LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 24

The Origin of Species

Lectures by
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- **Speciation**, the origin of new species, is at the focal point of evolutionary theory
- Evolutionary theory must explain how new species originate and how populations evolve
- **Microevolution** consists of changes in allele frequency in a population over time
- **Macroevolution** refers to 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 DNA sequences when grouping organisms

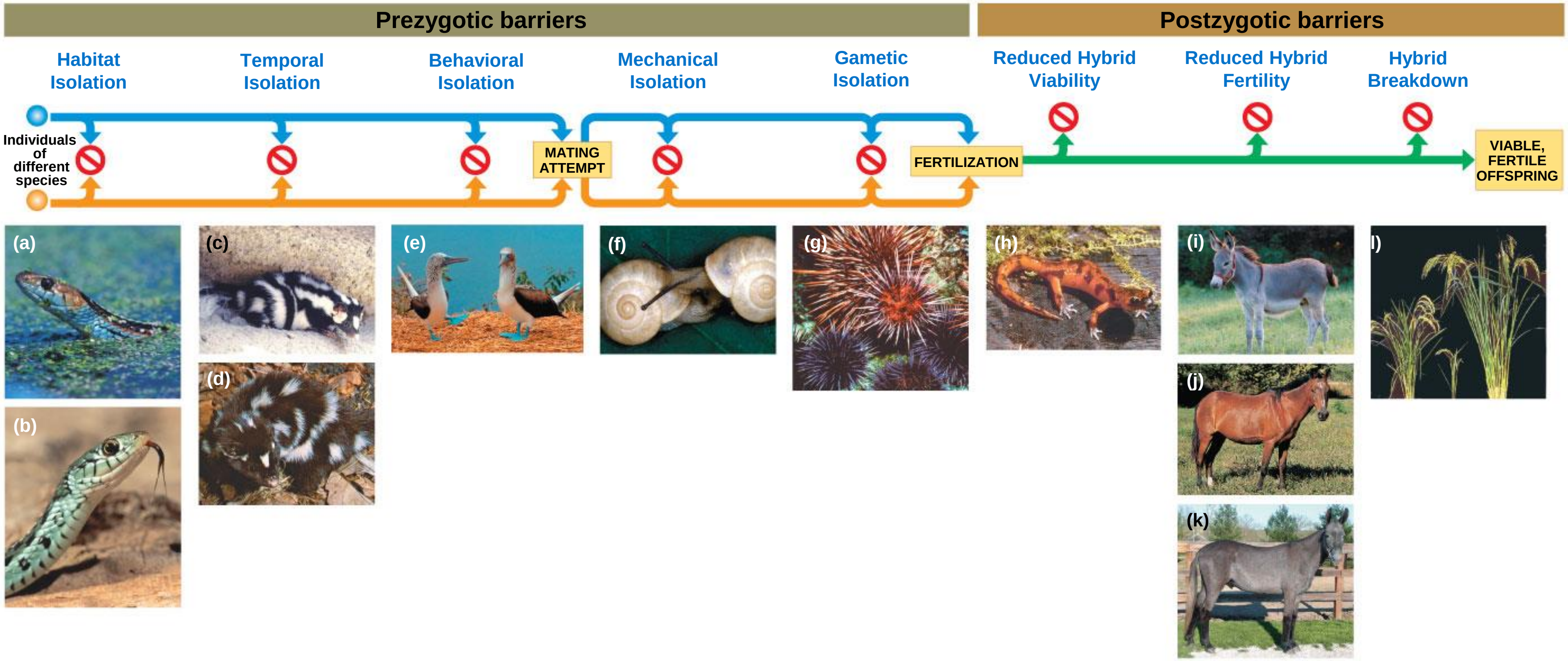
The Biological Species Concept

- 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
- Gene flow between populations holds the phenotype of a population together

Reproductive Isolation

- **Reproductive isolation** is the existence of biological factors (barriers) that impede two 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

Figure 24.3_a



Prezygotic barriers
Postzygotic barriers
Habitat Isolation
Temporal Isolation
Behavioral Isolation
Mechanical Isolation
Gametic Isolation
Reduced Hybrid Viability
Reduced Hybrid Fertility
Hybrid Breakdown
Individuals of different species
MATING ATTEMPT
FERTILIZATION
VIABLE, FERTILE OFFSPRING
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
l)

- **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

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

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

- **Reduced hybrid viability**: Genes of the different parent species may interact and impair the hybrid's development

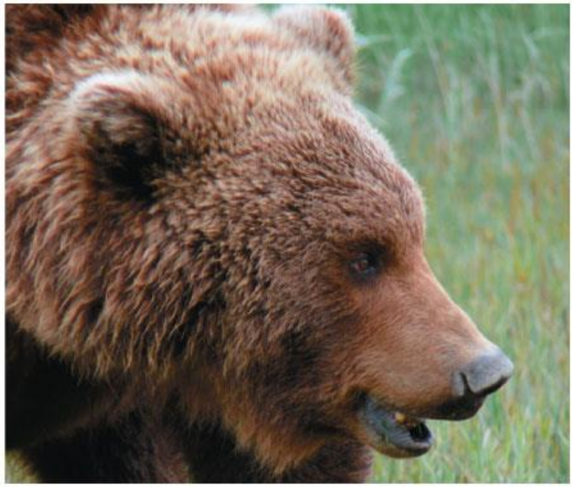
- **Reduced hybrid fertility**: Even if hybrids are vigorous, they may be sterile

- **Hybrid breakdown**: Some first-generation hybrids are fertile, but when they mate with another species or with either parent species, offspring of the next generation are feeble or sterile

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 distinct species
  - For example, 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 Definitions of Species

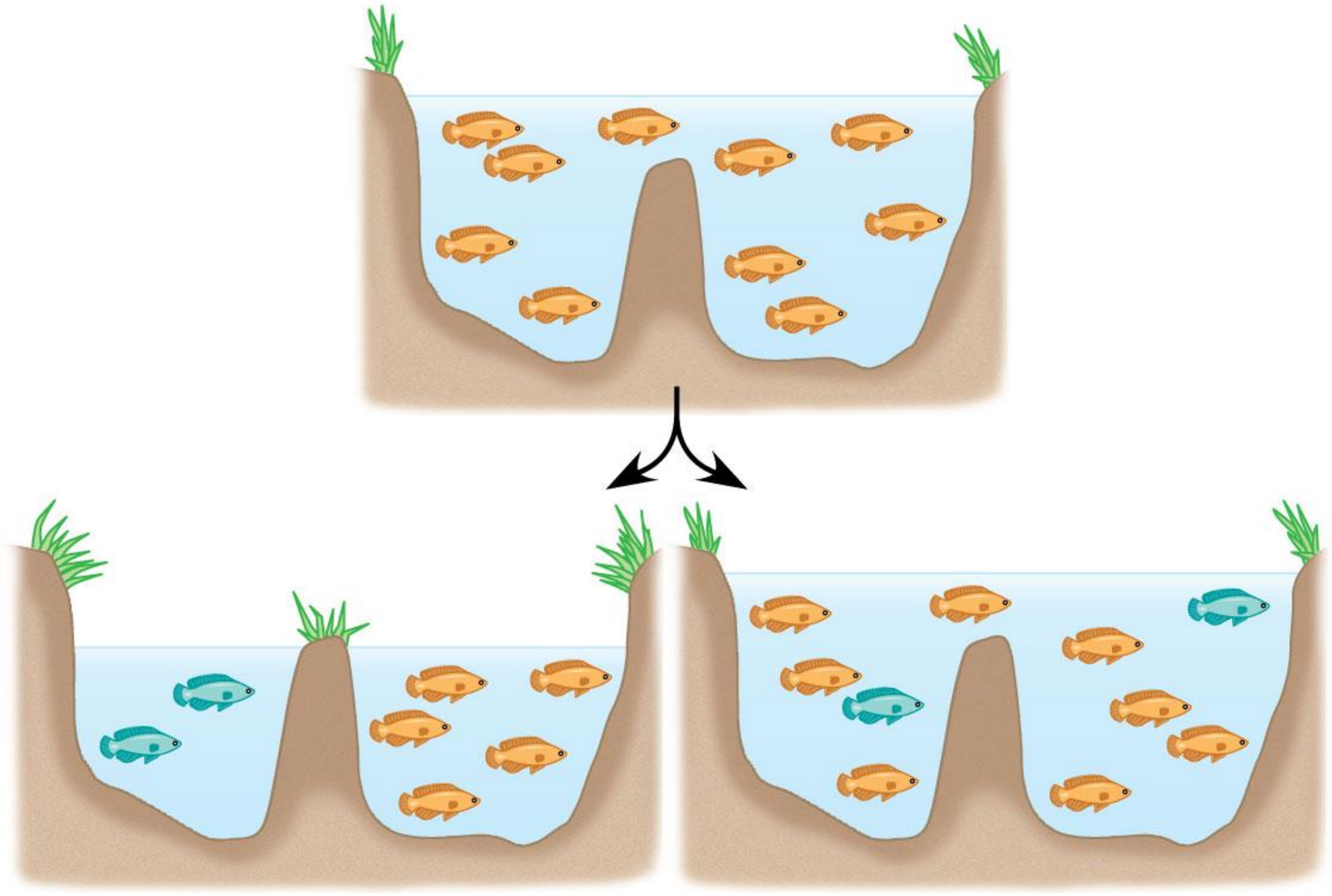
- Other species concepts emphasize the unity within a species rather than the separateness of different species
- The **morphological species concept** defines a species by structural features
  - It applies to sexual and asexual species but relies on subjective criteria

- The **ecological species concept** 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
  - Sympatric speciation

Figure 24.5



(a) **Allopatric speciation.** A population forms a new species while geographically isolated from its parent population.

(b) **Sympatric speciation.** A subset of a population forms a new species without geographic separation.

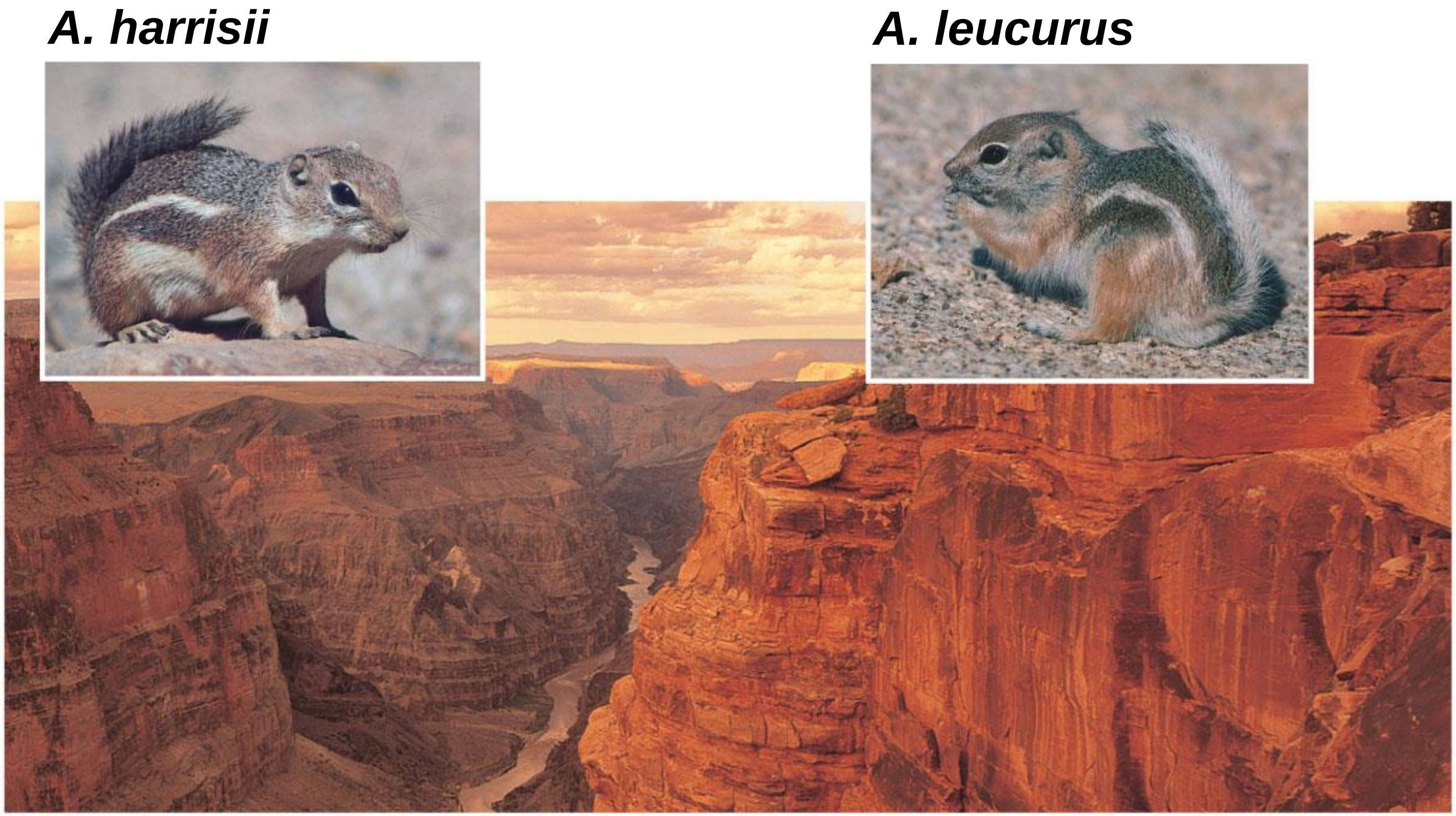
Allopatric (“Other Country”) Speciation

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

The Process of Allopatric Speciation

- The definition of barrier depends on the ability of a population to disperse
  - For example, a canyon may create a barrier for small rodents, but not birds, coyotes, or pollen

Figure 24.6

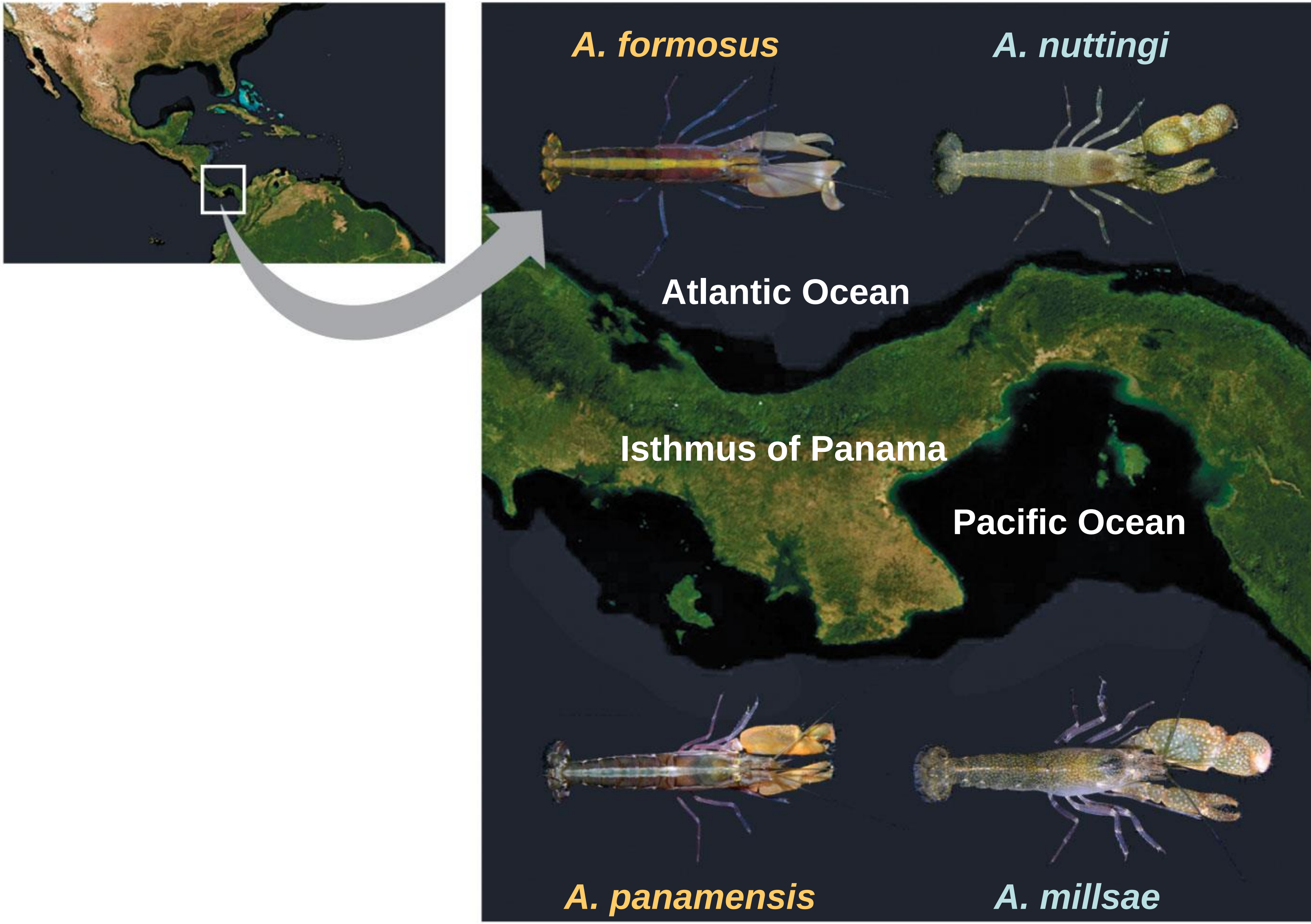


- Separate populations may evolve independently through mutation, natural selection, and genetic drift
- Reproductive isolation may arise as a result of genetic divergence
  - For example, mosquitofish in the Bahamas comprise several isolated populations in different ponds

Evidence of Allopatric Speciation

- 15 pairs of sibling species of snapping shrimp (*Alpheus*) are separated by the Isthmus of Panama
- These species originated 9 to 13 million years ago, when the Isthmus of Panama formed and separated the Atlantic and Pacific waters

Figure 24.8



A. formosus
A. nuttingi
Atlantic Ocean
Isthmus of Panama
Pacific Ocean
A. panamensis
A. millsae

- Regions with many geographic barriers typically have more species than do regions with fewer barriers
- Reproductive isolation between populations generally increases as the distance between them increases
  - For example, reproductive isolation increases between dusky salamanders that live further apart

Sympatric (“Same Country”) Speciation

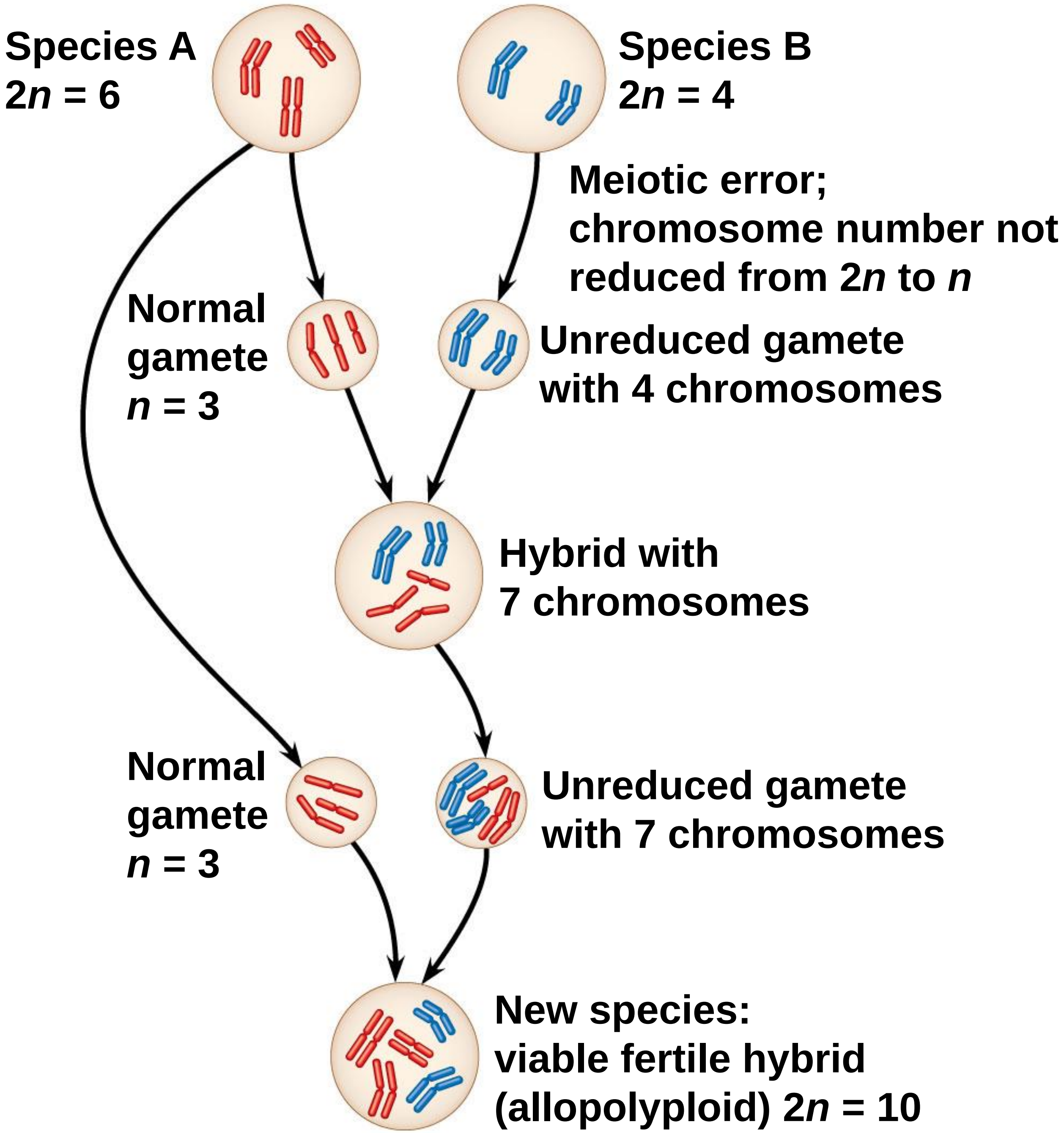
- In **sympatric speciation**, speciation takes place in geographically overlapping populations

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
- 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

Figure 24.11-4



- Many important crops (oats, cotton, potatoes, tobacco, and wheat) are polyploids

Habitat Differentiation

- 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

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

Allopatric and Sympatric Speciation: *A Review*

- In allopatric speciation, geographic isolation 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

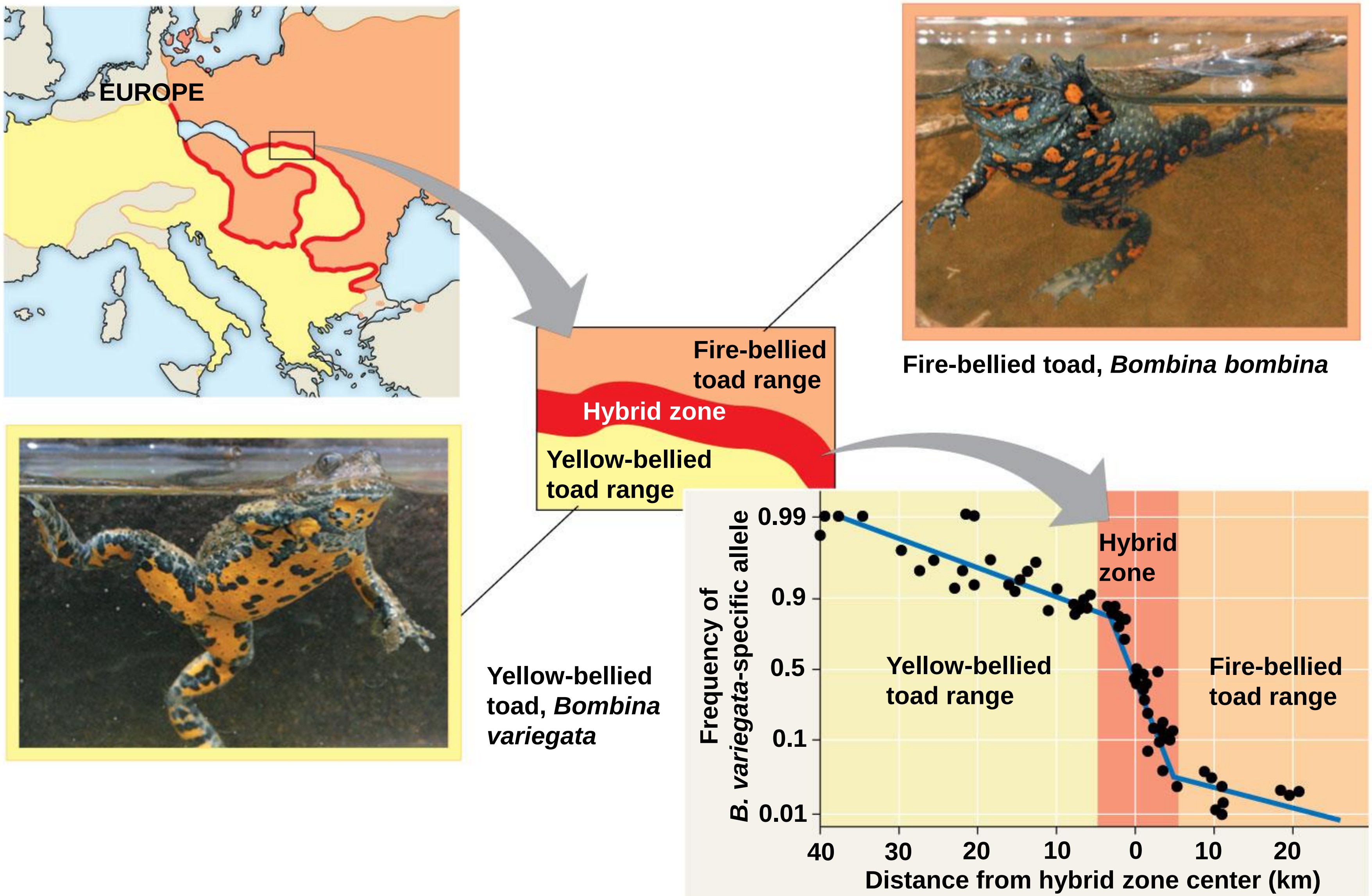
Concept 24.3: Hybrid zones reveal factors that cause reproductive isolation

- A **hybrid zone** is a region in which members of different species mate and produce hybrids
- Hybrids are the result of mating between species with incomplete reproductive barriers

Patterns Within Hybrid Zones

- A hybrid zone can occur in a single band where adjacent species meet
  – For example, two species of toad in the genus *Bombina* interbreed in a long and narrow hybrid zone

Figure 24.13

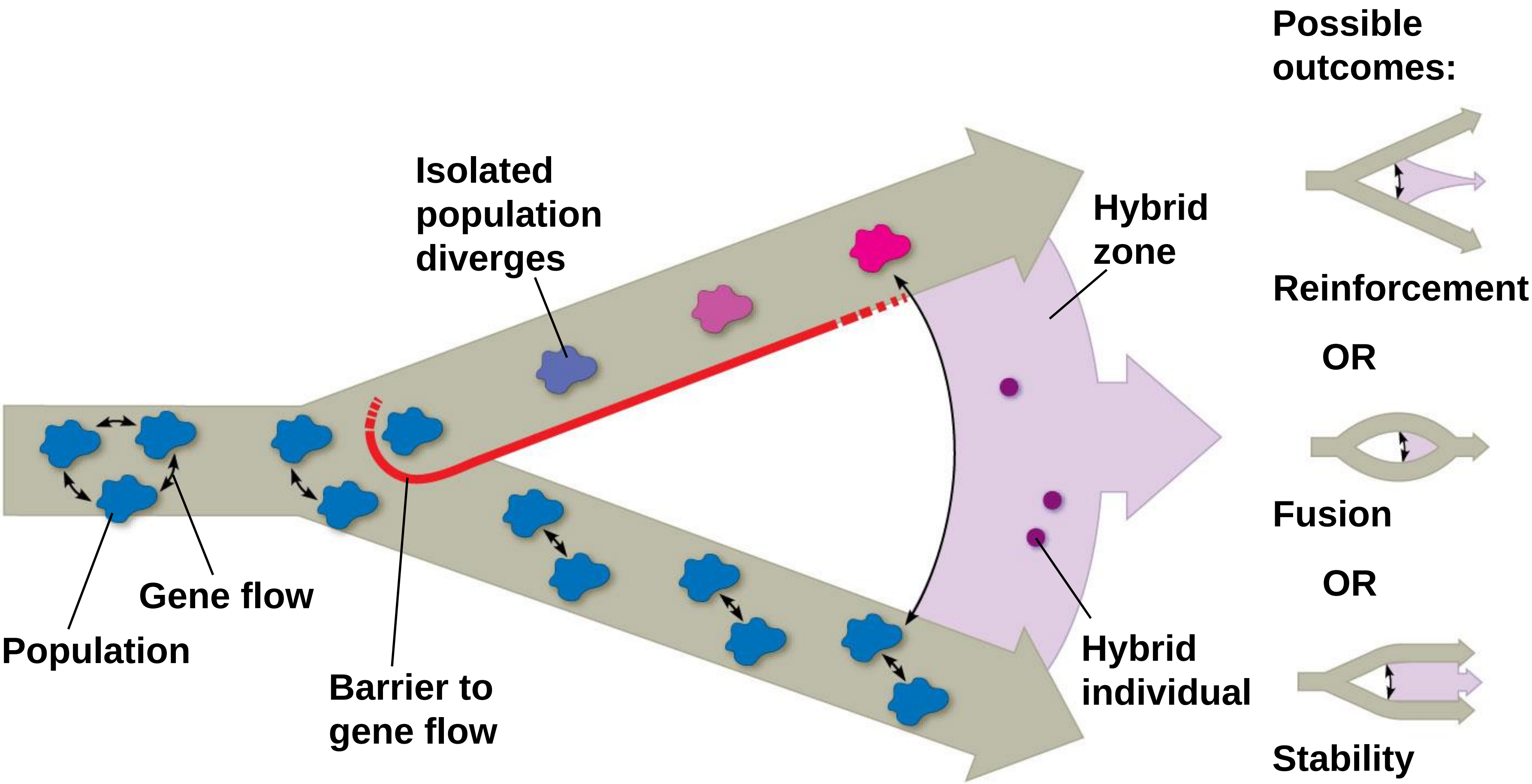

EUROPE
Fire-bellied
toad range
Hybrid zone
Yellow-bellied
toad range
Fire-bellied toad, Bombina bombina
Yellow-bellied
toad, Bombina
variegata
Frequency of
B. variegata-specific allele
0.99
0.9
0.5
0.1
0.01
Hybrid
zone
Yellow-bellied
toad range
Fire-bellied
toad range
40
30
20
10
0
10
20
Distance from hybrid zone center (km)

- Hybrids often have reduced fitness compared with parent species
- The distribution of hybrid zones can be more complex if parent species are found in patches within the same region

Hybrid Zones over Time

- When closely related species meet in a hybrid zone, there are three possible outcomes:
  - Reinforcement
  - Fusion
  - Stability

Figure 24.14-4



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

- Many questions remain concerning how long it takes for new species to form, or how many genes need to differ between species

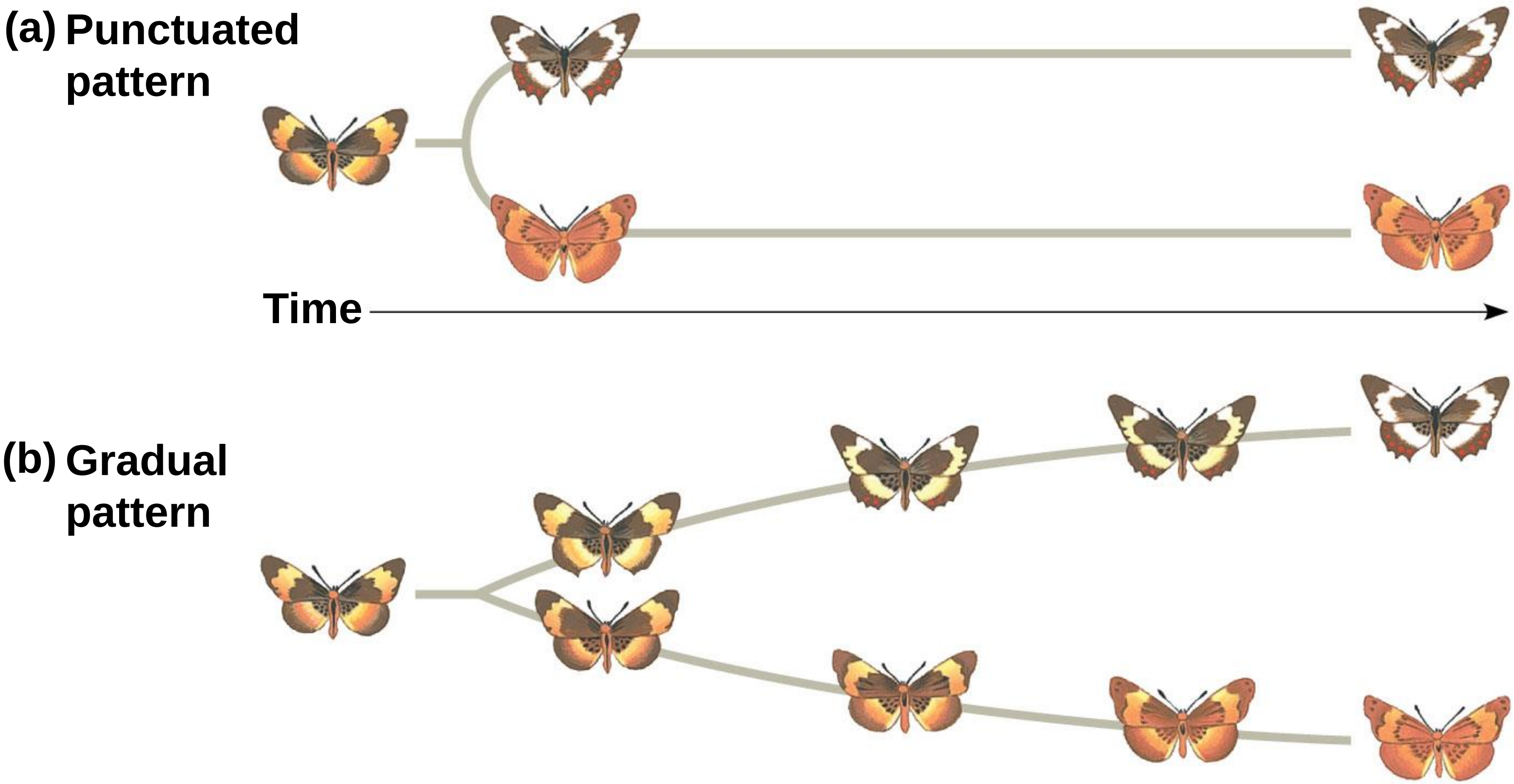
The Time Course of Speciation

- Broad patterns in speciation can be studied using the fossil record, morphological data, or molecular data

Patterns in the Fossil Record

- 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 equilibria** to describe periods of apparent stasis punctuated by sudden change
- The punctuated equilibrium model contrasts with a model of gradual change in a species' existence

Figure 24.17



Speciation Rates

- The punctuated pattern in the fossil record and evidence from lab studies suggest that speciation can be rapid
  - For example, the sunflower *Helianthus anomalus* originated from the hybridization of two other sunflower species

- The interval between speciation events can range from 4,000 years (some cichlids) to 40 million years (some beetles), with an average of 6.5 million years

Studying the Genetics of Speciation

- A fundamental question of evolutionary biology persists: How many genes change when a new species forms?
- Depending on the species in question, speciation might require the change of only a single allele or many alleles
  - For example, in Japanese *Euhadra* snails, the direction of shell spiral affects mating and is controlled by a single gene

- In monkey flowers (*Mimulus*), 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 species, speciation can be influenced by larger numbers of genes and gene interactions

From Speciation to Macroevolution

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

Figure 24.UN03

Ancestral species:

AA

Triticum monococcum
(2*n* = 14)

BB

Wild
Triticum
(2*n* = 14)

DD

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

Product:

AA BB DD

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