Chapter 20

Communities and Ecosystems

Biology and Society: Does Biodiversity Matter?

- The expanding human population threatens
  - Biodiversity
  - The loss of natural ecosystems

Healthy ecosystems
- Purify air and water
- Decompose wastes
- Recycle nutrients

Wetlands
- Buffer coastal populations against hurricanes
- Reduce the impact of flooding rivers
- Filter pollutants

It is estimated that the average annual value of ecosystem services each year in the United States is more than $33 trillion.

THE LOSS OF BIODIVERSITY

- Biological diversity, or biodiversity, includes
  - Genetic diversity
  - Species diversity
  - Ecosystem diversity

Genetic Diversity
- The genetic diversity within populations of a species is the raw material that makes microevolution and adaptation to the environment possible.
- Genetic resources for that species are lost if
  - Local populations are lost
  - The number of individuals in a species declines
Species Diversity

• Ecologists believe that we are pushing species toward extinction at an alarming rate.
  
• The present rate of species loss
    – May be 1,000 times higher than at any time in the past 100,000 years
    – May result in the loss of half of all living plant and animal species by the end of this century

Ecosystem Diversity

• The local extinction of one species can have a negative effect on the entire ecosystem.

• The loss of ecosystems risks the loss of ecosystem services, including
  – Air and water purification
  – Climate regulation
  – Erosion control

Coral reefs are rich in species diversity, yet
  – An estimated 20% of the world’s coral reefs have been destroyed by human activities
  – 24% are in imminent danger of collapse
  – Another 26% of coral reefs may succumb in the next few decades if they are not protected

Causes of Declining Biodiversity

• Ecologists have identified four main factors responsible for the loss of biodiversity:
  – Habitat destruction and fragmentation
  – Invasive species
  – Overexploitation
  – Pollution

Habitat Destruction

• Biodiversity is threatened by the destruction and fragmentation of habitats by
  – Agriculture
  – Urban development
  – Forestry
  – Mining

Two recent victims of human-caused extinctions are
  – Chinese river dolphins
  – Golden toads
### Invasive Species
- Invasive species have
  - Competed with native species
  - Preyed upon native species
  - Parasitized native species

### Overexploitation
- People have overexploited wildlife by harvesting at rates that exceed the ability of populations to rebound.
- Excessive harvesting has greatly affected populations of
  - Tigers
  - Whales
  - The American bison
  - Galápagos tortoises

### Pollution
- Acid precipitation is a threat to
  - Forest ecosystems
  - Aquatic ecosystems
- Aquatic ecosystems may be polluted by toxic
  - Chemicals
  - Nutrients

### COMMUNITY ECOLOGY
- An organism’s biotic environment includes
  - Other individuals in its own population
  - Populations of other species living in the same area
- An assemblage of species living close enough together for potential interaction is called a **community**.

### Interspecific Interactions
- **Interspecific interactions** are interactions between species.

- Interspecific interactions can be classified according to the effect on the populations concerned.
  - −/+ interactions occur when two populations in a community compete for a common resource.
  - ++ interactions are mutually beneficial, such as between plants and their pollinators.
  - +/− interactions occur when one population benefits and the other is harmed, such as in predation.
**Interspecific Competition (−/−)**

- **In interspecific (between species) competition**, the population growth of a species may be limited by
  - The population densities of competing species
  - By the density of its own population

- **An ecological niche** is the sum of an organism’s abiotic and biotic resources in its environment.

**The competitive exclusion principle** states that if two species have an ecological niche that is too similar, the two species cannot coexist in the same place.

**Mutualism (+/+)**

- In **mutualism**, both species benefit from an interaction.
- One example is the mutualistic relationship of coral animals and the unicellular algae that live inside their cells.
  - The coral gains energy from the sugars produced by the algae.
  - The algae gain
    - A secure shelter
    - Access to light
    - Carbon dioxide
    - Ammonia, a valuable source of nitrogen

**Predation (+/−)**

- **Predation** refers to an interaction in which one species (the predator) kills and eats another (the prey).
- Numerous adaptations for predator avoidance have evolved in prey populations through natural selection.
• **Cryptic coloration** is
  - Camouflage
  - A way for prey to hide from predators

• **A warning coloration** is a
  - Brightly colored pattern
  - Way to warn predators that an animal has an effective chemical defense

• Mimicry is a form of defense in which one animal looks like another species.

• Some insects have elaborate disguises that make them resemble
  - Twigs
  - Leaves
  - Bird droppings
  - Predators

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**Herbivory (+/-)**

• **Herbivory** is the consumption of plant parts or algae by an animal.

• Plants have evolved numerous defenses against herbivory, including
  - Spines
  - Thorns
  - Chemical toxins

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**Parasites and Pathogens (+/-)**

• Plants and animals can be victims of
  - **Parasites**, an animal that lives in or on a *host* from which it obtains nutrients
  - Pathogens, disease-causing
    - Bacteria
    - Viruses
    - Fungi
    - Protists
**Trophic Structure**

- **Trophic structure** is the feeding relationships among the various species in a community.
- A community’s trophic structure determines the passage of energy and nutrients from plants and other photosynthetic organisms
  - To herbivores
  - And then to predators

- The trophic level that supports all other trophic levels consists of autotrophs, also called **producers**.

- All organisms in trophic levels above the producers are heterotrophs, or **consumers**.
- **Primary consumers** are called **herbivores**, which eat plants.

- Above the level of primary consumers are carnivores, which eat the consumers from the level below.
  - **Secondary consumers** eat primary consumers.
  - **Tertiary consumers** eat secondary consumers.
  - **Quaternary consumers** eat tertiary consumers.

- **Detritivores**, which are often called scavengers, consume **detritus**, the dead material left by all trophic levels.
- **Decomposers** are prokaryotes and fungi, which secrete enzymes that digest molecules in organic material and convert them into inorganic forms.

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![Food Chain Diagram](image)
**Biological Magnification**

- Environmental toxins accumulate in consumers at higher concentrations up a trophic system in a process called **biological magnification**.

**Food Webs**

- Few ecosystems are as simple as an unbranched food chain.
- **Omnivores**
  - Eat producers and consumers
  - Form woven ecosystems called **food webs**

**Species Diversity in Communities**

- Species diversity of a community consists of
  - **Species richness**, the number of different species in the community
  - **Relative abundance** of the different species, the proportional representation of a species in a community
• The next figure shows that the relative abundance of one species in woodland A is much higher than the other three species.

![Figure 20.20](image)

• A **keystone species** is a species whose impact on its community is much larger than its total mass or abundance indicates.
• Experiments in the 1960s demonstrated that a sea star functioned as a keystone species in intertidal zones of the Washington coast.

**Disturbances in Communities**
• Disturbances are episodes that damage biological communities, at least temporarily, by
  - Destroying organisms
  - Altering the availability of resources such as mineral nutrients and water.

• Examples of disturbances are
  - Storms
  - Fires
  - Floods
  - Droughts

• Disturbances may cause
  - The emergence of a previously unknown disease
  - Opportunities for other organisms to grow
# Ecological Succession

- Disturbances may cause a gradual replacement by other species in a process called **ecological succession**.

- **Primary succession** begins
  - In a virtually lifeless area with no soil
  - In places such as
    - Lava flows or
    - The rubble left by a retreating glacier

- **Secondary succession** occurs where a disturbance has
  - Destroyed an existing community
  - Left the soil intact

- Examples of secondary succession are areas recovering from
  - Fires
  - Floods
  - Severe storms

## ECOSYSTEM ECOLOGY

- An **ecosystem** includes
  - The community of species in a given area
  - All the abiotic factors, such as
    - Energy
    - Soil characteristics
    - Water

- A simple terrarium is a microcosm that exhibits the two major processes that sustain all ecosystems:
  - Energy **flow**, the passage of energy through the components of the ecosystem
  - Chemical **cycling**, the use and reuse of chemical elements such as carbon and nitrogen within the ecosystem

- Energy **flows through** ecosystems.

- Chemicals are recycled **within** and **between** ecosystems.

![Diagram of energy flow and chemical cycling in a terrarium](image.png)
Energy Flow in Ecosystems

- All organisms require energy for
  - Growth
  - Maintenance
  - Reproduction
  - In many species, locomotion

Primary Production and the Energy Budgets of Ecosystems

- Each day, the Earth receives about $10^{19}$ kcal of solar energy, the energy equivalent of about 100 million atomic bombs.

- Most of this energy is absorbed, scattered, or reflected by the atmosphere or by Earth’s surface.
- About 1% is converted to chemical energy by photosynthesis.

- The amount, or mass, of living organic material in an ecosystem is the biomass.
- The rate at which an ecosystem’s producers convert solar energy to the chemical energy stored in biomass
  - Is primary production
  - Yields about 165 billion tons of biomass per year
- Different ecosystems vary considerably in their primary production.

Ecological Pyramids

- When energy flows as organic matter through the trophic levels of an ecosystem, much of it is lost at each link in the food chain.
- Consider the example of a caterpillar.
• A pyramid of production illustrates the cumulative loss of energy with each transfer in a food chain.
  • The energy level available to the next higher level
    - Ranges from 5–20%
    - Is illustrated here as 10%

• The energy available to top-level consumers is small compared to the energy available to lower-level consumers.
  • This explains why
    - Top-level consumers require more geographic area
    - Most food chains are limited to three to five levels

Ecosystem Energetics and Human Resource Use
  • The dynamics of energy flow apply to the human population as much as to other organisms.
  • When humans eat
    - Plants, we are primary consumers
    - Beef or other meat from herbivores, we are secondary consumers
    - Fish like trout or salmon, we are tertiary consumers

  • The two energy pyramids that follow compare the amount of food available to humans if we are strictly either:
    - Vegetarians or
    - Carnivores
  • Eating meat of any kind is expensive economically and environmentally.
Chemical Cycling in Ecosystems

- Life depends on the recycling of chemicals.
  - Nutrients are acquired and waste products are released by living organisms.
  - At death, decomposers return the complex molecules of an organism to the environment.
  - The pool of inorganic nutrients is used by plants and other producers to build new organic matter.

The General Scheme of Chemical Cycling

- Biogeochemical cycles involve
  - Biotic components
  - Abiotic components from an abiotic reservoir where a chemical accumulates or is stockpiled outside of living organisms

The Carbon Cycle

- The cycling of carbon between the biotic and abiotic worlds is accomplished mainly by the reciprocal metabolic processes of
  - Photosynthesis
  - Cellular respiration
**The Phosphorus Cycle**

- Organisms require phosphorus as an ingredient of
  - Nucleic acids
  - Phospholipids
  - ATP

- Phosphorus is also required as a mineral component of vertebrate bones and teeth.

- The phosphorus cycle does not have an atmospheric component.

**The Nitrogen Cycle**

- Nitrogen is
  - An ingredient of proteins and nucleic acids
  - Essential to the structure and functioning of all organisms

- Nitrogen has two abiotic reservoirs:
  - The atmosphere
  - The soil

- The process of nitrogen fixation converts gaseous $N_2$ to ammonia and nitrates, which can be used by plants.

- Most of the nitrogen available in natural ecosystems comes from biological fixation performed by two types of nitrogen-fixing bacteria.
Nutrient Pollution

- The growth of algae and cyanobacteria in aquatic ecosystems is limited by low nutrient levels, especially of phosphorus and nitrogen.
- Nutrient pollution occurs when human activities add excess amounts of these chemicals to aquatic ecosystems.

CONSERVATION AND RESTORATION BIOLOGY

- Ecologists have discovered many environmental problems caused by human enterprises.
- Ecological research is the foundation for
  - Finding solutions to these problems
  - Reversing the negative consequences of ecosystem alteration

Biodiversity “Hot Spots”

- Conservation efforts are often focused on biodiversity hot spots, relatively small areas that have
  - A large number of endangered and threatened species
  - An exceptional concentration of endemic species, those that are found nowhere else

- Nitrogen runoff from Midwestern farm fields has been linked to an annual summer dead zone in the Gulf of Mexico.

Conservation biology is a goal-oriented science that seeks to understand and counter the loss of biodiversity.

Restoration ecology uses ecological principles to develop methods of returning degraded areas to their natural state.
Conservation at the Ecosystem Level

- Conservation biology increasingly aims at sustaining the biodiversity of entire
  - Communities
  - Ecosystems
  - **Landscapes**, a regional assemblage of interacting ecosystems, such as an area with forest, adjacent fields, wetlands, streams, and streamside habitats
- **Landscape ecology** is the application of ecological principles to the study of land-use patterns.

- Edges between ecosystems
  - Are prominent features of landscapes, whether natural or altered by humans
  - Have their own sets of physical conditions, such as
    - Soil type
    - Surface features

- **A movement corridor**
  - Is a narrow strip or series of small clumps of suitable habitat
  - Connects otherwise isolated patches
- Corridors
  - Can promote dispersal and help sustain populations
  - Are especially important to species that migrate between different habitats seasonally

The Process of Science: How Does Tropical Forest Fragmentation Affect Biodiversity?

- **Observation**: Forests were becoming fragmented when cleared for agriculture.
- **Question**: How does fragmentation of tropical forests affect species diversity within the fragments?
- **Hypothesis**: Species diversity declines with the size of the forest fragment.
**Prediction:** Predators will only be found in the largest areas.

**Results:** Fragmentation of forests into smaller pieces does lead to declines in species diversity.

**Restoring Ecosystems**

- **Bioremediation** uses living organisms to detoxify polluted ecosystems.
- Researchers are investigating the use of plants to remove toxic substances from contaminated soil.

**The Kissimmee River was straightened into a canal between 1962–1971, draining the floodplain.**

- The Kissimmee River restoration project is reversing the engineering of the river by
  - Removing water control structures such as dams and reservoirs
  - Filling in about 35 km of the canal

**The Goal of Sustainable Development**

- As the world population grows and becomes more affluent, the demand increases for the provisioning services of ecosystems, such as
  - Food
  - Wood
  - Water

- The goal of sustainable development is to acquire the ecological information necessary for the responsible development, management, and conservation of Earth’s resources.
Sustainable development depends on
- Continued research
- Application of ecological knowledge
- The connection of the life sciences with
  - Social sciences
  - Economics
  - Humanities

Sustainable development aims to
- Conserve biodiversity
- Improve the human condition

Evolution Connection: Biophilia and an Environmental Ethic
- Edward O. Wilson makes the case that biophilia, the human desire to affiliate with other life in its many forms, is innate.

Most biologists have
- Embraced the concept of biophilia
- Turned their passion for nature into careers