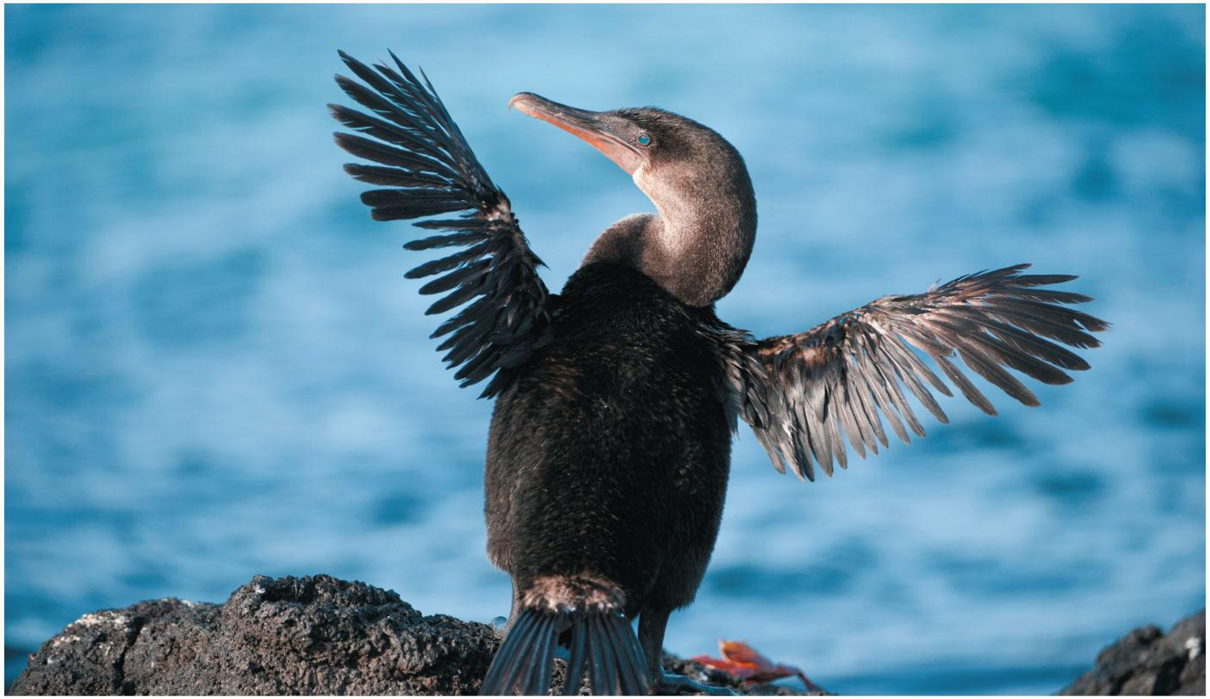
LSU BIOL 1202
General Biology II Lecture



CHAPTER 24
The Origin of Species
Dr. Adam Hrincevich

CH 24 Learning Objectives

1. Define the biological species concept, and identify reproductive barriers that could isolate a species' gene pool from that of other species.
2. Compare and contrast allopatric speciation and sympatric speciation.
3. Explain what a hybrid zone is, and identify possible outcomes for a hybrid zone over time.
4. Give examples that show how speciation can occur rapidly or slowly, and can result from changes in few or many genes.

I would suggest completing the crossword puzzle to help you understand the terminology and correlate how the terms relate to topics covered in this chapter.

That “Mystery of Mysteries”

- In the Galápagos Islands, Darwin discovered plants and animals found nowhere else on Earth
- Darwin was absolutely amazed at the diversity and number of organisms he observed
- The “mystery of mysteries” that captivated Darwin included…
  - **Speciation:** process by which one species splits into two or more species, is at the focal point of evolutionary theory
  - **Microevolution:** changes in allele frequency in a population over time
  - **Macroevolution:** broad patterns of evolutionary change above the species level

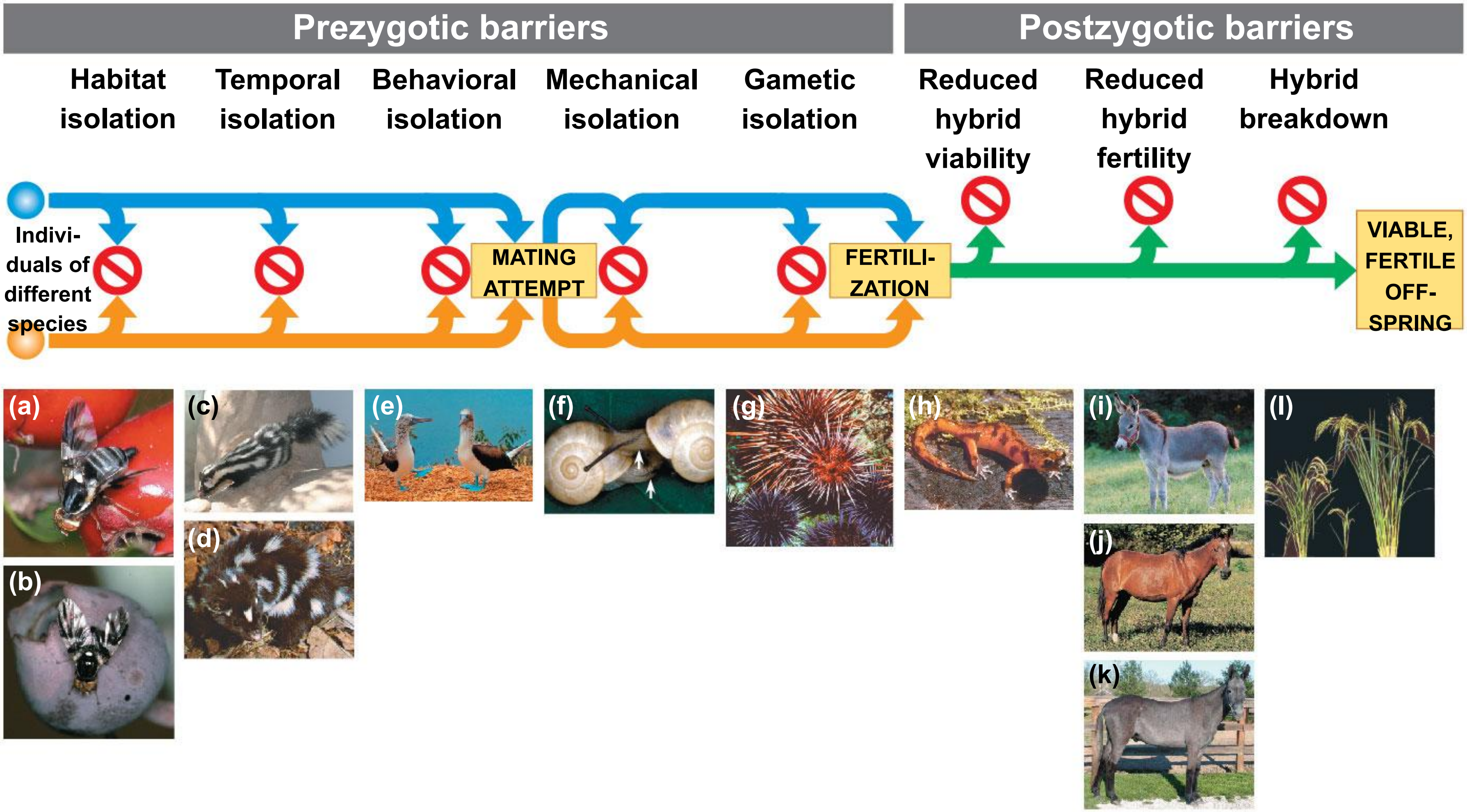
Concept 24.1: The biological species concept emphasizes reproductive isolation

- *Species* is a Latin word meaning "kind" or "appearance"
- Biologists compare morphology, physiology, biochemistry, and <u>DNA sequences when grouping organisms</u>
- 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 <u>with members of other such groups</u>
- Gene flow between populations holds a <u>species together genetically</u>

Reproductive Isolation

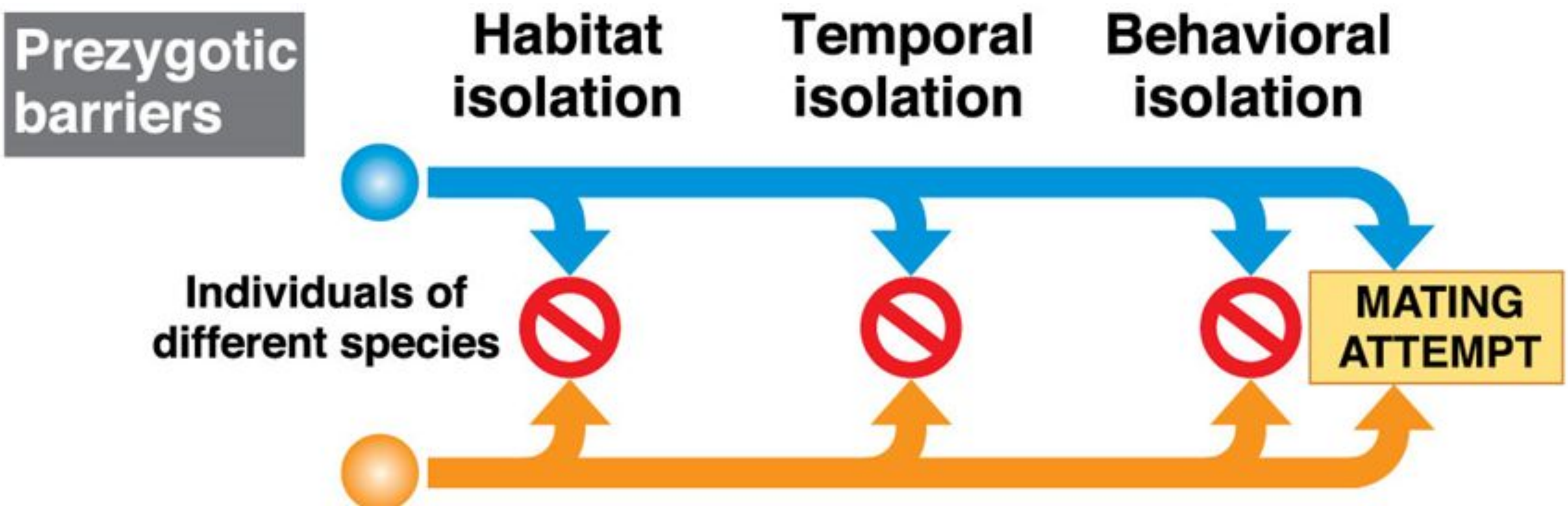
- **Reproductive isolation** is the existence of biological factors (barriers) that impede two species from producing viable, fertile offspring
- **Hybrids** are the offspring that result from mating between different species
- Reproductive isolation can be classified by whether factors act before or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

Figure 24.3

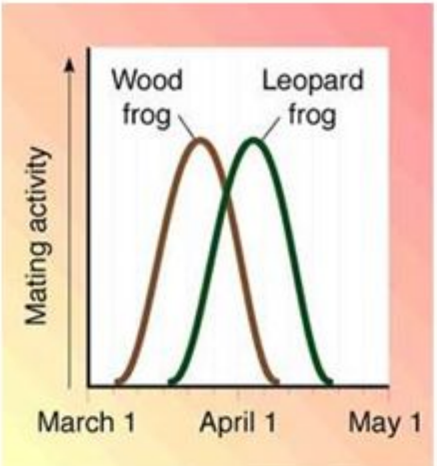


Prezygotic barriers
Postzygotic barriers
Habitat isolation
Temporal isolation
Behavioral isolation
Mechanical isolation
Gametic isolation
Reduced hybrid viability
Reduced hybrid fertility
Hybrid breakdown
Indivi-duals of different species
MATING ATTEMPT
FERTILI-ZATION
VIABLE, FERTILE OFF-SPRING
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)

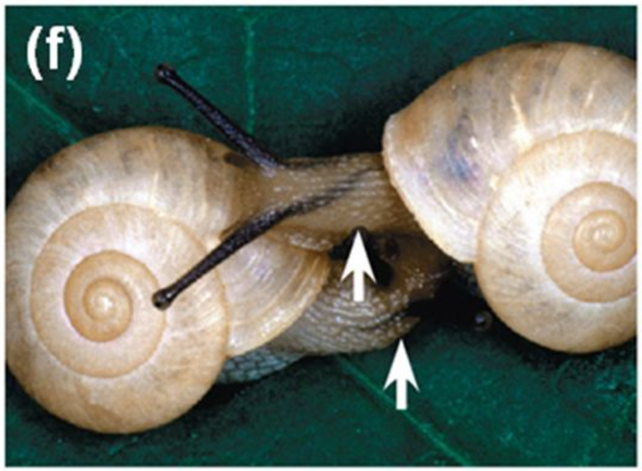
1. **Prezygotic barriers** block fertilization from occurring by
   - Impeding <u>different species from attempting to mate</u>
   - Preventing the <u>successful completion of mating</u>
   - Hindering <u>fertilization if mating is successful</u>

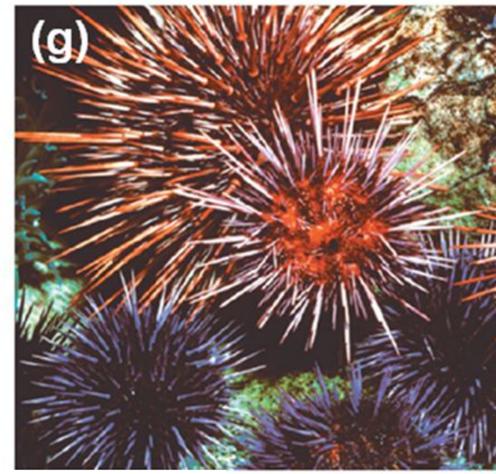


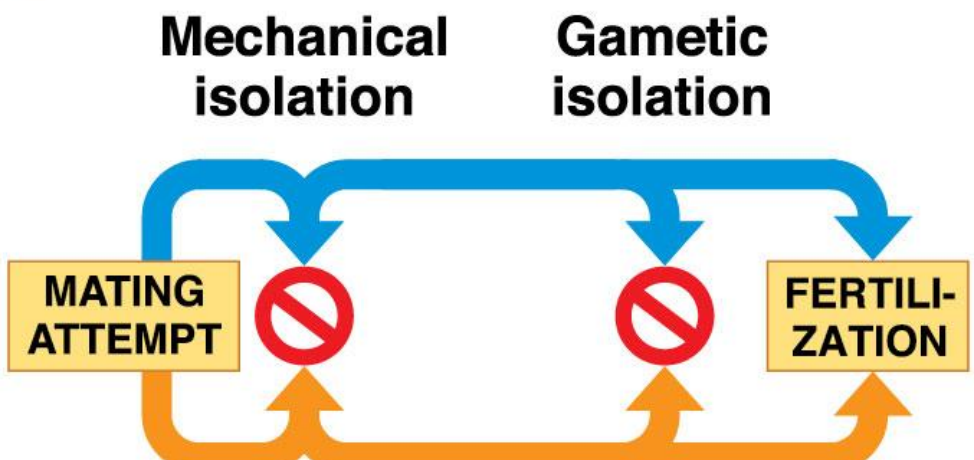
- **Habitat isolation**: Two species encounter each other rarely, or not at all, because they occupy different habitats, even though <u>not isolated by physical barriers</u>
- **Temporal isolation**: Species that breed at different times of the day, different seasons, or different years cannot <u>mix their gametes</u>
- **Behavioral isolation**: Courtship rituals & other unique behaviors to a <u>species are effective mating barriers</u>



- **Mechanical isolation**: Morphological differences can prevent successful completion of mating (snails)
- **Gametic Isolation:** Sperm of one species may not be able to fertilize eggs of another species (urchins)

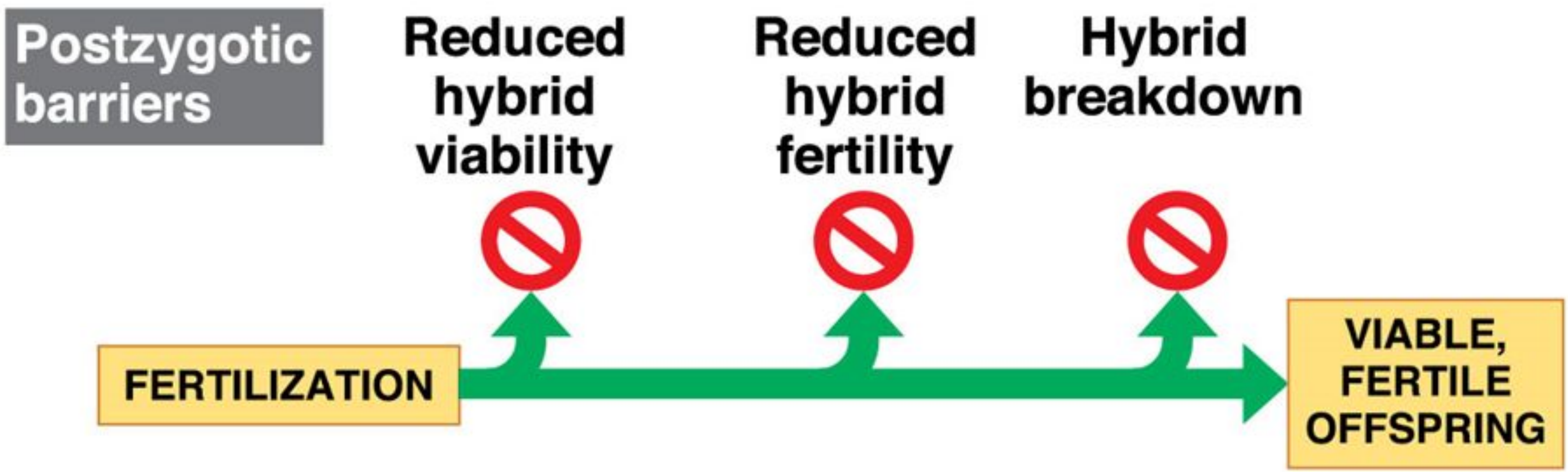






2. **Postzygotic barriers** prevent the hybrid zygote from developing into a viable, fertile adult by

- Reduced hybrid fertility
- Reduced hybrid viability
- Hybrid breakdown



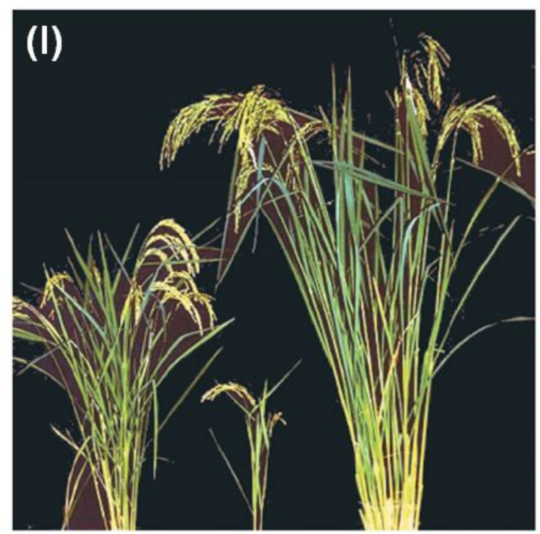
- **Reduced hybrid fertility**: Even if hybrids are vigorous, they may be sterile

62 chromosomes

64 chromosomes

63 chromosomes

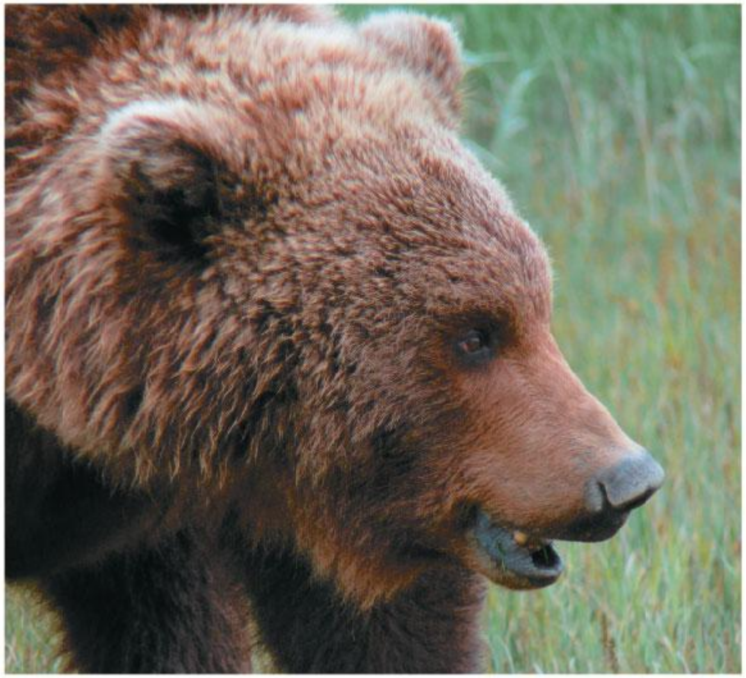
- **Reduced hybrid viability**: Genes of the different parent species may interact and impair the hybrid's development or survival in its environment (salamanders)
- **Hybrid breakdown**: Some first-generation hybrids are fertile, but when they mate with each other or with either parent species, offspring of the next generation are feeble or sterile (grasses)



Limitations of the Biological Species Concept

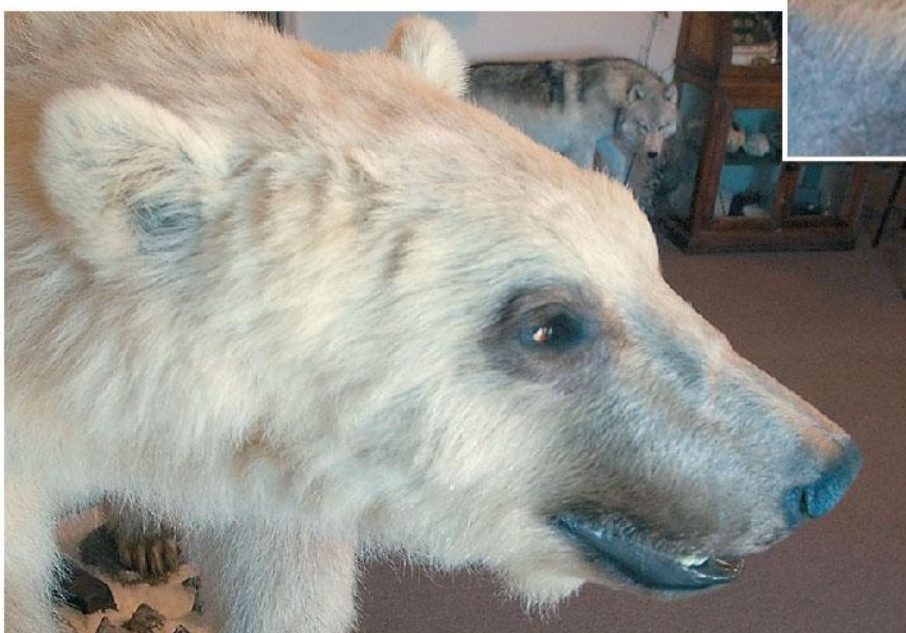
- The biological species concept cannot be applied to fossils or asexual organisms (including all prokaryotes)
- The biological species concept emphasizes absence of gene flow
- However, gene flow can occur between morphologically and ecologically distinct species
  - EX: grizzly bears and polar bears can mate to produce “grolar bears”

Figure 24.4



Grizzly bear (*U. arctos*)

Polar bear (*U. maritimus*)

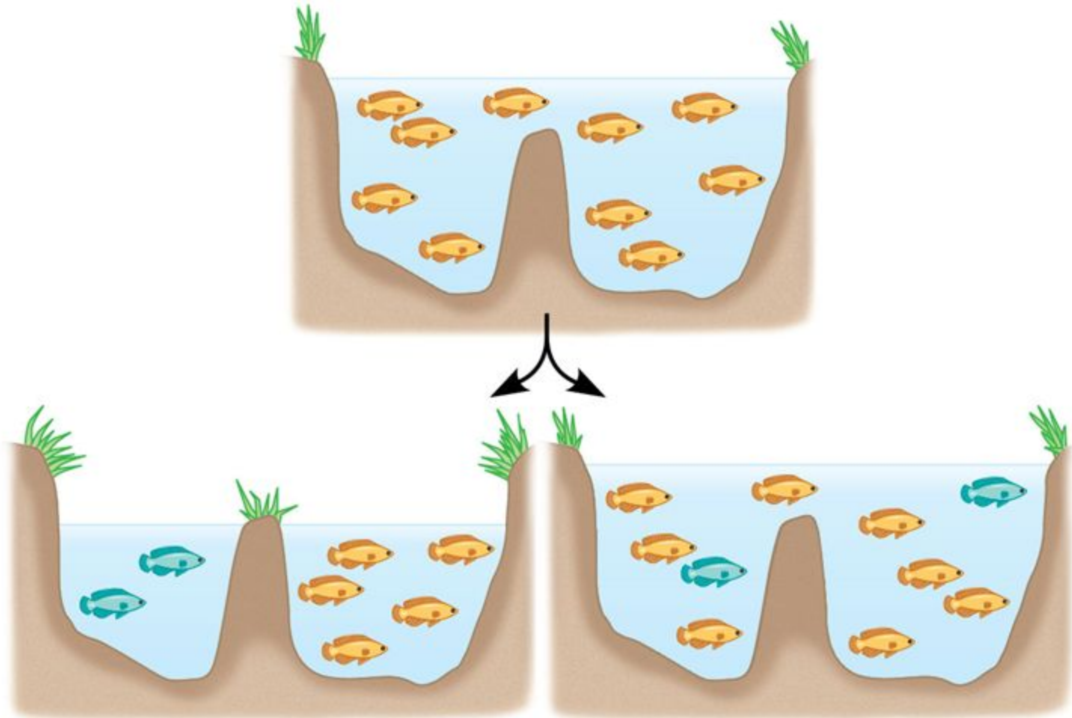


Hybrid “grolar bear”

- 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
- The **ecological species concept** defines a species in terms of its ecological niche
  - It applies to sexual and asexual species and emphasizes the role of disruptive selection
- Many species definitions have been proposed; the usefulness of each depends on the situation and the research questions being asked

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

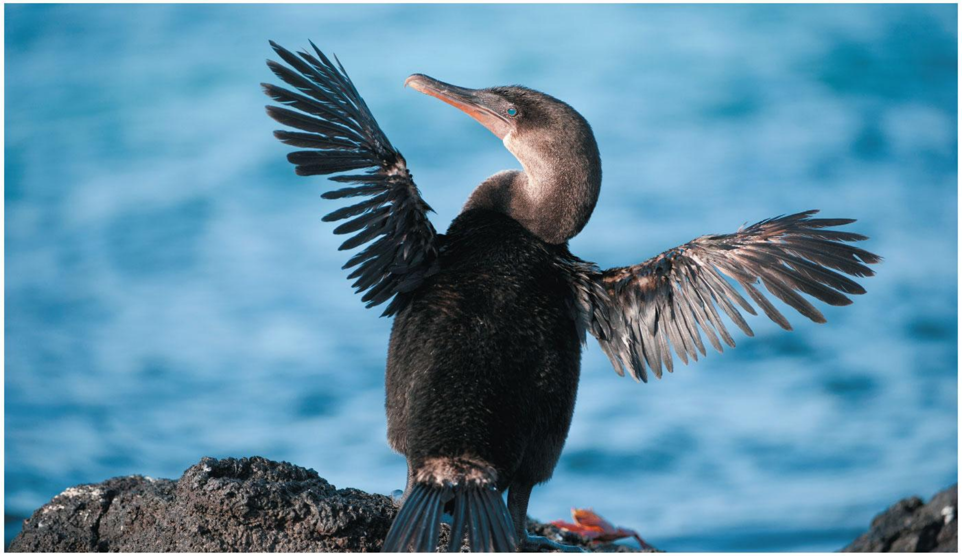
- Speciation can occur in two ways:
  1. <u>allopatric speciation</u>
  2. <u>sympatric speciation</u>



(a) Allopatric speciation (b) Sympatric speciation

1. Allopatric ("Other Country") Speciation

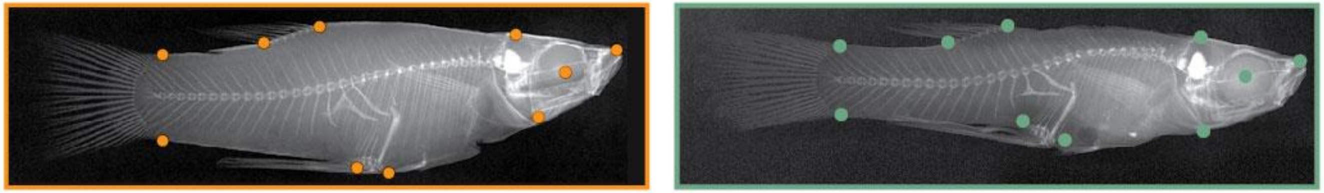
- In **allopatric speciation**, gene flow is interrupted or reduced when a population is divided into <u>geographically isolated subpopulations</u>
  - For example, the flightless cormorant of the Galápagos likely originated from a <u>flying species on the mainland</u>



The Process of Allopatric Speciation

- The definition of barrier depends on the ability of a population to <u>disperse</u>
  - EX: a canyon may create a barrier for small rodents, but <u>not birds, coyotes, or pollen</u>
- Separated populations may evolve independently through <u>mutation, natural selection, and genetic drift</u>
- Reproductive isolation may arise as a by-product of <u>genetic divergence</u>
  - EX: isolated populations of mosquitofish have become reproductively isolated as a result of <u>selection under different levels of predation</u>

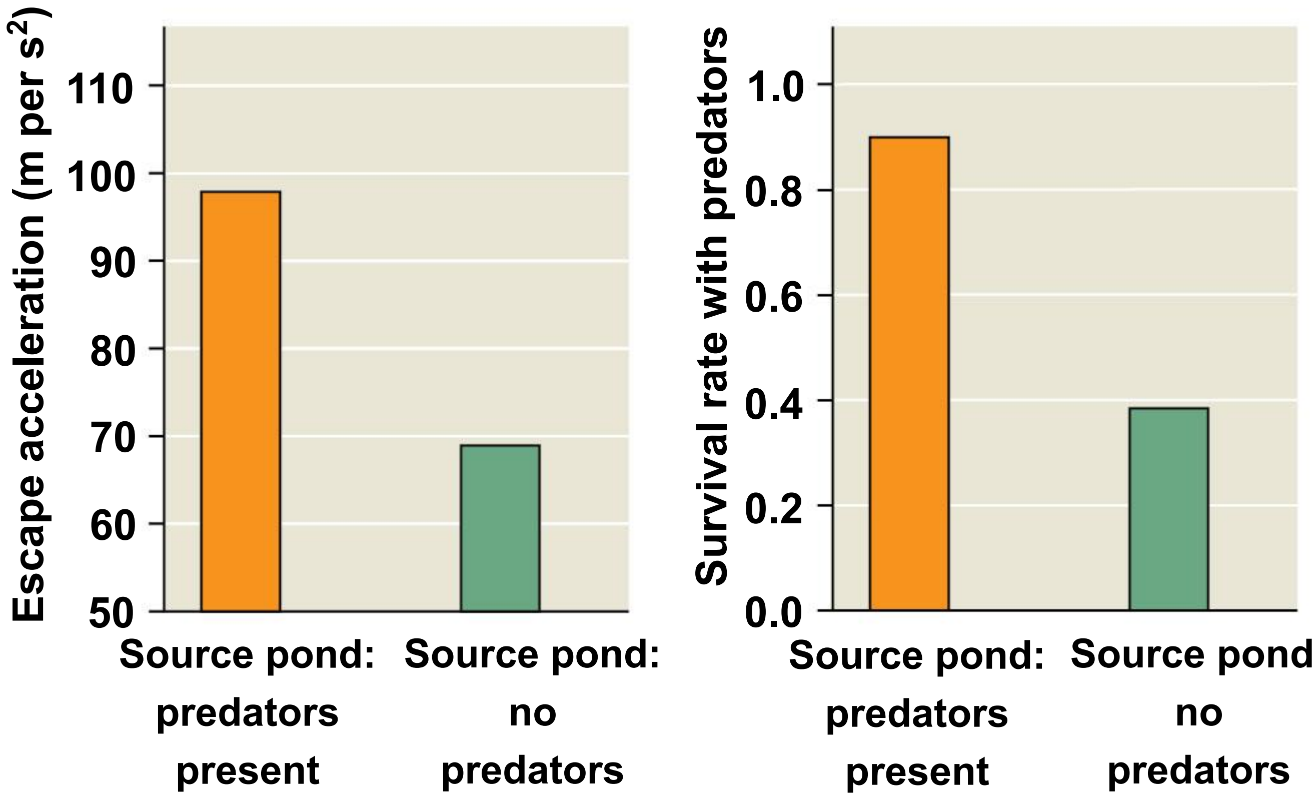
Figure 24.6



With predators: body shape that enables rapid bursts of speed

Without predators: body shape that favors long, steady swimming

(a) Differences in body shape



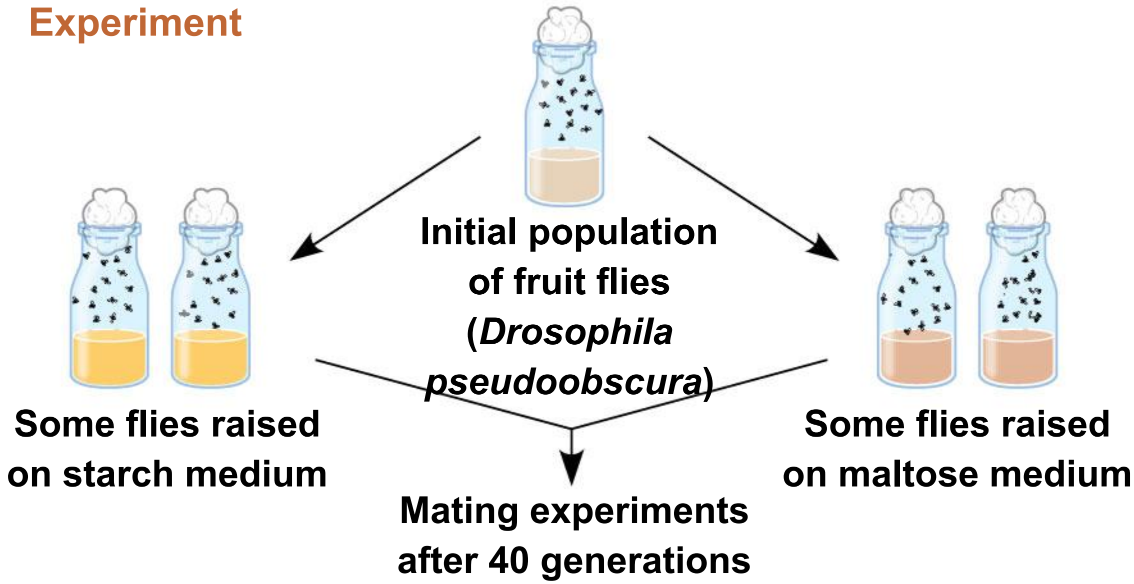
(b) Differences in escape acceleration and survival

Evidence of Allopatric Speciation

- Regions with many geographic barriers typically have more species than <u>regions with fewer barriers</u>
- Reproductive isolation between populations generally increases as the <u>distance between them increases</u>
- Physical separation alone is <u>not a biological barrier</u>
- Reproductive barriers can develop between experimentally isolated laboratory populations subjected to <u>different environment conditions</u>
  - EX: fruit flies taken from the same source population and allowed to adapt to different diets over several generations tend to choose mates <u>adapted to the same diet</u>

Figure 24.7

Experiment



Results

		Female	
		Starch	Maltose
Male	Starch	22	9
	Maltose	8	20

Number of matings in experimental group

		Female	
		Starch population 1	Starch population 2
Male	Starch population 1	18	15
	Starch population 2	12	15

Number of matings in control group

Data from D. M. B. Dodd, Reproductive isolation as a consequence of adaptive divergence in *Drosophila pseudoobscura, Evolution* 43:1308–1311 (1989).

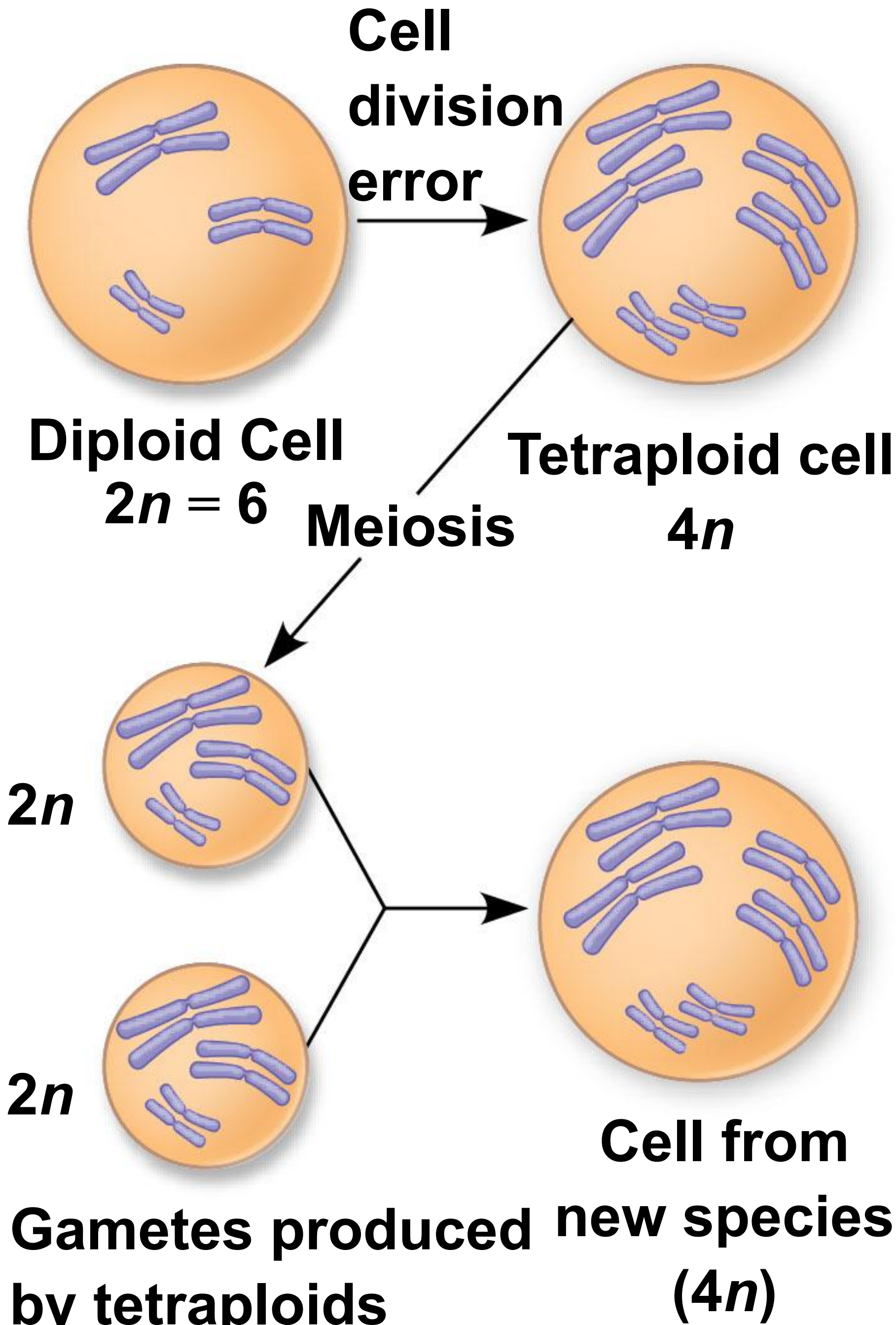
2. Sympatric ("Same Country") Speciation

- In **sympatric speciation**, speciation occurs in populations that live in <u>same geographic area</u>
- Sympatric speciation can occur if gene flow is reduced by factors including
  - <u>polyploidy</u>
  - <u>sexual selection</u>
  - <u>habitat differentiation</u>

Polyploidy

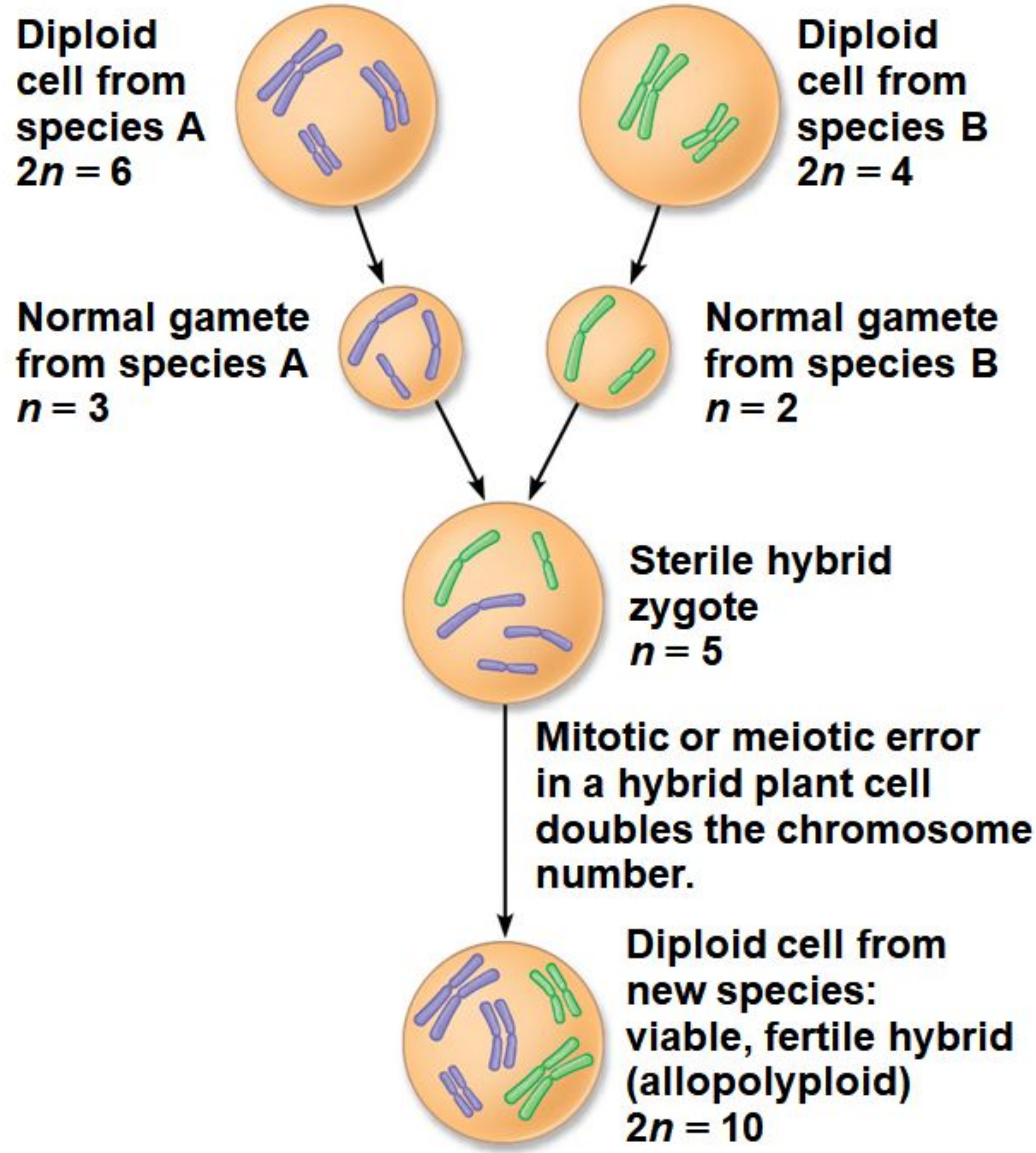
- **Polyploidy** is the presence of extra sets of chromosomes due to accidents during cell division
- Polyploidy is much more common in plants than in animals
- Polyploidy can produce new biological species in sympatry within a single generation
- An **autopolyploid** is an individual with more than two chromosome sets derived from a single species
- The offspring resulting from mating between polyploids and diploids have reduced fertility

Figure 24.9

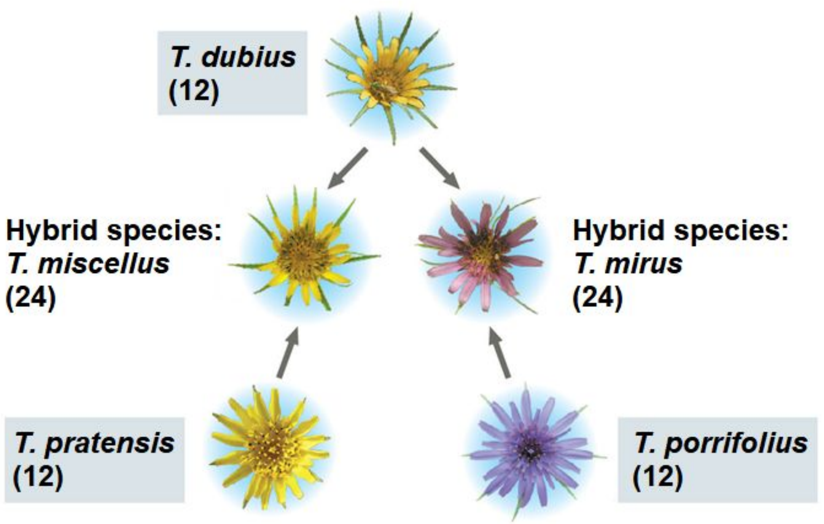


Cell
division
error
Diploid Cell
2n = 6
Tetraploid cell
4n
Meiosis
2n
2n
Gametes produced
by tetraploids
Cell from
new species
(4n)

- An **allopolyploid** is a species with multiple sets of chromosomes derived from <u>different species</u>
- Allopolyploids can successfully mate with each other, but cannot <u>interbreed with either parent species</u>

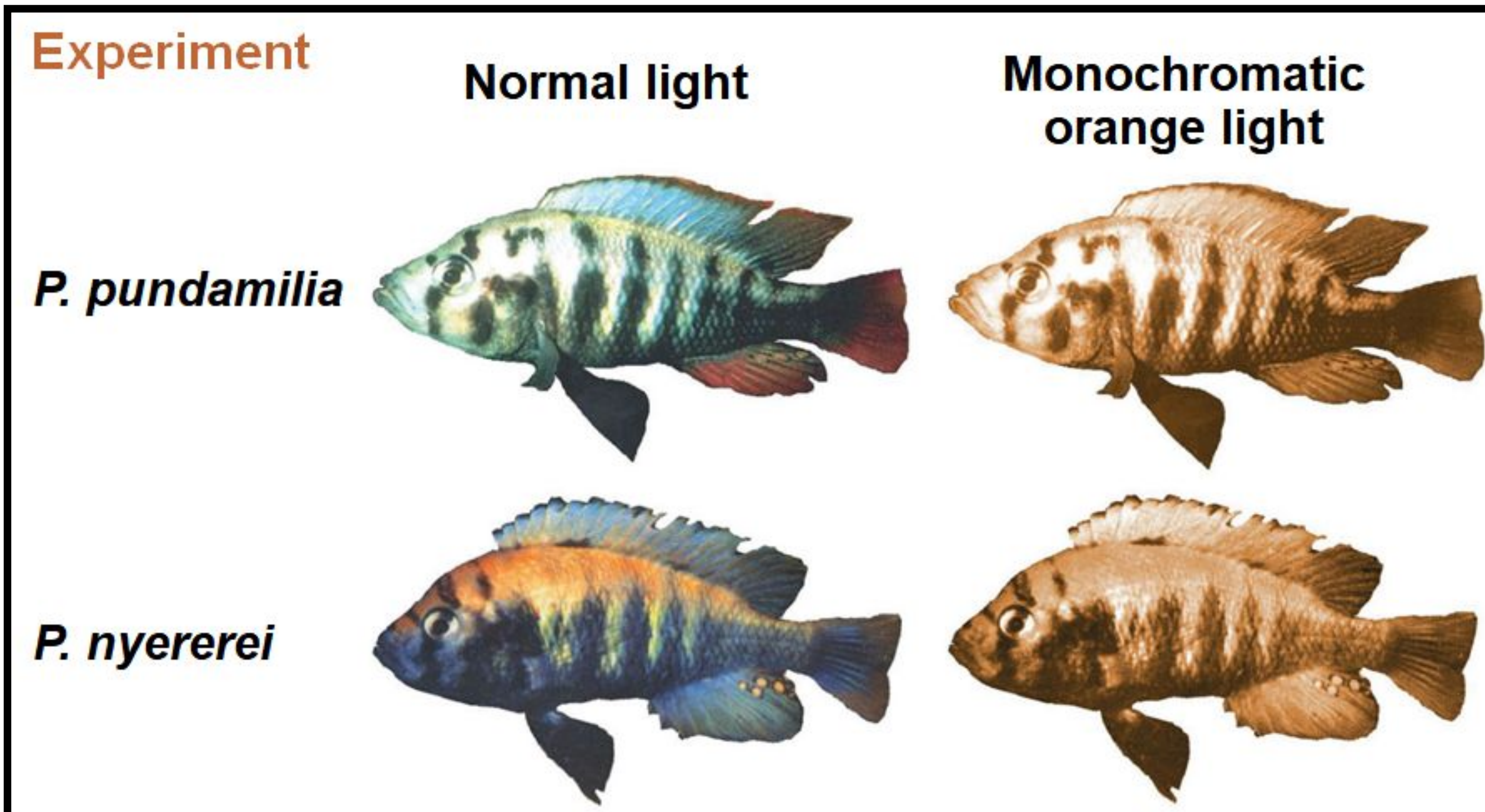


- At least five new plant species have originated by polyploid speciation since 1850
  - EX: in the genus *Tragopogon* (goatsbeard), 2 allopolyploid species have evolved from <u>3 diploid parent species</u>
- Many important crops (oats, cotton, potatoes, tobacco, and wheat) are <u>polyploids</u>
- Plant geneticists can produce new polyploid species using chemicals to <u>induce errors in cell division</u>



Sexual Selection

- Sexual selection can drive sympatric speciation
- Sexual selection for mates of different colors has likely contributed to speciation in cichlid fish in Lake Victoria



Habitat Differentiation

- Sympatric speciation can also result from the appearance of <u>new ecological niches</u>
  - EX: populations of the North American maggot fly (*Rhagoletis pomonella*) can live on native hawthorn trees, as well as <u>more recently introduced apple trees</u>
  - Flies that use different host species experience both

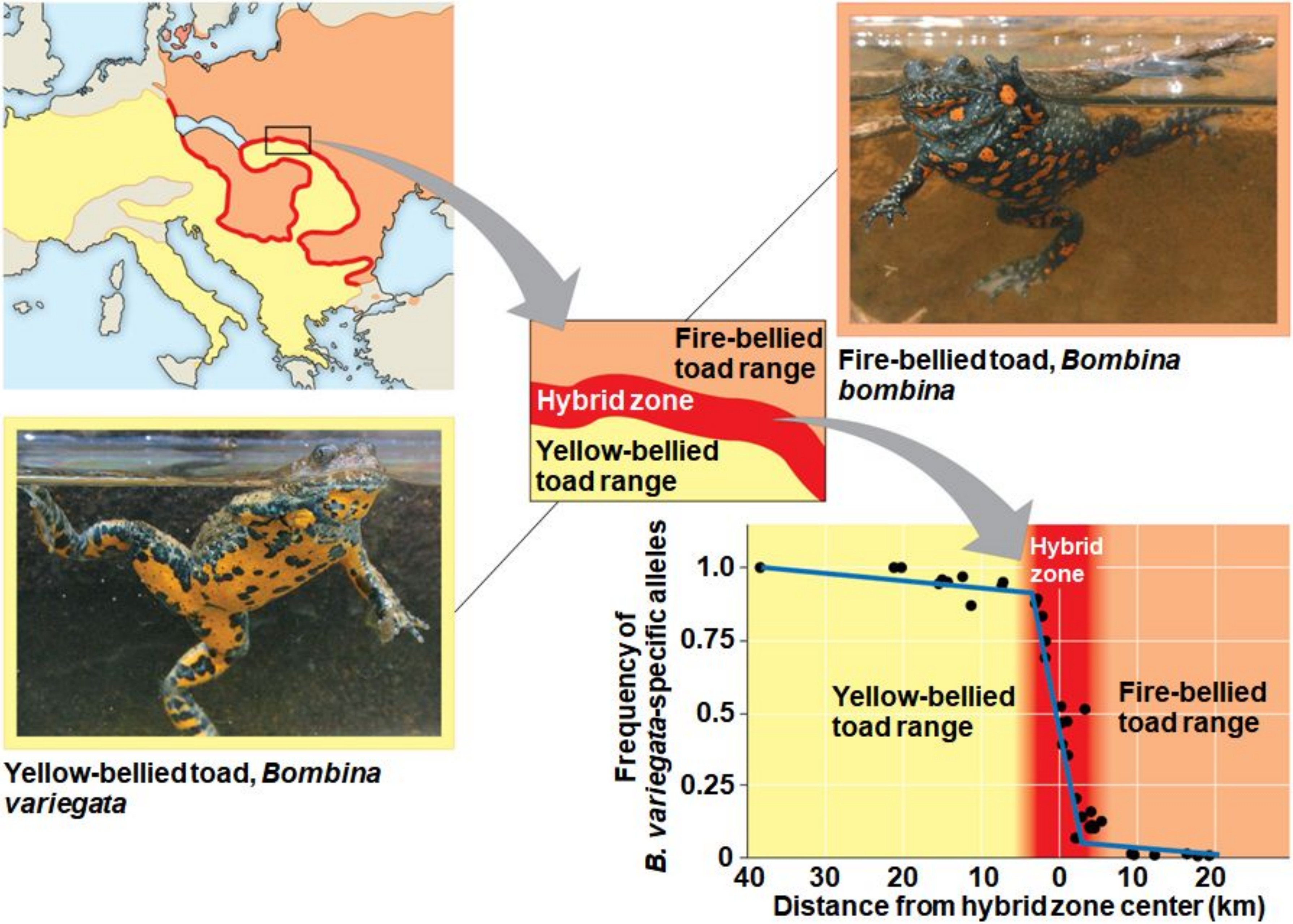
Allopatric & Sympatric Speciation: *A Review*

- In allopatric speciation, ***geographic isolation*** restricts gene flow between populations
- Reproductive isolation may then arise as a by-product of genetic changes resulting from divergent natural selection, genetic drift, or sexual selection
- 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 reveal 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
  - EX: two species of toad in the genus *Bombina* interbreed in a long and narrow hybrid zone
- Hybrids are the result of mating between species with incomplete reproductive barriers
- Hybrids often have reduced fitness vs. parent species
- The distribution of hybrid zones can be more complex if parent species are found in patches in the same region

Figure 24.13



Fire-bellied toad, *Bombina bombina*

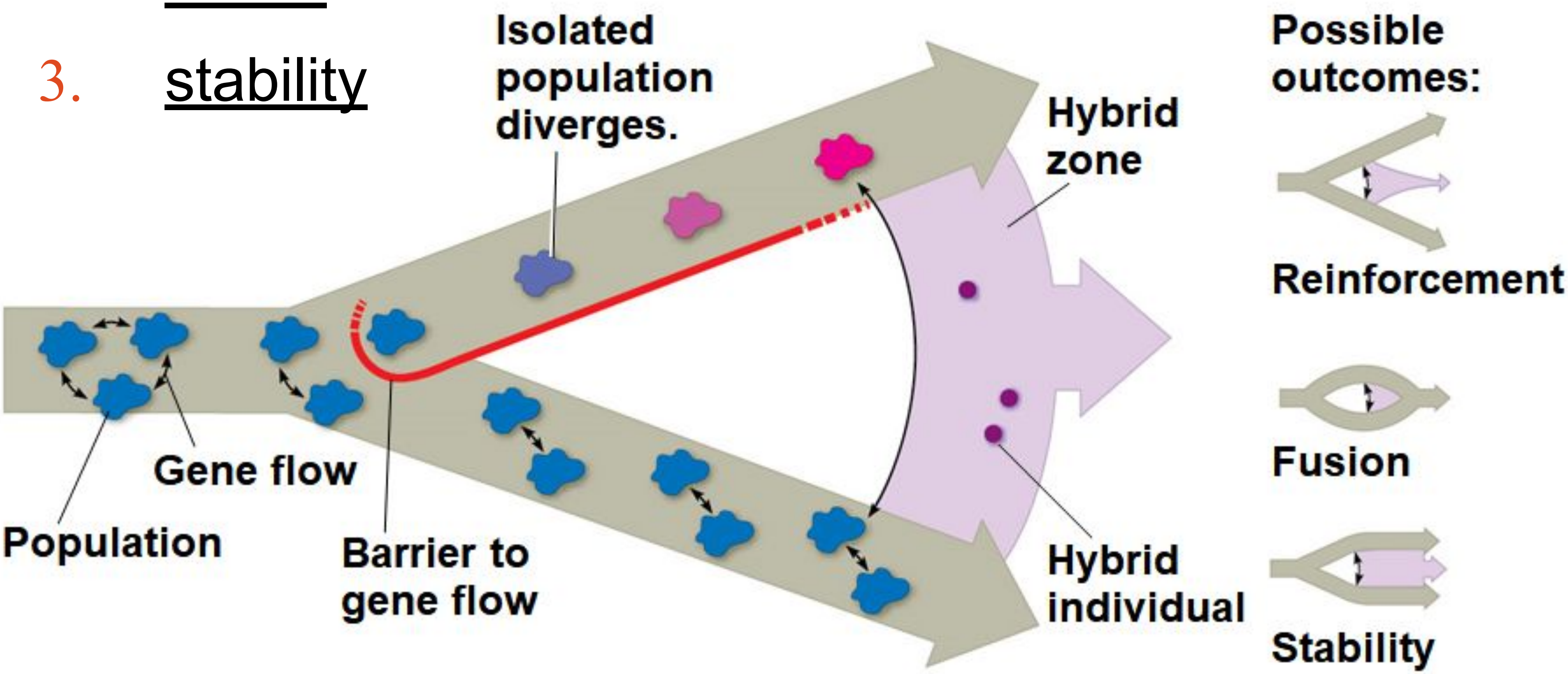
Yellow-bellied toad, *Bombina variegata*

Hybrid Zones and Environmental Change

- Change in environmental conditions can result in the relocation of existing hybrid zones or the production of <u>novel hybrid zones</u>
  - EX: the hybrid zone between black-capped and Carolina chickadees has shifted northward in response to <u>climate change</u>
  - EX: the species range of southern flying squirrels now overlaps with that of the <u>northern flying squirrel</u>
- Breeding between hybrids and parent species can result in the transfer of alleles from one parent species <u>to the other</u>
- The transfer of novel alleles may help parent species <u>cope with changing environments</u>

Hybrid Zones over Time

- If hybrids do not become reproductively isolated from their parent species, then three alternate outcomes are possible:
    1. reinforcement
    2. fusion
    3. stability



1. Reinforcement: Strengthening Reproductive Barriers

- When hybrids are less fit than parent species, **reinforcement** of reproductive barriers may occur through <u>strong selection for prezygotic barriers</u>
- Over time, the <u>rate of hybridization ***decreases***</u>
- Where reinforcement occurs, reproductive barriers should be stronger for <u>sympatric vs. allopatric species</u>
  - EX: female flycatchers in the genus *Ficedula* recognize and select mates of their own species when choosing between <u>males from sympatric populations</u>
  - Female flycatchers frequently make mistakes when selecting males from the <u>more similar allopatric populations</u>

2. 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, reproductive barriers weaken, the parent species can fuse into a single species
  - EX: pollution in Lake Victoria has reduced the ability of female cichlids to distinguish males of different species from males of their own species

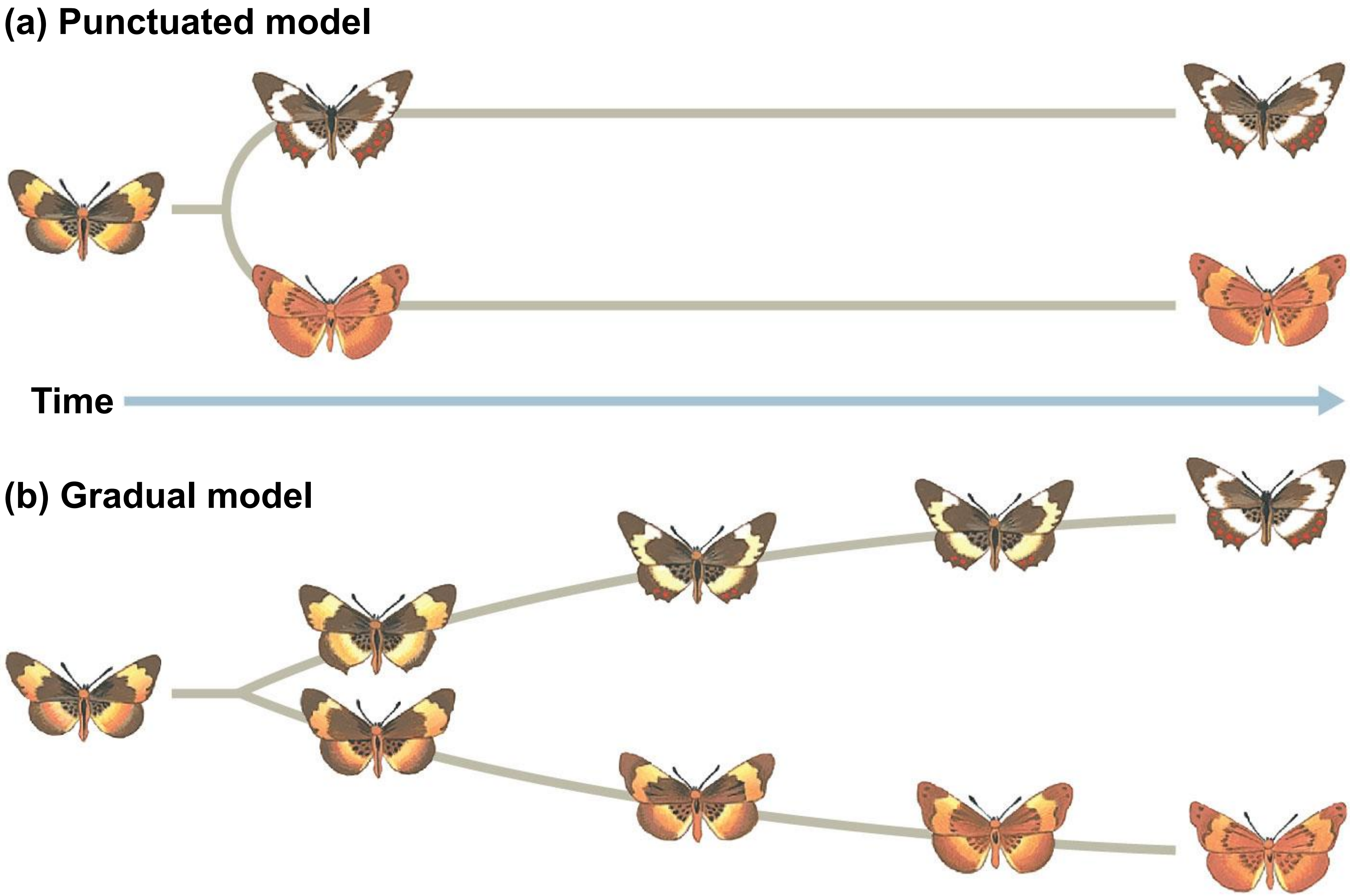
3. Stability: Continued Formation of Hybrid Individuals

- Extensive gene flow from outside the hybrid zone can overwhelm selection for increased reproductive isolation <u>inside the hybrid zone</u>
  - EX: parent species of *Bombina* routinely migrate into the narrow hybrid zone, resulting in <u>ongoing hybridization</u>

Concept 24.4: Speciation can occur rapidly or slowly and can result from changes in few or many genes

- Question: How long needed for new species to form and how many genes need to vary between species?
- The rate of speciation can be studied using the fossil record, morphological data, or molecular data
- The fossil record includes examples of species that appear suddenly, persist unchanged for some time, and then disappear
- **Punctuated equilibria** describes these periods of apparent stasis punctuated by sudden change
- The punctuated equilibrium model contrasts with a model of gradual change in a species over time

Figure 24.16



Speciation Rates

- The punctuated pattern in the fossil record suggests that <u>speciation can be rapid</u>
  - EX: Sunflower *Helianthus anomalus* was formed by hybridization between two other sunflower species followed by <u>rapid speciation</u>
  - The interval between speciation events can range from 4,000 years (some cichlids) to 40 million years (some beetles), with <u>an average of 6.5 million years</u>

Studying the Genetics of Speciation

- A fundamental question of evolutionary biology persists: How many genes influence the formation of new species?
- Depending on the species in question, speciation might require change in a single gene or many genes
  - EX: In Japanese *Euhadra* snails, the direction of shell spiral affects mating and is controlled by a single gene
  - In monkey flowers (*Mimulus*), at least two loci affect flower color, which influences pollinator preference
  - Pollination that is dominated by either hummingbirds or bees can lead to reproductive isolation of the flowers
  - In other organisms, speciation can be influenced by larger numbers of genes and gene interactions

From Speciation to Macroevolution

- Microevolution happens on a small scale (within a single population)
- Macroevolution happens on a scale that transcends the boundaries of a single species
- Evolution at both of these levels relies on the same, established mechanisms of evolutionary change: mutation