Biodiversity and Evolution

Chapter 4
Core Case Study: Why Should We Care about the American Alligator?

- Largest reptile in North America
- 1930s: Hunters and poachers
- Importance of gator holes and nesting mounds
- 1967: endangered species
- 1977: comeback, threatened species
The American Alligator
4-1 What Is Biodiversity and Why Is It Important?

- **Concept 4-1** The biodiversity found in genes, species, ecosystems, and ecosystem processes is vital to sustaining life on earth.
Biodiversity Is a Crucial Part of the Earth’s Natural Capital

- Vital renewable resource
- Species diversity
- Ecosystem diversity
- Functional diversity
Natural Capital: Major Components of the Earth’s Biodiversity

**Functional Diversity**
The biological and chemical processes such as energy flow and matter recycling needed for the survival of species, communities, and ecosystems.

**Ecological Diversity**
The variety of terrestrial and aquatic ecosystems found in an area or on the earth.

**Genetic Diversity**
The variety of genetic material within a species or a population.

**Species Diversity**
The number and abundance of species present in different communities.
Animation: Evolutionary tree of life
Active Figure: Matter recycling and energy flow
Video: Frogs galore
4-2 Where Do Species Come From?

- **Concept 4-2A** The scientific theory of evolution explains how life on earth changes over time through changes in the genes of populations.

- **Concept 4-2B** Populations evolve when genes mutate and give some individuals genetic traits that enhance their abilities to survive and to produce offspring with these traits (natural selection).
Biological Evolution by Natural Selection Explains How Life Changes over Time

- Biological evolution

- Natural selection
  - Charles Darwin
  - Alfred Russel Wallace

- Tree of Life
Six Major Kingdoms of Species as a Result of Natural Selection

- Prokaryotes
  - Eubacteria
  - Archaeobacteria
- Eukaryotes
  - Protists
  - Plants
  - Fungi
  - Animals
Cenozoic
Mesozoic
Paleozoic
Precambrian

Millions of years ago

First humans
Extinction of dinosaurs
Plants colonize land
Origin of multicellular organisms
Oldest eukaryotic fossils

Accumulation of O₂ in atmosphere from photosynthetic cyanobacterium
Oldest prokaryotic fossils
Earth cool enough for crust to solidify
Origin of Earth

Prokaryotes
Eubacteria
Archaeabacteria

Eukaryotes
Protists
Plants
Fungi
Animals

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The Fossil Record Tells Much of the Story of Evolution

- **Fossils**
  - Physical evidence of ancient organisms
  - Reveal what their internal structures looked like

- Fossil record is incomplete: why?
Fossilized Skeleton of an Herbivore that Lived during the Cenozoic Era
The Genetic Makeup of a Population Can Change

- Populations evolve by becoming genetically different

- Genetic variations
  - First step in biological evolution
  - Occurs through mutations in reproductive cells
Individuals in Populations with Beneficial Genetic Traits Can Leave More Offspring

- Natural selection: acts on individuals
  - Second step in biological evolution
  - Adaptation may lead to **differential reproduction**
  - Genetic resistance

- When environmental conditions change, populations
  - Adapt
  - Migrate
  - Become extinct
Evolution by Natural Selection

(a) A group of bacteria, including genetically resistant ones, are exposed to an antibiotic

(b) Most of the normal bacteria die

(c) The genetically resistant bacteria start multiplying

(d) Eventually the resistant strain replaces the strain affected by the antibiotic

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A group of bacteria, including genetically resistant ones, are exposed to an antibiotic. Most of the normal bacteria die, but the genetically resistant bacteria start multiplying. Eventually the resistant strain replaces the strain affected by the antibiotic.
Most of the normal bacteria die. The genetically resistant bacteria start multiplying. Eventually the resistant strain replaces the strain affected by the antibiotic.
Case Study: How Did Humans Become Such a Powerful Species?

- Three human adaptations
  - Strong opposable thumbs
  - Walk upright
  - Complex brain
Adaptation through Natural Selection Has Limits

- Genetic change must precede change in the environmental conditions
- Reproductive capacity
Three Common Myths about Evolution through Natural Selection

- “Survival of the fittest” is not “survival of the strongest”
- Organisms do not develop traits out of need or want
- No grand plan of nature for perfect adaptation
Animation: Adaptive trait
Animation: Modeling genetic drift
Animation: Disruptive selection
Animation: Evolutionary tree diagrams
Animation: Change in moth population
Animation: Stabilizing selection
Video: Dinosaur discovery
4-3 How Do Geological Processes and Climate Change Affect Evolution?

- **Concept 4-3** Tectonic plate movements, volcanic eruptions, earthquakes, and climate change have shifted wildlife habitats, wiped out large numbers of species, and created opportunities for the evolution of new species.
Geologic Processes Affect Natural Selection

- Tectonic plates affect evolution and the location of life on earth
  - Location of continents and oceans
  - Species physically move, or adapt, or form new species through natural selection

- Earthquakes

- Volcanic eruptions
Movement of the Earth’s Continents over Millions of Years

- 225 million years ago: Pangaea
- 135 million years ago: Gondwanaland
- 65 million years ago: Present: North America, Eurasia, Africa, South America, Antarctica, Australia

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225 million years ago

135 million years ago

65 million years ago

Present

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Fig. 4-6, p. 85
225 million years ago

135 million years ago

65 million years ago

Present

Stepped Art

Fig. 4-6, p. 85
Climate Change and Catastrophes Affect Natural Selection

- Ice ages followed by warming temperatures
- Collisions between the earth and large asteroids
  - New species
  - Extinction
Changes in Ice Coverage in the Northern Hemisphere During the last 18,000 Years
18,000 years before present

Northern Hemisphere Ice coverage

Modern day (August)

Legend
- Continental ice
- Sea ice
- Land above sea level

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Science Focus: Earth Is Just Right for Life to Thrive

- Certain temperature range
- Dependence on water
- Rotation on its axis
- Revolution around the sun
- Enough gravitational mass
Animation: Continental drift
Animation: Stanley Miller's experiment
Concept 4-4A  As environmental conditions change, the balance between formation of new species and extinction of existing species determines the earth’s biodiversity.

Concept 4-4B  Human activities can decrease biodiversity by causing the premature extinction of species and by destroying or degrading habitats needed for the development of new species.
How Do New Species Evolve?

- Geographic isolation
- Reproductive isolation
Geographic Isolation Can Lead to Reproductive Isolation

Early fox population spreads northward and southward and separates.

Arctic Fox: Adapted to cold through heavier fur, short ears, short legs, and short nose. White fur matches snow for camouflage.

Southern population

Different environmental conditions lead to different selective pressures and evolution into two different species.

Gray Fox: Adapted to heat through lightweight fur and long ears, legs, and nose, which give off more heat.
Early fox population spreads north and south and separates Northern population and Southern population.

**Arctic Fox**
Adapted to cold through heavier fur, short ears, short legs, and short nose. White fur matches snow for camouflage.

**Gray Fox**
Adapted to heat through lightweight fur and long ears, legs, and nose, which give off more heat.

Different environmental conditions lead to different selective pressures and evolution into two different species.
Extinction is Forever

- Extinction

- Endemic species
  - Particularly vulnerable
Golden Toad of Costa Rica, Extinct
Extinction Can Affect One Species or Many Species at a Time

- **Background extinction**

- **Mass extinction**
  - How numbered is debated: 3–5
Science Focus: We Have Two Ways to Change the Genetic Traits of Populations

- Artificial selection
- Genetic engineering, gene splicing

Consider
- Ethics
- Morals
- Privacy issues
- Harmful effects
Genetically Engineered Mice
Animation: Speciation on an archipelago
Animation: Transferring genes into plants

1. Genetically engineer bacteria
2. Make transgenic cell
3. Grow transgenic plant

Pause Animation

Reset Animation

PLAY
Video: Cloned pooch
Video: Creation vs. evolution
4-5 What Is Species Diversity and Why Is It Important?

- **Concept 4-5** Species diversity is a major component of biodiversity and tends to increase the sustainability of ecosystems.
Species Diversity: Variety, Abundance of Species in a Particular Place

- **Species diversity**
  - Species richness
  - Species evenness

- Diversity varies with geographical location
  - Most species-rich communities
    - Tropical rain forests
    - Coral reefs
    - Ocean bottom zone
    - Large tropical lakes
Variations in Species Richness and Species Evenness
Science Focus: Species Richness on Islands

- **Species equilibrium model, theory of island biogeography**
  - Rate of new species immigrating should balance with the rate of species extinction

- Island size and distance from the mainland need to be considered
Species-rich ecosystems tend to be productive and sustainable.

- Species richness seems to increase productivity and stability or sustainability.

- How much species richness is needed is debatable.
4-6 What Roles Do Species Play in Ecosystems?

- **Concept 4-6A** Each species plays a specific ecological role called its niche.

- **Concept 4-6B** Any given species may play one or more of five important roles—native, nonnative, indicator, keystone, or foundation roles—in a particular ecosystem.
Each Species Plays a Unique Role in Its Ecosystem

- **Ecological niche, niche**
  - Pattern of living

- **Generalist species**
  - Broad niche

- **Specialist species**
  - Narrow niche
Specialist Species and Generalist Species Niches

- Specialist species with a narrow niche
- Generalist species with a broad niche

Number of individuals vs. Resource use

Niche separation

Niche breadth

Region of niche overlap
Number of individuals

Specialist species with a narrow niche

Generalist species with a broad niche

Niche separation

Niche breadth

Region of niche overlap

Resource use

Fig. 4-11, p. 91
Case Study: Cockroaches: Nature’s Ultimate Survivors

- Cockroaches
  - Generalists
  - High reproductive rates

- Giant panda and tiger salamanders
  - Specialists
  - Low reproductive rates
Cockroach
Specialized Feeding Niches of Various Bird Species in a Coastal Wetland

- **Black skimmer** seizes small fish at water surface.
- **Brown pelican** dives for fish, which it locates from the air.
- **Avocet** sweeps bill through mud and surface water in search of small crustaceans, insects, and seeds.
- **Dowitcher** probes deeply into mud in search of snails, marine worms, and small crustaceans.
- **Herring gull** is a tireless scavenger.
- **Ruddy turnstone** searches under shells and pebbles for small invertebrates.
- **Flamingo** feeds on minute organisms in mud.
- **Scaup and other diving ducks** feed on mollusks, crustaceans, and aquatic vegetation.
- **Louisiana heron** wades into water to seize small fish.
- **Oystercatcher** feeds on clams, mussels, and other shellfish into which it pries its narrow beak.
- **Knot (sandpiper)** picks up worms and small crustaceans left by receding tide.
- **Piping plover** feeds on insects and tiny crustaceans on sandy beaches.

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Black skimmer seizes small fish at water surface
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Louisiana heron wades into water to seize small fish
Oystercatcher feeds on clams, mussels, and other shellfish into which it pries its narrow beak
Knot (sandpiper) picks up worms and small crustaceans left by receding tide
Piping plover feeds on insects and tiny crustaceans on sandy beaches
Niches Can Be Occupied by Native and Nonnative Species

- Native species

- Nonnative species; invasive, alien, or exotic species
  - May spread rapidly
  - Not all are villains
Indicator Species Serve as Biological Smoke Alarms

- **Indicator species**
  - Can monitor environmental quality
    - Trout
    - Birds
    - Butterflies
    - Frogs
Case Study: Why Are Amphibians Vanishing? (1)

- Habitat loss and fragmentation
- Prolonged drought
- Pollution
- Increase in UV radiation
- Parasites
- Viral and fungal diseases
- Climate change
- Overhunting
- Nonnative predators and competitors
Case Study: Why Are Amphibians Vanishing? (2)

- Importance of amphibians
  - Sensitive biological indicators of environmental changes
  - Adult amphibians
    - Important ecological roles in biological communities
  - Genetic storehouse of pharmaceutical products waiting to be discovered
Life Cycle of a Frog

1. **Eggs**
2. **Fertilized egg development**
3. **Tadpole**
4. **Tadpole develops into frog**
5. **Sexual reproduction**
6. **Adult frog (3 years)**
7. **Young frog**

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Keystone, Foundation Species Determine Structure, Function of Their Ecosystems

- **Keystone species**
  - Pollinators
  - Top predator

- **Foundation species**
  - Create or enhance their habitats, which benefit others
    - Elephants
    - Beavers
Case Study: Why Should We Protect Sharks?

- Keystone species
  - Eat dead and dying fish in the ocean
  - Strong immune systems
    - Wounds do not get infected
    - Almost never get cancer
    - Could help humans if we understood their immune system