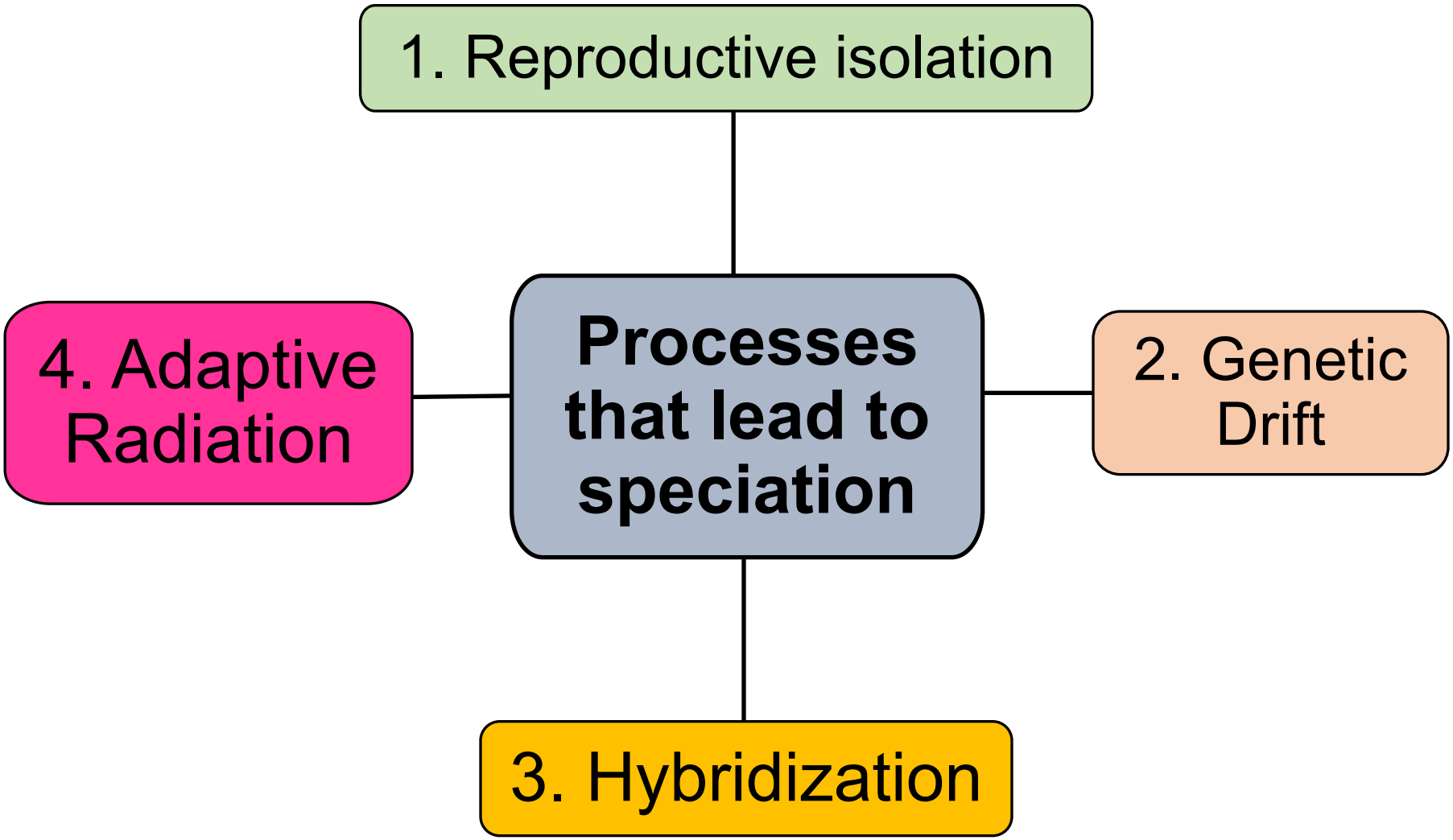
(a) The Kaibab squirrel, with its white tail and gray belly, is found north of the Grand Canyon.



(b) The Abert squirrel, with its gray tail and white belly, is found south of the Grand Canyon.



Figure 22


1. Reproductive isolation
4. Adaptive Radiation
Processes that lead to speciation
2. Genetic Drift
3. Hybridization

i) Reproductive Isolation

- Reproductive isolation is the **existence of biological factors (barrier) that prevent closely related species from interbreed and produce viable, fertile offspring.**
- And prevent the exchange of genetic materials (gene flow) between two different species in the same geographical area
- Two types of barriers (isolating mechanism):
  1. Prezygotic barrier
  2. Postzygotic barrier

LKC tips!!

-Must use term prezygotic 'barrier'(√)
- prezygotic mechanism (x),
- prezygotic isolation (x)

i) Reproductive Isolation

- Two types of isolating mechanisms

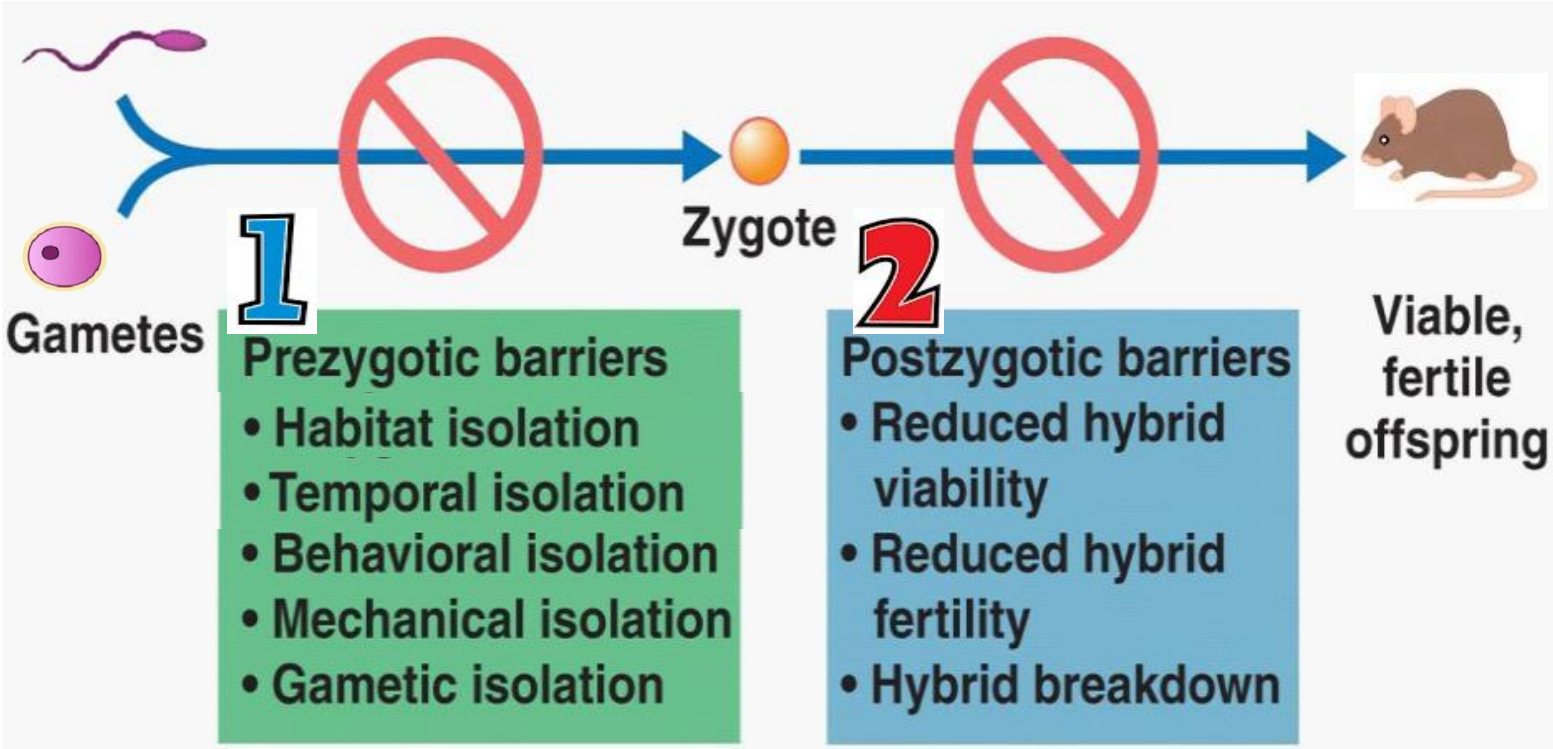


Figure 23

Isolating mechanism : Prezygotic barriers

- **Prezygotic barriers prevent mating or fertilization from taking place**
- Fertilization can be prevented by:
  - Prevent different species from attempting to mate
  - Prevent the successful completion of mating
  - Prevent fertilization if mating is completed successfully

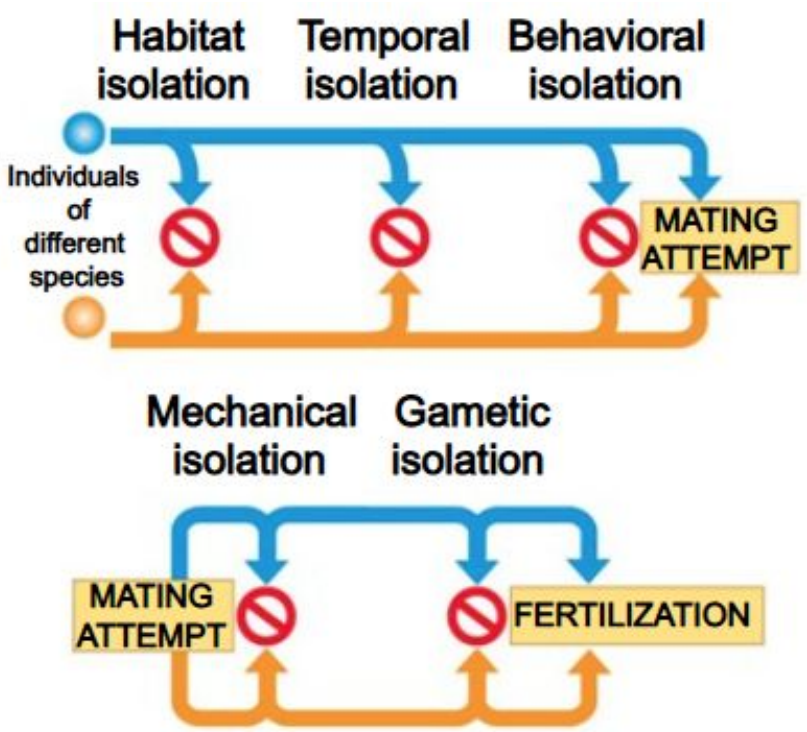


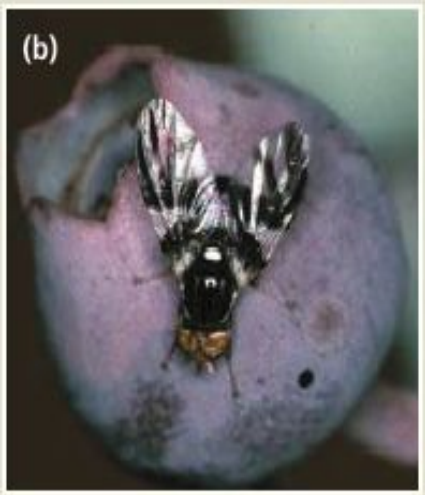
Figure 24

Prezygotic barrier : Habitat isolation



Apple maggot fly
(*Rhagoletis pomonella*)

Feeds & mates on apples



Bluberry maggot fly
(*Rhagoletis mendax*)

Feeds & mates on blueberries

Figure 25

- **Two species that occupy different habitats within the same geographic area rarely meet each other**
- Though they are not isolated by obvious physical barriers
- Reproduction is prevented as potential mates from different species do not meet

LKC tips!!

-Must use term '2 species' (√), 2 organisms @ 2 individuals (x)
-Must follow the sequence of the prezygotic barrier
-Must use term habitat 'isolation'(√) – mechanism (x), isolating (x), barrier (x)

Prezygotic barrier: Temporal isolation





Late Winter

Late Summer

Figure 26

- **Two species reproduce at different mating time/ season**
- Species that breed or mate during different times of the day, different seasons, or different years cannot mix their gametes.
- In North America, the western spotted skunk and the eastern spotted skunk lives in overlapping region, but they breed at different seasons.

LKC tips!!

Must use temporal isolation (√), seasonal isolation (x)

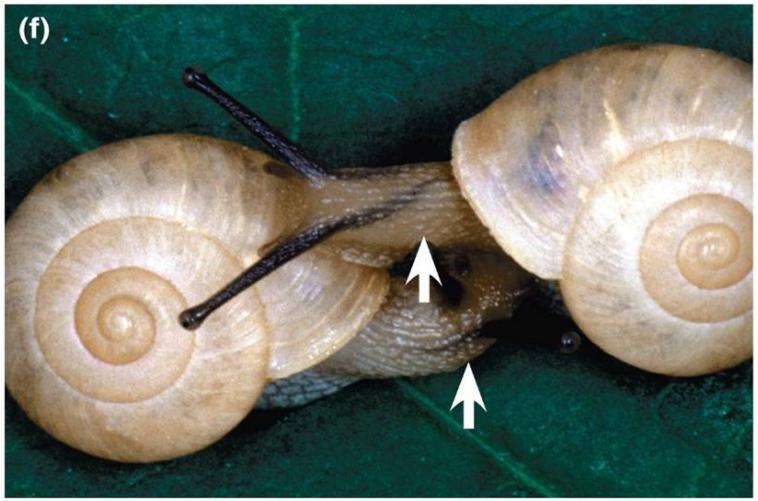
Prezygotic barrier: Behavioral isolation



Figure 27

- **Two species have different courtship behaviors/rituals to attract mates that unique to their species.**
- Mating can only occurs if the courtship display by one sex results in acceptance by the other sex.
- E.g: blue-footed boobies in Galapagos, mate only after a courtship display unique to their species.

Prezygotic barrier: Mechanical isolation



***Bradybaena* with shells spiraling in opposite directions**

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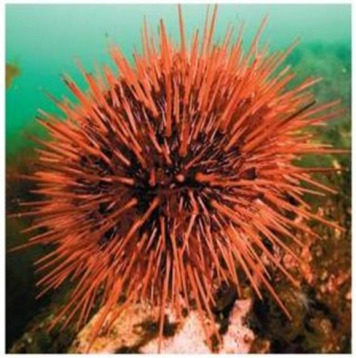
Figure 28

- **Two species have structural differences in their reproductive organs.**
- They try to mate but morphological differences prevent successful completion.
- Male and female organism cannot exchange gametes due to incompatibility of their reproductive structures.
- The two snails genital openings are not aligned, mating cannot be completed.

Prezygotic barrier: Gametic isolation



Purple sea urchin (*Strongylocentrotus purpuratus*)



Red sea urchin (*Strongylocentrotus franciscanus*)

Example : sea urchins release sperm and egg into surrounding water.

Figure 29

- **Gametes of two different species are chemically incompatible and fail to fuse.** Sperm of one species may not be able to fertilize the eggs of another species.
- E.g: sperms may not survive in the female's reproductive tract of another species.
- The chemical differences / incompatibilities of gametes of different species may prevent the sperm from penetrating the membrane surrounding the other species' eggs.

Isolating mechanism: Postzygotic barrier

- **Postzygotic barrier prevents a hybrid zygote from developing into a viable, fertile adult** (after mating and fertilization has occurred)

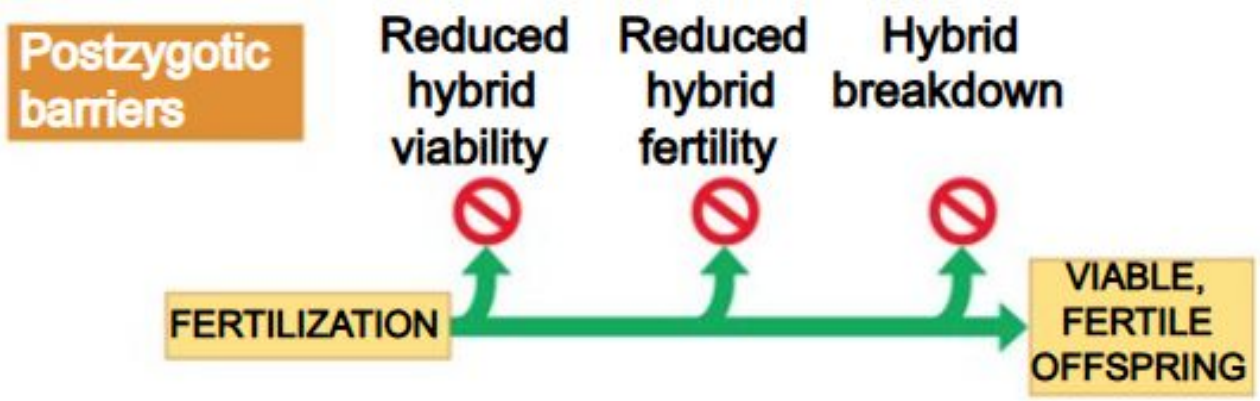


Figure 30

Postzygotic barrier: Reduced Hybrid Viability



Some salamander subspecies of the genus *Ensatina* live in the same regions and habitats, where they may occasionally hybridize.

Figure 31

LKC tips!!

-Must follow the sequence of the postzygotic barrier

- **Hybrid zygote is produced but fail to develop into viable fertile individual (cannot reach sexual maturity)**
- The genes of different parent species do not interact properly.
- It affects the hybrid's development or its survival
- Most hybrids do not complete development
- Hybrids die in embryonic stage before they reach

Postzygotic barrier: Reduced Hybrid Fertility

- **Hybrid offspring is developed/produced but sterile (fail to produce gamete)**
- If the chromosomes of the two parent species differ in number/structure, hybrids may fail to produce normal gametes during meiosis
- Infertile hybrid also cannot produce offspring if they mate with either parent species (no gene flow)



Figure 32

Postzygotic barrier: Hybrid Breakdown



In strains of cultivated rice, hybrids are vigorous but plants in next generation are small & sterile.
On path to separate species.

Figure 33

- **Some F_1 hybrids are viable and fertile**
- **but** when they mate with each other or with either parent species, **F_2 generations are weak or sterile.**
- F_2 hybrid shows hybrid breakdown, cannot reproduce due to some defect.

(ii) Genetic drift

- Refers to a **gradual change in allele frequencies of a gene pool within population due to chance from random events**

- **Reduce genetic variation**
- Shift the **Hardy-Weinberg equilibrium.**
- Effects are more severe in a small population but insignificant in very large populations.

- **Two types :**
  - Founder effect
  - Bottleneck effect

Tips LKC!!

Founder effect (√); Founder principle (x)

Bottleneck effect (√); Bottle neck effect (x)

Genetic drift : Founder effect

- Definition: **Genetic drift that occurs when a few individuals become isolated from a larger population and form a new population** whose gene pool is different from original population. *(Campbell 12th ed 2021, G-14)*
- Occurs when **small population is isolated/migrated from the original/main population**
- By chance, the **allele frequencies of new smaller population may not be the same with original population**.
- They will become pioneer organism in the new area
- **Small pioneer population has less genetic variation from original population**
- Causes **genetic drift in small pioneer population**

Genetic drift : Founder effect

- Mutation and natural selection occurs in the pioneer population over several generations **produces new allele frequency that is different from the original population.**
- Causing **certain alleles in the pioneer population maybe eliminated, overrepresented or underrepresented**

Genetic drift : Founder effect

- Example: in 1814, 15 British colonists founded a settlement on a small island, Tristan da Cunha in Atlantic Ocean.
- 1 out of 15 people carried a recessive allele for retinitis pigmentosa, a progressive form of blindness that affects homozygous individuals.
- 4 out of 240 descendants had retinitis pigmentosa in late 1960s
- The frequency of recessive allele that causes this disease is 10 times higher on this island than in the population from which the founders came.

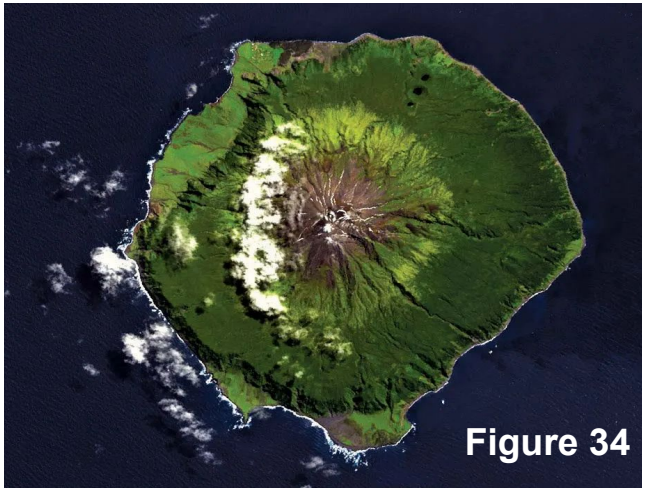


Figure 34

Genetic drift : Bottleneck effect

Definition: **Genetic drift that occurs when the size of a population is reduced by a natural disaster or human actions.** *(Campbell 12th edition (2021) , G-5)*

- Occurs when a population undergoes a **sudden decrease in the original population size which is caused by natural disasters or human action.**
- The natural disaster randomly eliminates a major proportion of the population.
- **Small surviving population has less genetic variation from the original population.**
- Causes **genetic drift in small population of survivors.**

Tips LKC!!
For bottleneck effect:
- Must use sudden decrease in population size
- Must use small surviving population
- Less/decrease/reduce the genetic variation (√) Change/different/alter the genetic variation (x)

Genetic drift : Bottleneck effect

- A **small population that survives has a different allele frequencies compared to original population**
- They contribute genes to the entire future populations.
- **Certain alleles may be eliminated, underrepresented or overrepresented by chance** regardless whether that allele is beneficial or harmful.

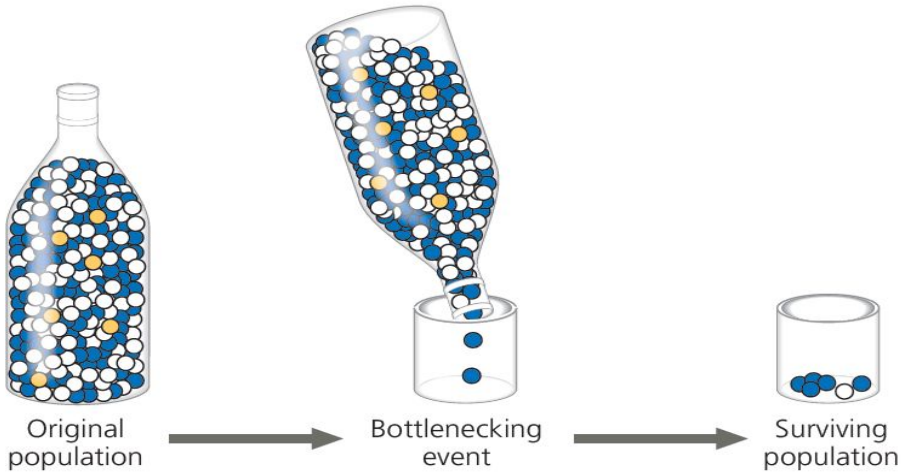


Figure 35

Tips LKC!!

For bottleneck effect:

- Change/different/alter the allele frequency (√)
- Reduce/decrease the allele frequency (x)
- Change/different/alter gene pool (√)
- Reduce/Decrease gene pool (x)
- Certain allele eliminated …… (√)
- Certain gene/genotype eliminated …..(x)
- Overrepresented (√) , more represented (x)
- Underrepresented (√) , less represented (x)

Genetic drift : Bottleneck effect

- **Example** : Cheetahs
- Very small allele diversity in cheetah's gene pool (<1%)
- As if all cheetahs are identical twins.
- Caused by 2 bottleneck effects:
  1. Ice age (~10,000 years ago)
  2. Poaching & lost of habitat (~100 years ago)

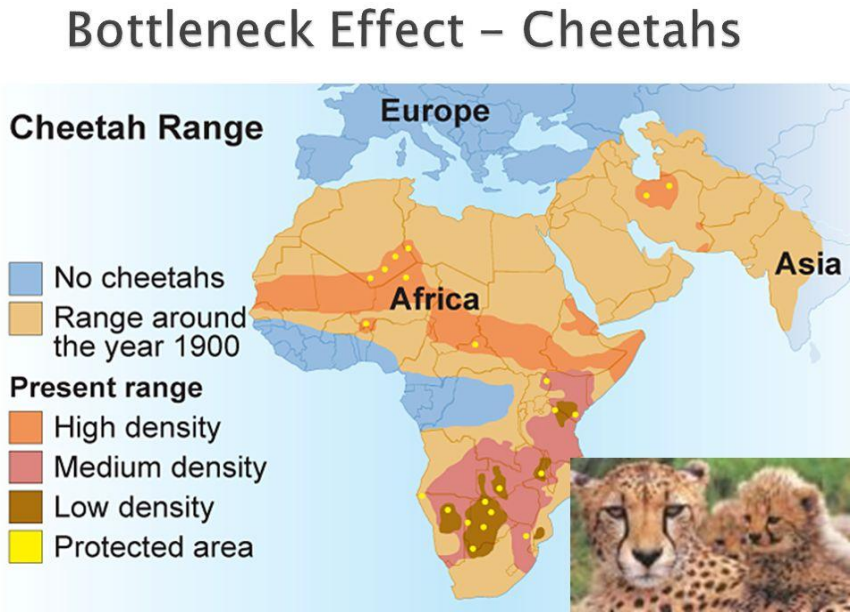


Figure 36

(iii) Hybridization

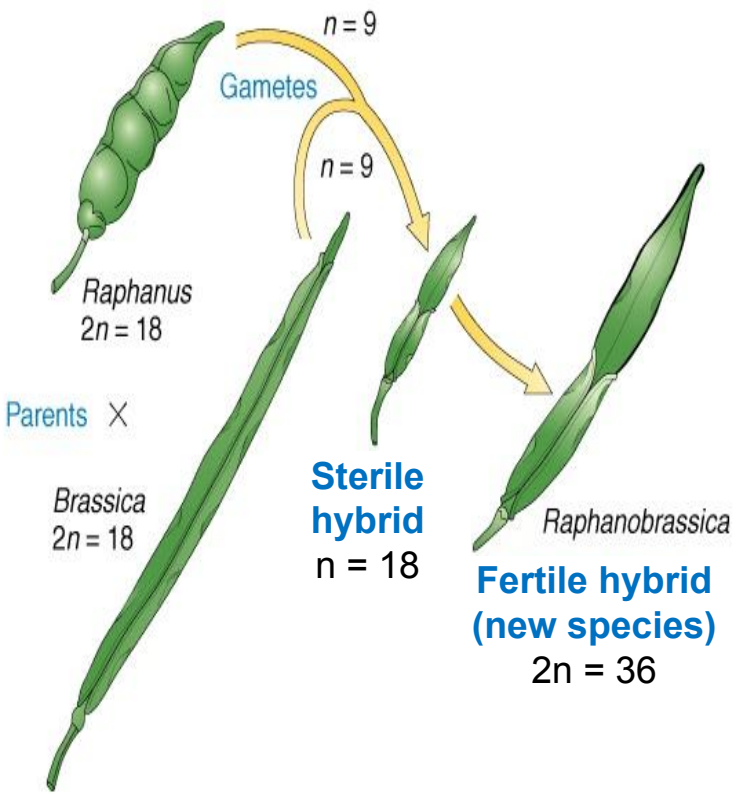


Figure 37

- **Production of hybrid (new species) through interbreeding between two different species (that are closely related)**
- Crossing between different species produces **sterile F_1 hybrids** because its chromosomes are not homologous.
- Nondisjunction during meiosis of F_1 hybrid results in **fertile F_2 generation**
- **Allopolyploidy can directly cause speciation** because it can overcome hybrid sterility (form new species)

(iv) Adaptive Radiation

- Definition: **Evolutionary change of one or a few ancestral species forming many new species when they are adapted to different ecological roles/niche in their communities.**
- These different species **share a homologous structure which is modified to perform variety of functions (as adaptation to different habitat)**
- Usually occurs when many ecological opportunities are not yet exploited, have less competition.

Homologous structure :
Structure in different species that are similar because they originate from a common ancestor

(iv) Adaptive Radiation

E.g: Galapagos finches :
The size and shape of beaks are adapted for specific diet.

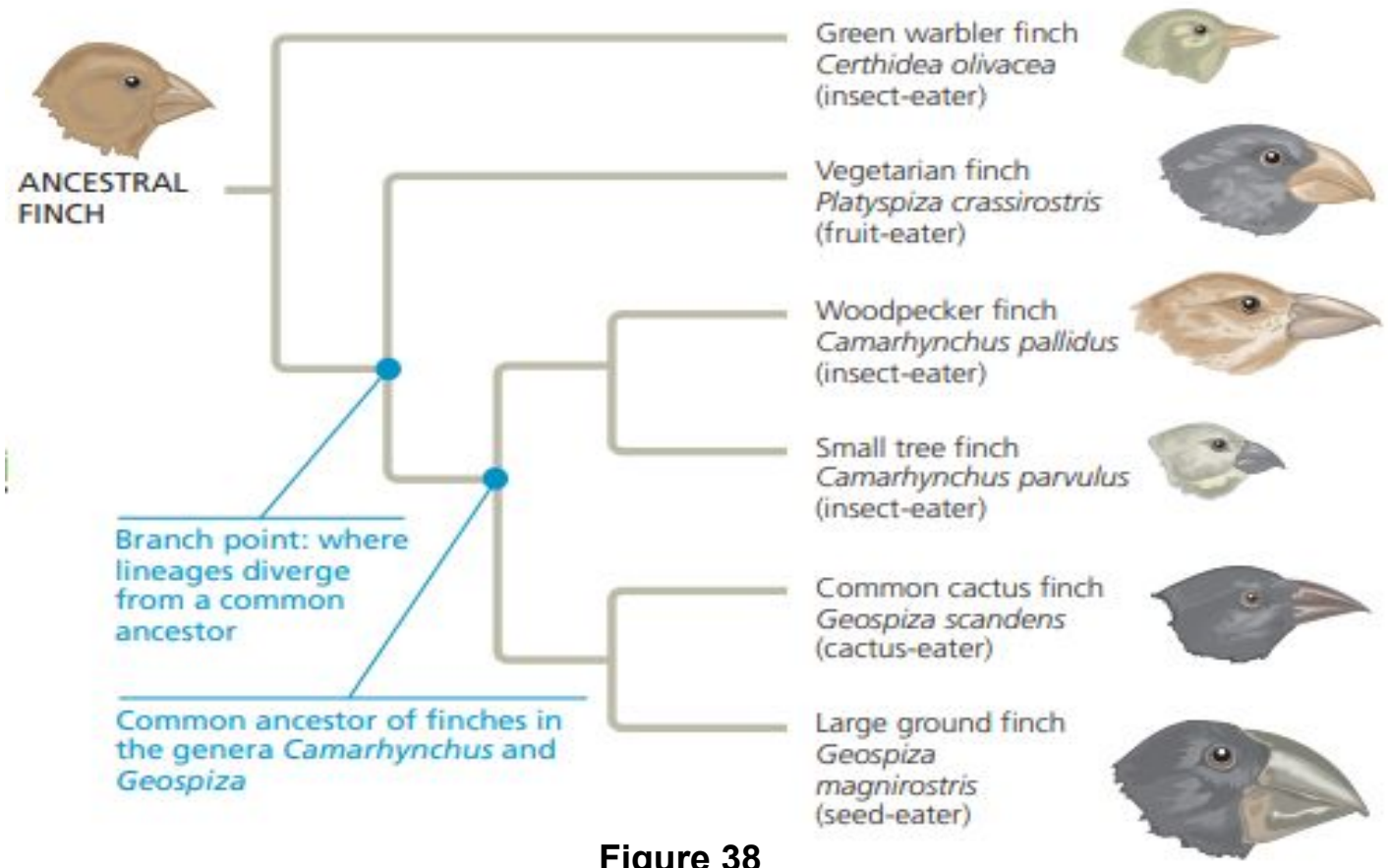


Figure 38

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