Environmental Science, 15e

G. TYLER MILLER | SCOTT E. SPOOLMAN

4

Biodiversity and Evolution

Core Case Study: Why Are Amphibians Vanishing?

- Amphibians (frogs, toads, and salamanders) show great biodiversity (more than 6,700 species)
  - Many populations have declined or vanished
- Why is the loss of amphibian populations significant?
- Why are pharmaceutical companies interested in the preservation of amphibian species?

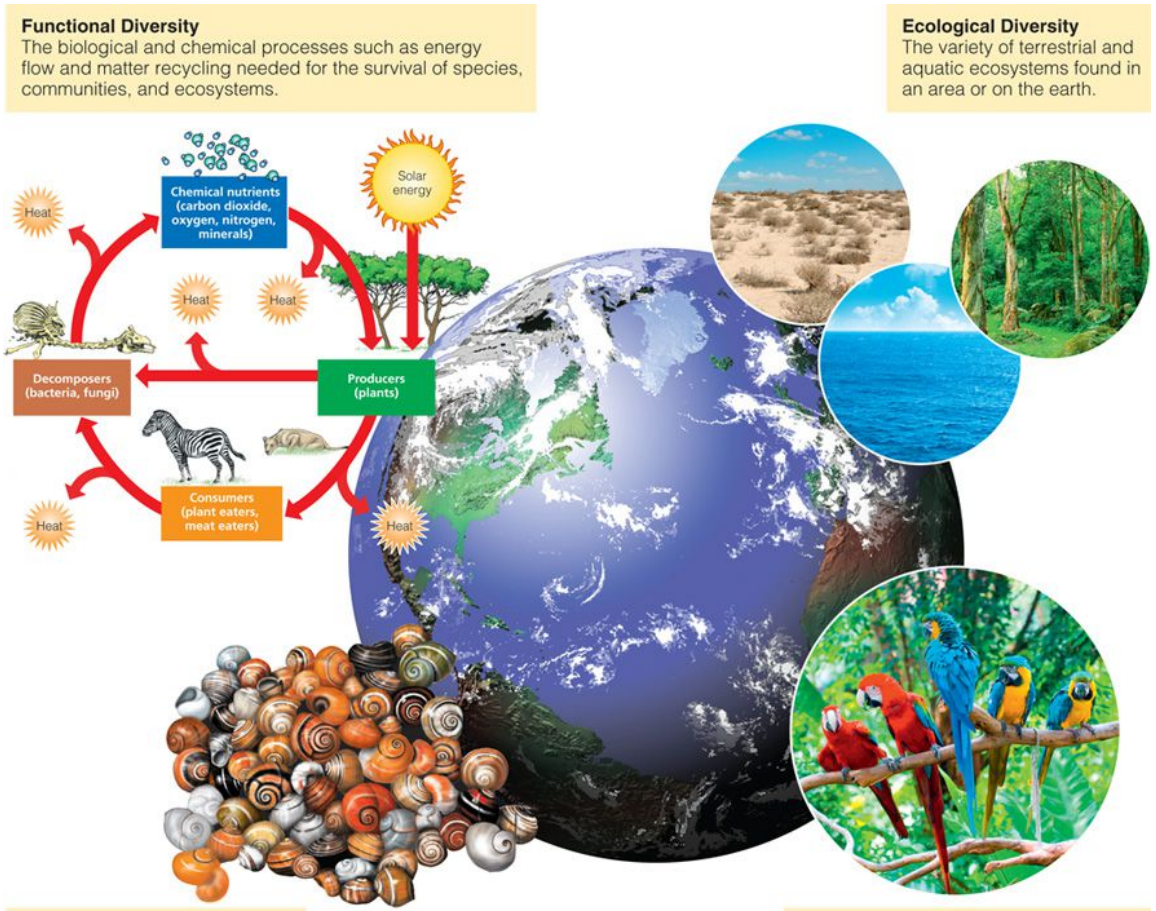
4.1 What Is Biodiversity and Why Is It Important?

- Sustaining life on the earth depends on the biodiversity found in genes, species, ecosystems, and ecosystem processes

Biodiversity Is a Crucial Part of the Earth's Natural Capital

- Biodiversity is the variety in:
  - Species (species diversity)
  - The genes they contain (genetic diversity)
  - Ecosystems (ecological diversity)
  - Ecosystem processes, such as energy flow and nutrient cycling (functional diversity)

Natural Capital: Earth's Biodiversity



Right side, Top left: Laborant/Shutterstock.com; Right side, Top right: leungchopan/Shutterstock.com; Right side, Top center: Elenamiv/Shutterstock.com; Bottom right: Juriah Mosin/Shutterstock.com. © Cengage Learning

Biodiversity Includes a Number of Components

- Species diversity is the number and variety of species in a biological community
- Genetic diversity is the variety of genes in a population or species

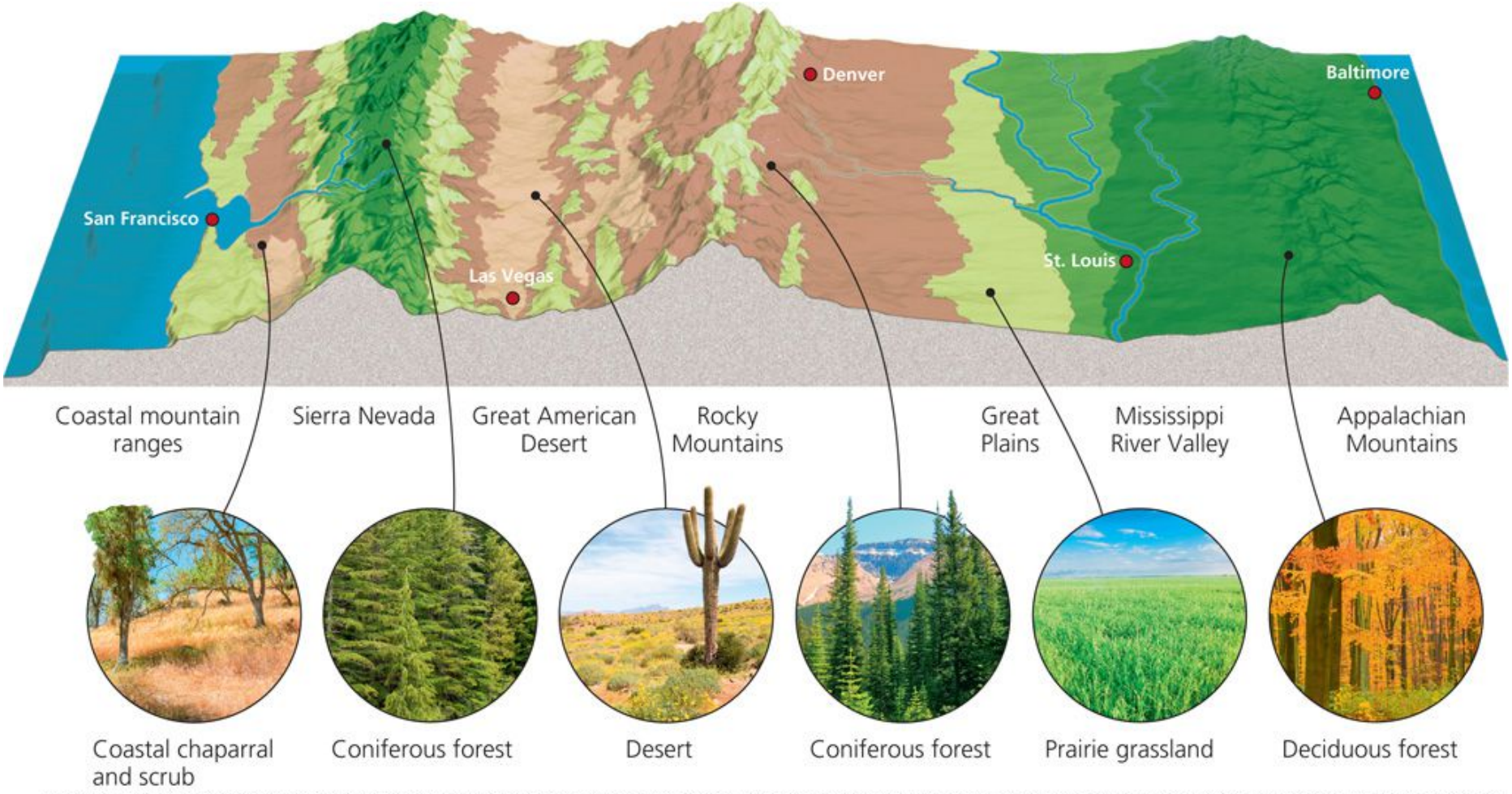
Genetic Diversity

© Cengage Learning

Species and Biomes

- Species
  - Set of individuals that can mate and produce fertile offspring – every organism is a member of a certain species
- Ecosystem diversity
  - Deserts, grasslands, forests, mountains, oceans, lakes, rivers, and wetlands
  - Biomes are major habitations/large ecosystems with distinct climates and species

A Variety of Biomes



First: Zack Frank/Shutterstock.com; Second: Robert Crum/Shutterstock.com; Third: Joe Belanger/Shutterstock; Fourth: Protasov AN/Shutterstock.com; Fifth: Maya Kruchankova/Shutterstock.com; Sixth: Marc von Hacht/Shutterstock.com.

4.2 What Roles Do Species Play in Ecosystems?

- Each species has a specific ecological role called its niche (what the species does)
- There are four important roles that a species can play in a particular ecosystem
  - Native
  - Nonnative
  - Indicator
  - Keystone

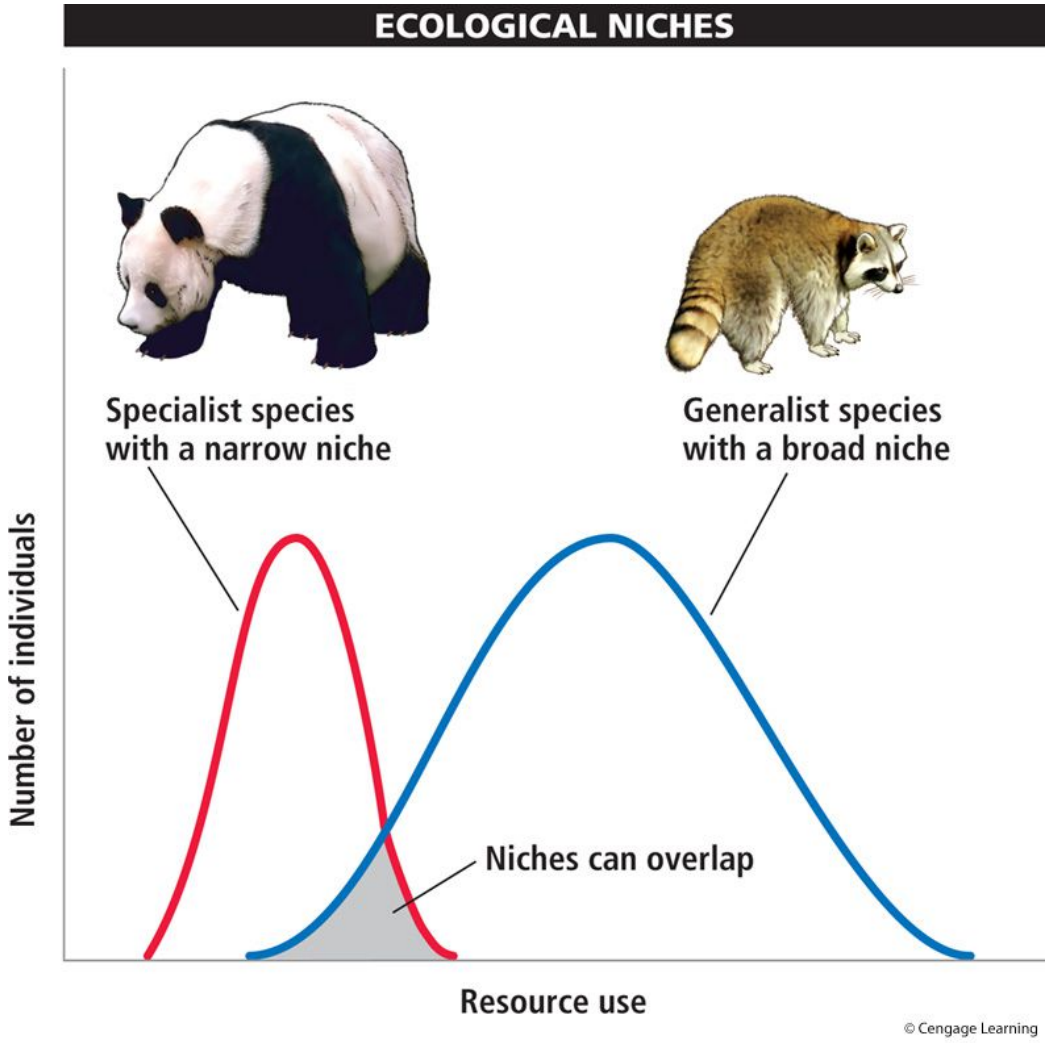
Each Species Plays a Role in Its Ecosystem

- Niche
  - The role the species plays in an ecosystem and everything that affects its survival and reproduction
- Habitat
  - The geographic location of the species
- Species
  - May be generalists with broad niches, or specialists with narrow niches

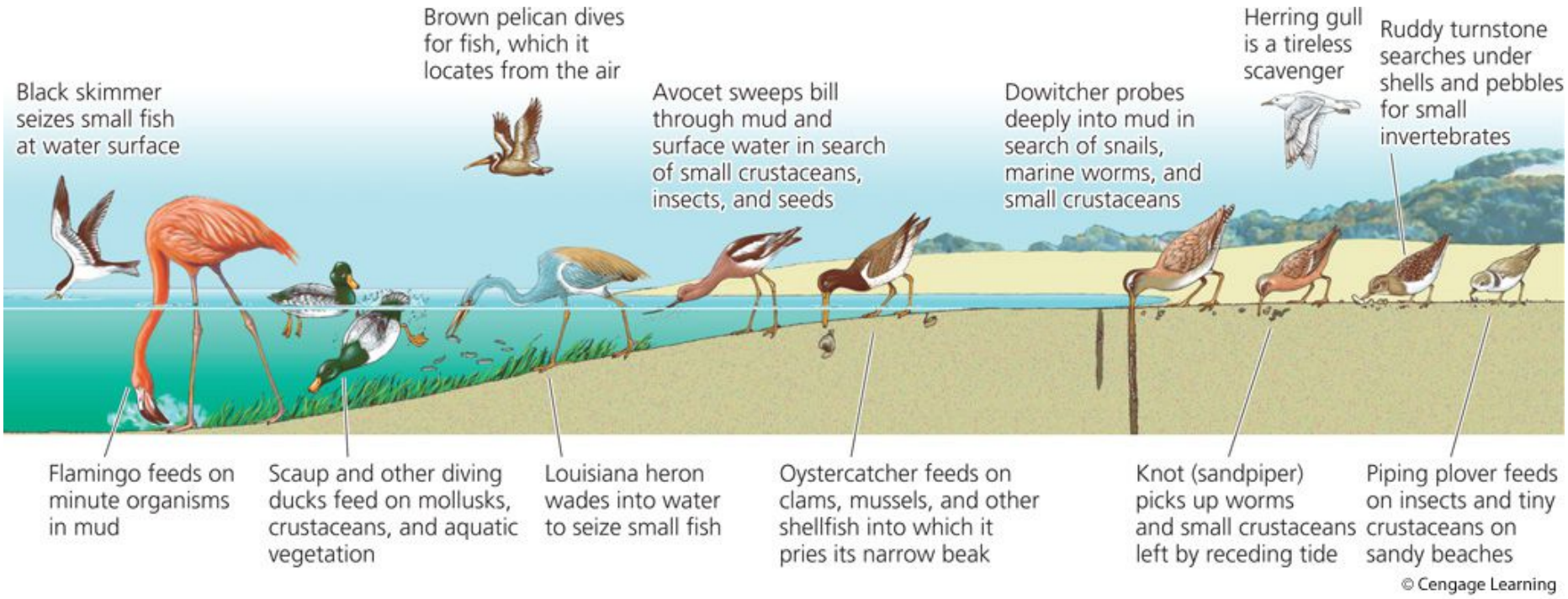
Generalist and Specialist Species

- Generalist species (broad niches)
  - Can live in a wide range of environments; less prone to extinction
- Specialist species (narrow niches)
  - Live in only a few types of habitats; more prone to extinction because of their inability to tolerate environmental change
- Is it better to be a generalist or a specialist?

A Specialist and a Generalist



Specialization Reduces Competition



Native and Nonnative Species

- Native species
  - Live and thrive in a specific ecosystem
- Nonnative species
  - Immigrate into, or are deliberately or accidentally introduced, into an ecosystem
  - Can threaten native species through competition for resources, reducing the number native species
  - Can spread rapidly if they find a favorable niche

Indicator Species Serve as an Biological Smoke Alarm

- An indicator species is sensitive to changes in an ecosystem
  - Provide early warnings of community and ecosystem change
  - Some amphibian species are good indicator species – their extinction in Central and South American tropical forests has been tied to climate change

Keystone Species Play Critical Roles in Their Ecosystems

- Keystone species affect the type and abundance of other species in an ecosystem and can be responsible for:
  - Pollination of flowering species (butterflies, honeybees)
  - Regulation of populations of other species (wolves, alligators)
  - May cause population crashes and extinction of dependent species if drawn to extinction itself

Case Study: The American Alligator – A Keystone Species

- The American alligator, a keystone species of subtropical wetland ecosystems
  - Almost hunted to extinction – so much so it was placed on the endangered species list
  - Today, it has recovered and been removed from this list
- Why is this an important success story?
- What nonnative invader species is now threatening American alligators?

Case Study: Why Should We Protect Sharks?

- Sharks, a keystone species, are being degraded by human activities:
  - Over a million are killed annually in response to exaggerated media reports on shark attacks
  - Harvested for their fins and for Asian pharmaceutical cure-alls
- Do you think sharks should be a protected species?

4.3 How Does the Earth's Life Change Over Time?

- The theory of evolution as demonstrated in the process of natural selection
  - Explains how life on the earth changes over time due to changes in the genes of populations
- Population evolution occurs through gene mutation
  - Gives individuals genetic traits that enhance their ability to survive and produce offspring

Biological Evolution by Natural Selection Explains How Life Changes Over Time

- Fossils reveal the history of life
- Biological evolution
  - The expression of genetic variation over time by succeeding generations (natural selection)
  - Through natural selection, species evolve over time from earlier ancestral ones
  - Individuals with traits that increase their survivability are more likely to produce offspring and pass on these traits

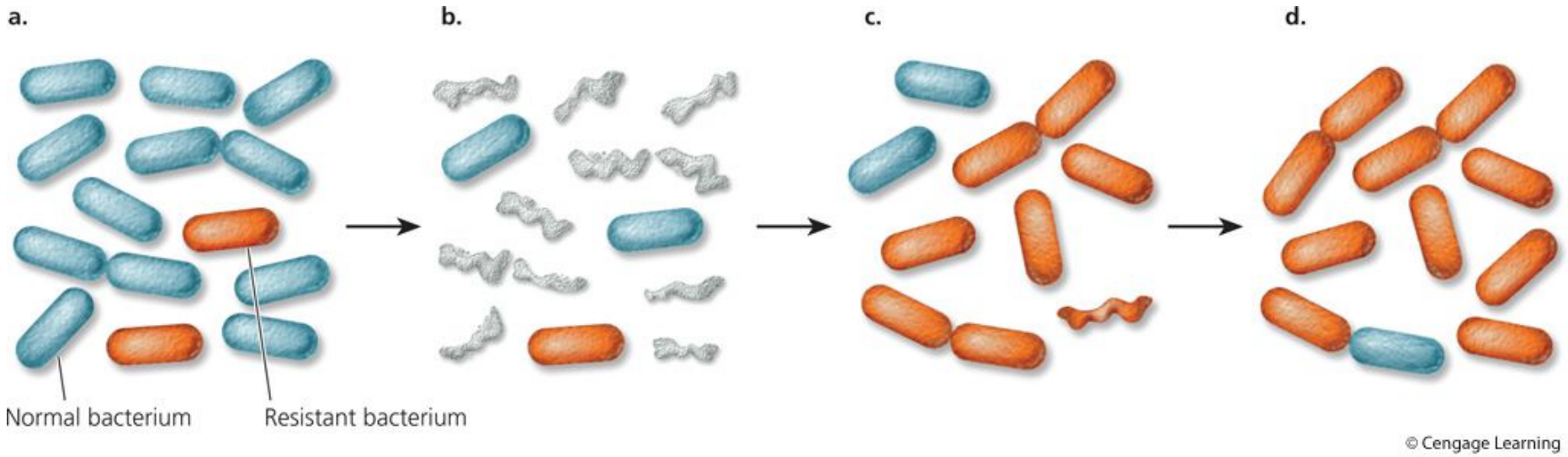
Mutations Are Changes in Genetic Composition (DNA)

- Some are random; others occur by exposure to radioactivity, ultraviolet radiation, and chemicals (mutagens)
- Genetic changes in reproductive cells are inherited by offspring (heritable traits)
- Some heritable traits give individuals advantages that improve their ability to survive and reproduce (adaptive traits)

Biological Evolution By Natural Selection Depends on Genetic Diversity

- Genetic resistance
  - The ability of one or more organisms in a population to tolerate chemicals designed to kill the population
  - Develops in bacteria and insect species because they rapidly produce large numbers of offspring (antibiotic-resistant bacteria)

Evolution by Natural Selection



Adaptation Through Natural Selection Has Limits

- Limiting factors for adaptation:
  - Organisms can only adapt to a change in environmental conditions if the necessary genetic traits are already present in a population's gene pool
  - Even if a beneficial heritable trait is present in a population, the population's ability to adapt may be limited by its reproductive capacity

Some Common Myths About Evolution Through Natural Selection

- "Survival of the fittest" means "survival of the strongest"
  - For biologists, fittest are those that are most reproductively successful and leave the most descendants, not the strongest physically
- "Evolution explains the origins of life"
  - Instead, evolution explains how species developed after life began

More Common Myths

- "Humans evolved from apes or monkeys"
  - Humans, apes and monkeys evolved along different paths from a common ancestor
- "Evolution by natural selection involves a grand plan of nature in which species are to become more perfectly adapted"
  - There is no clear path – forces of natural selection and random mutation can push evolution along many different paths

4.4 What Factors Affect Biodiversity?

- As environmental conditions change, biodiversity is determined by the balance between formation of new species and the extinction of existing species
- Human activity has caused loss of biodiversity:
  - By causing extinction of species
  - Through degradation of habitats needed for development of new species

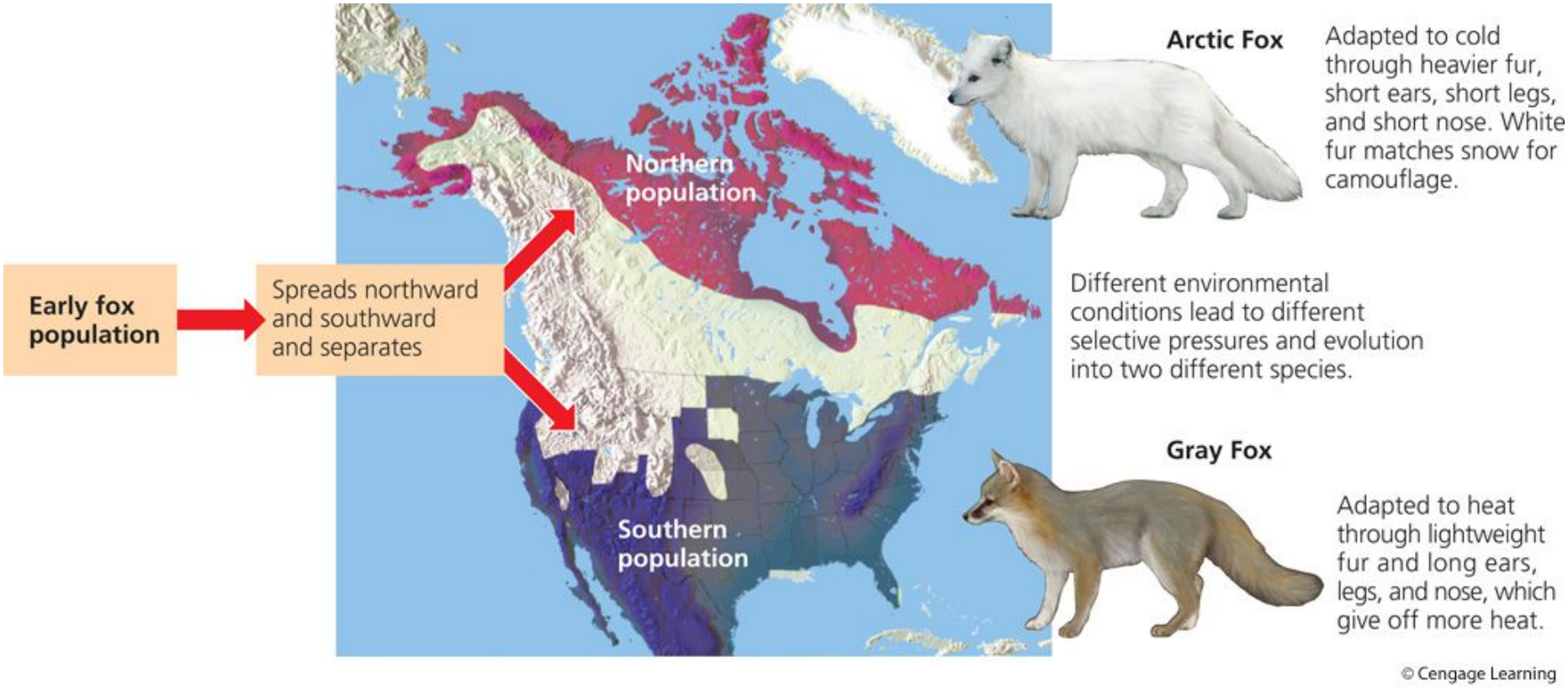
How Do New Species Arise?

- Speciation occurs when one species splits into two or more different species
  - Species are considered different when individuals can no longer breed and reproduce fertile offspring

Geographic and Reproductive Isolation

- Geographic isolation
  - Occurs when groups of the same population become physically isolated (by mountains, rivers, roads or distance) from one another over time
- Reproductive isolation
  - Occurs when mutation and change by natural selection operate independently in the gene pool of geographically isolated populations

Geographic Isolation Can Lead to Reproductive Isolation



How Do Humans Affect Biodiversity?

- By contributing to the rise of new species through artificial selection
  - Selectively breed or crossbreed between genetic variations of the same species
- By using genetic engineering to quickly manipulate genes
  - Alter segments of DNA for desired traits
  - Transfer genes between different species that would not interbreed in nature

All Species Eventually Become Extinct

- Extinction occurs when a species ceases to exist (biological extinction)
- A species facing a crisis may:
  - Adapt to the new changes in the environment
  - Migrate to a new geographic location that is more suitable to their lifestyle
  - Become extinct

Endemic Species Are Very Vulnerable to Extinction

- Found in only unique geographic areas – making it difficult for them to migrate or adapt during rapidly changing environmental conditions
- Many endangered endemic species are amphibians

Background Versus Mass Extinction

- Background extinction – slower rate that existed before human population became significant
- Mass extinction – significant rise in extinction over background extinction rate
  - Often global events tied to major widespread environmental change
  - Have also occurred as a result of human activity

A Short History of Mass Extinctions

- Fossil and geological evidence indicate that there have probably been five mass extinctions during the past 500 million years
- These mass extinctions have been followed by an increase in species diversity
  - New species arise to fill unoccupied niches or to exploit newly available ones

When Will the Next Mass Extinction Occur?

- Evidence suggests that speciation on average through time has kept ahead of extinction
- However, scientists now think we may be experiencing the beginning of a new mass extinction that is the result of human activity

Additional Case Study: The Ivory-Billed Woodpecker – Extinct?

- Native to southeast U.S. wetlands and forests
  - Last sighted in the 1940s and was deemed extinct in the mid-1990s – due to deforestation/habitat loss and overhunting
  - In the early 2000s, Cornell Ornithology Lab scientists searched more than half a million acres over eight states looking for the ivory-billed woodpecker

Additional Case Study: Ivory-Billed Woodpecker – Sighted

- No confirmed sightings until 2005
  - A single male was sighted (confirmed by the research team and the director of the Cornell Ornithology Lab)
- How does this case study pertain to biodiversity and extinction?
- Why should you be concerned about species going extinct?

The Ivory-Billed Woodpecker and the Three Big Ideas

- These woodpeckers' niche involves stripping bark from dead trees to feed on beetle larvae inside the trees
  - As environmental conditions changed, their habitat was destroyed so thoroughly that they may not have had a chance to genetically adapt to these changes
- Sometimes organisms deemed extinct are actually rediscovered as still living