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Environmental Science
A Study of Interrelationships

Twelfth Edition

Enger & Smith

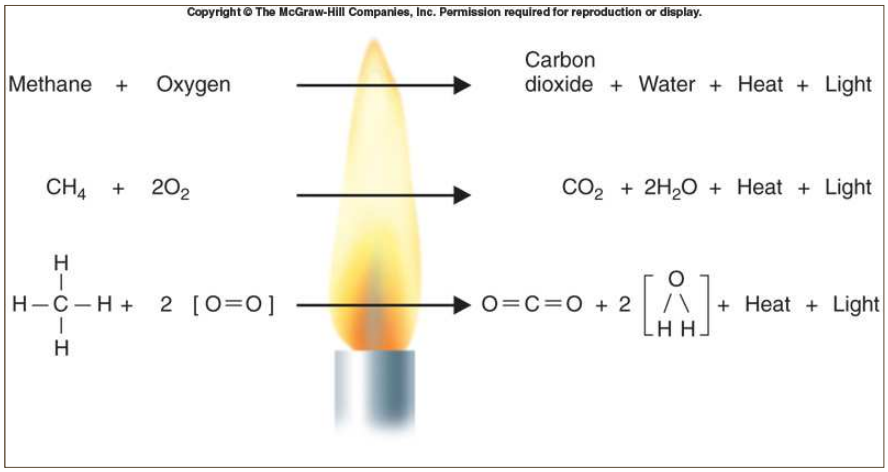
Selected material
from Chapter 4

Interrelated Scientific Principles:
Matter, Energy, and Environment

Inorganic and Organic Matter

- Organic matter consists of molecules built on carbon frameworks
  - All living things contain organic molecules.
    - Proteins, carbohydrates, lipids, and nucleic acids
    - These molecules contain energy in their bonds used in the activities of organisms.
    - They contain materials (atoms) used to build structures within organisms.

Chemical Reactions

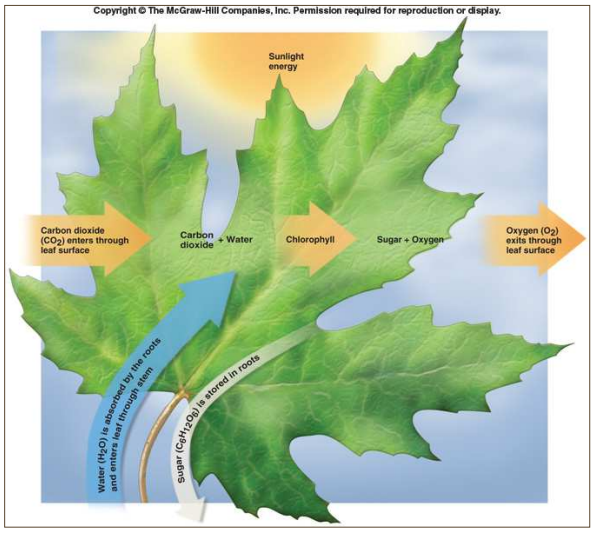


Note: all atoms in reactants (left) are found in the products (right). This is known as the **conservation of mass**.

The Chemical Nature Life

- **Photosynthesis** is a process used by plants to convert inorganic material into organic material using light.
  - Carbon dioxide + water (in the presence of sunlight) produces glucose + oxygen.
  - $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
- This represents a constant removal of carbon dioxide from the environment and addition of oxygen to the environment, while creating the organic molecules (sugar) that are the basis of all* life on earth
  - *(well, almost all life; see lithoautotrophs)

The Chemical Nature of Life

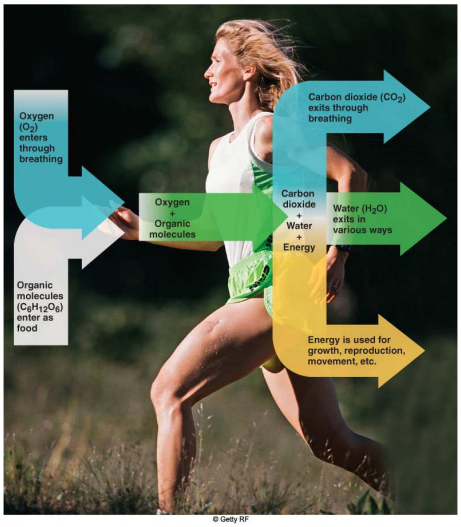


Photosynthesis

The Chemical Nature of Life

- **Respiration** is the process that uses oxygen to break down large, organic molecules into smaller inorganic molecules (releases energy organisms can use).
  - Glucose + oxygen produces carbon dioxide + water + energy
  - $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy
- This represents a constant removal of oxygen and addition of carbon dioxide to the environment , and gives organisms the energy they need to live and materials to build with

Chemical Reactions in Living Things



Respiration

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Chapter 5

Interactions: Environments and Organisms

Interactions: Environments and Organisms

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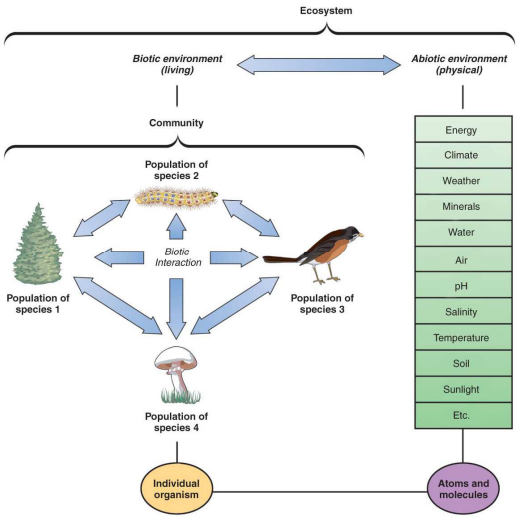
Ecological Concepts

- **Ecology** is the study of ways organisms interact with each other and with their nonliving surroundings.
- **Environment** means everything that affects an organism during its lifetime.
  - **Abiotic factors**: Nonliving things that influence an organism, such as energy, nonliving matter, living space, and ecological processes.
  - **Biotic factors**: All forms of life with which the organism interacts.

Ecological Concepts

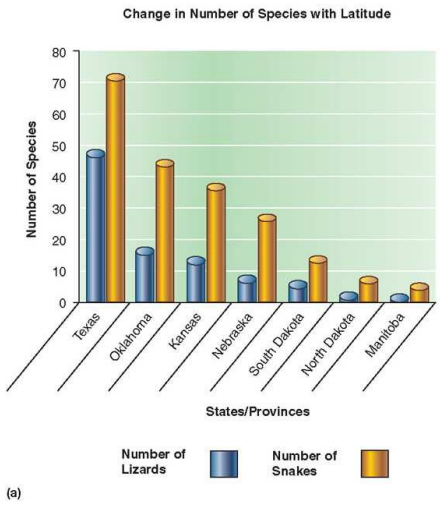


Levels of organization in ecology

Limiting Factors

- **Limiting factors** are any factors whose shortage or absence restricts species success.
  - Scarcity of water or specific nutrients (plants).
  - Climate, availability of a specific food (animals).
- **Range of tolerance** indicates a range of conditions in which an organism can survive.
- Some species have a broad range of tolerance, while others have a narrow range of tolerance.

Ecological Concepts



Limiting factors

Habitat and Niche

- The **habitat** of an organism is the space in which an organism lives; it is defined by the biological requirements of each particular organism.
  - Usually highlighted by prominent physical or biological features.
- The **niche** of an organism is the functional role (profession) the organism has in its surroundings.
  - This term includes all the ways an organism affects the organisms with which it interacts as well as how it modifies its physical surroundings.

Habitat and Niche

Ecological niche of a beaver

Genes, Populations, and Species

- Genes are distinct pieces of DNA that determine the characteristics an individual displays.
- A **population** includes all organisms of the same kind found within a specific geographic region.
  - A population contains more kinds of genes than any single individual within the population.
- A **species** is a population of all the organisms potentially capable of reproducing naturally among themselves and having offspring that also reproduce.

Natural Selection

- **Natural selection** is the process that determines which individuals within a species will reproduce and pass their genes to the next generation.
- The changes seen in the genes and characteristics displayed by successive generations of a population of organisms over time is known as **evolution.**

Evolutionary Patterns

- **Speciation** is the production of new species from previously existing species.
  - Can be the result of a species dividing into two isolated subpopulations.
- **Extinction** is the loss of an entire species.
  - Of the estimated 500 million species believed to have ever existed on Earth, 98-99% have gone extinct.
- **Coevolution** is the concept that two or more species can reciprocally influence the evolutionary direction of the other.
  - Grazing animals and grass species.

Kinds of Organism Interactions

- **Predation** is a kind of interaction in which one animal kills/eats another.
  - Predator benefits from food.
  - Prey adaptation is manifested in a higher reproduction rate.

Competition

- **Competition** is a kind of interaction in which two organisms strive to obtain the same limited resource.
  - **Intraspecific competition** is competition between members of same species.
    - Males fighting for territory
  - **Interspecific competition** is competition between members of different species.
    - Green and brown anoles fighting for food and basking areas

Competition

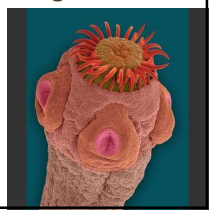
- The **competitive exclusion principle** holds that no two species can occupy the same ecological niche in the same place at the same time.
  - Less-fit species must use a slightly different niche.

Symbiotic Relationships

- **Symbiosis** is a close, long-lasting, physical relationship between two different species. At least one species derives benefit from the interaction.
- There are three categories of symbiotic relationships:
  - Parasitism
  - Commensalism
  - Mutualism

Symbiotic Relationships

- **Parasitism** is a relationship in which one organism (parasite) lives in or on another organism (host), from which it derives nourishment.
  - Ectoparasites live on the host's surface.
    - Fleas, lice, molds, mildews
  - Endoparasites live inside the body of the host.
    - Tapeworms, malaria parasites, bacteria, fungi



Symbiotic Relationships

- **Commensalism** is a relationship in which one organism benefits while the other is not affected.
  - Remoras and sharks
- **Mutualism** is a relationship in which both species benefit. The relationship is obligatory in many cases, as neither can exist without the other.
  - Mycorrhizae

Symbiotic Relationships

U.S. Department of Agriculture

Varroa mite (ectoparasite)

Examples of symbiotic relationships

Community and Ecosystem Interactions

- A **community** is an assemblage of all interacting species of organisms in an area.
- An **ecosystem** is a defined space in which interactions take place between a community, with all its complex interrelationships, and the physical environment.

Major Roles of Organisms in Ecosystems

- Ecologists have divided organisms' roles in ecosystems into three broad categories:
  1. **Producers**: Organisms that are able to use sources of energy to make complex organic molecules from simple inorganic substances in their environment.
  2. **Consumers:** Organisms that require organic matter as a source of food. They consume organic matter to provide themselves with energy and organic molecules necessary for growth and survival.

Major Roles of Organisms in Ecosystems

- Consumers can be further divided into categories based on the things they eat and the way they obtain food.
  - **Primary consumers,** or **herbivores,** eat plants as a source of food.
  - **Secondary consumers,** or **carnivores,** are animals that eat other animals.
  - **Omnivores** consume both plants and animals.

3. **Decomposers** use nonliving organic matter as a source of energy and raw materials to build their bodies. Many small animals, bacteria, and fungi fill this niche.

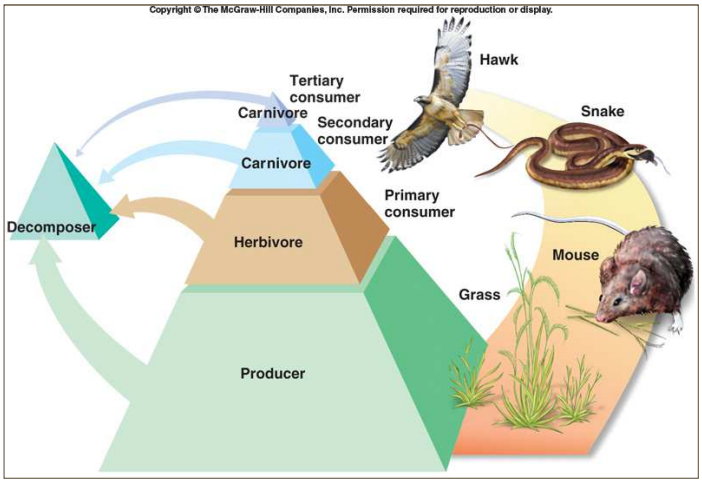
Keystone Species

- A **keystone species** plays a critical role in the maintenance of specific ecosystems.
  - When bison are present in American tall grass prairie ecosystems, they increase the biodiversity of the site.
    - Smaller plant species normally shaded by the tall grasses are allowed to be successful.
    - Bison wallows retain many species of plants that typically live in disturbed areas.
    - Their feeding patterns affect the extent and impact of fire.

Energy Flow Through Ecosystems

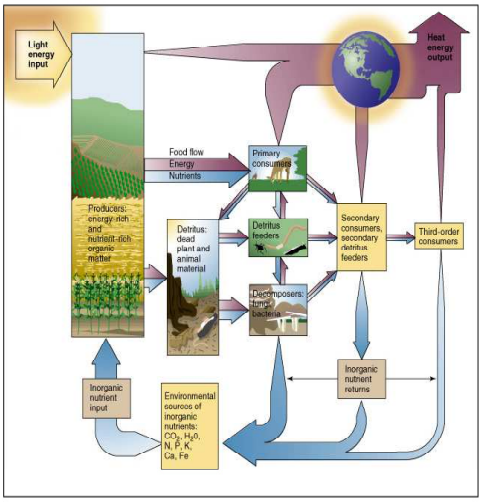
- Each step in the flow of energy through an ecosystem is known as a **trophic level.**
- As energy moves from one trophic level to the next, most of the useful energy (90%) is lost as heat (second law of thermodynamics).
- Because it is difficult to measure the amount of energy contained in each trophic level, **biomass** (weight of living material) is often used as a proxy.

Energy Flow Through Ecosystems



Categories of organisms within an ecosystem.

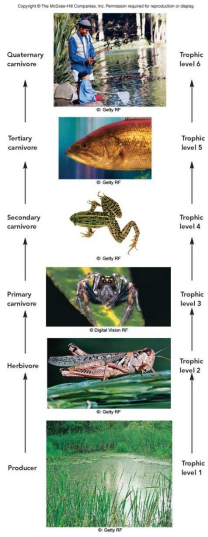
Nutrient Recycling and Energy Flow through an Ecosystem



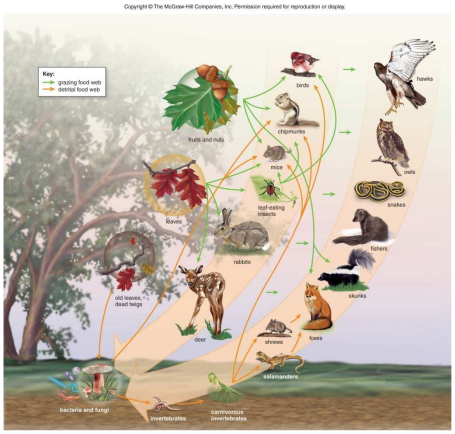
Food Chains and Food Webs

- A **food chain** is a series of organisms occupying different trophic levels through which energy passes as a result of one organism consuming another.
  - Some chains rely on detritus.
- A **food web** is a series of multiple, overlapping food chains.
  - A single predator can have multiple prey species at the same time.

Food Chains and Food Webs



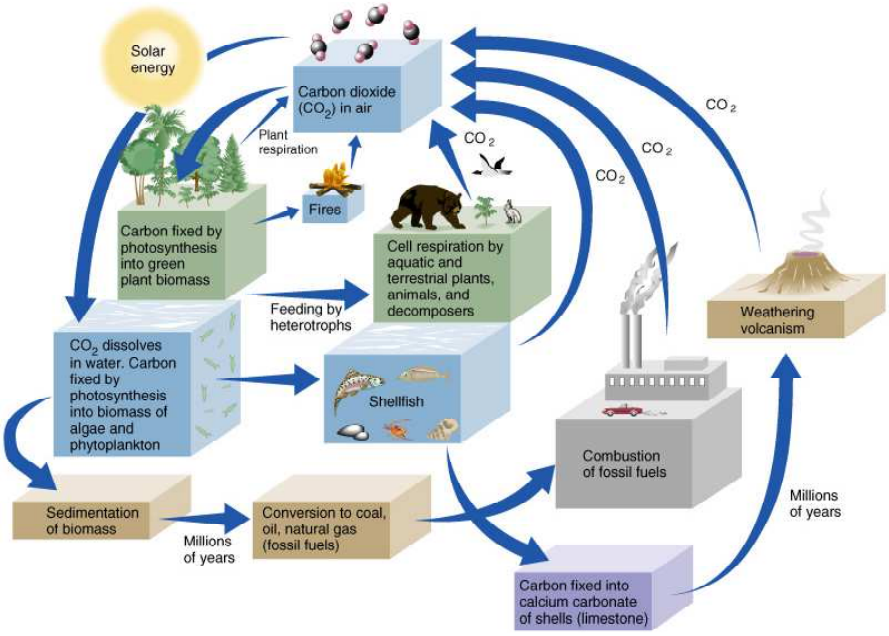
Food chain



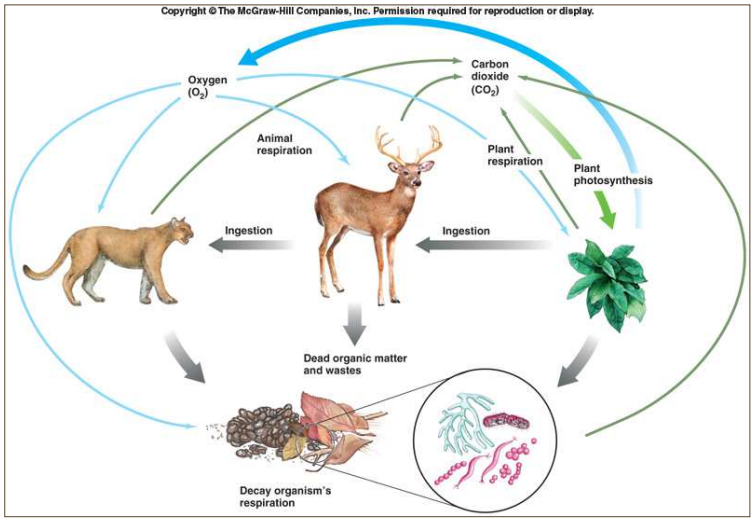
Food web

Nutrient Cycles in Ecosystems—Biogeochemical Cycles

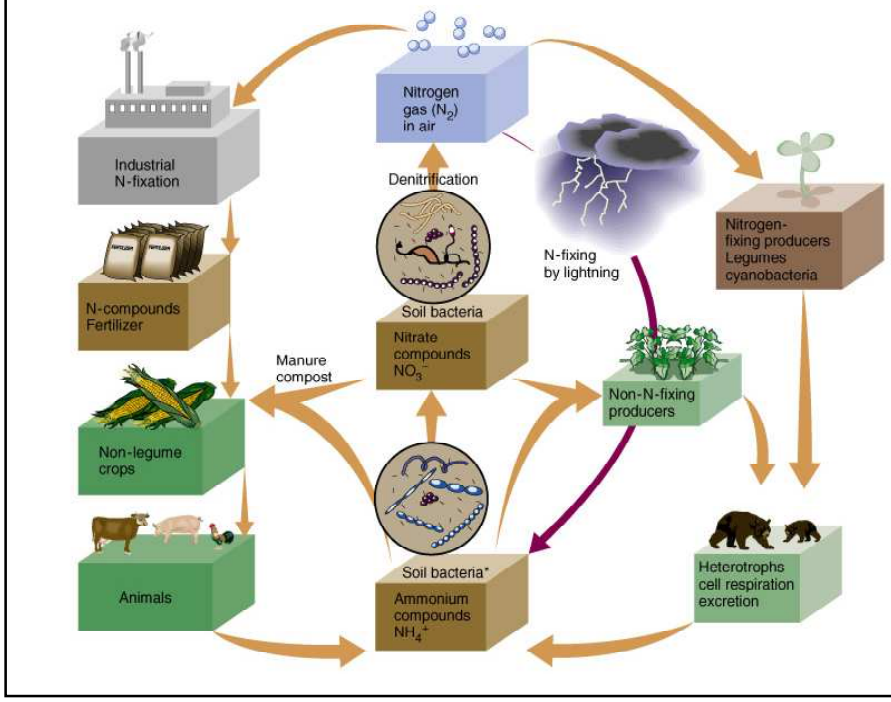
- Organisms are composed of molecules and atoms that are cycled between living and non-living portions of an ecosystem.
- These nutrient cycles are called **biogeochemical cycles.**
- These are raw materials needed to build organisms, just as you need the right amount of certain parts to build a machine



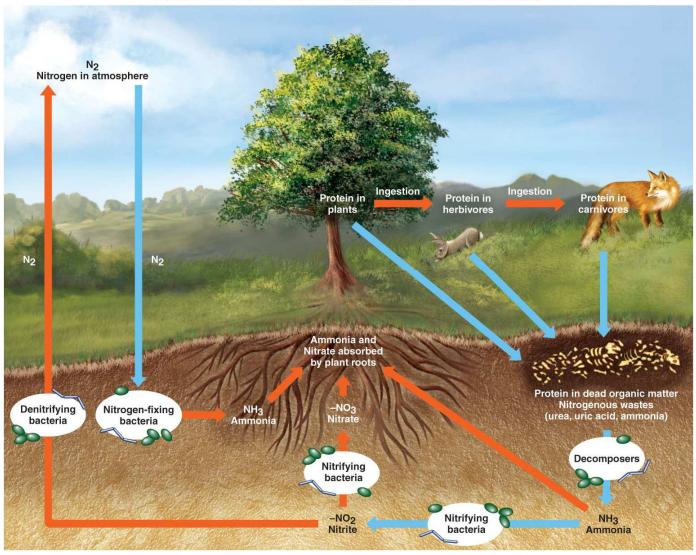
Carbon Cycle



Carbon cycle



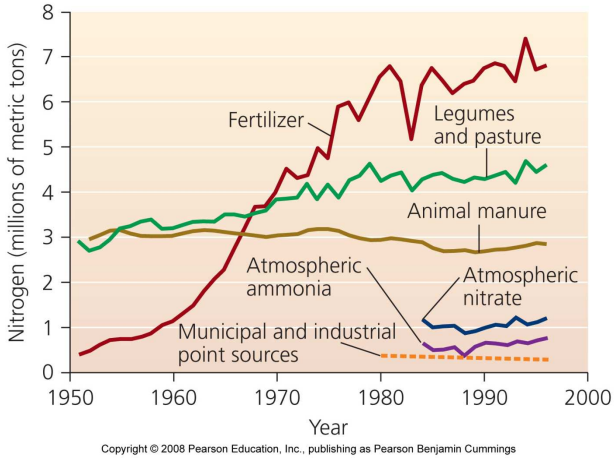
Nitrogen Cycle

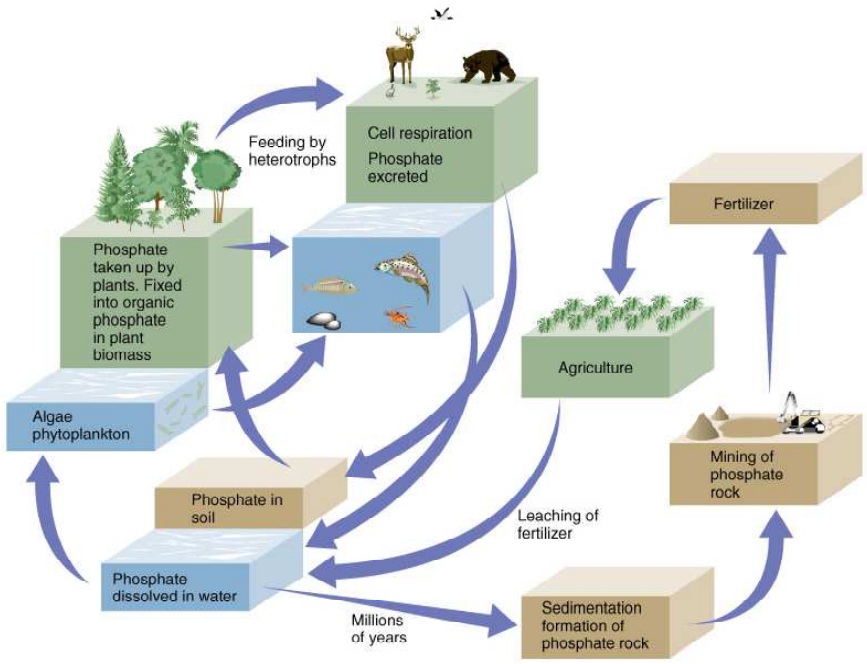


Nitrogen cycle

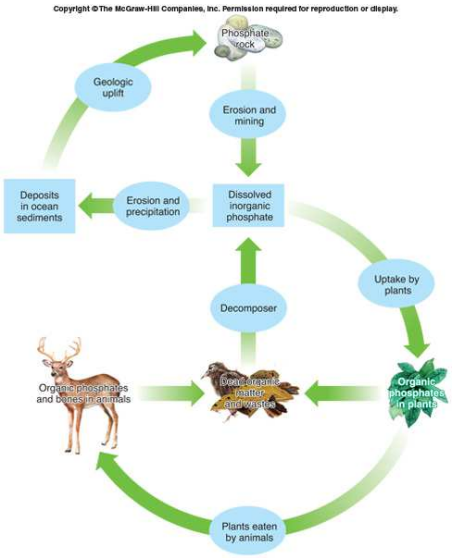
Human inputs of nitrogen into the environment

Fully half of nitrogen entering the environment is of human origin





Phosphorus Cycle



Phosphorus cycle

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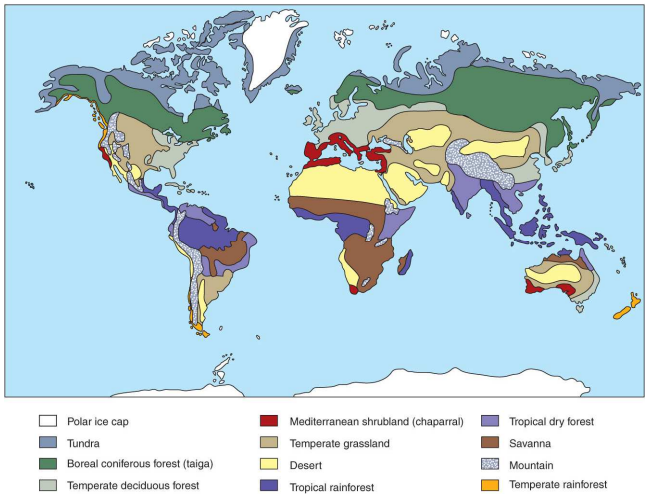
Chapter 6

Kinds of Ecosystems and Communities

Biomes Are Determined By Climate

- **Biomes** are terrestrial (land) climax communities with wide geographic distributions.
  - When different communities within a biome are examined, they will show differences in the exact species present, but the general structure of the ecosystem and the kinds of niches and habitats present are similar throughout.

Biomes: Major Types of Terrestrial Climax Communities

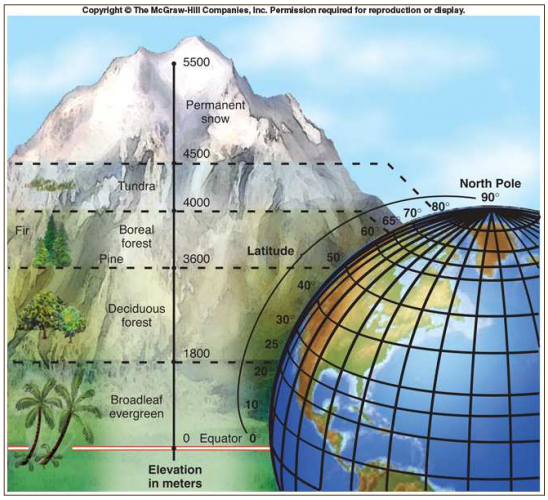


Biomes of the world

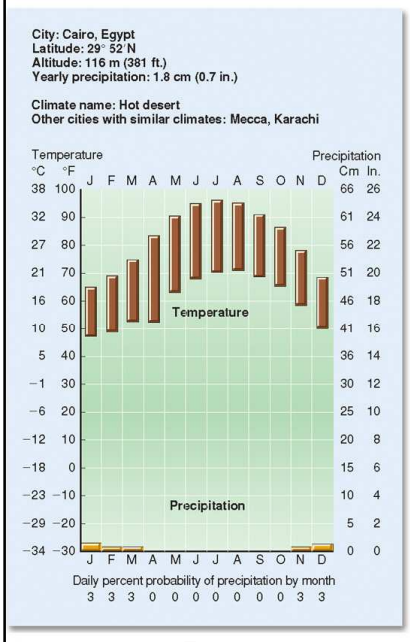
The Effect of Elevation on Climate and Vegetation

- The distribution of terrestrial ecosystems is primarily related to precipitation and temperature.
  - Temperature is warmest near the equator and cooler toward the poles.
  - As altitude increases, average temperature decreases.
  - Moving from sea level to mountain tops, it is possible to pass through a series of biomes similar to what would be encountered moving from the equator to the North Pole.

The Effect of Elevation on Climate and Vegetation



Relationship between height above sea level, latitude, and vegetation.



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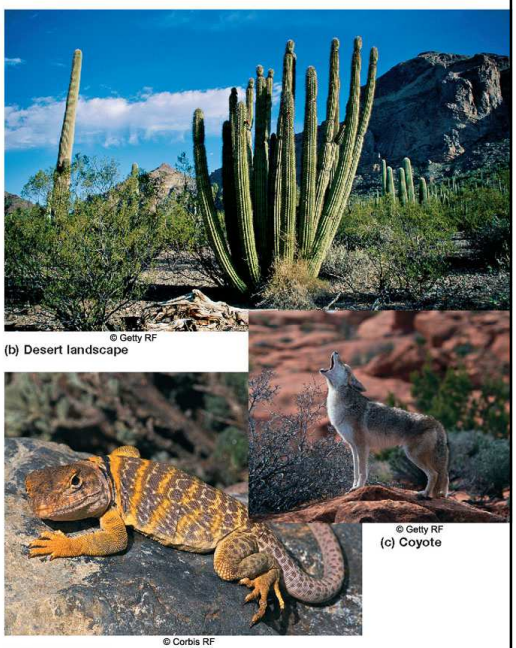
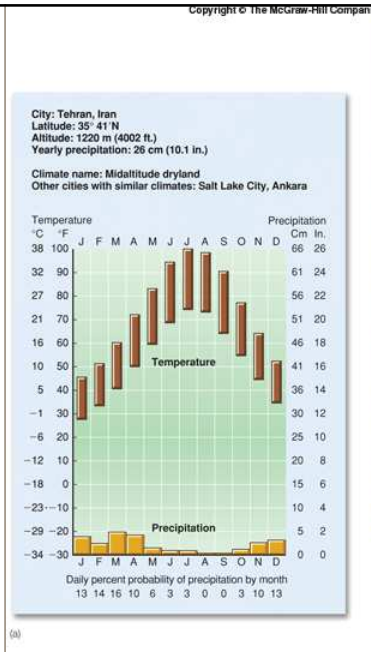
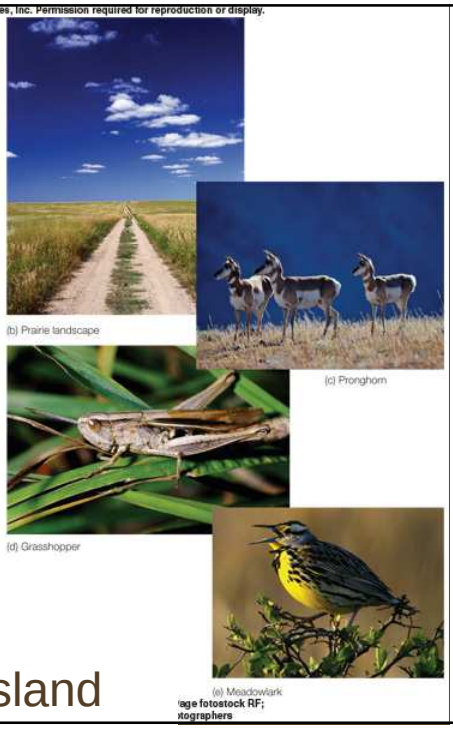
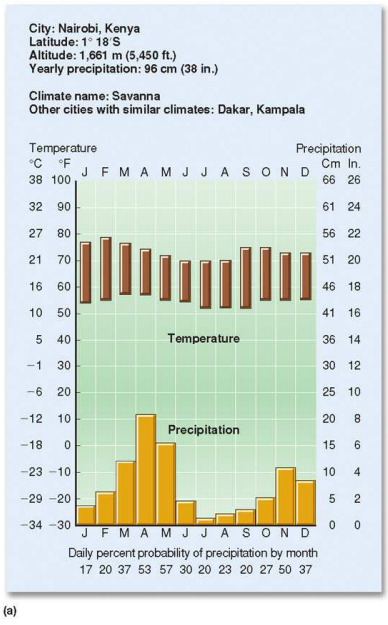


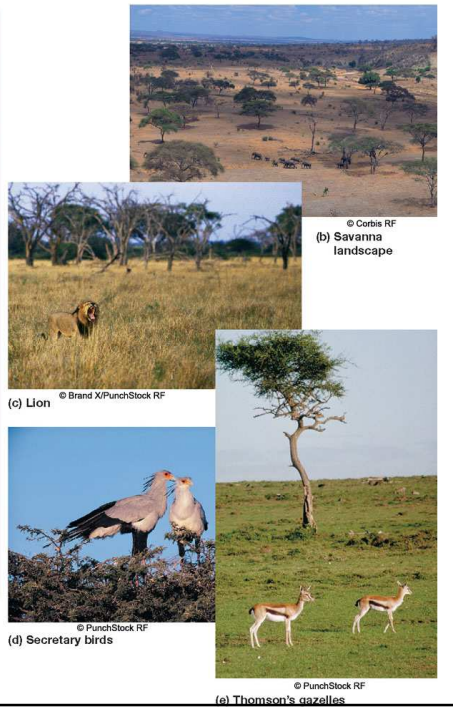
Desert



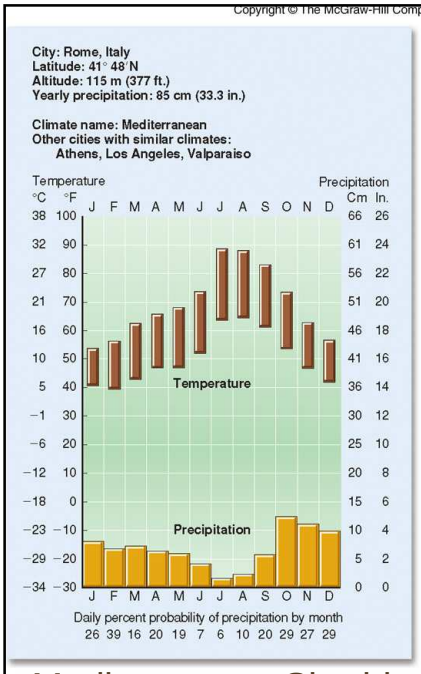


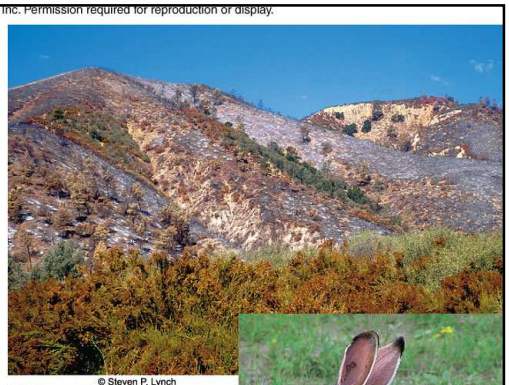
Temperate Grassland



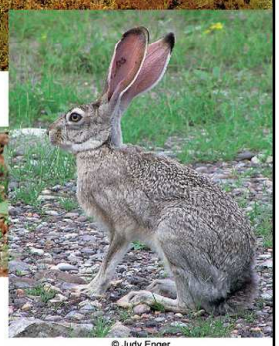


Savanna

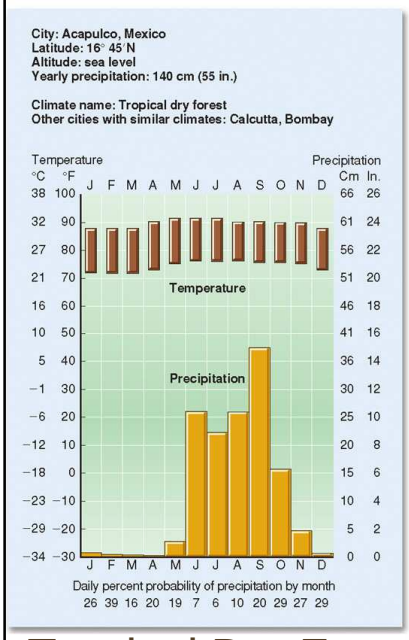



© Steven P. Lynch
(b) Chaparral landscape

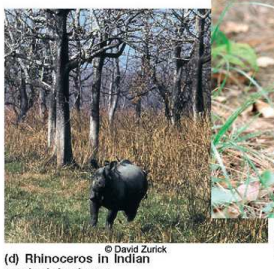

© U.S. Fish and Wildlife Service/ Lee Karney photographer
(c) California quail


© Judy Enger
(d) Black-tailed jack rabbit

(a) Mediterranean Shrubland (Chaparral)

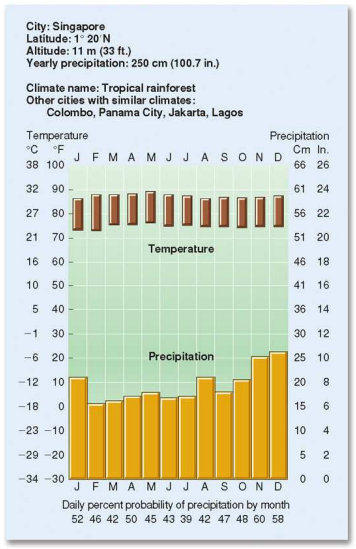



© Doug Wechsler/Animals Animals/ Earth Scenes
(b) Tropical dry forest landscape


© David Zurick
(d) Rhinoceros in Indian tropical dry forest


© Superstock RF
(c) White-faced coati in Costa Rica

(a) Tropical Dry Forest



(a)

© Stephen P. Lynch

(b) Tropical rainforest landscape

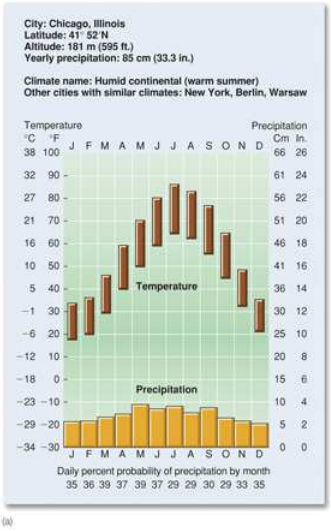
© Getty RF

(c) Blue morpho butterfly

© PunchStock RF

(d) Squirrel monkey

Tropical Rainforest



(a)

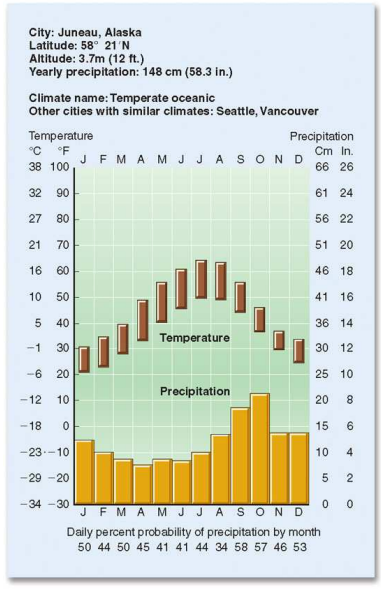
(b) Temperate deciduous forest in summer

(c) Temperate deciduous forest in fall

(d) Raccoon

isc/Getty Images

Temperate Deciduous Forest



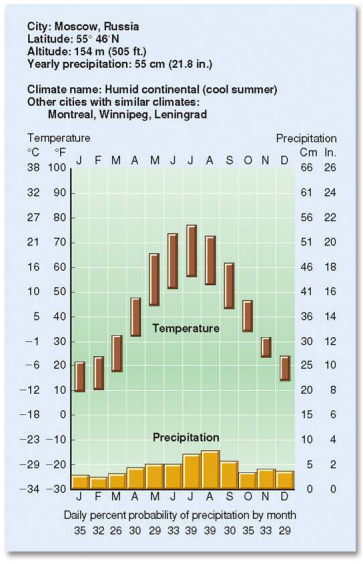
(a)

U.S. Fish and Wildlife Service
(b) Temperate rainforest landscape

© Corbis RF
(c) Northern spotted owl

© Getty RF
(d) Blacktail deer

Temperate Rainforest



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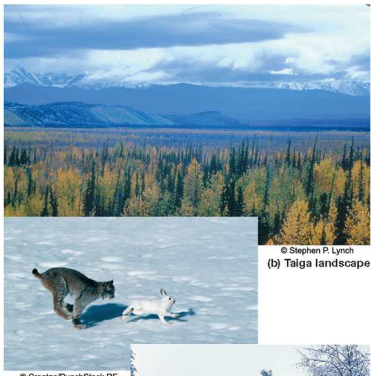
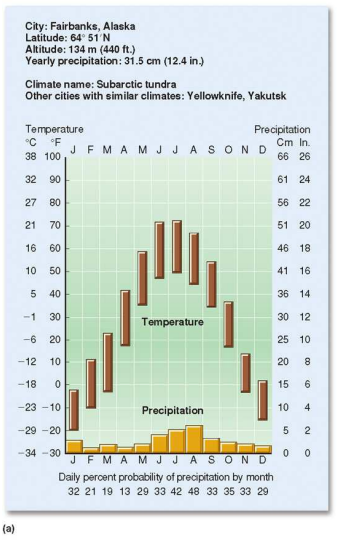


© Stephen P. Lynch
(b) Taiga landscape

© Creatas/PunchStock RF
(c) Lynx and snow-shoe hare

© Corbis RF
(d) Taiga in winter

Taiga, Northern Coniferous Forest, or Boreal Forest



(a)

© Corbis RF
(b) Tundra landscape

© Getty RF
(c) Frozen tundra

© Getty RF
(d) Caribou

© Getty RF
(e) Snowy owl

Tundra

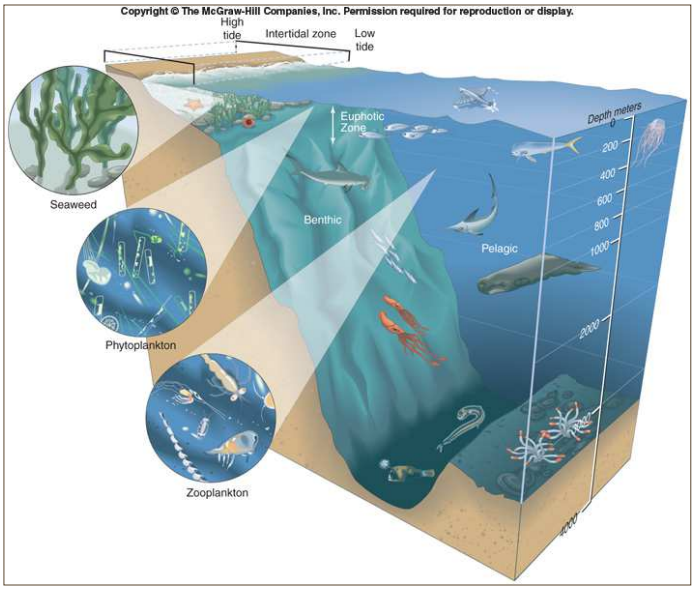
Major Aquatic Ecosystems

- Aquatic ecosystems are shaped by key environmental factors:
  - The ability of the sun's rays to penetrate the water
  - Depth of the water
  - Movement of the water
  - The nature of the bottom substrate
  - The water temperature
  - The amount of dissolved salts

Major Aquatic Ecosystems

- Aquatic ecosystems with little dissolved salt are called **freshwater ecosystems.**
- **Marine ecosystems** have a high dissolved salt content.

Marine Ecosystems



Coral Reef Systems

Coral reef organisms

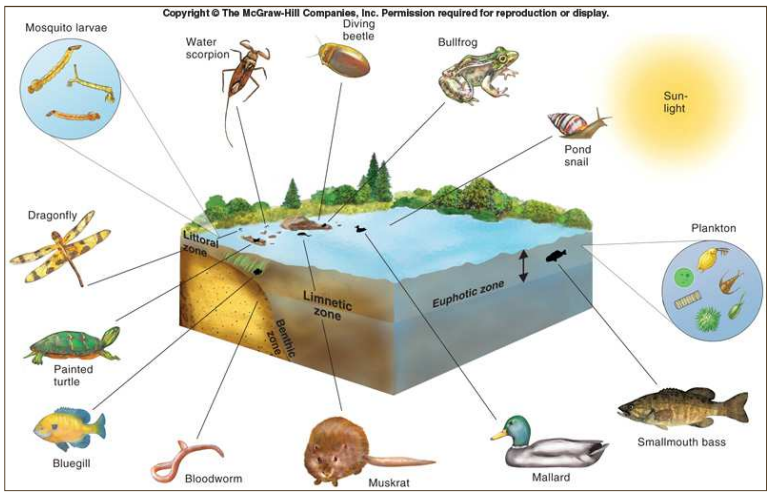
Great Barrier Reef

Coral reef.

Mangrove Systems

Estuaries

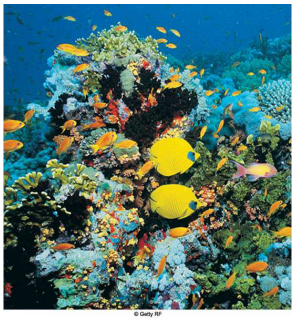
Freshwater Ecosystems



Lake ecosystem

The McGraw-Hill Companies

Environmental Science
A Study of Interrelationships



Twelfth Edition

Enger & Smith

Chapter 11

Biodiversity Issues

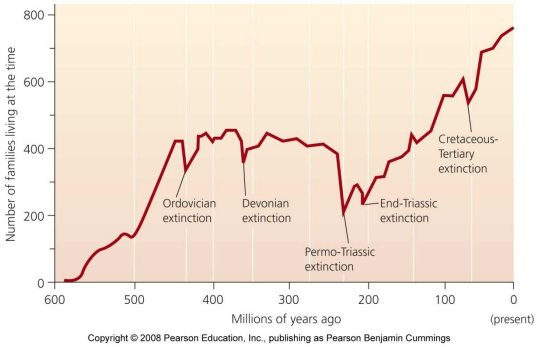
Biodiversity Loss and Extinction

- **Biodiversity** is a broad term used to describe the diversity of genes, species, and ecosystems in a region.
- **Extinction** is the elimination of all the individuals of a particular species.
  - Extinction is a natural and common event in the history of biological evolution.
  - It, and the resulting loss of biodiversity, is also a major consequence of large-scale changes brought by humans.
- **Extirpation** is the elimination of a species from a particular ecosystem or region, though it may still occur elsewhere.
  - Can lead to dramatic ecological changes
  - Questions the importance of current policies focused on extinction

Biodiversity Loss and Extinction

- Over the past few hundred years, humans are estimated to have increased the extinction rate by a factor of 1,000 to 10,000 times above background rates typical over the planet's history.
  - 1/8 of bird species, 1/4 of mammal species, 1/3 of amphibian species, and 1/2 of turtle species are currently threatened.
  - 10% of the world's coral reefs have been lost.
  - Mangrove forests are reduced by over 1% a year.
  - >25% of global land is used for agriculture.

Earth has experienced five mass extinctions



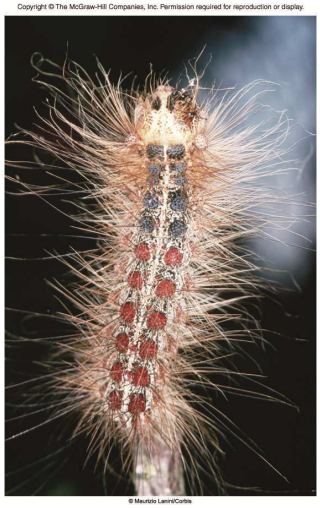
- In the past 440 million years, mass extinctions have eliminated at least 50% of all species.
- Most dinosaurs went extinct at the end of the Cretaceous period (65 million years ago).

Describing Biodiversity

- **Species diversity** is a measure of the number of different species present in an area.
  - **Species richness** refers to the number of different kinds of species in an area.
    - For example, 100 vertebrate species in a forest
  - **Taxonomic richness** takes into account the number of different taxonomic categories of the species present.
    - Of the 100 species, 14 mammals; 32 birds; 4 turtles; 12 lizards; 23 frogs; 15 snakes

Describing Biodiversity

- Estimates of the actual number of species range from a few million to 100 million.
  - About 1.4 million species have been described.
    - Many species are naturally rare, and others live in areas difficult to reach.



Threats to Biodiversity

- Five major human activities threaten to reduce biodiversity.
  - Habitat loss
  - Overexploitation
  - Introduction of exotic species
  - Predator and pest control activities
  - Climate change

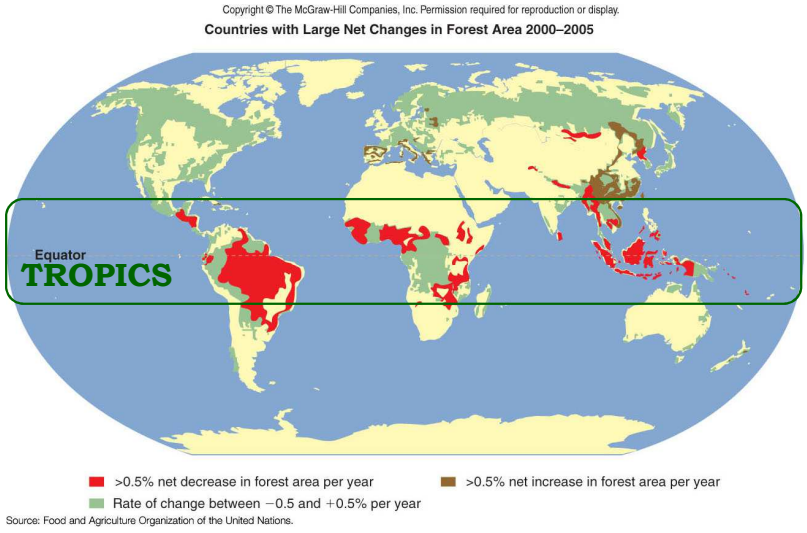
Habitat Loss

- The International Union for Conservation of Nature and Natural Resources (IUCN) estimates that 80%-90% of threatened species are under threat as a result of habitat loss or fragmentation.
- About 40% of the world's land surface is used for some type of agriculture.
- Typically, the most productive natural ecosystems (forests and grasslands) are the first to be modified by humans.

Habitat Loss

- Originally, half of the U.S., three-fourths of Canada, and almost all of Europe, and significant portions of the rest of the world were forested.
  - These were **old-growth forests** with a mix of trees of varying ages, including dead ones, and many microhabitats (gaps, rotting logs, etc.)
- **Deforestation** is the process of destroying a forest, often for the purposes of fuel, building materials, or to clear land for farming.
  - Eventually may be replaced by **secondary forests**, forests that are more homogenous in almost every way

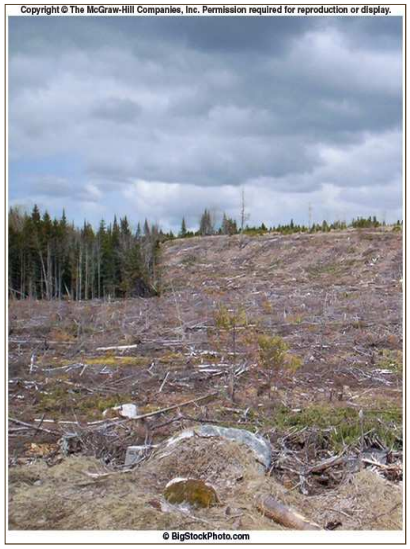
Habitat Loss



Changes in forest area

Habitat Loss

- Tropical forests have greater species diversity than any other ecosystem.
- They are not as likely as temperate forests to regenerate after logging due to poor soil characteristics.
- Currently, few tropical forests are being managed for long-term productivity.



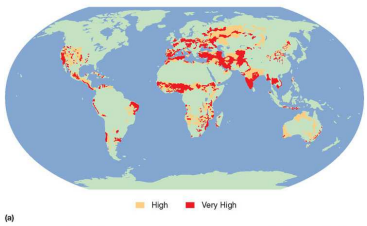
Habitat Loss - **Sylviculture**

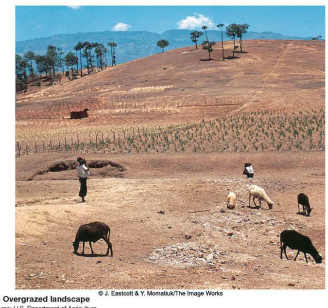
- Many lumber companies maintain forest plantations as crops and manage them in the same way farmers manage crops.
  - Plant single species, even-aged forests of fast growing hybrid trees.
  - Competing species are controlled by fire, and insects controlled by spraying.
  - Trees mature to harvestable size in as low as 20 years (vs. 100 or more).
    - Quality of lumber reduced.
    - Low species diversity and wildlife value.

Habitat Loss - Agriculture

- The conversion of rangelands to grazing by domesticated animals has major impacts on biodiversity.
  - Selective eating habits of livestock tend to reduce certain species of native plants and encourage others.
  - Important to regulate number of livestock on rangelands, especially in dry areas.
    - Overgrazing is a severe problem where human population pressures are great.
    - **Desertification** is the process of converting arid or semiarid land to desert because of improper human use.

Habitat Loss - Agriculture





(b) Overgrazed landscape © J. Eastcott & Y. Momatiuk/The Image Works
Source: U.S. Department of Agriculture.

Desertification

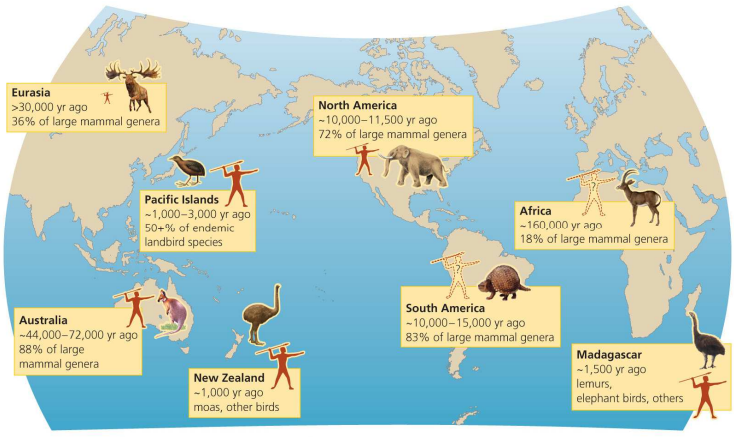
Overexploitation

- In marine ecosystems, much of the harvest is restricted to shallow parts of the ocean where bottom-dwelling fish can be easily harvested.
- Trawls are nets dragged along the bottom.
  - They disturb the seafloor and cause habitat damage.
- About 25% of catch is undesirable (called **by-catch**), and thus discarded, but they are usually dead, and their removal further alters the ecological nature of the seafloor.

Overexploitation

- According to the IUCN, overexploitation is responsible for over 30% of endangered animal species and 8% of endangered plant species.
  - Overexploitation occurs when humans harvest organisms faster than the organisms are able to reproduce, threatening some, and causing extinction in others.

People have hunted species to extinction for millennia



Extinctions followed human arrival on islands and continents.

Overexploitation

- U.N. estimates 70% of world's marine fisheries are overexploited or are fully exploited and in danger of being overexploited.
  - Amount of fish caught has remained relatively constant, while the amount produced by fish farming has increased.
  - The commercial fishing industry has been attempting to market species previously regarded as unacceptable.

Overexploitation

- Meat from wild animals is often referred to as **bush meat.**
- The Wildlife Conservation Society estimates 70% of wildlife species in Asia and Africa and about 40% of species in Latin America are being hunted unsustainably.
  - Hunting of wildlife is a part of all subsistence cultures.
  - Many kinds of wildlife are considered delicacies and are highly prized for the home and restaurant trade.
- Many animals are collected for the pet trade
  - Often use dangerous methods that harm many species

Invasive Exotic Species

- Some introductions of exotic species are purposeful, while others are accidental.
- The IUCN estimates about 30% of birds and 15% of plants are threatened because they are unable to successfully compete against invasive exotic species.

Threats to Biodiversity

- Introduction of disease has had considerable impact on American forests.
  - Chestnut blight
  - Dutch elm disease
- Various insects have had an effect on ecosystem structure.
  - Asian long horned beetle
- Freshwater ecosystems have been greatly affected.
  - Zebra mussel

Climate Change

- The role of climate change on the survival of species has become an issue.
  - Many species live near the limit of their physiological tolerance. A slight change in the temperature may push them over the brink.
  - Amphibians, corals, and arctic species are greatly affected by climate change.
    - Planet warming may have caused a fungal disease in frogs.
    - Melting sea ice is changing migration patterns and food availability.

Biodiversity benefits: free ecosystem services

- Provides food, shelter, fuel
- Purifies air and water and detoxifies wastes
- Stabilizes climate, moderates floods, droughts, wind, temperature
- Generates and renews soil fertility and cycles nutrients
- Pollinates plants and controls pests and disease
- Maintains genetic resources
- Provides cultural and aesthetic benefits
- Allows us to adapt to change

The annual value of just 17 ecosystem services = $16 - 54 trillion per year