

Chapter 24

The Origin of Species

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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- **Speciation**, the origin of new species, is at the focal point of Darwin's evolutionary theory.
 - Evolutionary theory must explain how new species originate and how populations evolve.
 - **Microevolution** consists of adaptations that evolve within a population, confined to one gene pool.
 - **Macroevolution** refers to evolutionary change above the species level.

In the Galápagos Islands Darwin discovered plants and animals found nowhere else on Earth



The Biological Species Concept emphasizes reproductive isolation

- Biologists compare morphology, physiology, biochemistry, and DNA sequences when grouping organisms.
- The **biological species concept** states that a **species** is a group of populations whose members have the potential to **interbreed** in nature and produce viable, **fertile offspring**; they do not breed successfully with other populations.



(a) Similarity between different species



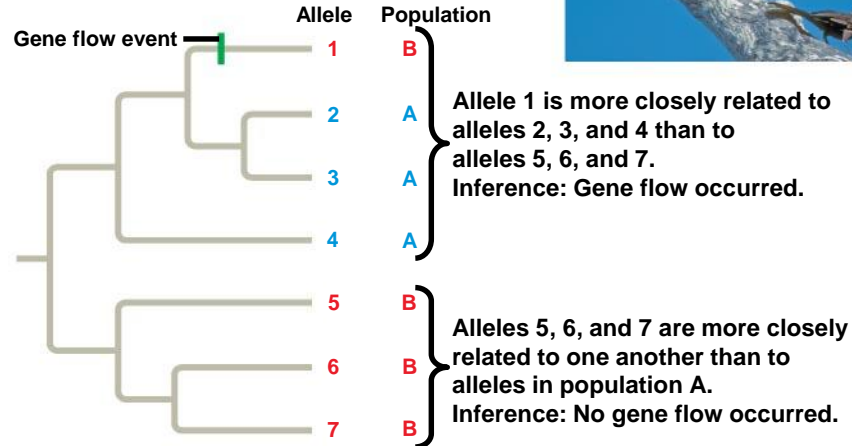
(b) Diversity within a species

Gene Flow Between Populations



EXPERIMENT

▼ Example of a gene tree for population pair A-B



RESULTS

Pair of populations with detected gene flow	Estimated minimum number of gene flow events to account for genetic patterns	Distance between populations (km)
A-B	5	340
K-L	3	720
A-C	2-3	1,390
B-C	2	1,190
F-G	2	760
G-I	2	1,110
C-E	1-2	1,310

Reproductive Isolation = Barriers to Interbreeding

- **Reproductive isolation** is the existence of biological **factors** (barriers) **that impede two different species** from producing viable, fertile offspring.
- **Hybrids** are the offspring of crosses between different species.
- Reproductive isolation can be classified by whether factors act before or after fertilization.

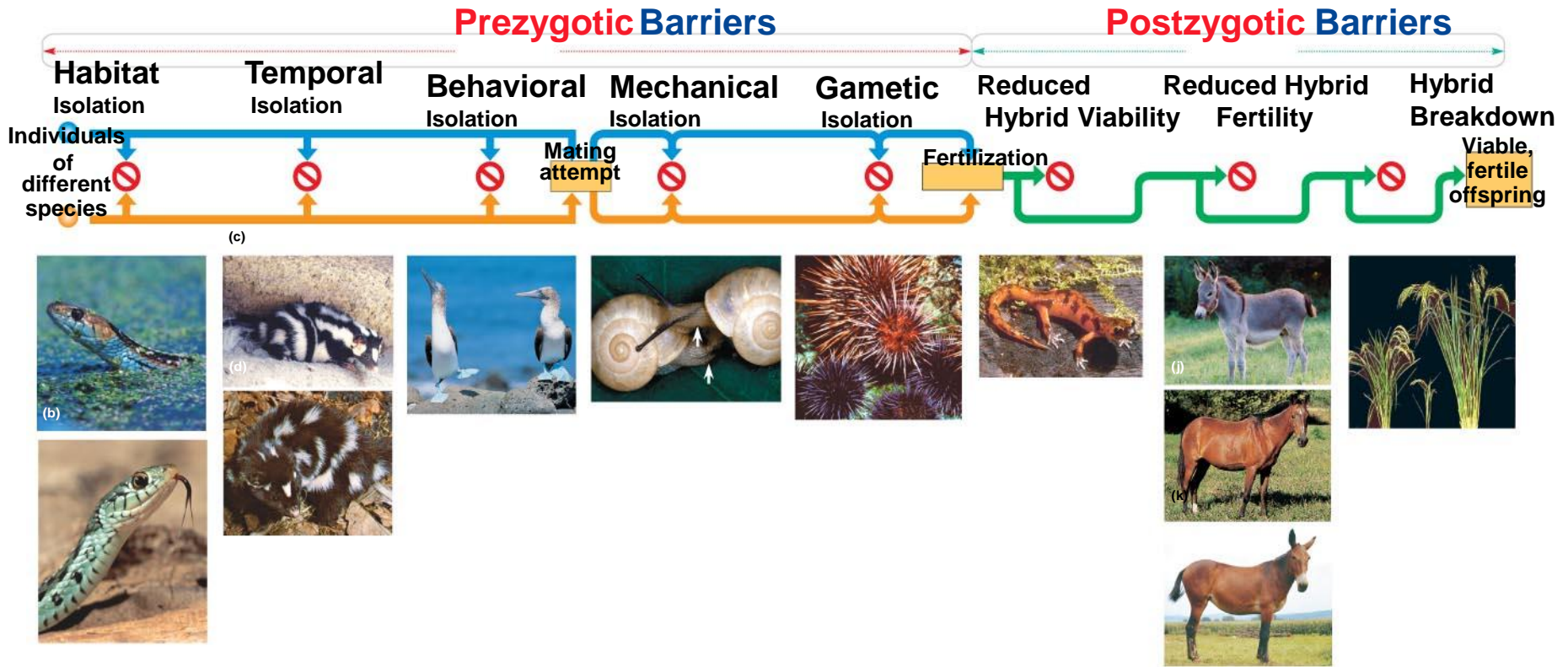
Reproductive Barriers Between Species

- **Prezygotic barriers** block fertilization from occurring by:
 - Impeding different species from attempting to mate.
 - Preventing the successful completion of mating.
 - Hindering fertilization if mating is successful.

Prezygotic barriers maintain ***reproductive isolation*** and include:

Temporal, Habitat, Behavioral, Mechanical, and Gamete Isolation.

Reproductive Barriers Between Species



PreZygotic Reproductive Barriers

- **Habitat isolation:** Two species encounter each other rarely, or not at all, because they occupy different habitats, even though not isolated by physical barriers.

Habitat Isolation



Water-dwelling *Thamnophis*

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Habitat Isolation



Terrestrial *Thamnophis*

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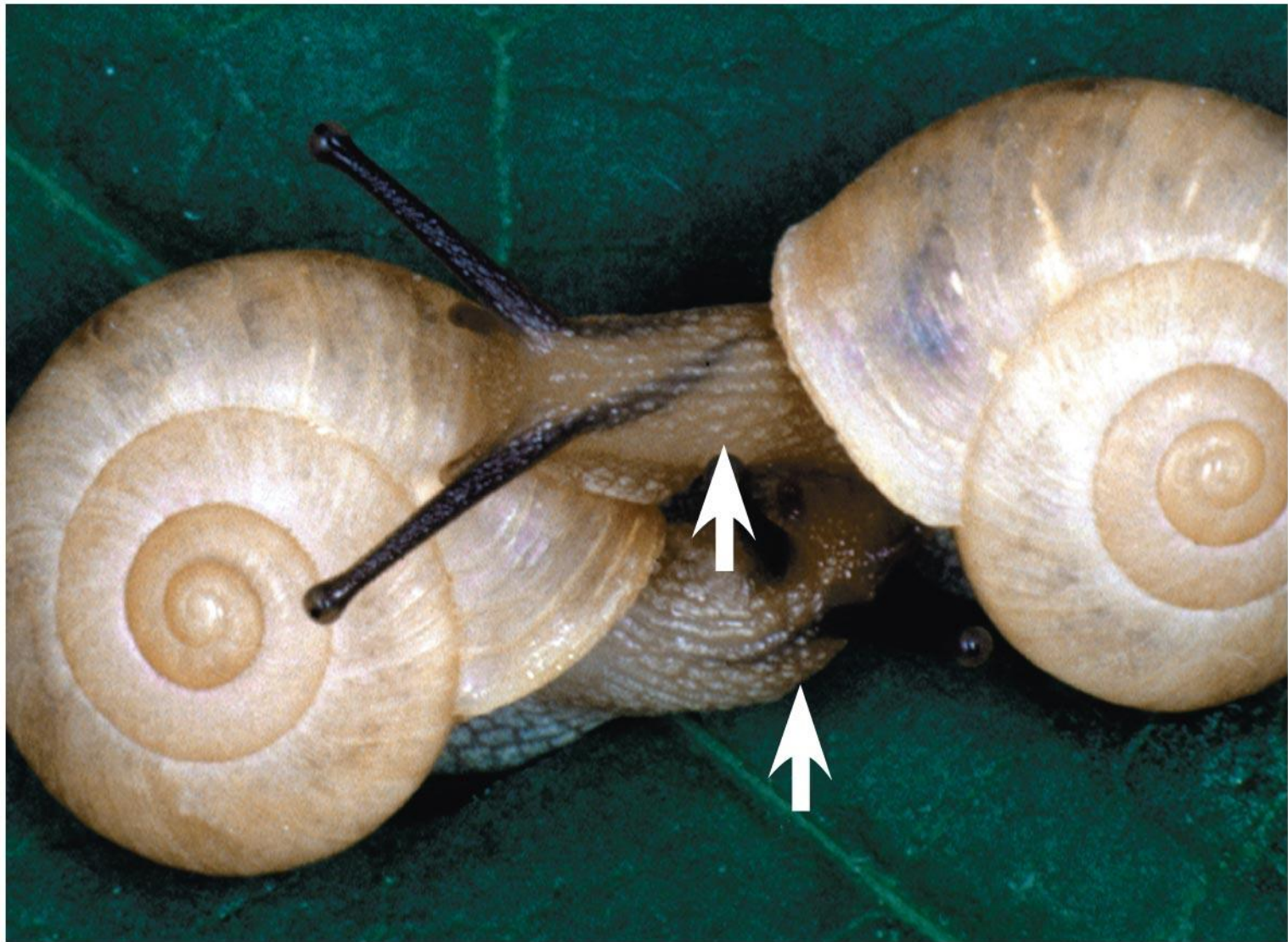
PreZygotic Reproductive Barriers

- **Temporal Isolation:** Species that breed at different times of the day, different seasons, or different years cannot mix their gametes.
- **Behavioral isolation:** Courtship rituals and other behaviors unique to a species are effective barriers.
- **Mechanical isolation:** Morphological differences can prevent successful mating.
- **Gametic isolation:** Sperm of one species may not be able to fertilize eggs of another species.

Behavioral Isolation Occurs Without Appropriate Mating Rituals



Courtship ritual of blue-footed boobies



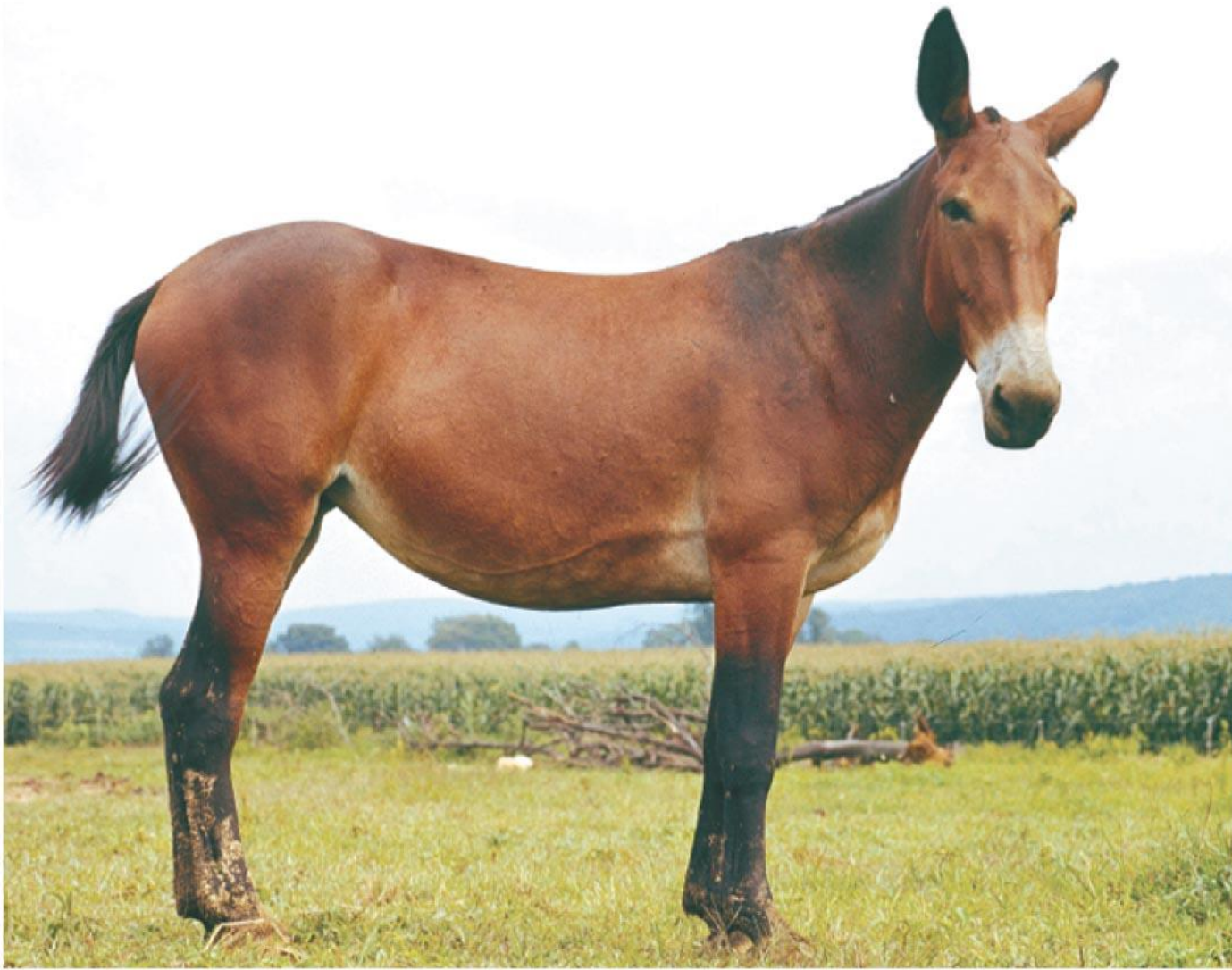
Mechanical Isolation:

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

PostZygotic Reproductive Barriers

- **Postzygotic barriers** prevent the hybrid zygote from developing into a viable, fertile adult:
 - Reduced hybrid viability -- **weak offspring**
 - Reduced hybrid fertility -- **sterile offspring**
 - Hybrid breakdown.

PostZygotic Reproductive Barrier



Mule: **sterile** hybrid offspring between horse and donkey

Other Definitions of Species

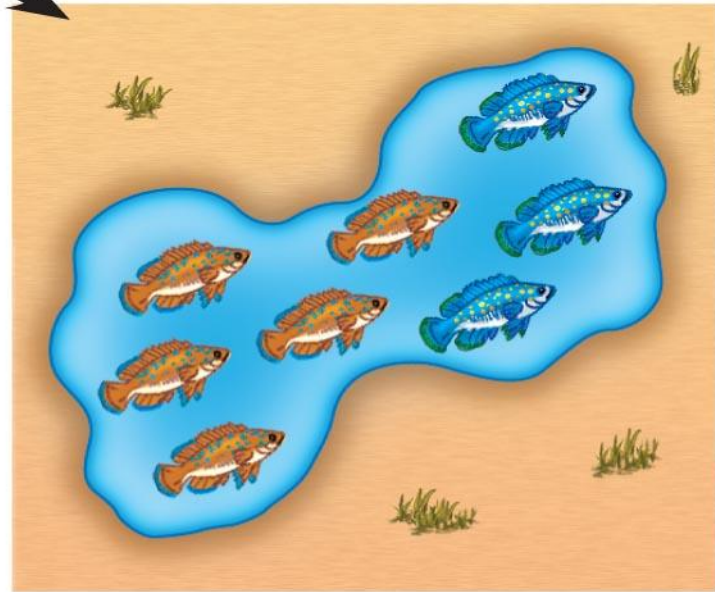
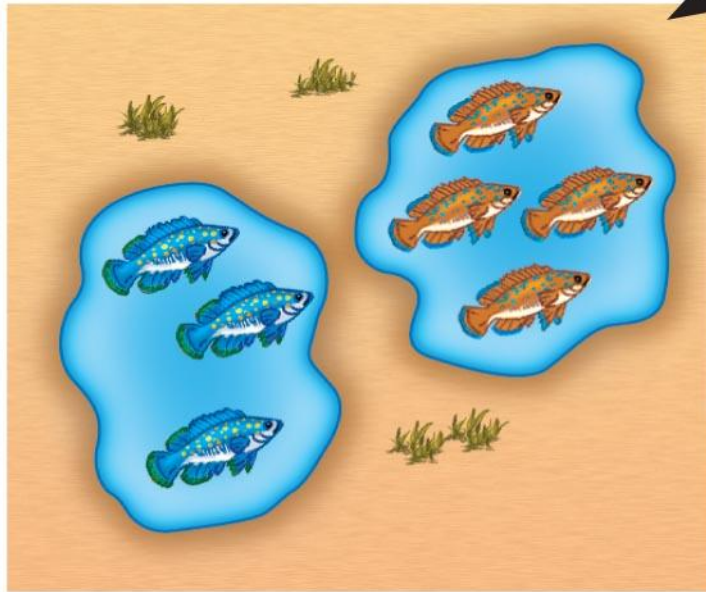
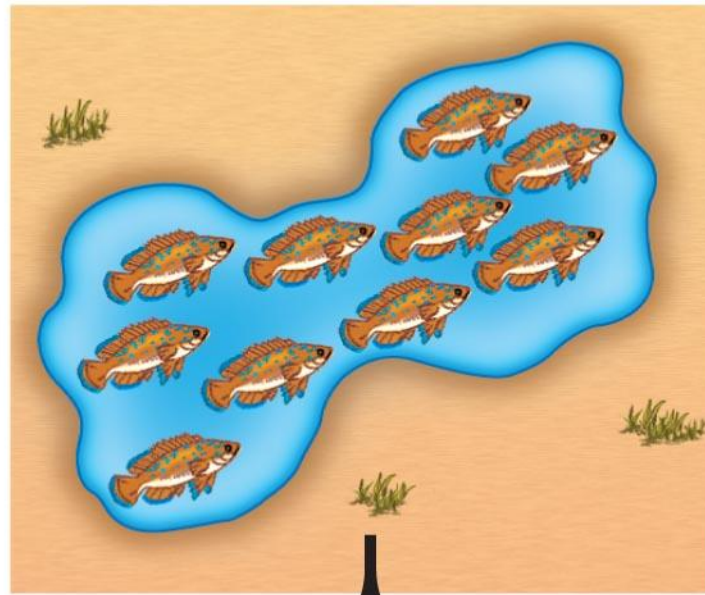
- The biological species concept cannot be applied to fossils or asexual organisms (including all prokaryotes).
- Other species concepts emphasize the unity within a species rather than the separateness of different species.
- The **morphological species concept** defines a species by structural features.
- It applies to sexual and asexual species but relies on subjective criteria.

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- The **ecological species concept** views a species in terms of its ecological niche.
 - It applies to sexual and asexual species and emphasizes the role of disruptive selection.
 - The **phylogenetic species concept**: defines a species as the smallest group of individuals on a phylogenetic tree.
 - It applies to sexual and asexual species, but it can be difficult to determine the degree of difference required for separate species.

Concept 24.2: Speciation can take place with or without geographic separation

- **Speciation** can occur in **two ways**:
 - **Allopatric** speciation: geographic barrier separates populations.
 - **Sympatric** speciation: no geographic barrier

Speciation



(a) Allopatric speciation

(b) Sympatric speciation

Allopatric (“Other Country”) Speciation

- In **allopatric speciation**, gene flow is interrupted or **macroevolution** is the cumulative effect of many speciation and extinction events.
- reduced when a population is divided into geographically isolated subpopulations ... A **geographic barrier** separates the original population.
- **Separate populations** may evolve independently through mutation, natural selection, and genetic drift.
- **Reproductive isolation** between populations generally increases as the distance between them increases.
- Barriers to reproduction are intrinsic; separation itself is not a biological barrier.

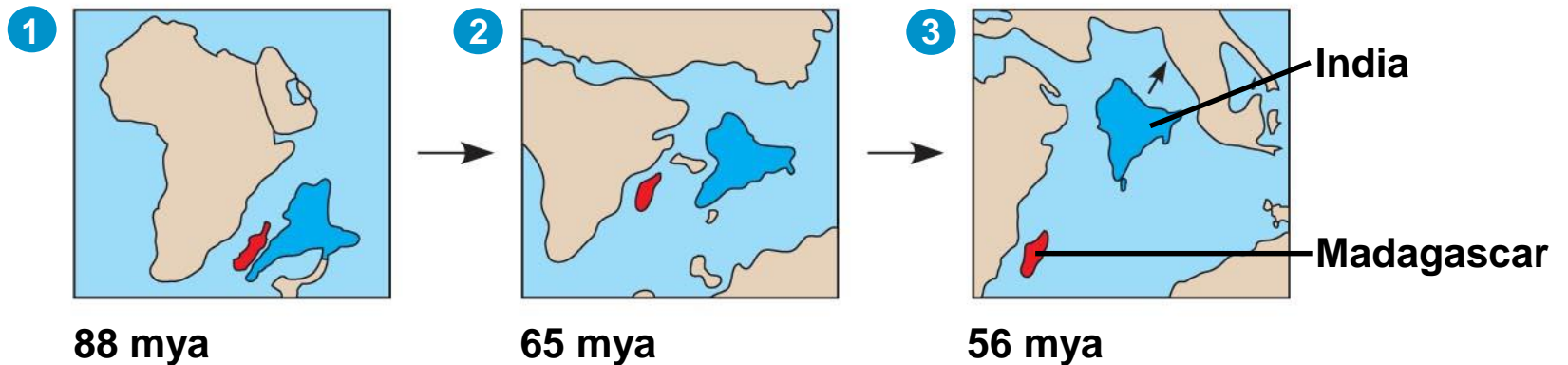
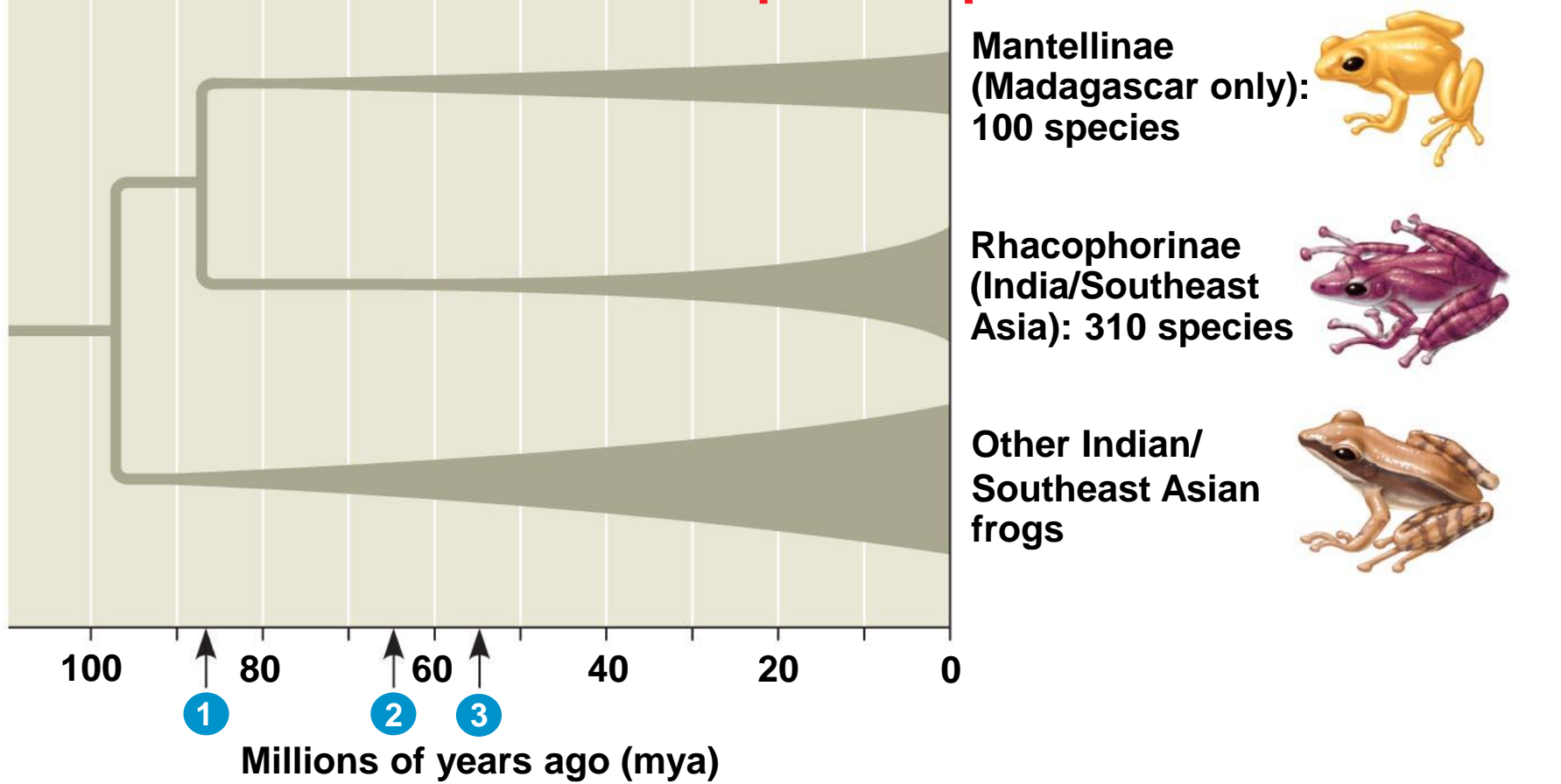
Allopatric Speciation



A. harrisi

A. leucurus

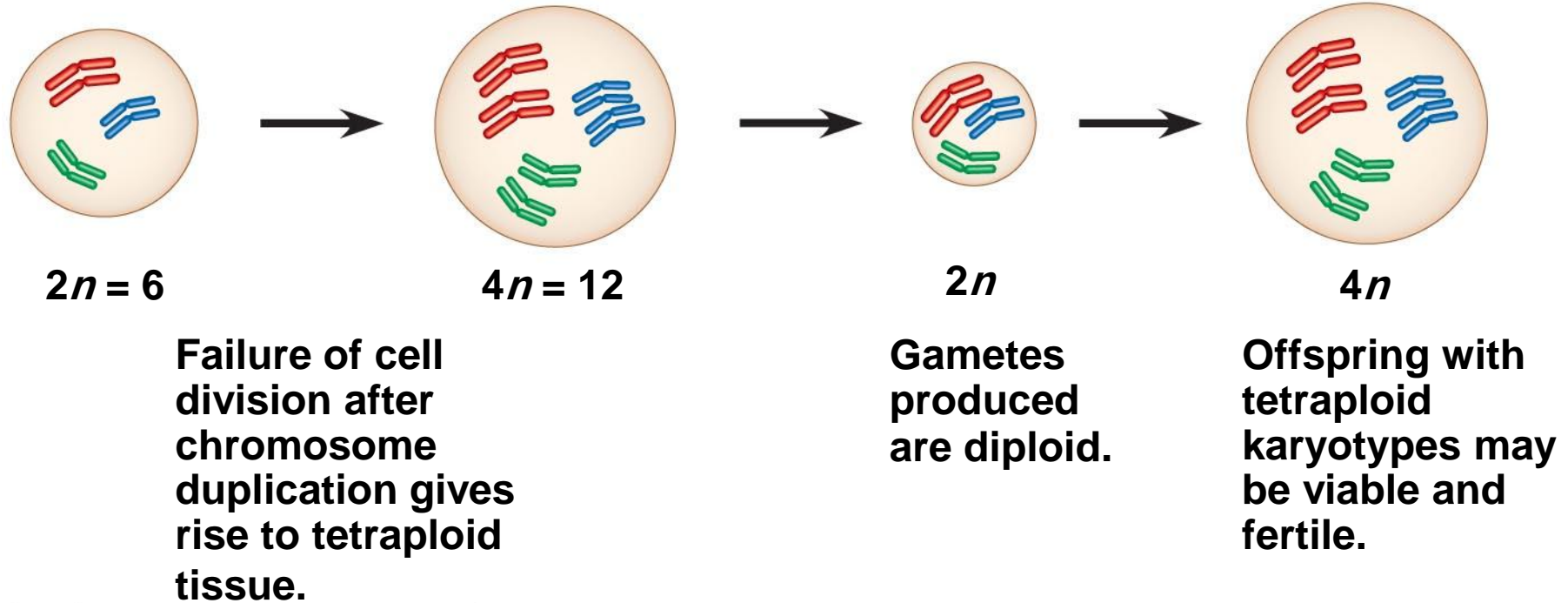
Continental Drift Caused Allopatric Speciation



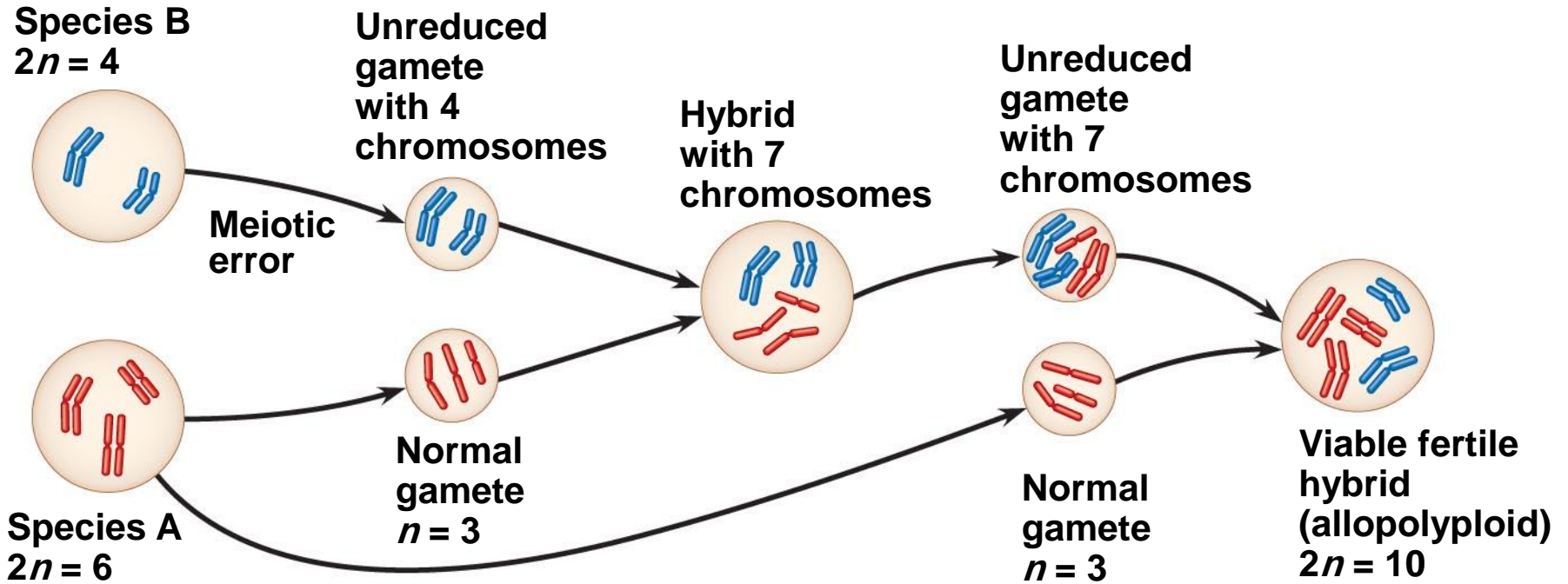
Sympatric (“Same Country”) Speciation

- In **sympatric speciation**, speciation takes place in geographically overlapping populations.
- ***Polyploidy*** is the presence of extra sets of chromosomes due to accidents during cell division.
- An ***autopolyploid*** is an individual with more than two chromosome sets, ***derived from one species***.
- An ***allopolyploid*** is a species with multiple sets of chromosomes ***derived from different species***.
- Polyploidy is common in plants. Many important crops (oats, cotton, potatoes, tobacco, and wheat) are polyploids.

Sympatric Speciation via Polyploidy is Common in Plants



Sympatric Speciation - Polyploidy --> Allopolyploid



Sympatric Speciation: Habitat Differentiation and Sexual Selection

- **Sympatric speciation** can also result from the appearance of **new ecological niches**.
- For example, the North American maggot fly can live on native hawthorn trees as well as more recently introduced apple trees.
- **Sexual selection** can drive **sympatric speciation**.
- Sexual selection for mates of different colors has likely contributed to the speciation in cichlid fish in Lake Victoria.

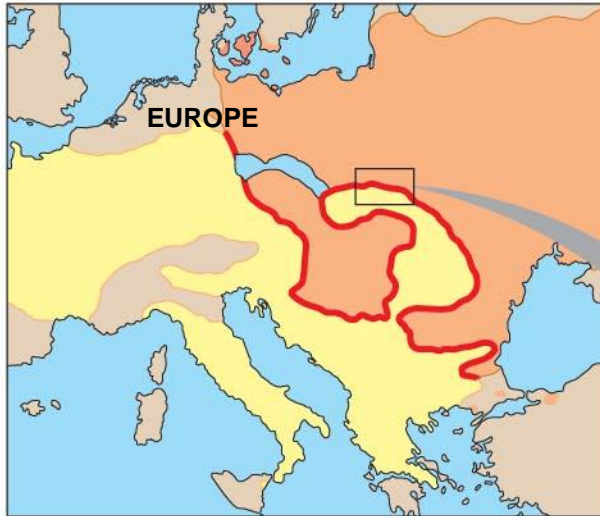
Allopatric and Sympatric Speciation May Cause Reproductive Isolation: *A Review*

- In *allopatric speciation*, geographic **separation** restricts gene flow between populations.
- *Reproductive isolation* may then arise by natural selection, genetic drift, or sexual selection in the isolated populations.
- Even if contact is restored between populations, interbreeding is prevented.
- In *sympatric speciation*, a reproductive barrier isolates a subset of a population **without geographic separation** from the parent species.
- Sympatric speciation can result from polyploidy, natural selection, or sexual selection.

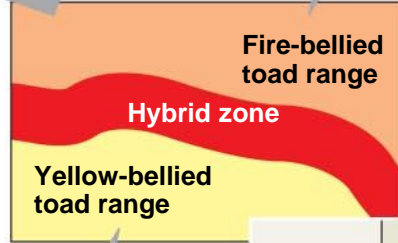
Concept 24.3: Hybrid zones provide opportunities to study factors that cause reproductive isolation

- A **hybrid zone** is a region in which members of different species mate and produce hybrids.
- A hybrid zone can occur in a single band **where adjacent species meet**.
- Hybrids often have **reduced fitness** compared with parent species.
- The distribution of hybrid zones can be more complex if parent species are found in multiple habitats within the same region.

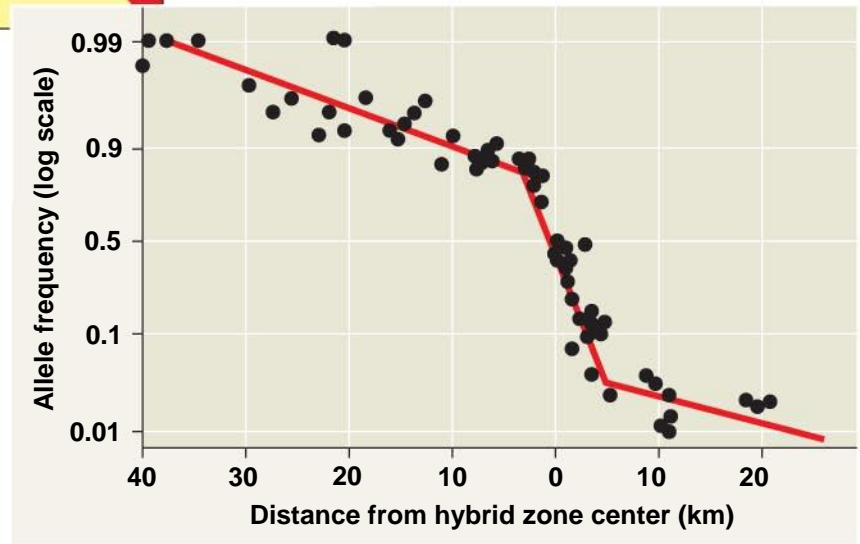
Hybrid Zones



Yellow-bellied toad,
Bombina variegata



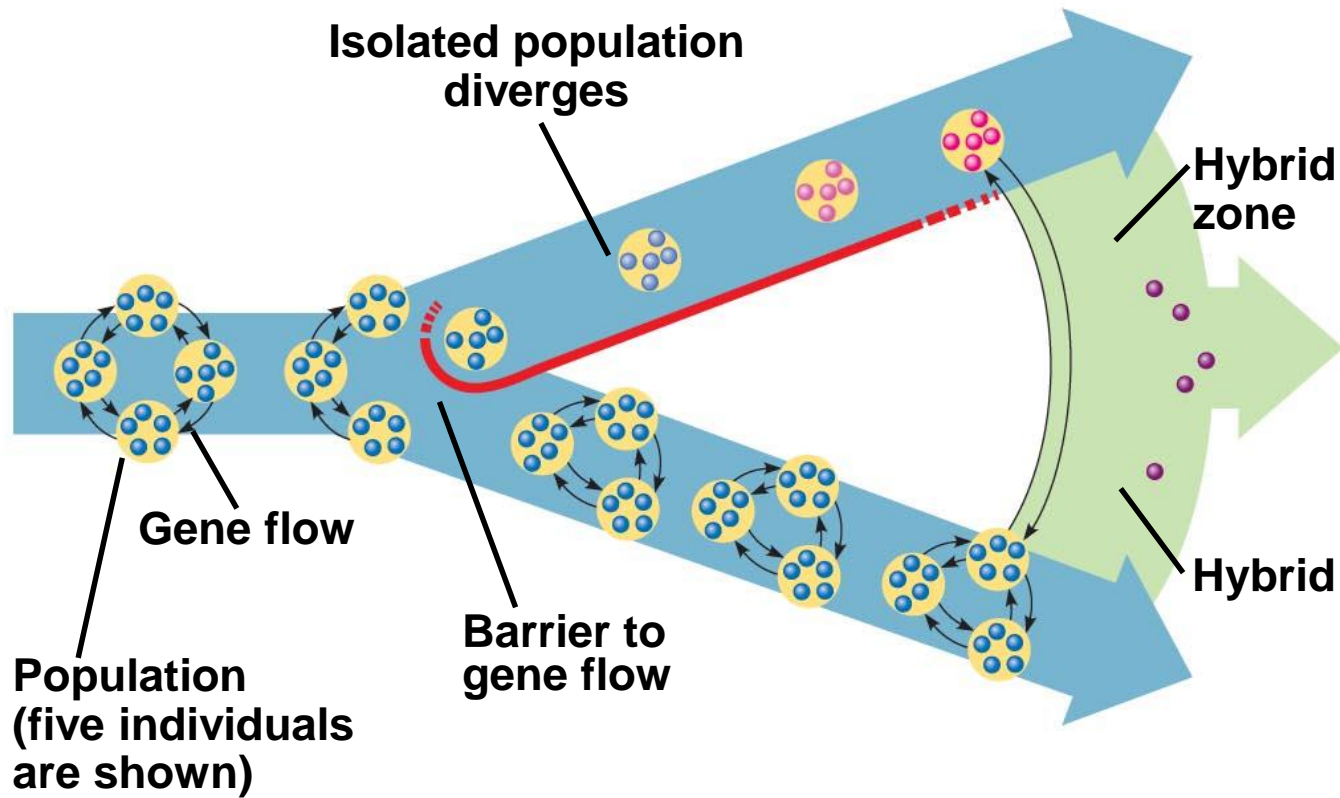
Fire-bellied toad,
Bombina orientalis



Hybrid Zones over Time

- 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.

Hybrid Zones Over Time



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Possible outcomes:

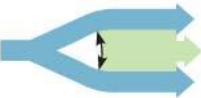
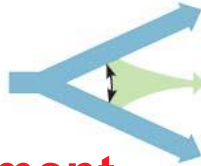
Reinforcement of gene flow barrier.

OR

Fusion into one species.

OR

Stability: Continued formation of hybrid individuals.



The Time Course of Speciation

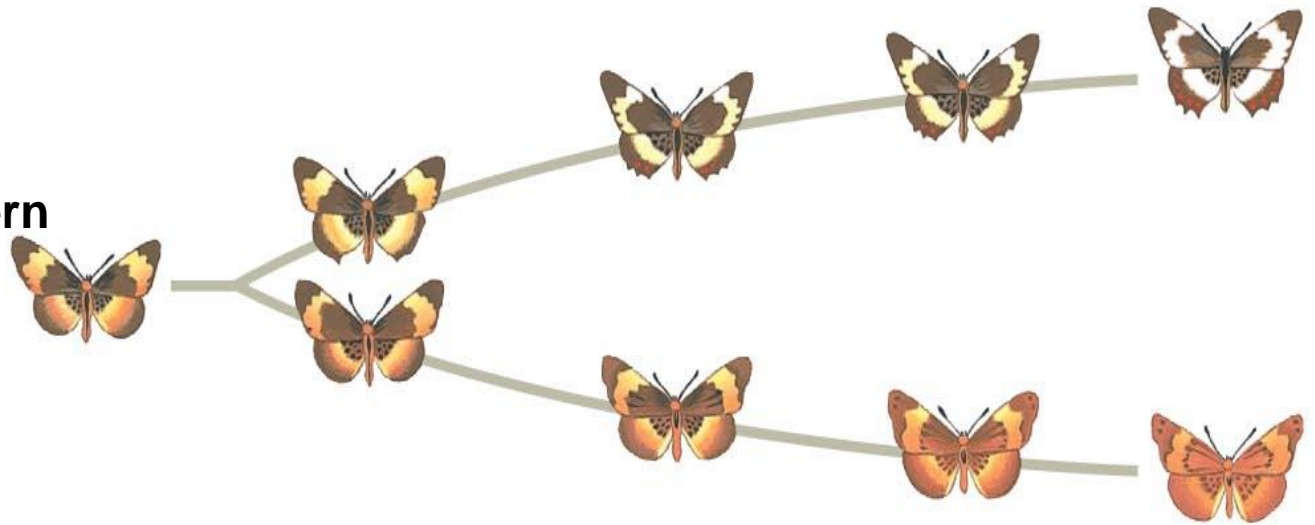
- Broad patterns in speciation can be studied using the fossil record, morphological data, or molecular data.
- The fossil record includes examples of species that appear suddenly, persist essentially unchanged for some time, and then apparently disappear
- Niles **Eldredge** and Stephen Jay **Gould** coined the term **punctuated equilibrium** to describe periods of apparent stasis (no change) punctuated by brief periods of rapid change.
- The punctuated equilibrium model contrasts with a **Darwinian** model of **gradualism**: slow continuous change over time in a species' existence.

Patterns in Speciation

Punctuated Equilibrium
pattern



Gradualism pattern



Studying the Genetics of Speciation

- The explosion of genomics is enabling researchers to identify specific genes involved in some cases of speciation.
- Depending on the species in question, speciation might require the change of only a single allele or many alleles.

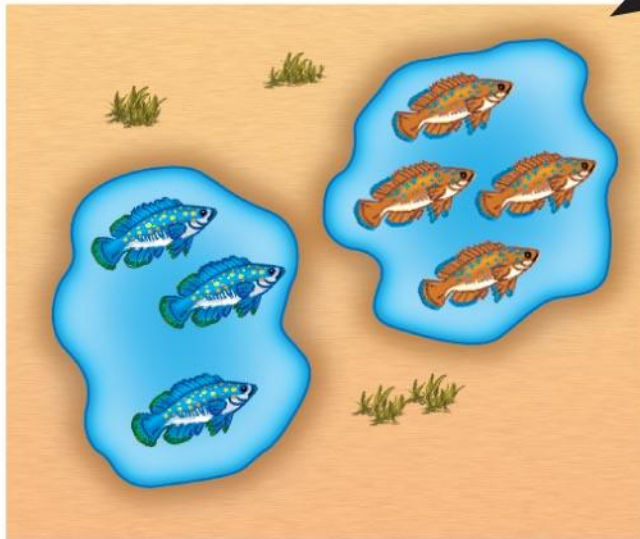
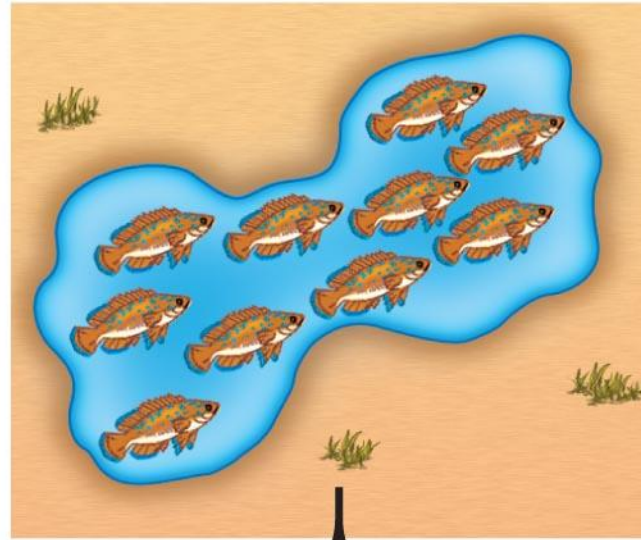
From Speciation to Macroevolution:

- **Macroevolution** is the cumulative effect of many speciation and extinction events.

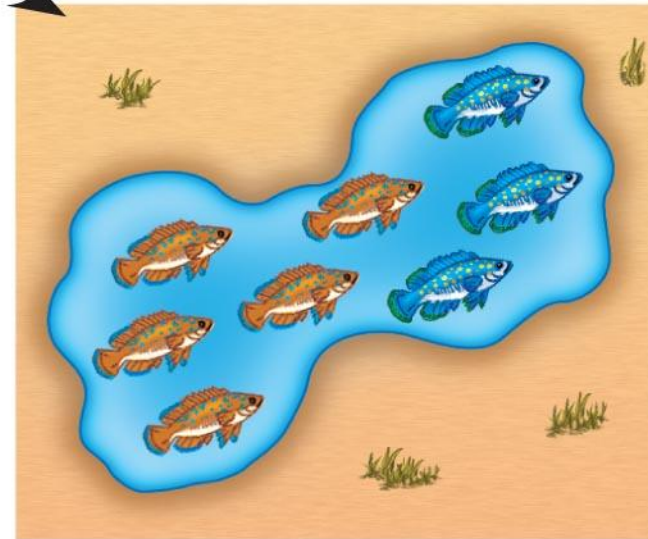
Speciation

Review

Original population



Allopatric speciation



Sympatric speciation

Speciation

Ancestral species:



AA

Triticum monococcum
($2n = 14$)



BB

Wild
Triticum
($2n = 14$)



DD

Wild
T. tauschii
($2n = 14$)

Product:



AA BB DD

T. aestivum
(bread wheat)
($2n = 42$)

You should now be able to:

1. Define and discuss the limitations of the four species concepts.
 2. Describe and provide examples of prezygotic and postzygotic reproductive barriers.
 3. Distinguish between and provide examples of allopatric and sympatric speciation.
 4. Explain how polyploidy can cause reproductive isolation.
 5. Define the term hybrid zone and describe three outcomes for hybrid zones over time.
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