Evolution ... is opportunistic, hence unpredictable.

Ernst Mayr

# Speciation





# Macroevolution

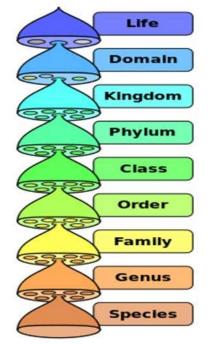
- Major Changes
- Whole Taxonomic Groups
- Factors
  - Reproductive Isolation
  - Rate
    - Gradual
    - Punctuated
      - Mass Extinction
      - Low competition
      - Stable Environment

#### Supporting Evidence

- Fossils
- Living Organism
  - Homologous
  - Analogous
  - Vestigial

### Macroevolution

- Macroevolution: Largescale evolutionary changes including the formation of new species and taxa
- We can examine this to study evolutionary relationships between species



### Macroevolution Describes Large-Scale Alterations in Form

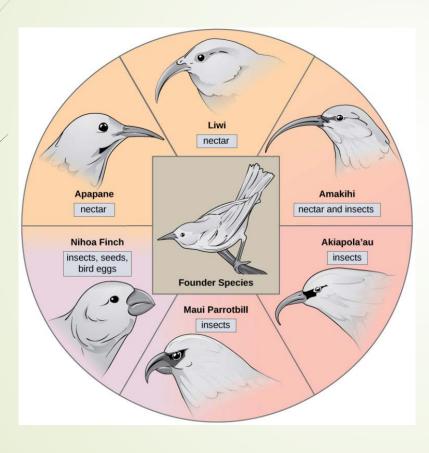
- Organisms differ radically in form, in embryological development, in body plans, in behavior, and in ecology.
- Macroevolution refers to large-scale changes in organisms, generally occurring over millions of years.

The body plan of whales has been radically altered by adaptations to aquatic life compared with the body plan of their terrestrial ungulate (hoofed) ancestors.

#### **Evolution of the Whales** The oldest whale ancestor. Pakicetus, lived on land 53 million years ago. Pakicetus 1.8 meters long, 53 mya Ambulocetus 4.2 meters long, 49 mya Ambulocetus had strong, well-developed legs and probably was semiaguatic, living at the water's edge and hunting in much the same way that a crocodile does today. In Rodhocetus, the body was more streamlined and the front legs were Rodhocetus shaped more like flippers. 3 meters long, 48 mya By 40 mya, Dorudon Dorudon was fully aquatic. 4.5 meters long, 40 mya Orcinus orca (killer whale) 4.5-9.1 meters long, 00 mya

Discover Biology, 6/e Figure 16.1 © 2015 W. W. Norton & Company, Inc.

# Macroeveolution: Adaptive Radiation





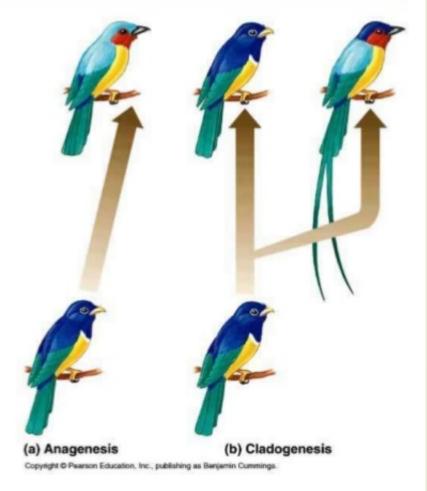
### **Two Patterns of Speciation**

#### 1. Gradualism (Anagenesis)

A slow, gradual accumulation of heritable changes (adaptations) in a population, due to many small episodes of natural selection. So, one species changes slowly, stepby-step, until it looks so different that we call it a new species.

#### 2. Branching (Cladogenesis)

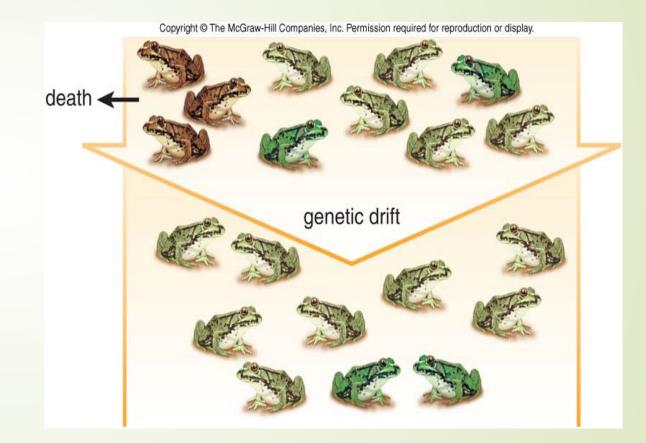
A more rapid splitting of one or more new species from an original species that may or may not continue to exist. So one species branches into two or more new ones. This process is the basis for all biological diversity.



#### Time

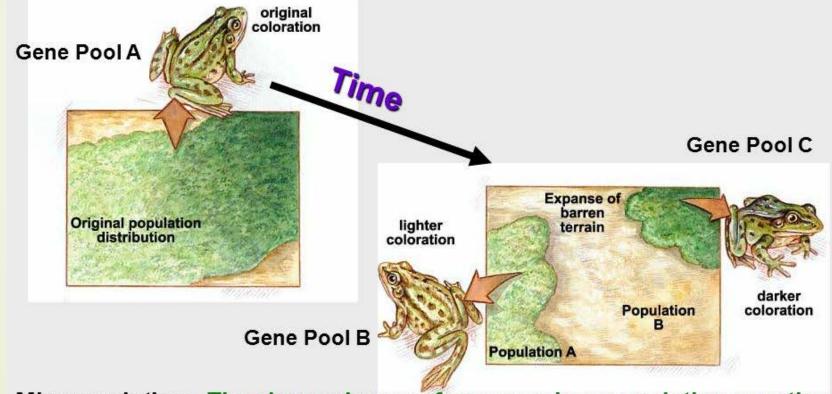
# Microevolution

- Survival through inheritance
  - Gene Pool Population
  - Change in allele frequencies
  - Time: one generation to the next
- Causes
  - Gene Flow
  - Genetic Drift
  - Mutations
  - Inbreeding
  - Selection
    - Artificial
    - Natural  $\rightarrow$  Adaptation



The Evolution of Population: The Mechanisms of Microevolution

- I. Evolution (What actually changes?)
  - A. Gene frequency: the amount of a particular allele as found in the gene pool
  - B. Gene Pool: sum total of all the alleles in a population

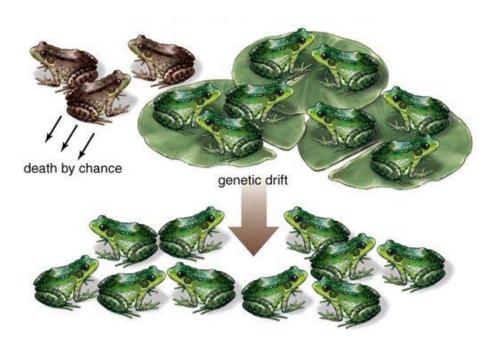


Microevolution: The change in gene frequency in a population over time

### What are some causes of microevolution-

- Genetic mutations
  - Increases diversity
- Gene flow Into or out of
  - More gene flow = less diversity
- Nonrandom mating
  - Inbreeding decreases diversity
  - Assortative mating
  - Sexual selection
- Genetic drift
  - Random change in allele frequencies





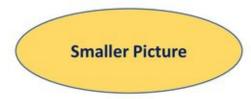
# Macroevolution/Microevolution



Dog Variability When bred for certain traits, dogs become different and distinctive. This is a common example of microevolution—changes in size, shape, and color—or minor genetic alterations. It is not macroevolution: an upward, beneficial increase in complexity.

### MICROEVOLUTION

- Mutations & Gene shuffling
- Natural selection of traits
  - Single gene traits
  - Polygenic traits
- Genetic drift
- Gene flow



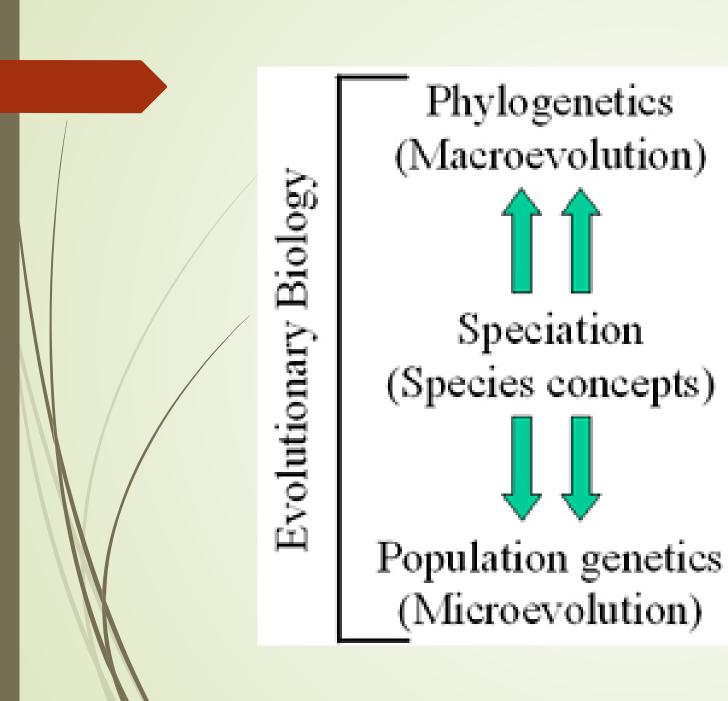
## MACROEVOLUTION

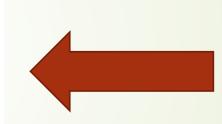
#### **Mutations**

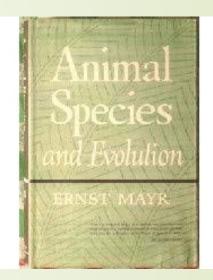
Natural selection + 3.8 billion years = Macroevolution Genetic Drift Gene flow

- Adaptive radiation
- Convergent & divergent evolution
- Coevolution
- Gradualism
- Punctuated equilibrium
- Mass extinction



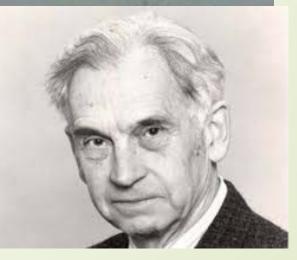


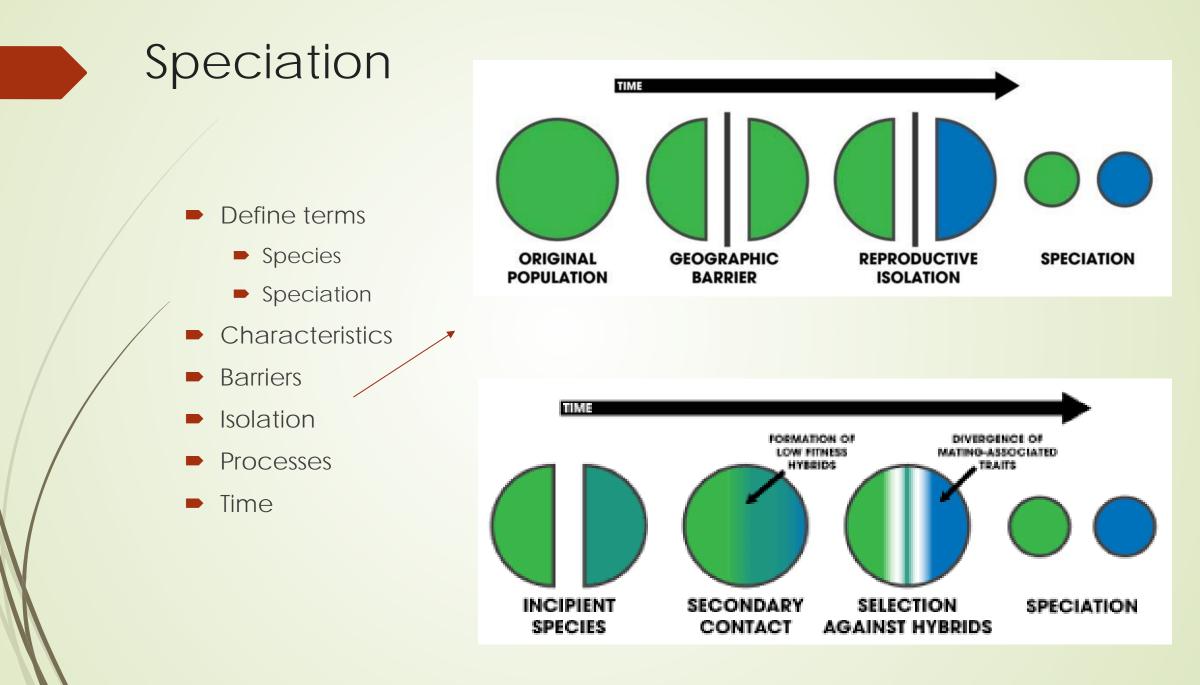




A species is a reproductive community of populations reproductively isolated from others that occupies a specific niche in nature.

### Ernst Mayr





Natural selection and genetic drift can change the relative frequencies of alleles in a population and lead to speciation.

Speciation is the formation of new species.

A species is a group of organisms whose members can interbreed with one another and produce fertile offspring.

This means that the members of a species share a common gene pool. A genetic change in one individual can spread through the population if it increases fitness.

Slide 2 of 33

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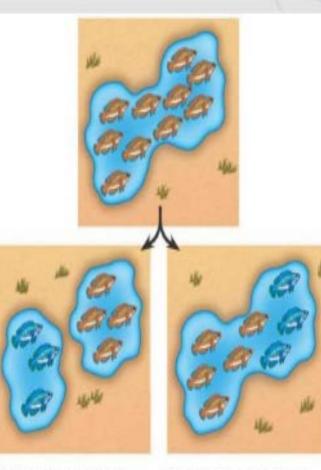


# **Causes of Speciation**

- Populations must become isolated
  - geographically isolated
    - allopatric
      - » geographic separation; "other island"
    - <u>sympatric</u>
      - » still live in same area; "same island"

### reproductively isolated

- -before fertilization (prezygotic barries)
- -after fertilization (postzygotic barriers)
- isolated populations evolve independently

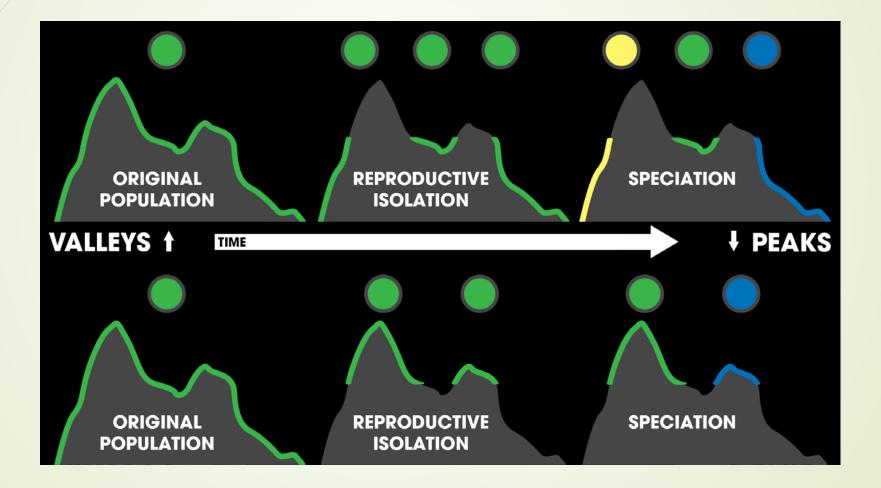


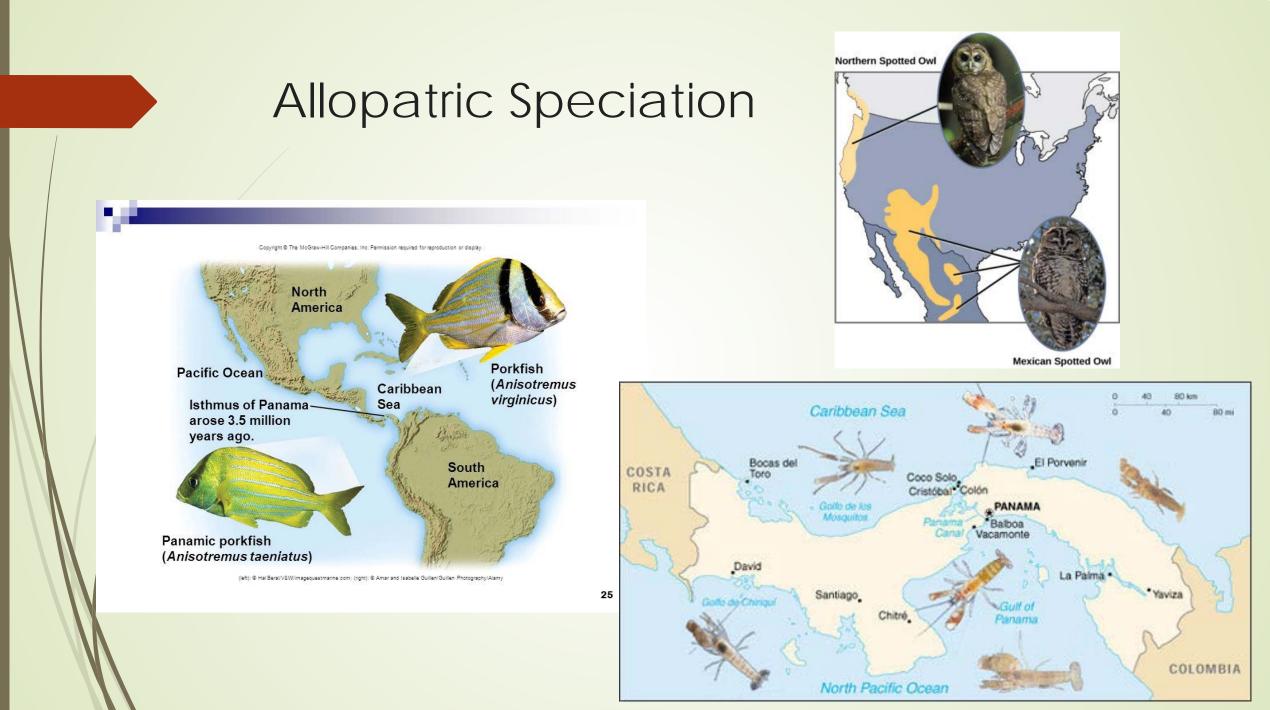
(a) Allopatric speciation. A pop- (b) Sympatric speciation. A

# Geographic Modes of Speciation

Mode of speciation	New species formed from	
Allopatric (allo = other, patric = place)	geographically isolated populations	激感感 微感感 化氨酸 化氨酸酸 化氨酸酸 化氨酸酸 化乙基基化 化乙基基化 化乙基基化 化乙基 化乙基 化乙基 化乙基
Peripatric (peri = near, patric = place)	a small population isolated at the edge of a larger population	微微 微感液液液 低 微感
Parapatric (para = beside, patric = place)	a continuously distributed population	微微微微 演 微 微 微 微 微 微 微 微 微 微 微 微 微 微 微 微 微
Sympatric (sym = same, patric = place)	within the range of the ancestral population	● 依然低 @ 成 成 依然 低 g g g g g g g g g g g g g g g g g g g

# Geographic Barriers

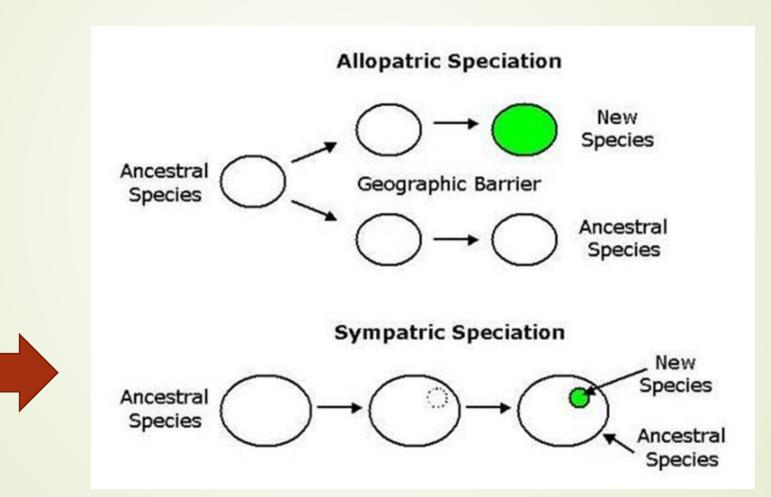




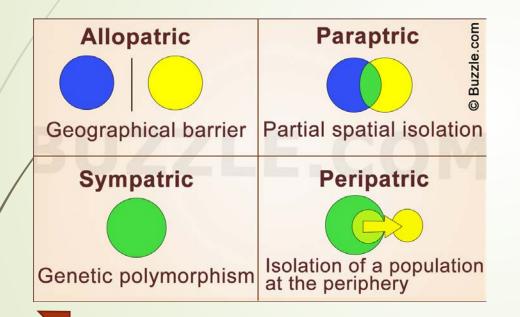


Allopatric	Paraptric
Geographical barrier	Partial spatial isolation
Sympatric	Peripatric
Genetic polymorphism	Isolation of a population at the periphery

# Sympatric Speciation

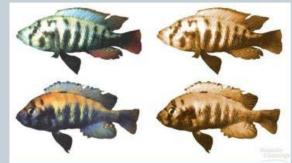


# Sympatric Speciation

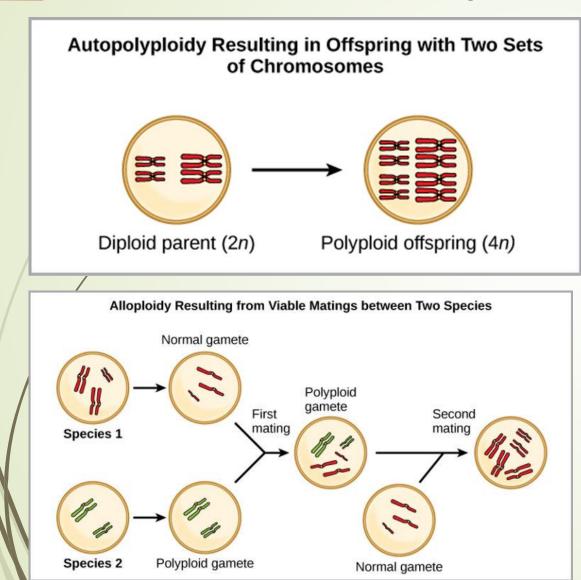


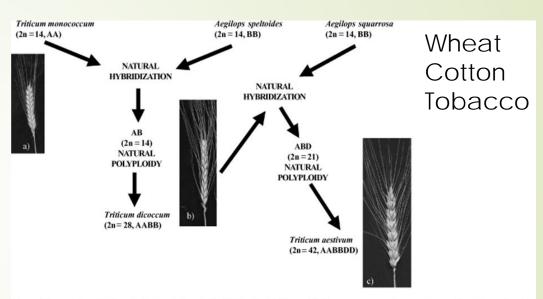
### An Example of Sympatric Speciation

- Individuals of two closely related sympatric cichlid species will not mate under normal light because females have specific color preferences and males differ in color.
  - However, under light conditions that de-emphasize color differences, females will mate with males of the other species and this results in viable, fertile offspring.
  - The lack of postzygotic barriers would indicate that speciation occurred relatively recently.



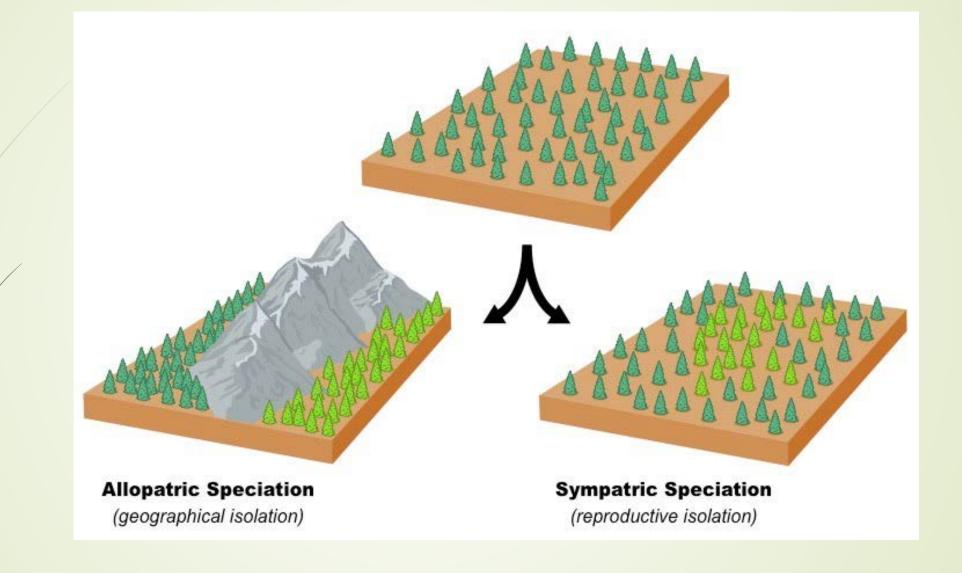
## **Causes for Sympatric Speciation**





**Figure 1** - Synoptic chart of cultivated wheats evolution: the diploid (2n = 14, AA) forms of *Triticum monococcum* (**a**) were naturally pollinated by weed species, possible *Aegilops speltoides* (2n = 14, BB?), in about 10,000 B.C. primitive farms. The subsequent genome duplication of hybrids by natural polyploidy gave rise to several wild and cultivated tetraploid species (2n = 28, AABB) like *Triticum dicoccum* (**b**) and *Triticum durum* (Figure 2a); again, the natural pollination of the tetraploid *T. dicoccum* (**b**) by another weed species, *Aegilops squarrosa* (2n = 14, DD) gave rise to the hexaploid (2n = 42, AABBD) species (**c**).

Polyploidy



# Reproductive Barriers → Speciation

Seasonal
Ecological
Behavioral
Mechanical
Mutations

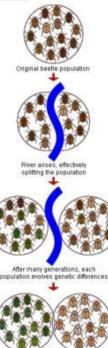
### What can cause speciation?

### 2. REPRODUCTIVE ISOLATION

- •Organisms can no longer mate to produce offspring
- •Timing
- Behavior
- Habitat
- Infertile Hybrid offspring

### Sympatric Speciation

 New species arise as a result of reproductive isolation



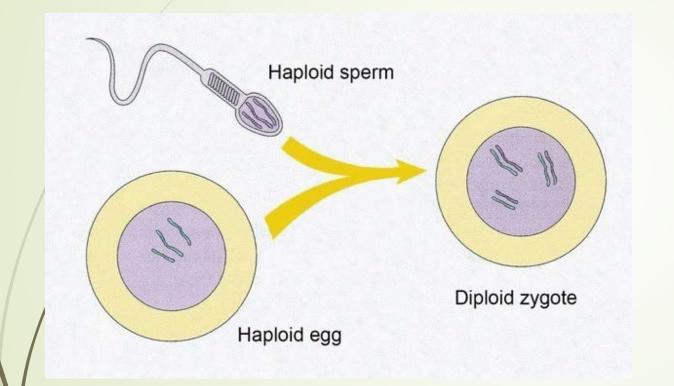
# **Species Characteristics**



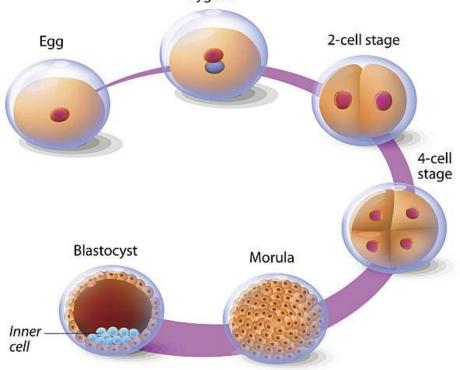
### African Fish Eagle

American Bald Eagle

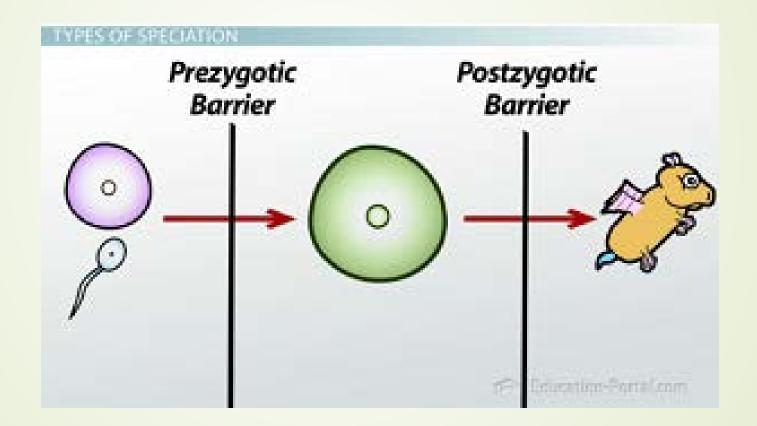
# Zygote Review



### DEVELOPMENT OF THE EMBRYO Zygote



# Prezygotic and Postzygotic Reproductive Barriers



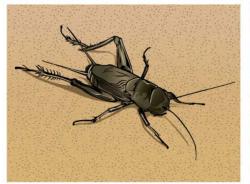
# Prezygotic Barriers: Environmental

### Temporal

### Habitat (Ecological)



(a)



(a) Gryllus pennsylvanicus prefers sandy soil.



(b) Gryllus firmus prefers loamy soil.

# Prezygotic Barriers: Behavioral

### Prezygotic barriers: Behavioral isolation

#### • Unique behavioral patterns & rituals isolate species

- identifies members of species
- attract mates of same species  $\Box$ 
  - courtship rituals, mating calls
  - reproductive isolation





Blue footed boobies mate only after a courtship display unique to their species

### **Behavioral Isolation**

- When two populations are capable of interbreeding but don't since they have differences in reproductive strategies that involve behavior. (*Eastern/Western Meadowlark*)
- They use different songs to attract mates.



#### Mating Songs

#### Courtship rituals

# Prezygotic Barriers: Mating and Gametes

Plants

### Prezygotic barriers: Mechanical isolation

- Morphological differences can prevent successful mating
  - reproductive isolation

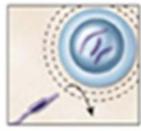
Even in closely related species of plants, the flowers often have distinct appearances that attract different pollinators. These 2 species of monkey flower differ greatly in shape & color, therefore cross-pollination does not happen.





**A) Prezygotic Barriers** 

- A5) Gametic Isolation
  - **oPrevention of Gamete Fusion**
  - Sperm can only fertilize correct egg
  - Usually chemically-based (protein receptors on cell membranes)







### **Peripatric Speciation**

- Reproductive isolation evolves in a small population, isolated from its parent population.
- Also known as founder effect speciation.
- Genetic divergence arises largely through genetic drift and natural selection.
- Proposed explanation for the rapid speciation of Hawaiian Drosophila.



Hawaiian fruit fly Drosophila setosimentum



### **BioEd** Online

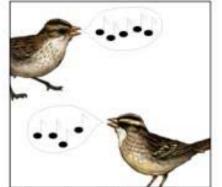


### **Prezygotic barriers**

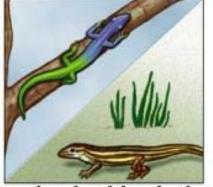
Obstacle to mating or to fertilization if mating occurs



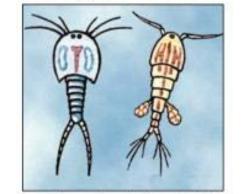
geographic isolation



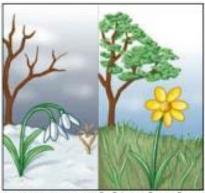
behavioral isolation



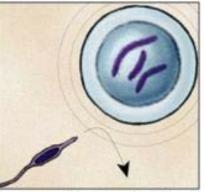
ecological isolation



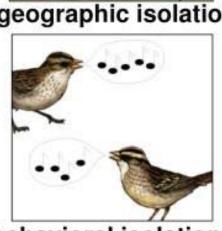
mechanical isolation



temporal isolation



gametic isolation



# Postzygotic barriers

- Prevent reproduction in offspring
- Examples
  - Hybrid Inviability (Zygotic Mortality)
  - Hybrid Breakdown (F2)
  - Hybrid infertility (sterility)

Hybrid survives Can not reproduce

#### One postzygotic barrier is <u>hybrid sterility</u>

• Where hybrid offspring between two species are sterile and therefore cannot mate.

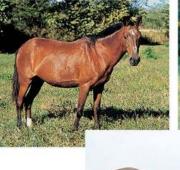
#### **Hybrid Inviability**

• In other cases the hybrid does not survive

#### Hybrid Breakdown

1<sup>st</sup> generation is fertile,
2<sup>nd</sup> generation is either sterile or produce feeble offspring.

#### Horse x Donkey → Mule







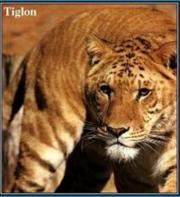
# Hybrid Sterility: F2 reduced fitness

- Hinny
  - Donkey x Stallion
- Cama (F Llama x M Camel)
- Zebra
  - Zedonk
  - Zebroid
  - Zorse
  - Zonkey
  - Zony
- Leopon
  - Lioness x Leopard
- Lipard
  - Leopardess x Lion

### Postmating Isolating Mechanism: Hybrid Breakdown



Liger



Tiglion

Hybrids of Lions and Tigers have been obtained through zoo breeding programs. While the first generation may be healthy, hybrids become weak or sterile in future generations.

Hybrid Breakdown

# Postzygotic Barrier: Hybrid Inviability

### **ZYGOTIC MORTALITY**



 Mating and fertilization are possible but genetic differences result in a zygote that is unable to develop properly

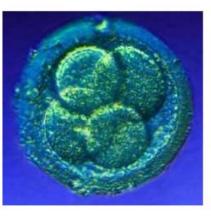
**EXAMPLE:** Sheep and goats may mate but the zygote is not viable

#### Fail to complete gastrulation

#### **Reproductive Isolating Mechanisms**

2) Postzygotic isolating mechanisms include:

i) Zygotic Mortality: The fertilized egg can not develop properly.



### Reduced hybrid fertility

- Even if hybrids are vigorous/viable they may be sterile
  - chromosomes of parents may differ in number or structure & meiosis in hybrids may fail to produce normal gametes





XX

Horses have 64 chromosomes (32 pairs)

Mules have 63 chromosomes!

chromosomes es! (31 pairs)

Donkeys have 62

# Hybrids that are Fertile

- Plants
- Birds (sparrows)
- Insects
- Some Mammals
  - Cats
  - Dogs

#### Beefalo

are a <u>fertile hybrid</u> offspring of domestic <u>cattle</u>, Bos taurus, and the <u>American Bison</u>



#### Summary

# **Types of Reproductive Barriers**

#### **Prezygotic Barriers:**

 Impede mating/fertilization

#### Types:

- Habitat isolation
- Temporal isolation
- Behavioral isolation
- Mechanical isolation
- Gametic isolation

#### **Postzygotic Barriers:**

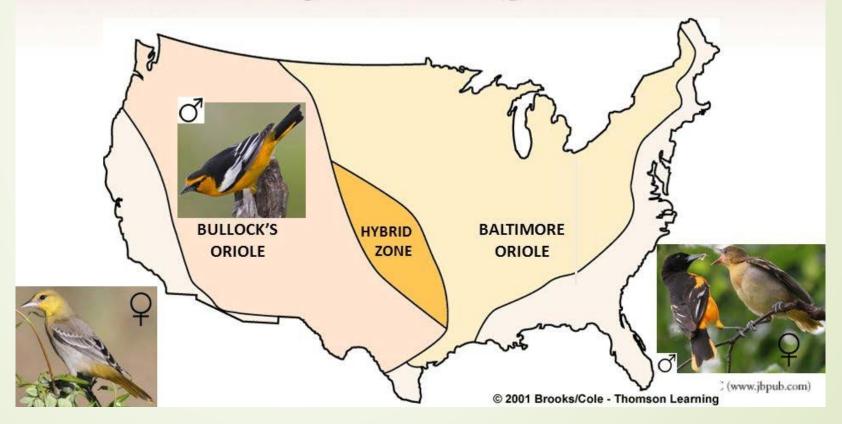
 Prevent hybrid zygote from developing into viable adult

#### Types:

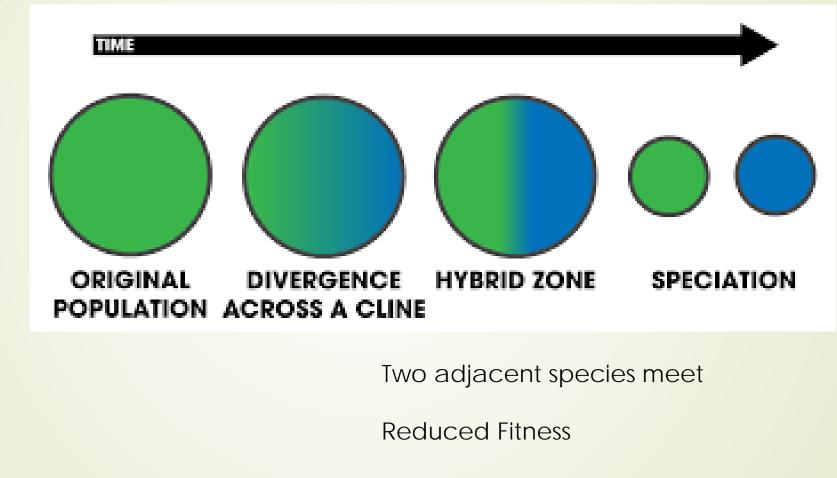
- Reduced hybrid viability
- Reduced hybrid fertility
- Hybrid breakdown

#### **Parapatric Speciation**

Adjacent populations evolve into distinct species while maintaining contact along a common border



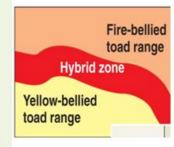
# Hybrid Zone



Complex interactions

Hybrid Zones cause reproductive isolation

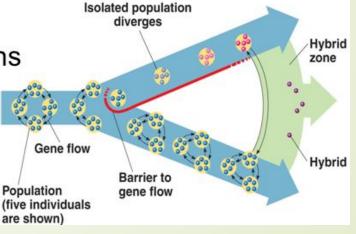
- 1. A <u>Hybrid Zone</u> is a region in which members of different species meet and mate, producing at least some offspring of mixed ancestry.
  - a. Narrow band pattern



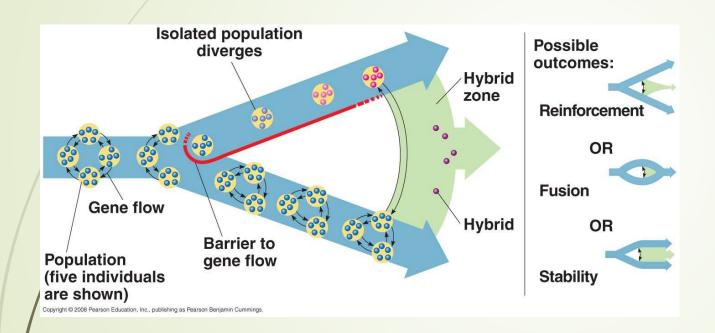
 there is an obstacle to gene flow
 obstacle is probably that hybrids have increased rates of embryonic mortality and a variety or morphological abnormalities (therefore, poor survival and reproductive rates)

b. Complicated spatial patterns

C. ENVIRONMENTAL CHANGES



# Hybrid Zones: A Reconnection



- Species
  - Closely Related
  - Interaction
- Zone changes
  - Reinforcement
  - Fusion
  - Stability
- Reproduction
  - New Species (hybrid)
  - Reconnection



- When closely related species meet in a hybrid zone, there are *three possible outcomes*:
  - Reinforcement -- Strengthening of reproductive barriers reducing gene flow.
  - Fusion -- Weakening of reproductive barriers with eventual fusion into one species.
  - Stabilizing -- Continued formation of hybrid individuals.

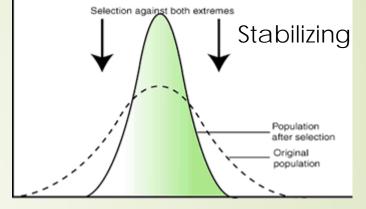
# Reproductive Results for Hybrids

<u> Peinforcement: Strengthening</u>

#### **Reproductive Barriers**

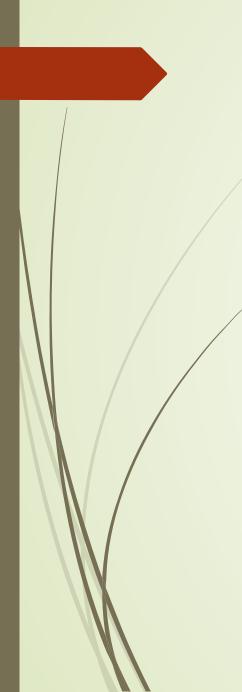
- The reinforcement of barriers occurs when hybrids <u>are less fit</u> than the parent species that is reproduce less successfully.
- Where reinforcement occurs, reproductive barriers should be stronger for sympatric than allopatric species

#### Reduced Gene Flow

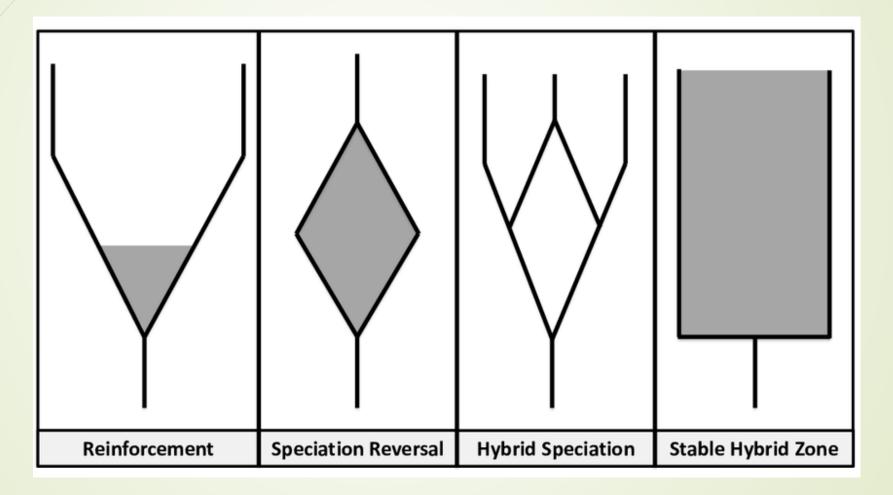


#### Fusion: Weakening Reproductive Barriers

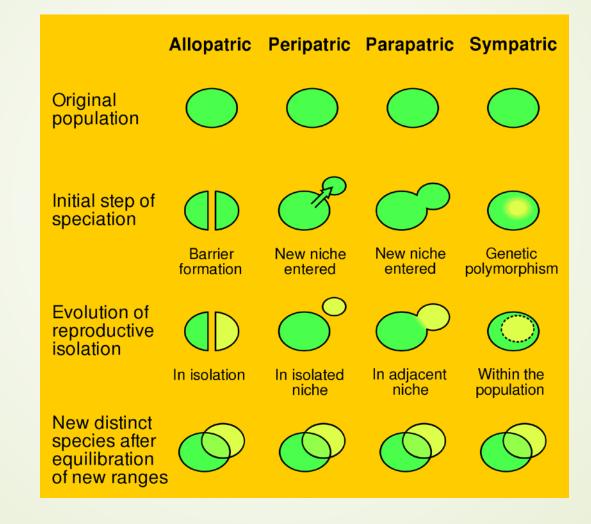
- If hybrids are as fit as parents, there can be substantial gene flow between species
- If gene flow is great enough, the parent species <u>can fuse into a</u> <u>single species</u>



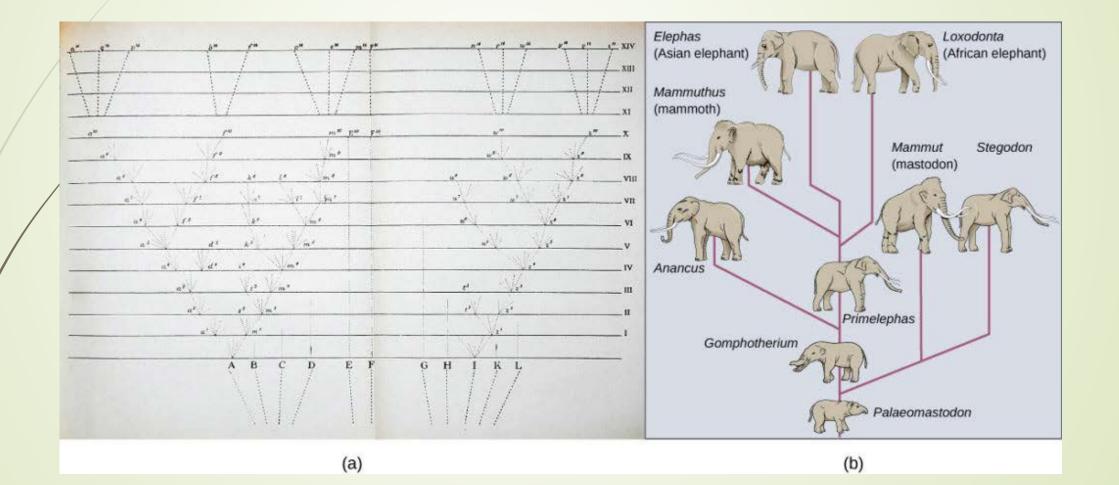
# Hybrid Outcomes



# **Speciation Types: Summary**

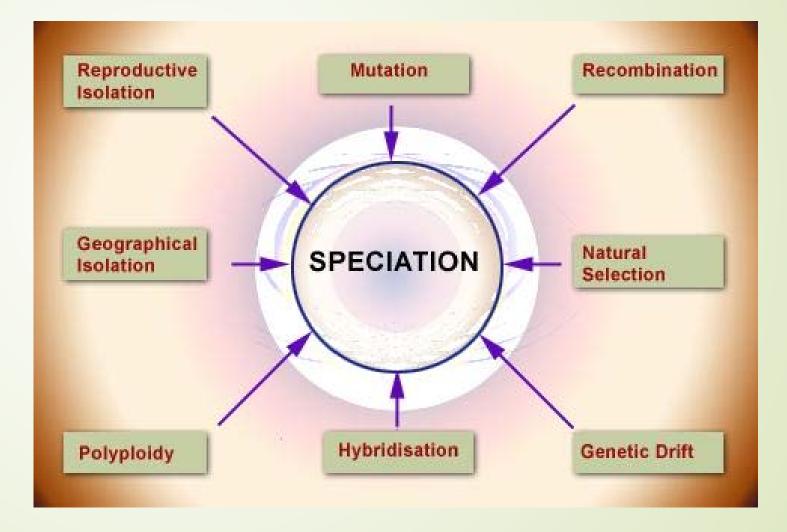


# Speciation $\rightarrow$ Biological Diversity

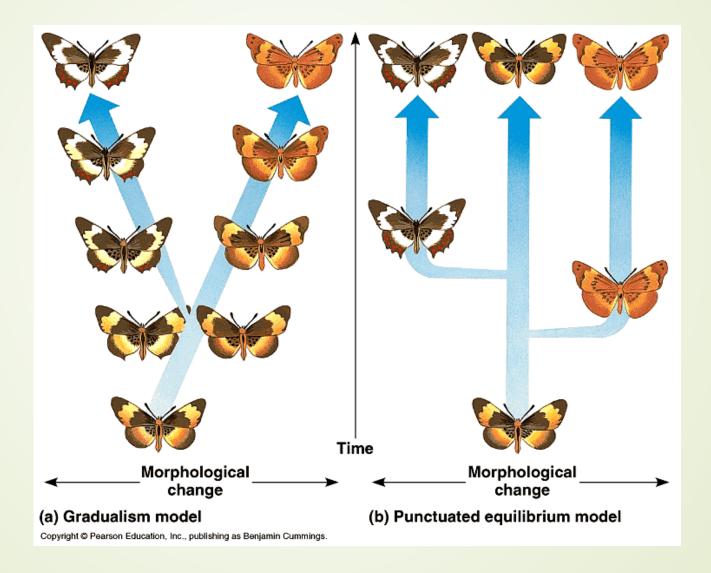


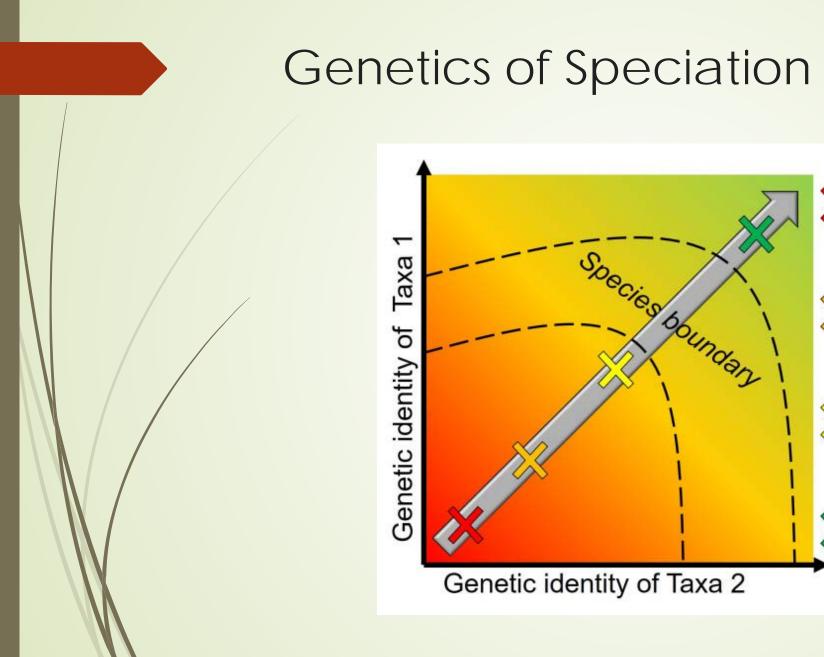
## **Species Concepts and Interactions**

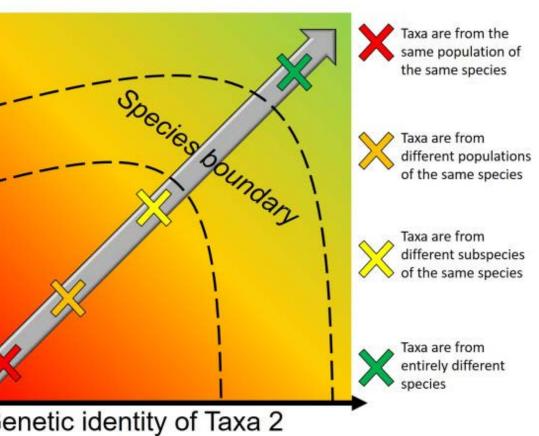
- Morphological
- Ecological
- Phylogenic



# Speciation rates



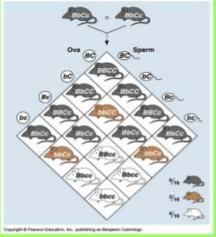




# Genetic Selection: Polygenic Traits

#### Polygenic Traits

- Traits are influenced by more than one gene
- Ex. skin color



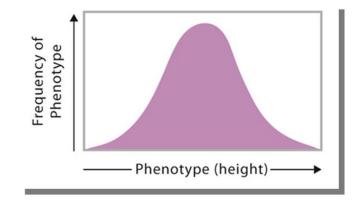
# **Natural Selection on Polygenic Traits** Oviginal populatio

# Fitness of Phenotypes

#### **Natural Selection on Polygenic Traits**

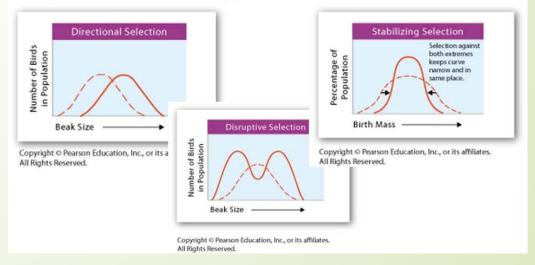
Natural selection on polygenic traits can produce three types of selection:

- directional selection
- stabilizing selection
- disruptive selection



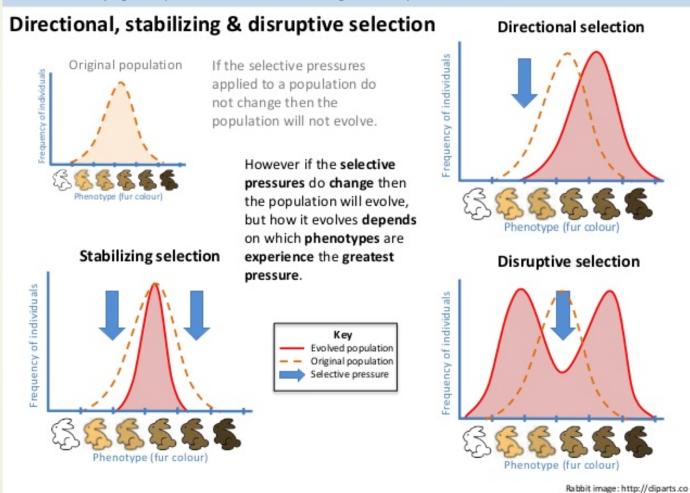
#### Natural Selection on Polygenic Traits

• Natural Selection on polygenic traits can affect the relative fitness of phenotypes and thereby produce one of 3 types of selection.



# Selective Pressures

10.3.A1 Identifying examples of directional, stabilizing and disruptive selection.



#### Genes and Variation

### Single-Gene and Polygenic Traits

- Single-Gene Trait
  - Controlled by one gene that has two alleles
  - Two distinct phenotypes
  - Ex: bands or no bands on snails

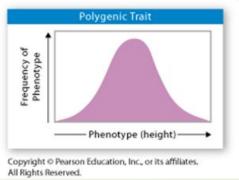
Single-Gene Trait

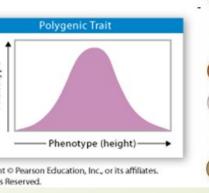
Without bands

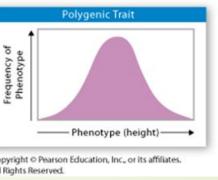
Phenotype

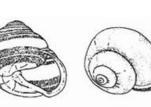
With bands

- Polygenic Trait
  - Controlled by more than one gene
  - Many possible genotypes and phenotypes
  - Ex: Human Height









Banded snail



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Relative Frequency of Phenotype (%)

Quantitative

Qualitative

10.2.U3 Variation can be discrete or continuous. AND 10.2.U4 The phenotypes of polygenic characteristics tend to show continuous variation.

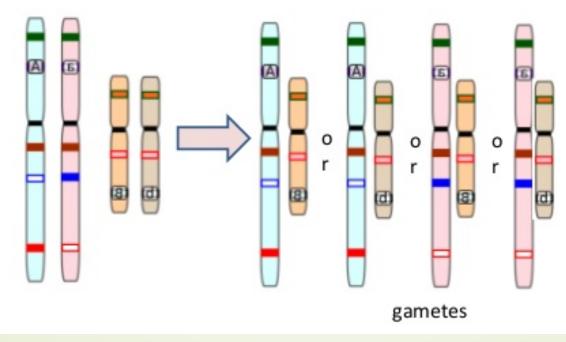
#### **Polygenic Inheritance of Skin Colour**

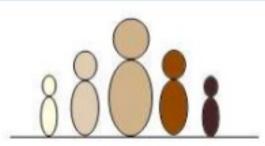
Example: 2 genes (A and B), 2 alleles each Assume: genes are not linked (separate chromosomes)

In polygenics, alleles can be:

- Contributing (they add to the phenotype)
- Non-contributing (they do not add to the phenotype)

How many genotypes are possible?





Key to alleles: A = add melanin a = don't add melanin B = add melanin b = don't add melanin

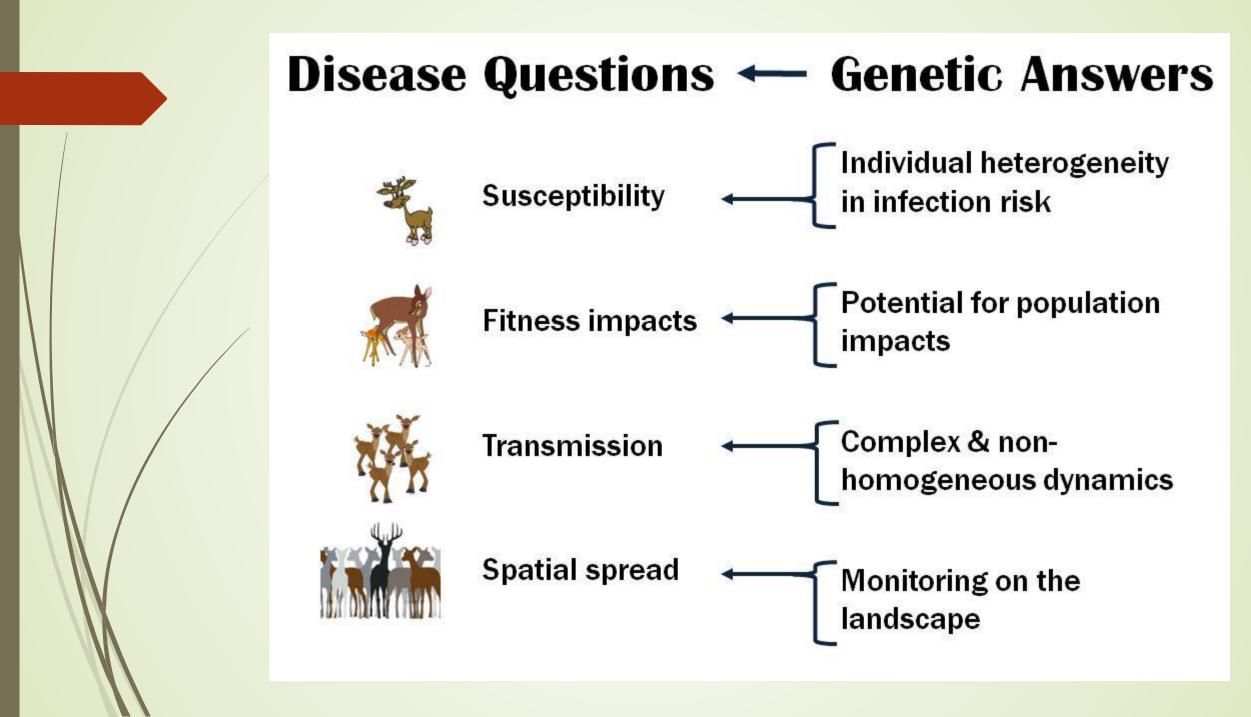
Remember that alleles segregate during meiosis.

Alleles of unlinked chromosomes orient randomly.

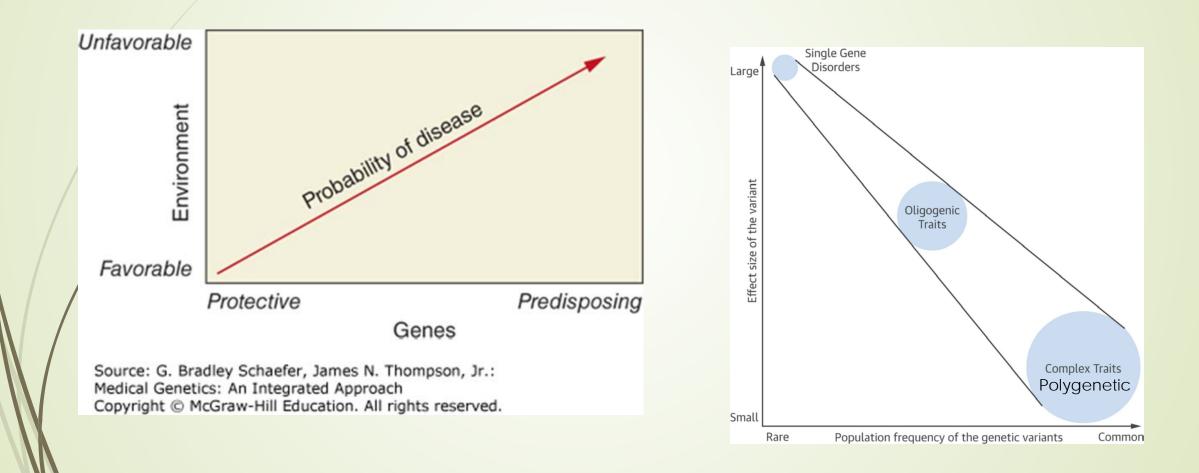
There is also random fertilisation of gametes.

So many combinations!

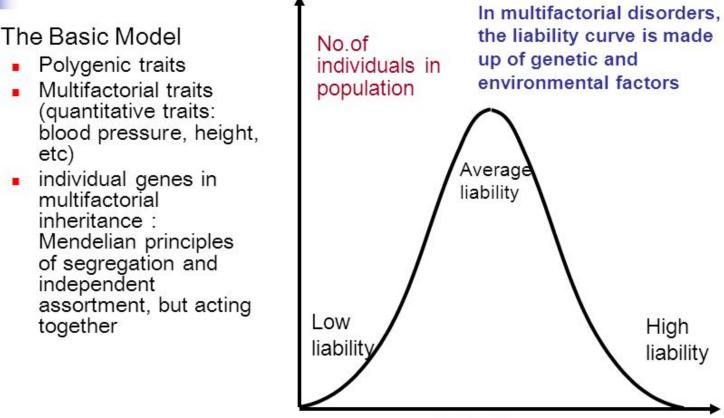




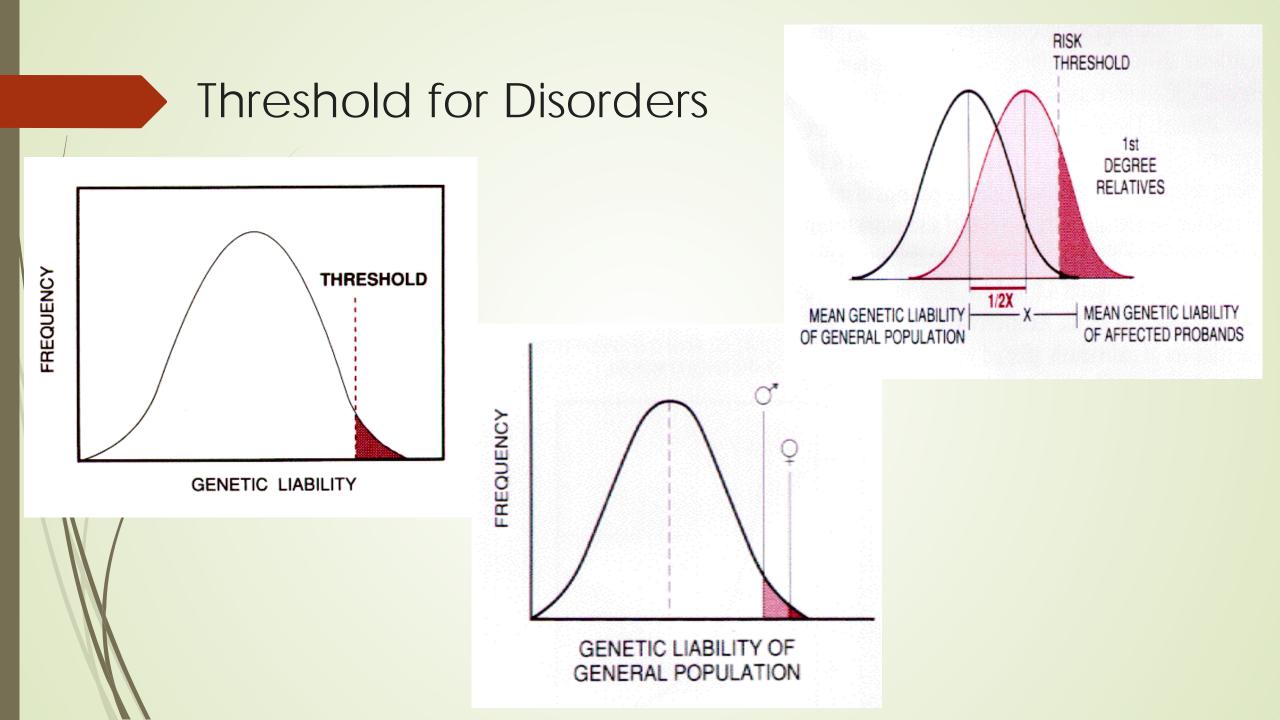
## Monofactoral vs Multifactoral



#### **Principles of Multifactorial Inheritance**

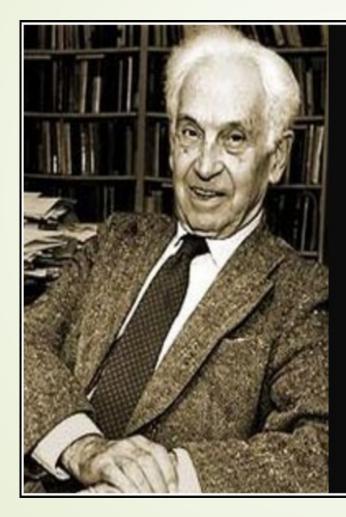


Liability





# Ernst Mayr quote:



Every politician, clergyman, educator, or physician, in short, anyone dealing with human individuals, is bound to make grave mistakes if he ignores these two great truths of population zoology: (1) no two individuals are alike, and (2) both environment and genetic endowment make a contribution to nearly every trait.

— Ernst Mayr —

AZQUOTES

I love the diversity of the world. I feel that one species, mankind, doesn't have the right to exterminate part of this creation, this wonderful evolutionary development, and that we must do our part to preserve what nature, what evolution, has produced.

- Ernst Mayr



