Fundamental Biology
BI 1101

an interdisciplinary approach to introductory biology

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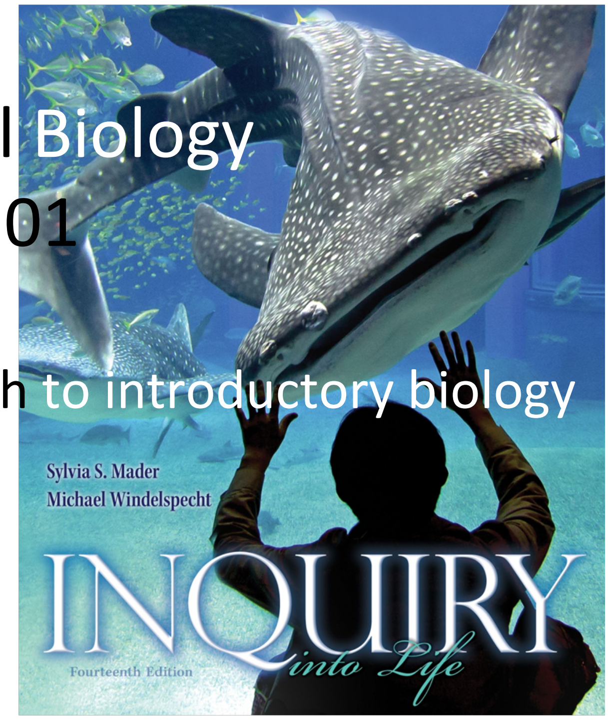
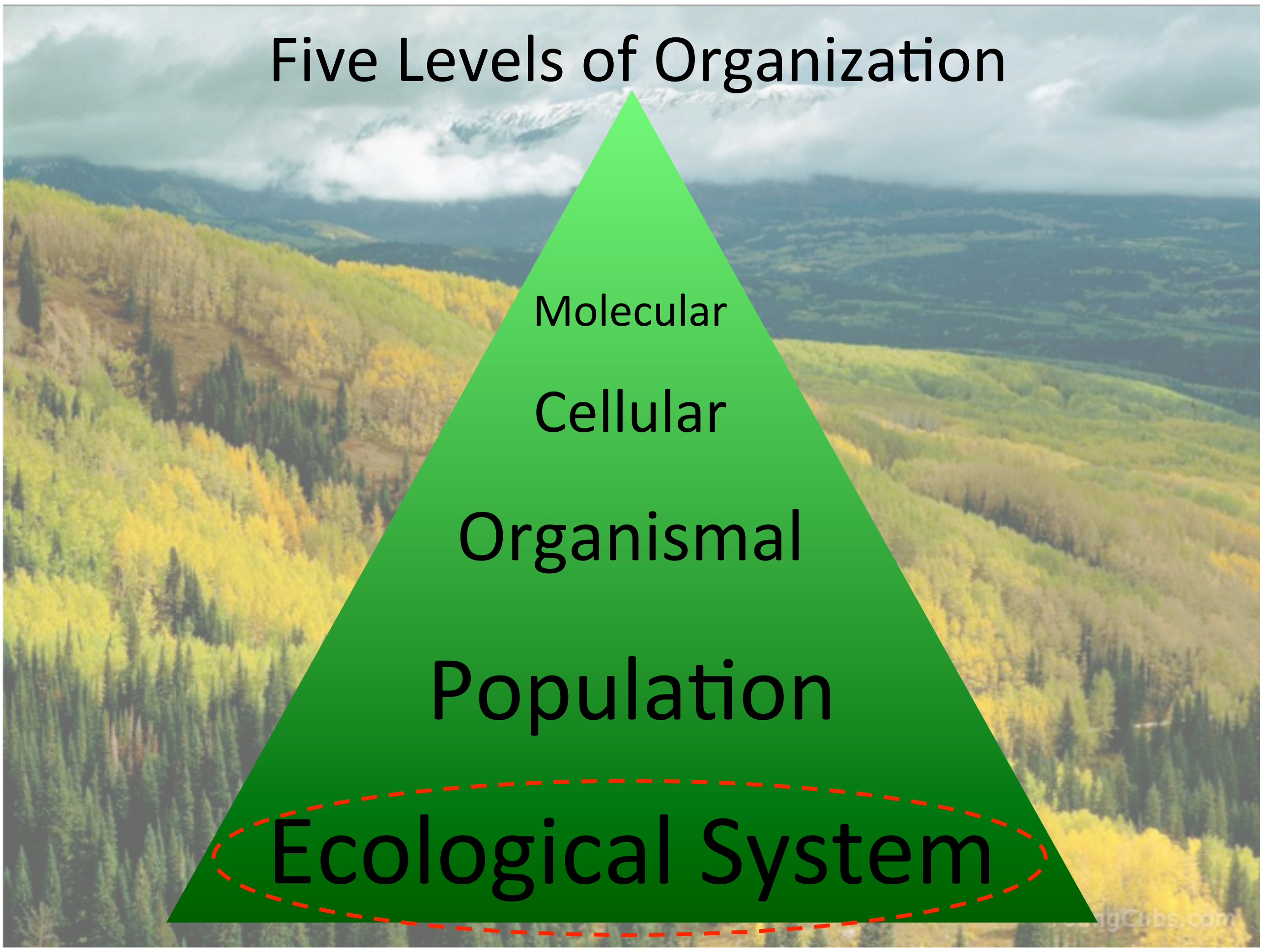




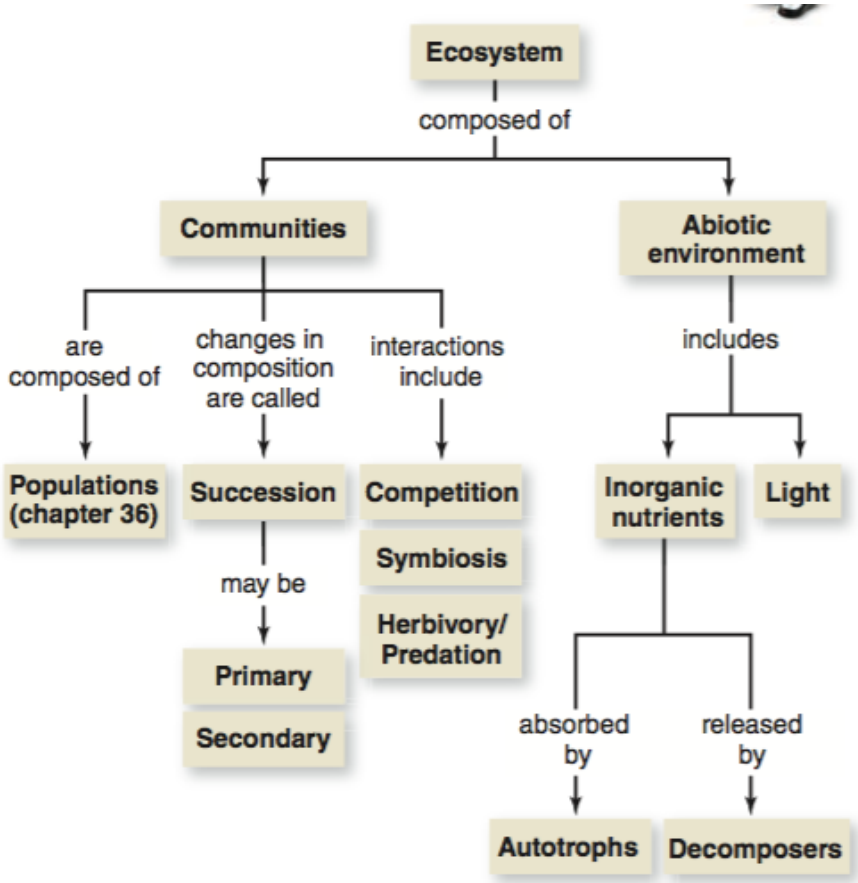
Learning outcome

After this chapter, students are able to:

1. Define a biological community. Explain why the study of community ecology is important.
2. Define interspecific competition, mutualism, predation, herbivory, and parasitism, and provide examples of each.
3. Define an ecological niche. Explain how interspecific competition can occur when the niches of two populations overlap.
4. Describe the mutualistic relationship between corals and dinoflagellates.
5. Define predation. Describe the protective strategies potential prey employ to avoid predators.
6. Explain why many plants have chemical toxins, spines, or thorns. Define coevolution and describe an example.
7. Explain how parasites and pathogens can affect community composition.
8. Identify and compare the trophic levels of terrestrial and aquatic food chains.
9. Explain how food chains interconnect to form food webs.
10. Describe the two components of species diversity.
11. Define a keystone species.
12. Explain how disturbances can benefit communities. Distinguish between primary and secondary succession.
13. Explain how invasive species can affect communities.

You should now be able to

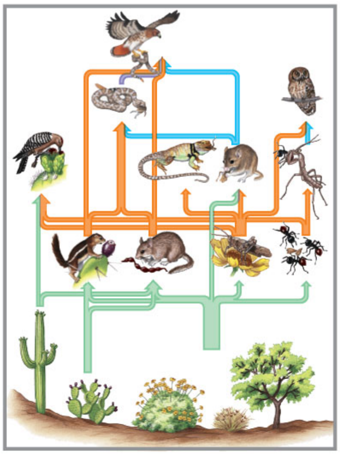
14. Compare the movement of energy and chemicals within and through ecosystems.
15. Compare the primary production of tropical rain forests, coral reefs, and open ocean. Explain why the differences between them exist.
16. Describe the movement of energy through a food chain.
17. Explain how carbon, nitrogen, and phosphorus cycle within ecosystems.
18. Explain how rapid eutrophication of aquatic ecosystems affects species diversity and oxygen levels.
19. Explain how human activities are threatening natural ecosystems.



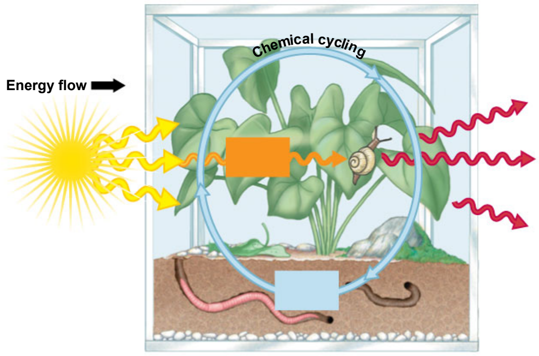
Introduction

- Natural ecosystems are valuable because they
  - provide natural resources,
  - support outdoor recreation, and
  - provide natural services including
    - buffering against hurricane damage,
    - recycling nutrients,
    - preventing erosion, and
    - pollinating crops.

Big Ideas



Community Structure and Dynamics



Ecosystem Structure and Dynamics

Figure 37.0_2

COMMUNITY STRUCTURE AND DYNAMICS

A community includes all the organisms inhabiting a particular area

- Community ecology is concerned with factors that
  - influence species composition and distribution of communities and
  - affect community stability.

37.1 A community includes all the organisms inhabiting a particular area

- A biological **community** is
  - an assemblage of all the populations of organisms living close enough together for potential interaction and
  - described by its species composition.
- The boundaries of a community vary with the research question to be investigated. For example, the boundaries of a community could be defined as
  - a pond or
  - the intestinal microbes of a pond organism.

37.2 Interspecific interactions are fundamental to community structure

- **Interspecific interactions**
  - are relationships with individuals of other species in the community,
  - greatly affect population structure and dynamics, and
  - can be categorized according to their effect on the interacting populations.

Type	Definition and Fitness Effects	Example(s)
Competition	Two or more species vie for the same limited resource (–/–)	Two species of barnacles compete for space in the intertidal zone
Mutualism	Symbiosis in which both partners benefit (+/+)	Algae in coral animals; mycorrhizal fungi in plant roots; animal pollinators of flowering plants
Commensalism	Symbiosis in which one partner benefits with no effect on the other (+/0)	Moss plants on tree bark
Parasitism	Symbiosis in which one partner benefits and the other is harmed (+/–)	Tick on a deer; tapeworm in a human (see chapters 16, 17, 19, and 20 for many examples of disease-causing organisms)
Herbivory	Animal consumes a plant or other photosynthetic organism (+/–)	Cattle grazing on grassland; caterpillar eating tree leaves
Predation	Animal consumes another animal (+/–)	Cat eating birds; bat eating insects

Interspecific interactions are fundamental to community structure

- **Interspecific competition** occurs when populations of two different species compete for the same limited resource.
  - In **mutualism**, both populations benefit.
  - In **predation**, one species (the predator) kills and eats another (the prey).
  - In **herbivory**, an animal consumes plant parts or algae.
  - In parasitism, the host plants or animals are victimized by parasites or pathogens.

Table 37.2

TABLE 37.2 | INTERSPECIFIC INTERACTIONS

Interspecific Interaction	Effect on Species 1	Effect on Species 2	Example
Competition	–	–	Squirrels/ black bears
Mutualism	+	+	Plants/ mycorrhizae
Predation	+	–	Crocodiles/fish
Herbivory	+	–	Caterpillars/ leaves
Parasites and pathogens	+	–	Heartworm/dogs; Salmonella / humans

Competition may occur when a shared resource is limited

- An **ecological niche** is the sum of an organism's use of the biotic and abiotic resources in its environment.
- Interspecific competition occurs when the niches of two populations overlap.
- Competition lowers the carrying capacity of competing populations because the resources used by one population are not available to the other population.

Figure 37.3A

Figure 37.3B

Mutualism benefits both partners

- Reef-building corals and photosynthetic dinoflagellates illustrate the win/win nature of mutualism. Photosynthetic dinoflagellates
  - gain shelter in the cells of each coral polyp,
  - produce sugars used by the polyps, and
  - provide at least half of the energy used by the coral animals.

37.5 EVOLUTION CONNECTION: Predation leads to diverse adaptations in prey species

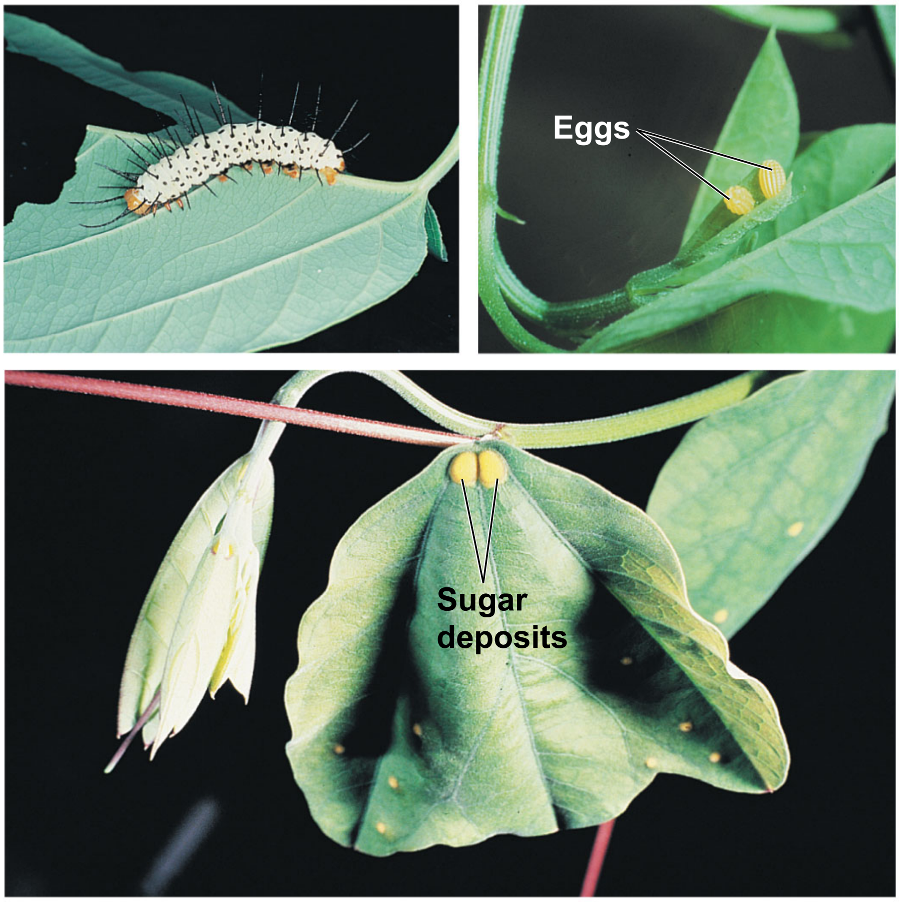
- Predation benefits the predator but kills the prey.
- Prey adapt using protective strategies that include
  - camouflage,
  - mechanical defenses, and
  - chemical defenses.

EVOLUTION CONNECTION: Herbivory leads to diverse adaptations in plants

- Herbivores and plants undergo **coevolution**,
  - a series of reciprocal evolutionary adaptations in two species,
  - in which change in one species acts as a new selective force on another.

- A plant whose body parts have been eaten by an animal must expend energy to replace the loss.
  - Thus, numerous defenses against herbivores have evolved in plants.
  - Plant defenses against herbivores include
    - spines and thorns and
    - chemical toxins.

Figure 37.6



Parasites and pathogens can affect community composition

- A parasite lives on or in a host from which it obtains nourishment.
  - Internal parasites include nematodes and tapeworms.
  - External parasites include mosquitoes, ticks, and aphids.
- Pathogens are disease-causing microscopic parasites that include
  - bacteria,
  - viruses,
  - fungi, or
  - protists.

Parasites and pathogens can affect community composition

- Non-native pathogens can have rapid and dramatic impacts.
  - The American chestnut was devastated by the chestnut blight protist.
  - A fungus-like pathogen is currently causing sudden oak death on the West Coast.
- Non-native pathogens can cause a decline of the ecosystem.

Trophic structure is a key factor in community dynamics

- The **trophic structure** of a community is a pattern of feeding relationships consisting of several different levels.
  - The sequence of food transfer up the trophic levels is known as a **food chain**.
  - The transfer of food moves chemical nutrients and energy from producers up through the trophic levels in a community.

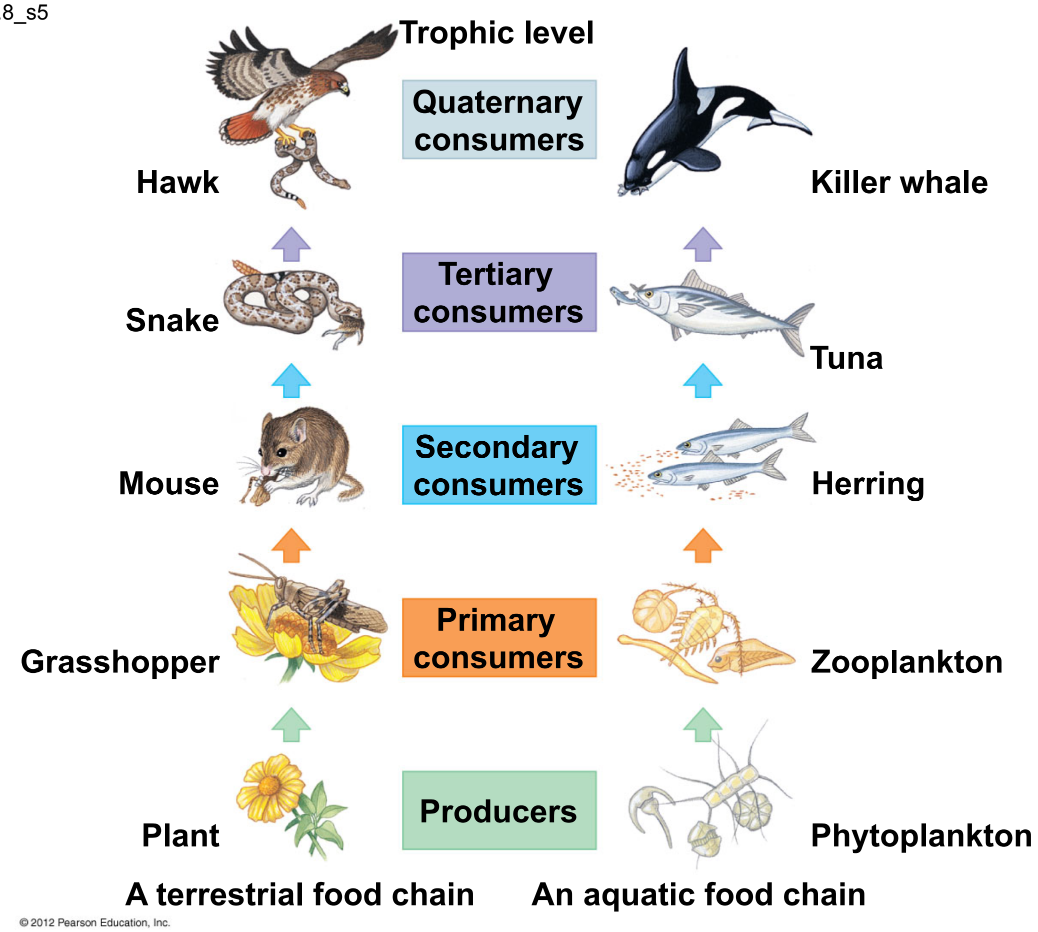
Trophic structure is a key factor in community dynamics

- **Producers**
  - are autotrophs and
  - support all other trophic levels.
- Consumers are heterotrophs.
  - Herbivores are **primary consumers**.
  - **Secondary consumers** typically eat herbivores.
  - **Tertiary consumers** typically eat secondary consumers.
  - **Quaternary consumers** typically eat tertiary consumers.

Trophic structure is a key factor in community dynamics

- **Detritivores** derive their energy from **detritus**, the dead material produced at all the trophic levels.
- **Decomposers**
  - are mainly prokaryotes and fungi and
  - secrete enzymes that digest molecules in organic materials and convert them into inorganic forms, in the process called **decomposition**.

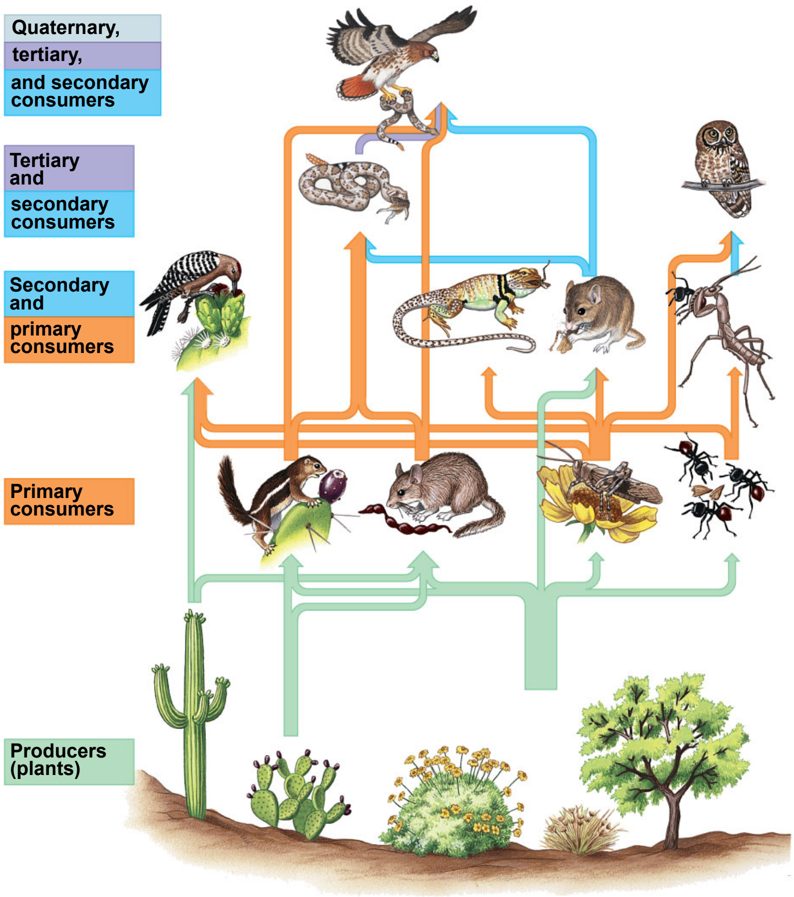
Figure 37.8_s5



Food chains interconnect, forming food webs

- A **food web** is a network of interconnecting food chains.
- Notice that
  - consumers may eat more than one type of producer and
  - several species of consumers may feed on the same species of producer.

Figure 37.9

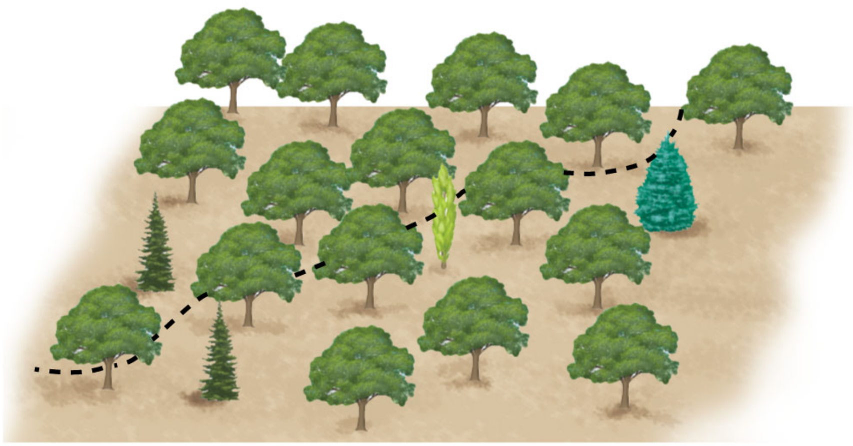


Species diversity includes relative abundance and species richness

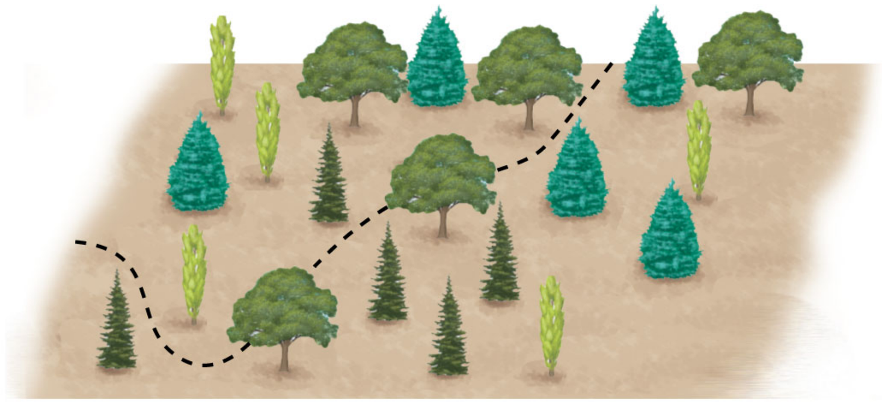
- **Species diversity** is defined by two components:
  1. Species richness, the number of species in a community, and
  2. Relative abundance, the proportional representation of a species in a community.

Species diversity includes relative abundance and species richness

- Plant species diversity in a community affects the species diversity of animals.
- Species diversity has consequences for pathogens.
- Low species diversity is characteristic of most modern agricultural ecosystems.



Woodlot A



Woodlot B

TABLE 37.10 RELATIVE ABUNDANCE OF TREE SPECIES IN WOODLOTS A AND B

Species	Relative Abundance in Woodlot A (%)	Relative Abundance in Woodlot B (%)
	80	25
	10	25
	5	25
	5	25

Keystone species have a disproportionate impact on diversity

- A **keystone species**
  - is a species whose impact on its community is larger than its biomass or abundance indicates and
  - occupies a niche that holds the rest of its community in place.
- Examples of keystone species in marine ecosystems include
  - *Pisaster* sea stars and
  - long-spined sea urchins.

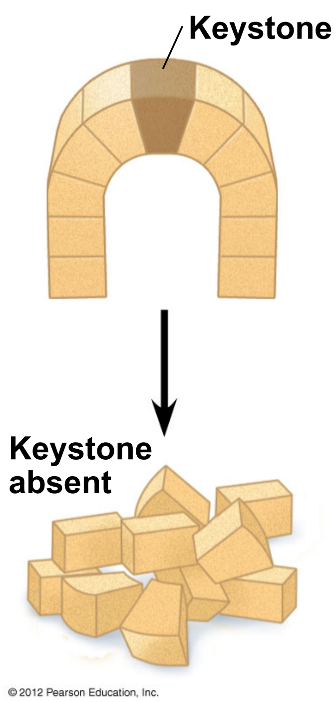
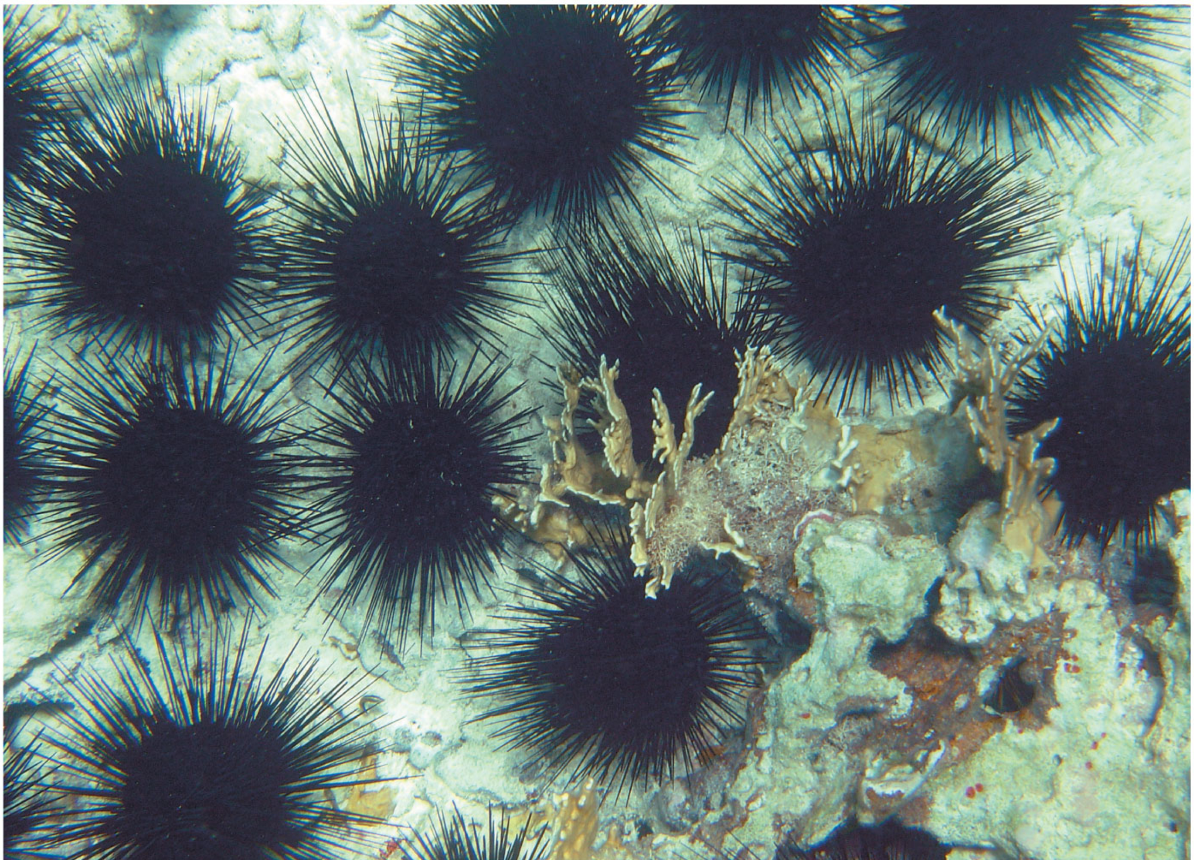


Figure 37.11C



Disturbance is a prominent feature of most communities

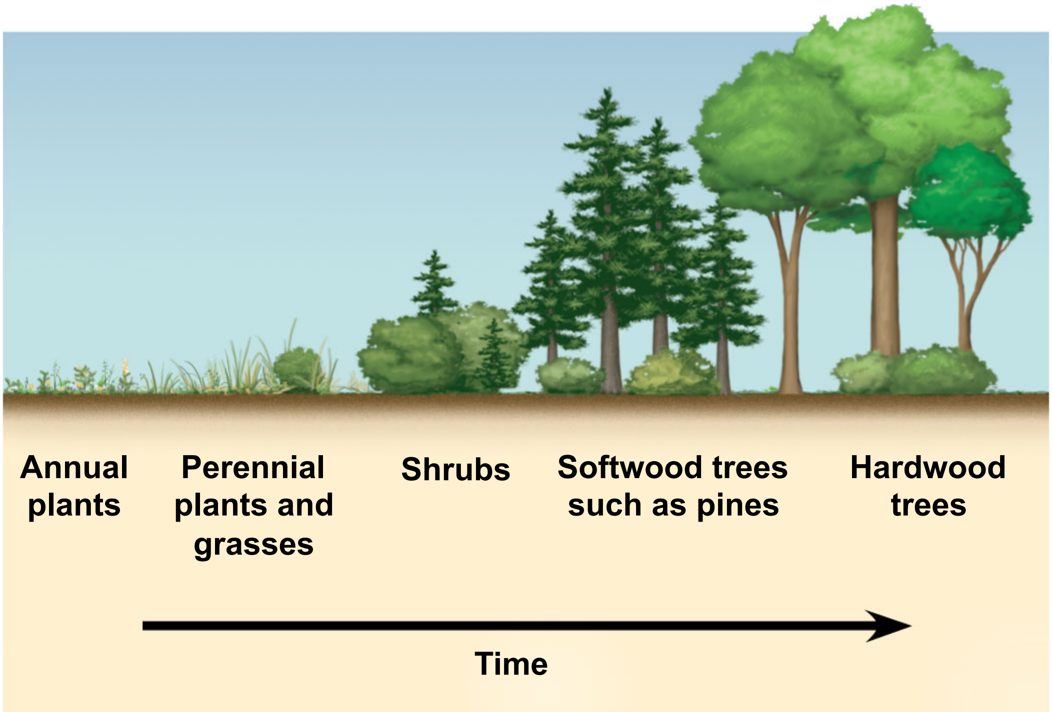
- **Disturbances**
  - are events that damage biological communities and
  - include storms, fires, floods, droughts, overgrazing, or human activity.
  - The types, frequency, and severity of disturbances vary from community to community.

Disturbance is a prominent feature of most communities

- Communities change drastically following a severe disturbance that
  - strips away vegetation and
  - removes significant amounts of soil.
- **Ecological succession** results from colonization by a variety of species, which are replaced by a succession of other species.

Disturbance is a prominent feature of most communities

- **Primary succession** begins in a virtually lifeless area with no soil.
- **Secondary succession** occurs when a disturbance destroys an existing community but leaves the soil intact.


Annual plants
Perennial plants and grasses
Shrubs
Softwood trees such as pines
Hardwood trees
Time

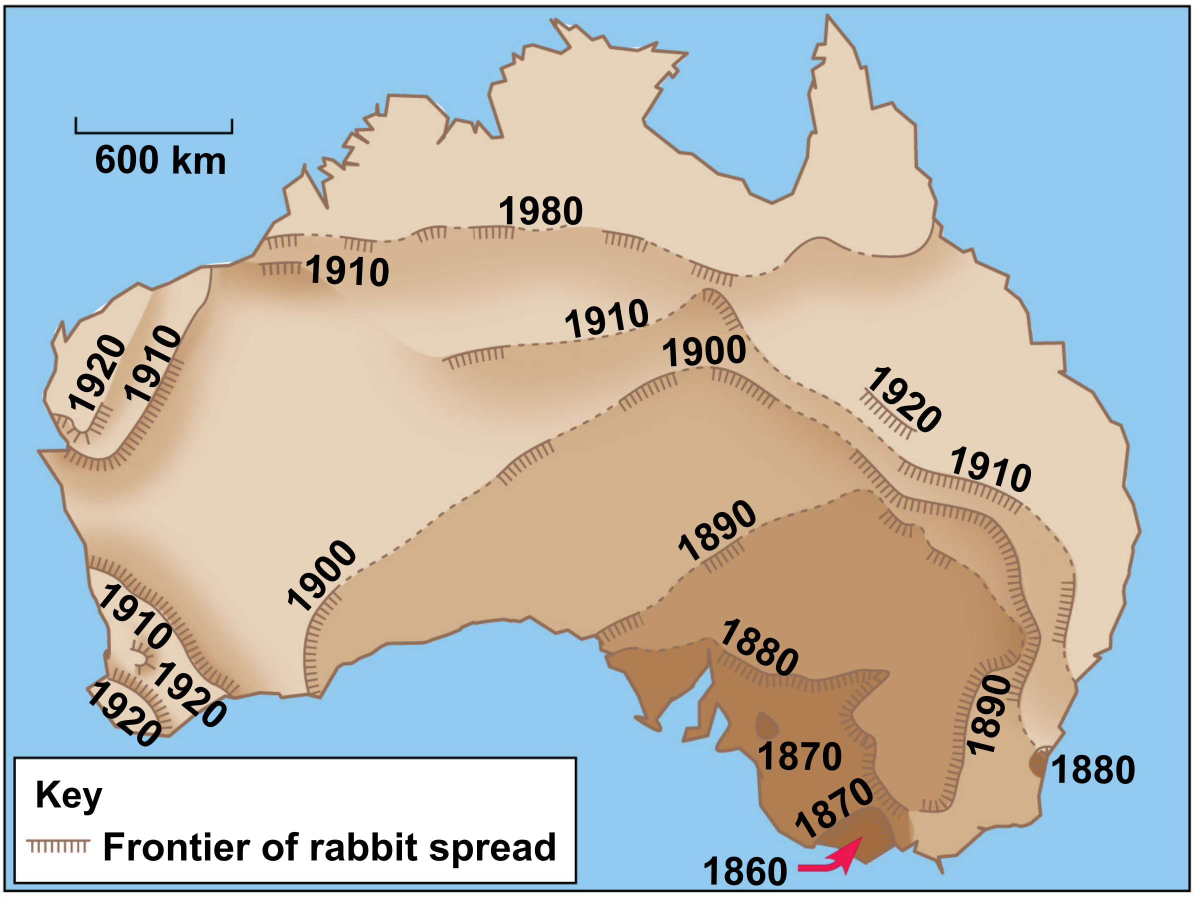
CONNECTION: Invasive species can devastate communities

- **Invasive species**
  - are organisms that have been introduced into non-native habitats by human actions and
  - have established themselves at the expense of native communities.
  - The absence of natural enemies often allows rapid population growth of invasive species.

CONNECTION: Invasive species can devastate communities

- Examples of invasive species include the deliberate introduction of
  - rabbits into Australia and
  - cane toads into Australia.

Figure 37.13A



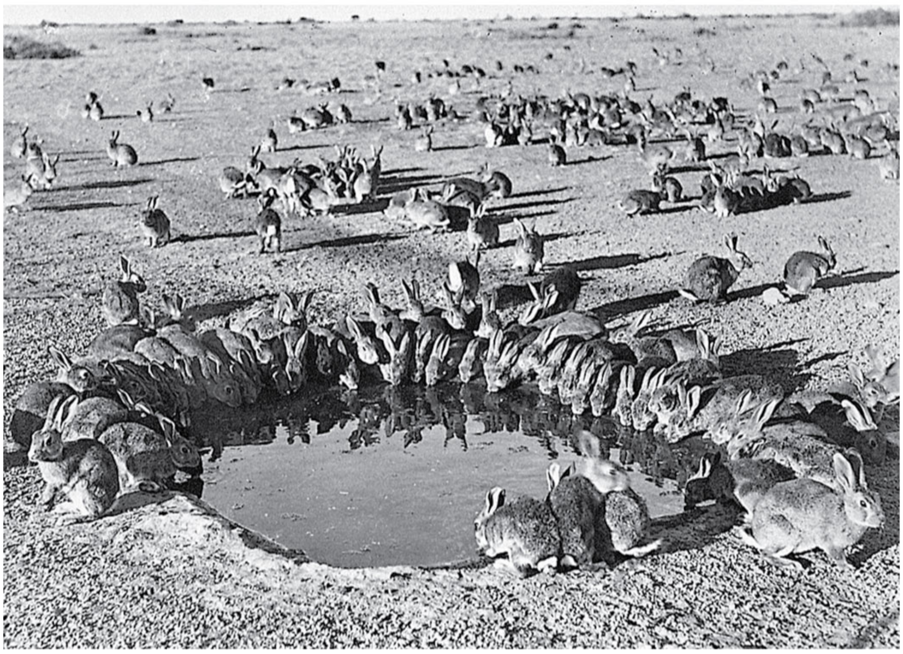


Figure 37.13C

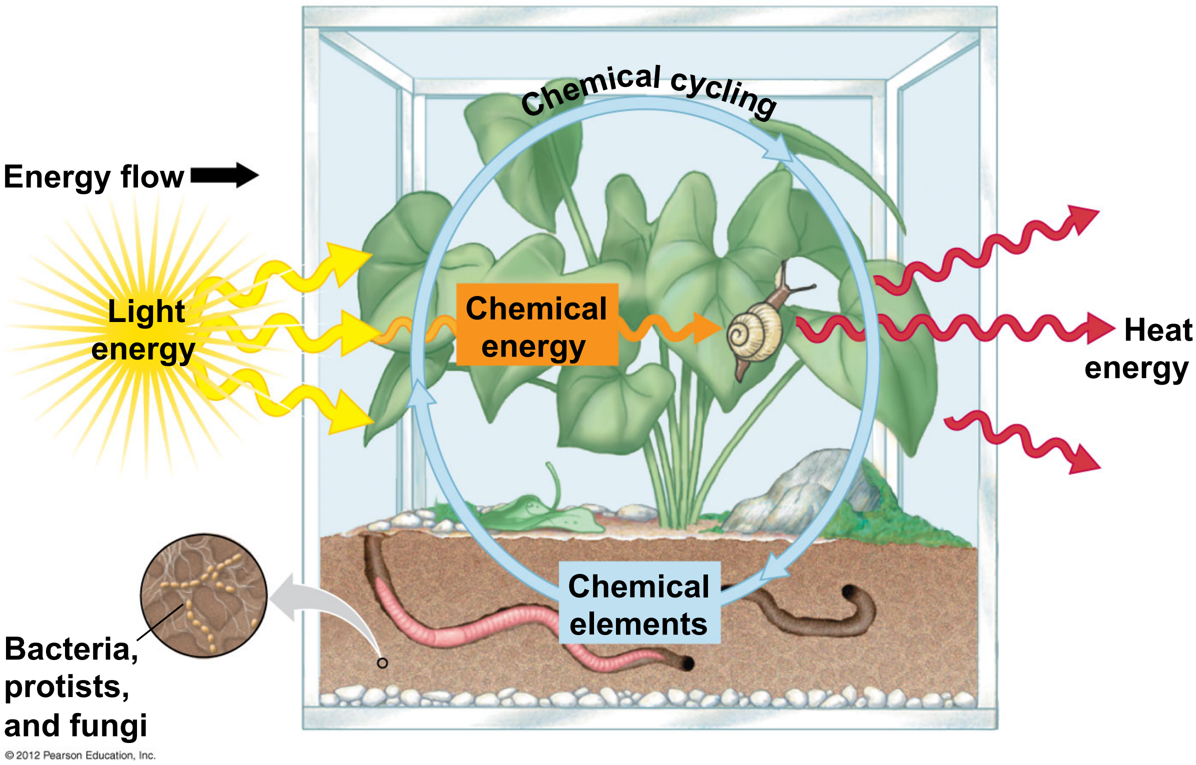
ECOSYSTEM STRUCTURE AND DYNAMICS

Ecosystem ecology emphasizes energy flow and chemical cycling

- An **ecosystem** consists of
  - all the organisms in a community and
  - the abiotic environment with which the organisms interact.
- In an ecosystem,
  - **energy flow** moves *through* the components of an ecosystem and
  - **chemical cycling** is the transfer of materials *within* the ecosystem.

Ecosystem ecology emphasizes energy flow and chemical cycling

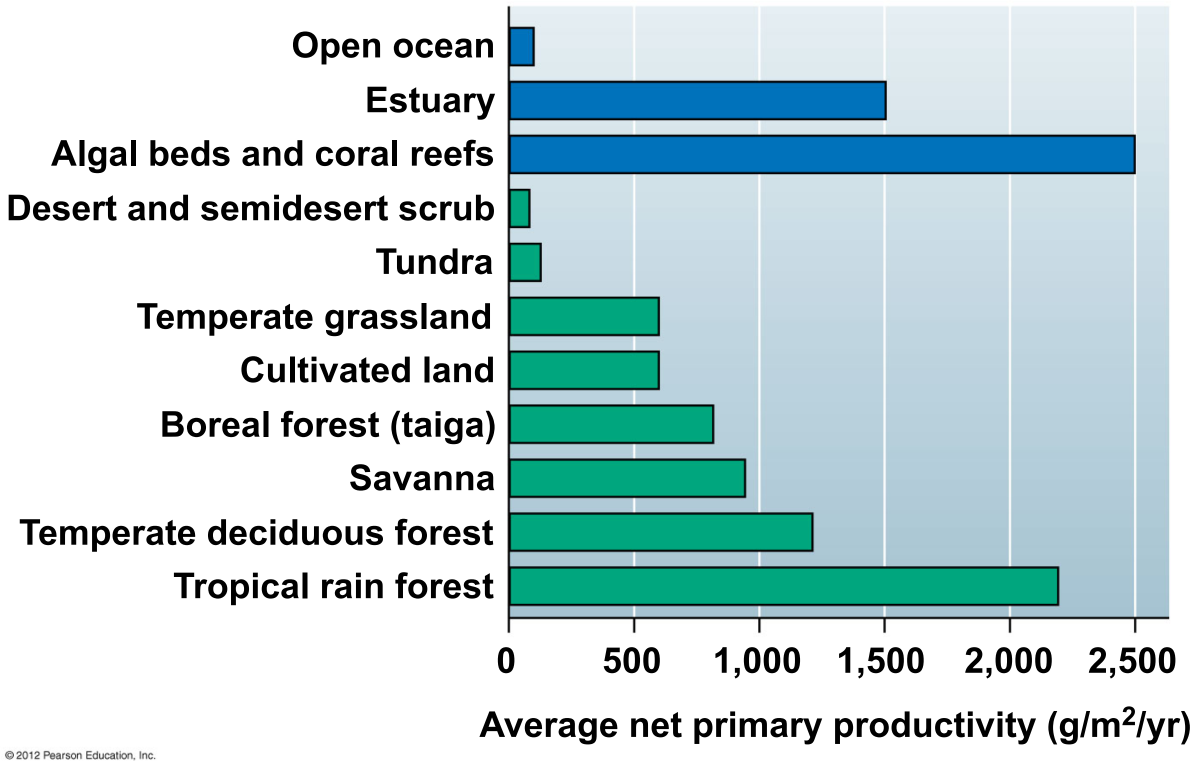
- A terrarium
  - represents the components of an ecosystem and
  - illustrates the fundamentals of energy flow.



Primary production sets the energy budget for ecosystems

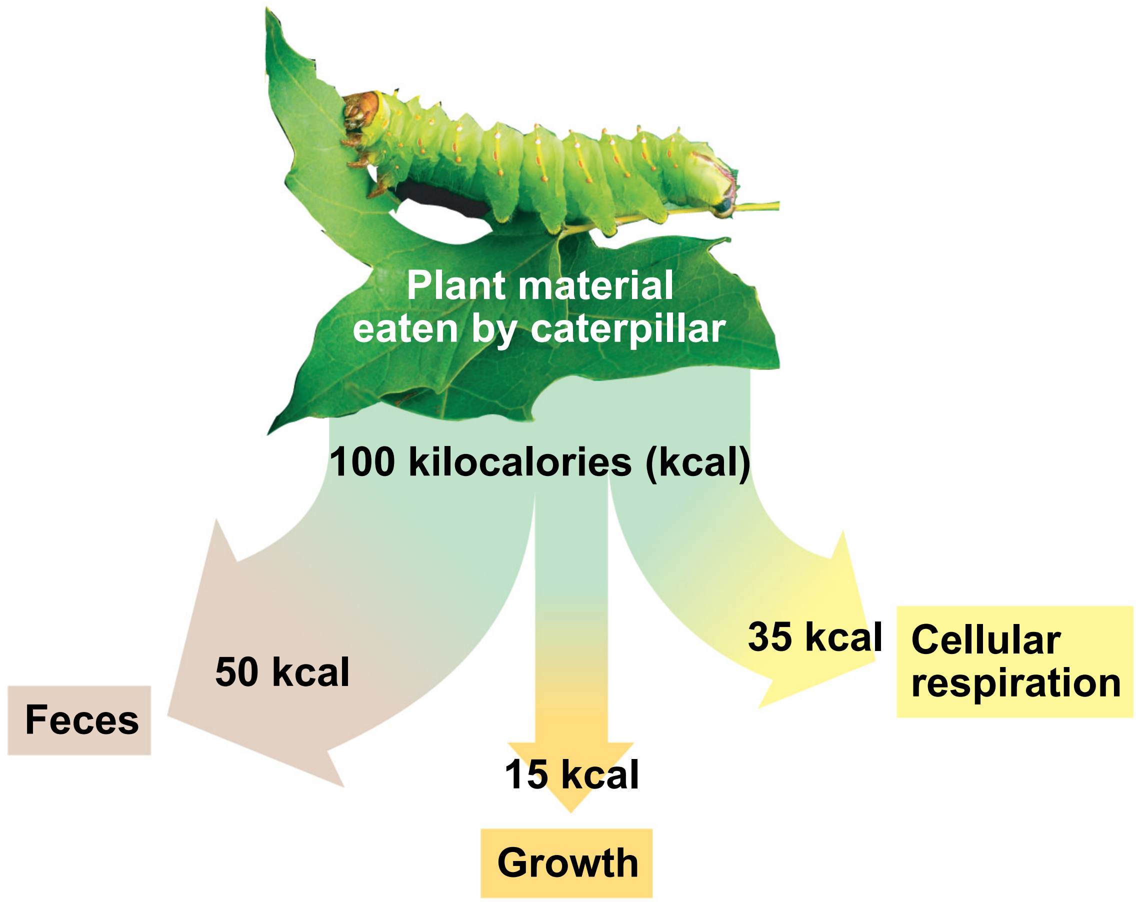
- **Primary production**
  - is carried out by producers,
  - is the amount of solar energy converted to chemical energy by an ecosystem's producers for a given area and during a given time period, and
  - produces **biomass**, the amount of living organic material in an ecosystem.
- Different ecosystems vary in their
  - primary production and
  - contribution to the total production of the biosphere.

Figure 37.15



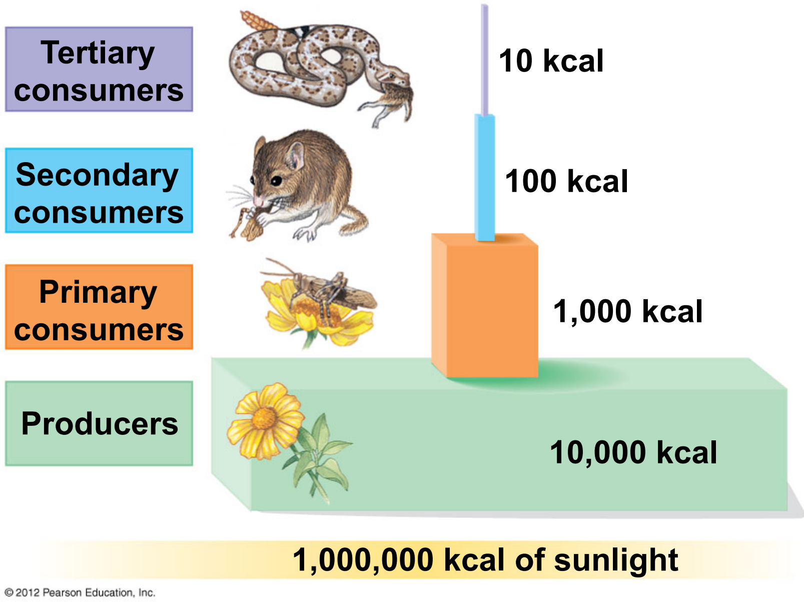
Energy supply limits the length of food chains

- A caterpillar represents a primary consumer.
- Of the organic compounds a caterpillar ingests, about
  - 50% is eliminated in feces,
  - 35% is used in cellular respiration, and
  - 15% is used for growth.



Energy supply limits the length of food chains

- A pyramid of production shows the flow of energy
  - from producers to primary consumers and
  - to higher trophic levels.
- Only about 10% of the energy stored at each trophic level is available to the next level.

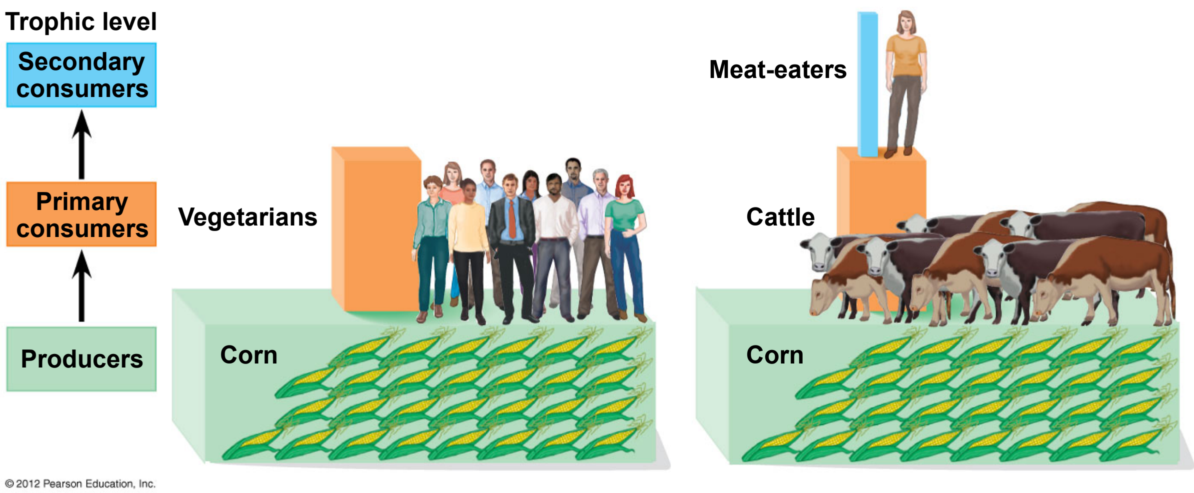


CONNECTION: A pyramid of production explains the ecological cost of meat

- When humans eat
  - grain or fruit, we are primary consumers,
  - beef or other meat from herbivores, we are secondary consumers, and
  - fish like trout or salmon, we are tertiary or quaternary consumers.

CONNECTION: A pyramid of production explains the ecological cost of meat

- Only about 10% of the chemical energy available in a trophic level is passed to the next higher trophic level.
- Therefore, the human population has about ten times more energy available to it when people eat plants instead of the meat of herbivores.
- Eating meat of any kind is expensive
  - economically and
  - environmentally.

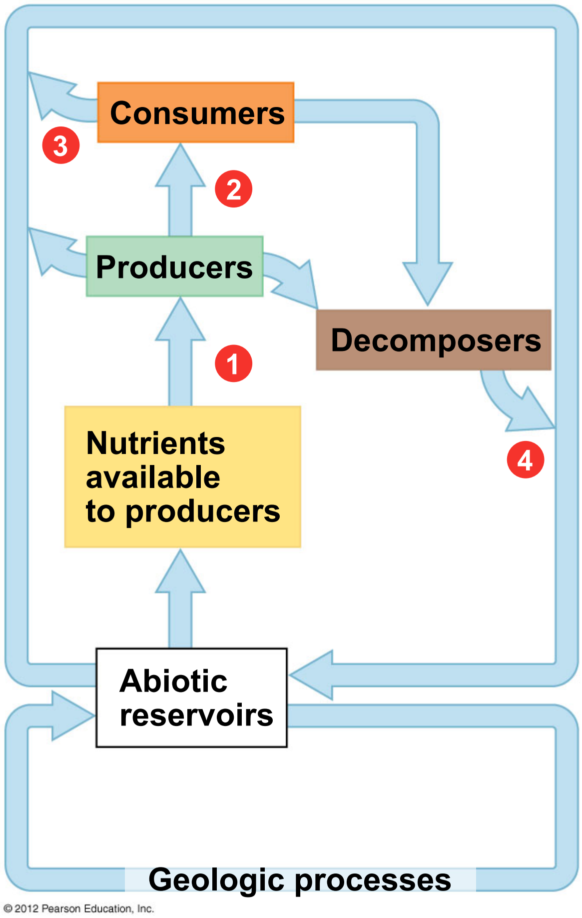


Chemicals are cycled between organic matter and abiotic reservoirs

- Ecosystems are supplied with a continual influx of energy from the
  - sun and
  - Earth's interior.
- Except for meteorites, there are no extraterrestrial sources of chemical elements.
- Thus, life also depends on the recycling of chemicals.

Chemicals are cycled between organic matter and abiotic reservoirs

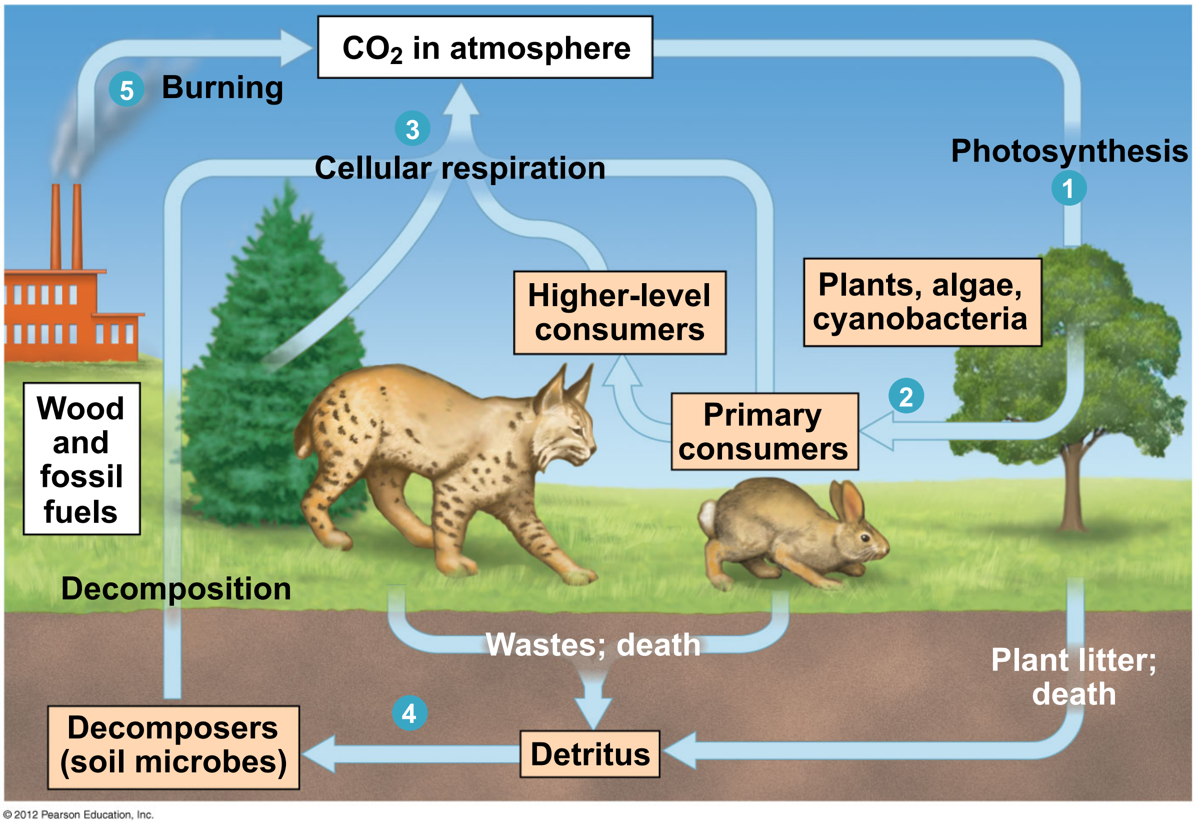
- **Biogeochemical cycles** include
  - biotic components,
  - abiotic components, and
  - **abiotic reservoirs**, where a chemical accumulates or is stockpiled outside of living organisms.
- Biogeochemical cycles can be
  - local or
  - global.



The carbon cycle depends on photosynthesis and respiration

- Carbon is
  - the major ingredient of all organic molecules and
  - found in
    - the atmosphere,
    - fossil fuels, and
    - dissolved in carbon compounds in the ocean.
- The return of CO_2 to the atmosphere by respiration closely balances its removal by photosynthesis.
- The carbon cycle is affected by burning wood and fossil fuels.

Figure 37.19



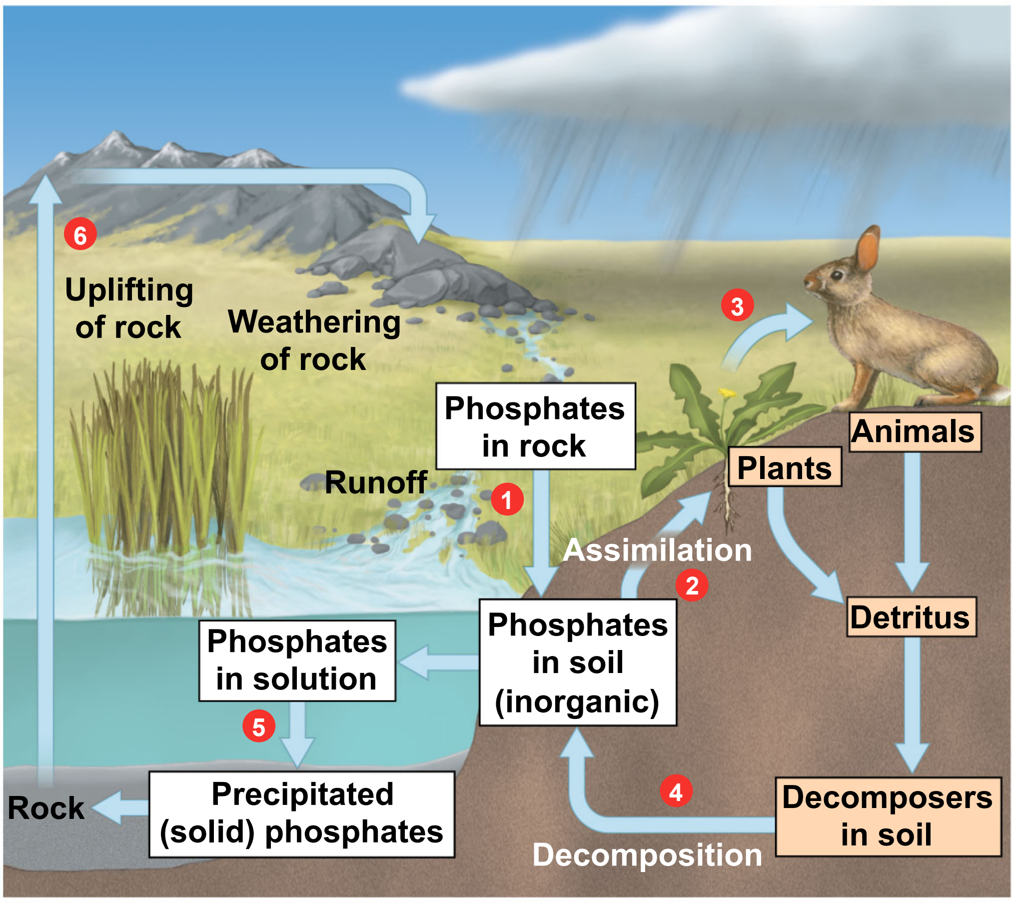
The phosphorus cycle depends on the weathering of rock

- Organisms require phosphorus for
  - nucleic acids,
  - phospholipids, and
  - ATP.

The phosphorus cycle depends on the weathering of rock

- The phosphorus cycle does not have an atmospheric component.
- Rocks are the only source of phosphorus for terrestrial ecosystems.
- Plants absorb phosphate ions in the soil and build them into organic compounds.
- Phosphates are returned to the soil by decomposers.
- Phosphate levels in aquatic ecosystems are typically low enough to be a limiting factor.

Figure 37.20



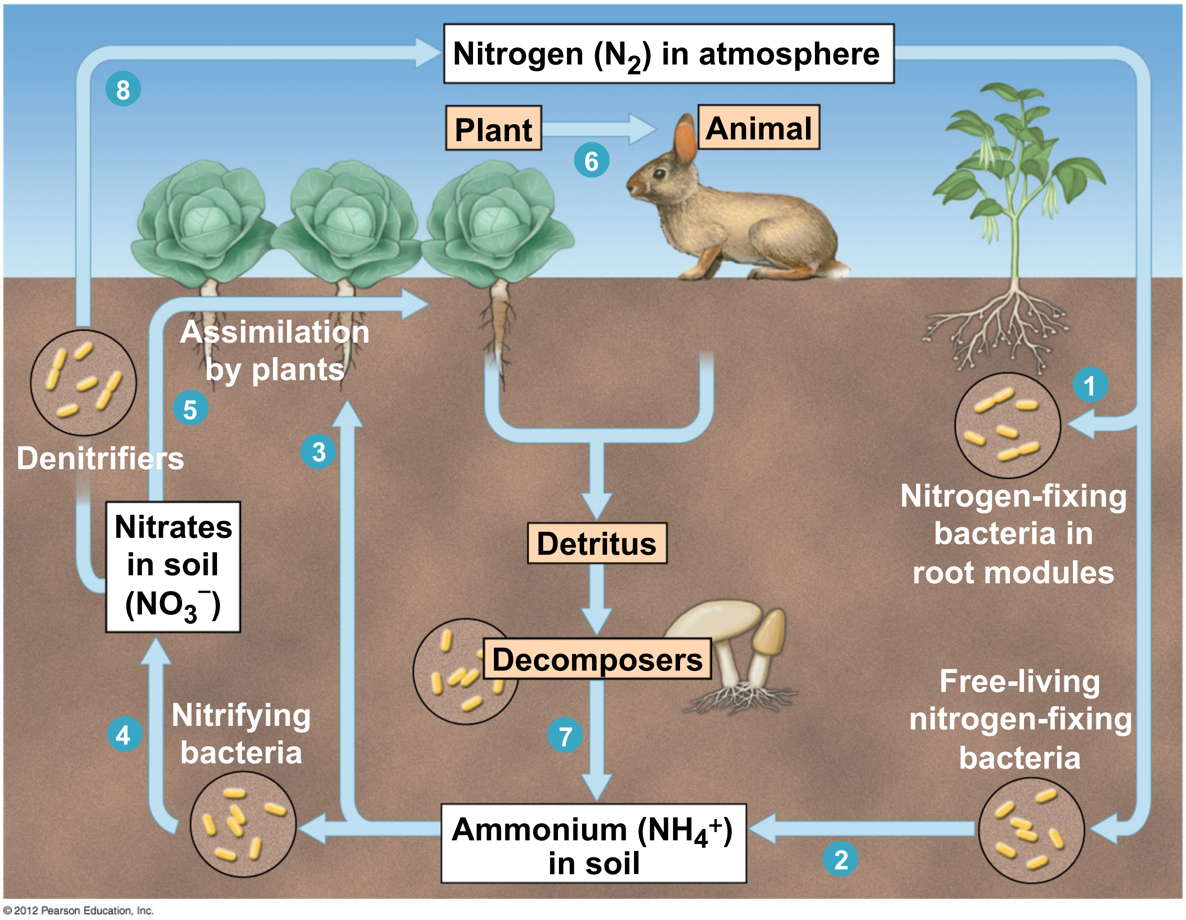
The nitrogen cycle depends on bacteria

- Nitrogen is
  - an ingredient of proteins and nucleic acids,
  - essential to the structure and functioning of all organisms, and
  - a crucial and often limiting plant nutrient.
- Nitrogen has two abiotic reservoirs:
  1. the atmosphere, of which about 80% is nitrogen gas, and
  2. soil.

The nitrogen cycle depends on bacteria

- **Nitrogen fixation**
  - converts N_2 to compounds of nitrogen that can be used by plants and
  - is carried out by some bacteria.

Figure 37.21



CONNECTION: A rapid inflow of nutrients degrades aquatic ecosystems

- In aquatic ecosystems, primary production is limited by low nutrient levels of
  - phosphorus and
  - nitrogen.
- Over time, standing water ecosystems
  - gradually accumulate nutrients from the decomposition of organic matter and fresh influx from the land, and
  - primary production increases in a process known as eutrophication.

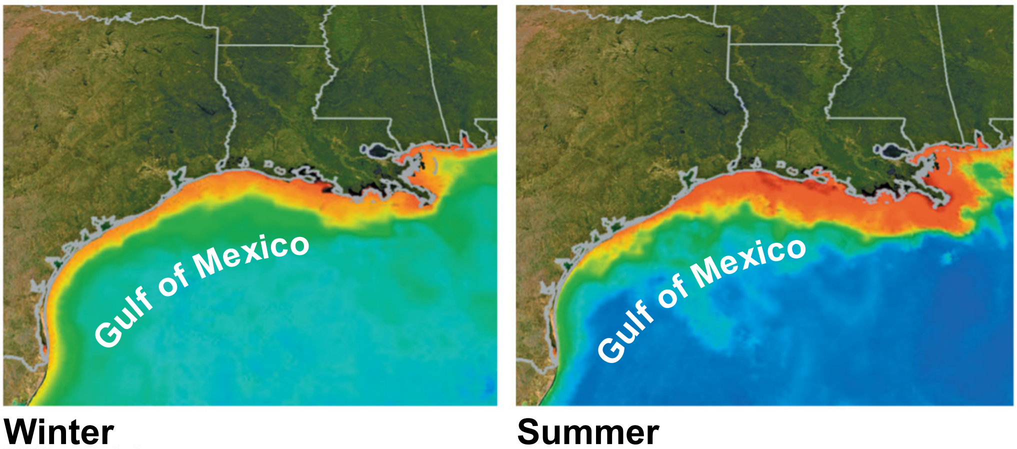
CONNECTION: A rapid inflow of nutrients degrades aquatic ecosystems

- Eutrophication of lakes, rivers, and coastal waters
  - depletes oxygen levels and
  - decreases species diversity.
- In many areas, phosphate pollution leading to eutrophication comes from
  - agricultural fertilizers,
  - pesticides,
  - sewage treatment facilities, and
  - runoff of animal waste from feedlots

CONNECTION: A rapid inflow of nutrients degrades aquatic ecosystems

- Eutrophication of aquatic systems may also result from increased levels of nitrogen from
  - feedlots and
  - applications of large amounts of fertilizer.

Figure 37.22A

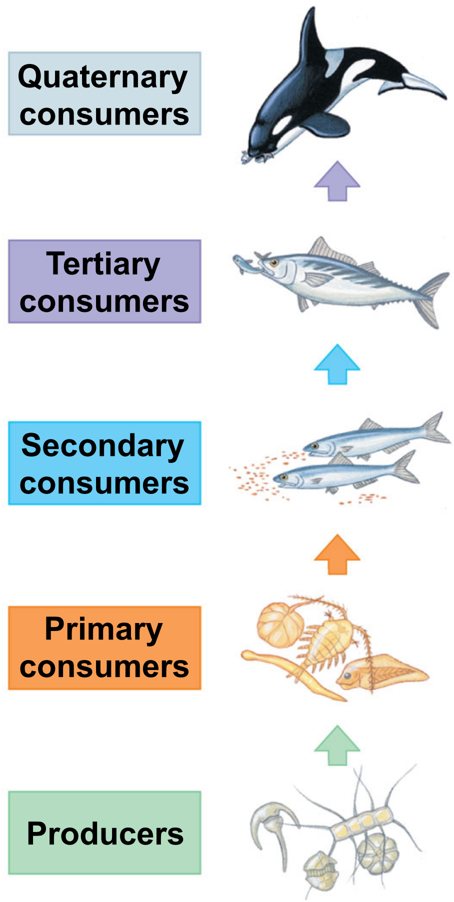


CONNECTION: Ecosystem services are essential to human well-being

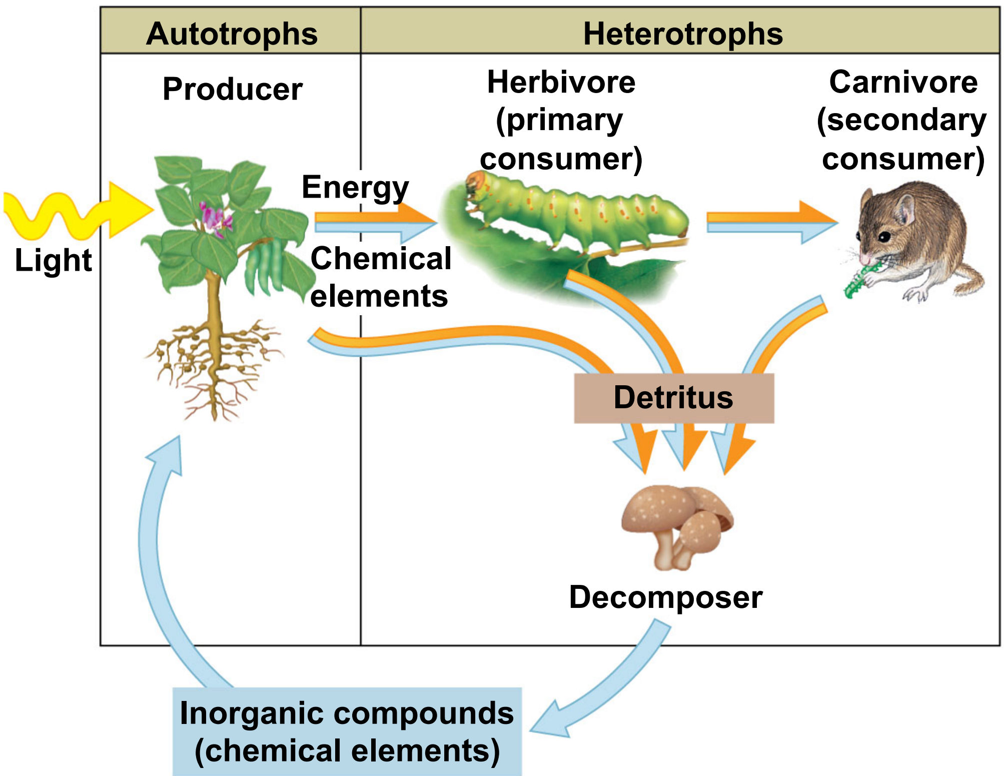
- Although agricultural and other managed ecosystems are necessary to supply our needs, we also depend on services provided by natural ecosystems.
- Healthy ecosystems
  - supply fresh water and some foods,
  - recycle nutrients,
  - decompose wastes, and
  - regulate climate and air quality.

CONNECTION: Ecosystem services are essential to human well-being

- Enormous increases in food production have come at the expense of
  - natural ecosystems and
  - the services they provide.
- Human activities also threaten many forest ecosystems and the services they provide.



Quaternary consumers
Tertiary consumers
Secondary consumers
Primary consumers
Producers



Autotrophs
Heterotrophs
Producer
Herbivore (primary consumer)
Carnivore (secondary consumer)
Light
Energy
Chemical elements
Detritus
Decomposer
Inorganic compounds (chemical elements)

Figure 37.UN03