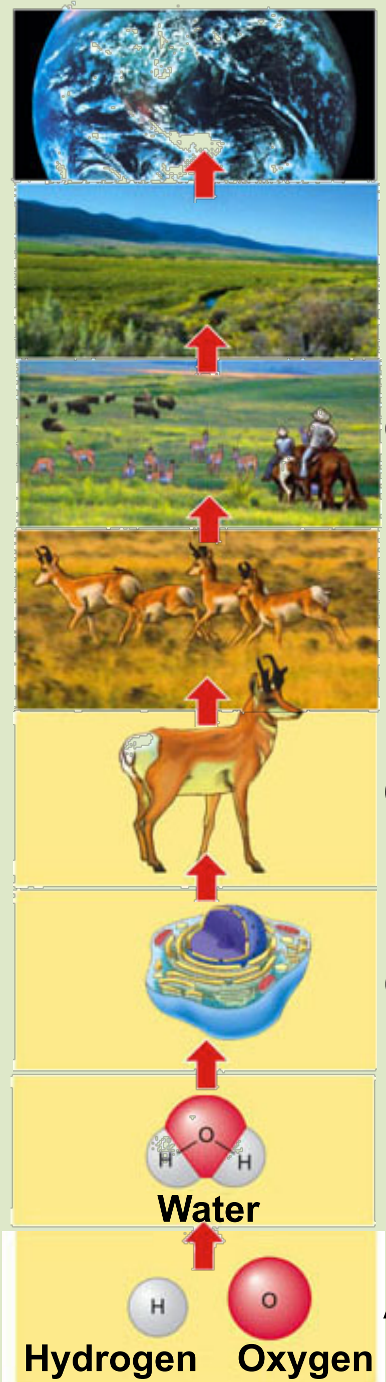


Biosphere	Parts of the earth's air,water, and soil where life is found
Ecosystem	A community of different species interacting with one another and with their nonliving environment of matter and energy
Community	Populations of different species living in a particular place, and potentially interacting with each other
Population	A group of individuals of the same species living in a particular place
Organism	An individual living being
Cell	The fundamental structural and functional unit of life
Molecule	Chemical combination of two or more atoms of the same or different elements
Atom	Smallest unit of a chemical element that exhibits its chemical properties

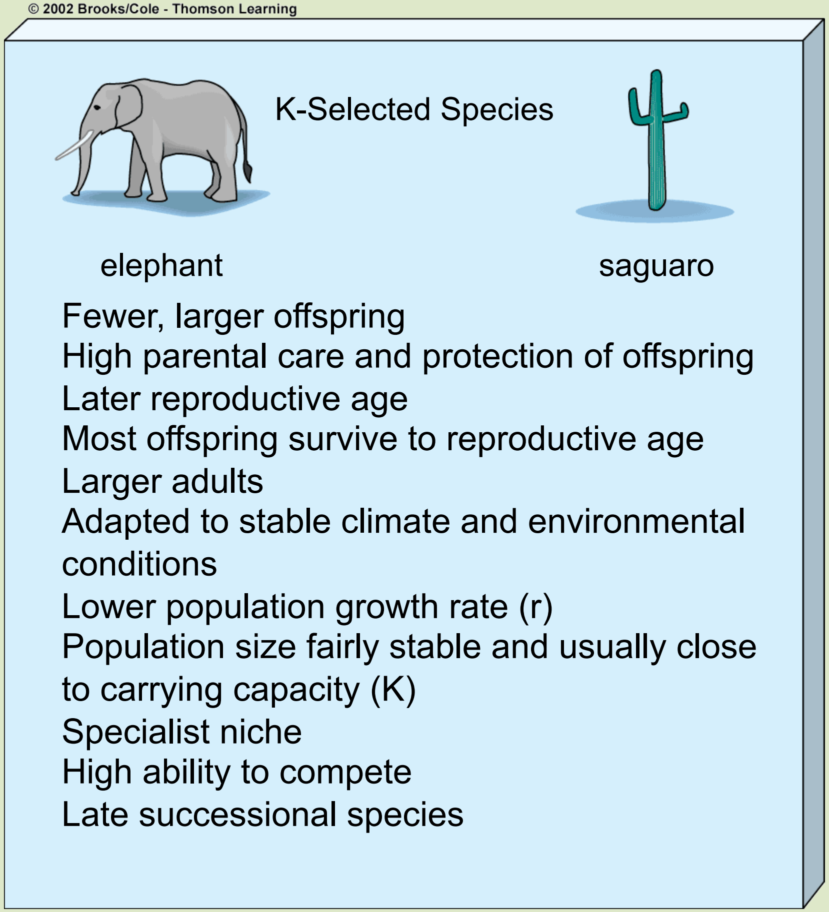
Stepped Art

Fig. 3-5, p. 58

r- and K-Stratigies

Characteristics of contrasting reproductive strategies	
r-adapted species	**K-adapted species**
1.Short life	1.Long life
2.Rapid growth	2.Slower growth
3.Early maturity	3.Late maturity
4.Many small offspring	4.Fewer large offspring
5.Little parental care or protection	5.High parental care and protection
6.Little investment in individual offspring	6.High investment in individual offspring
7.Adapted to unstable environment	7.Adapted to stable environment
8.Pioneers, colonizers	8.Later stages of succession
9.Niche generalists	9.Niche specialists
10.Prey	10.Predators
11.Regulated mainly by extrinsic factors	11.Regulated mainly by intrinsic factors
12.Low trophic level	12.High trophic level

Reproductive Patterns and Survival



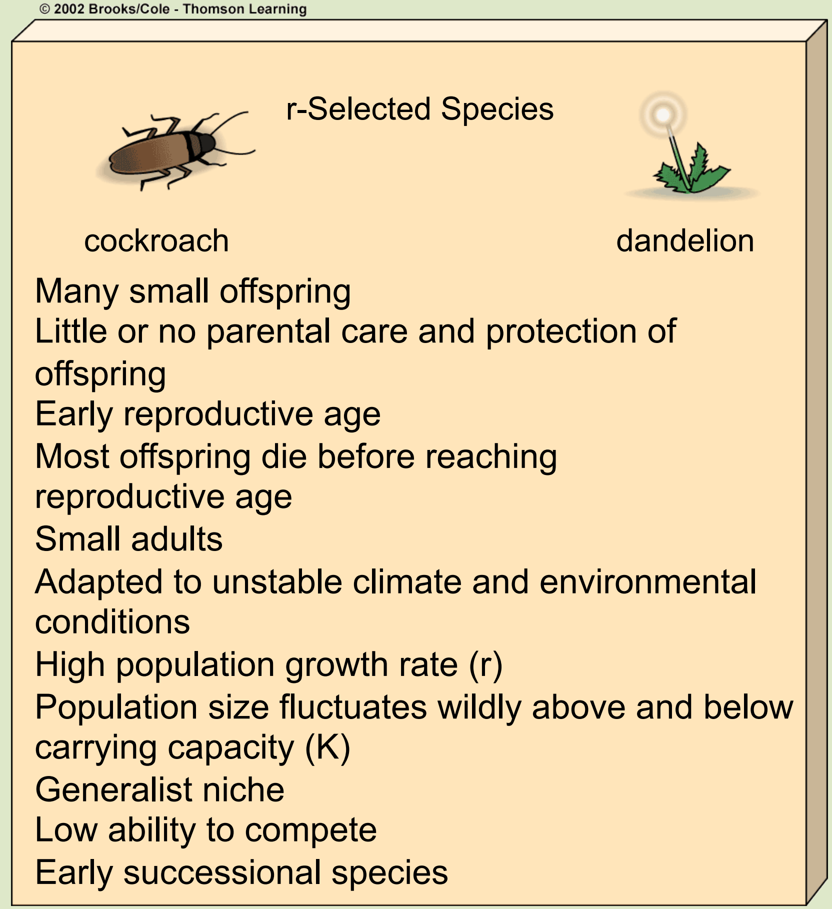


Fig. 9.10b, p. 205

Survivorship Curves

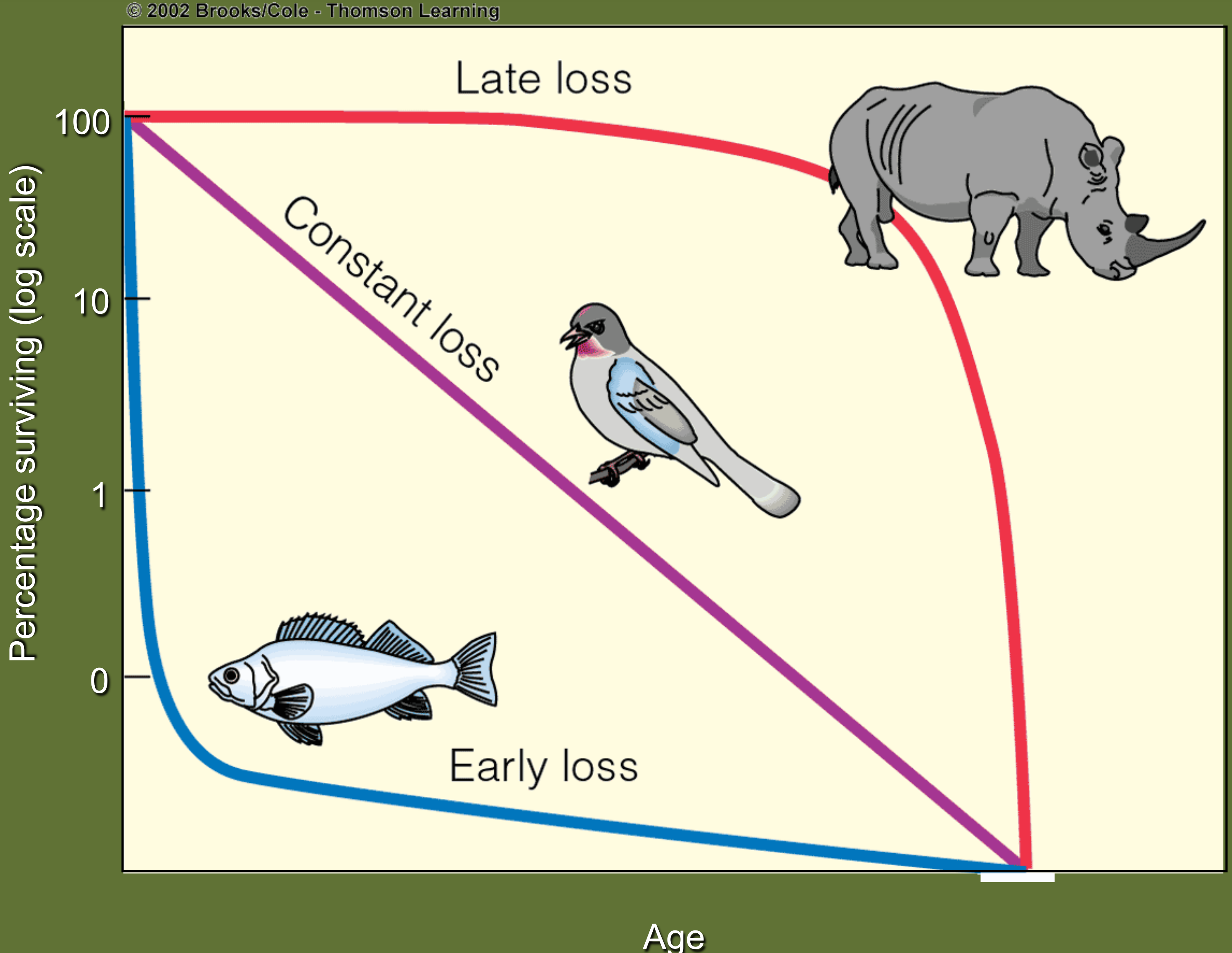
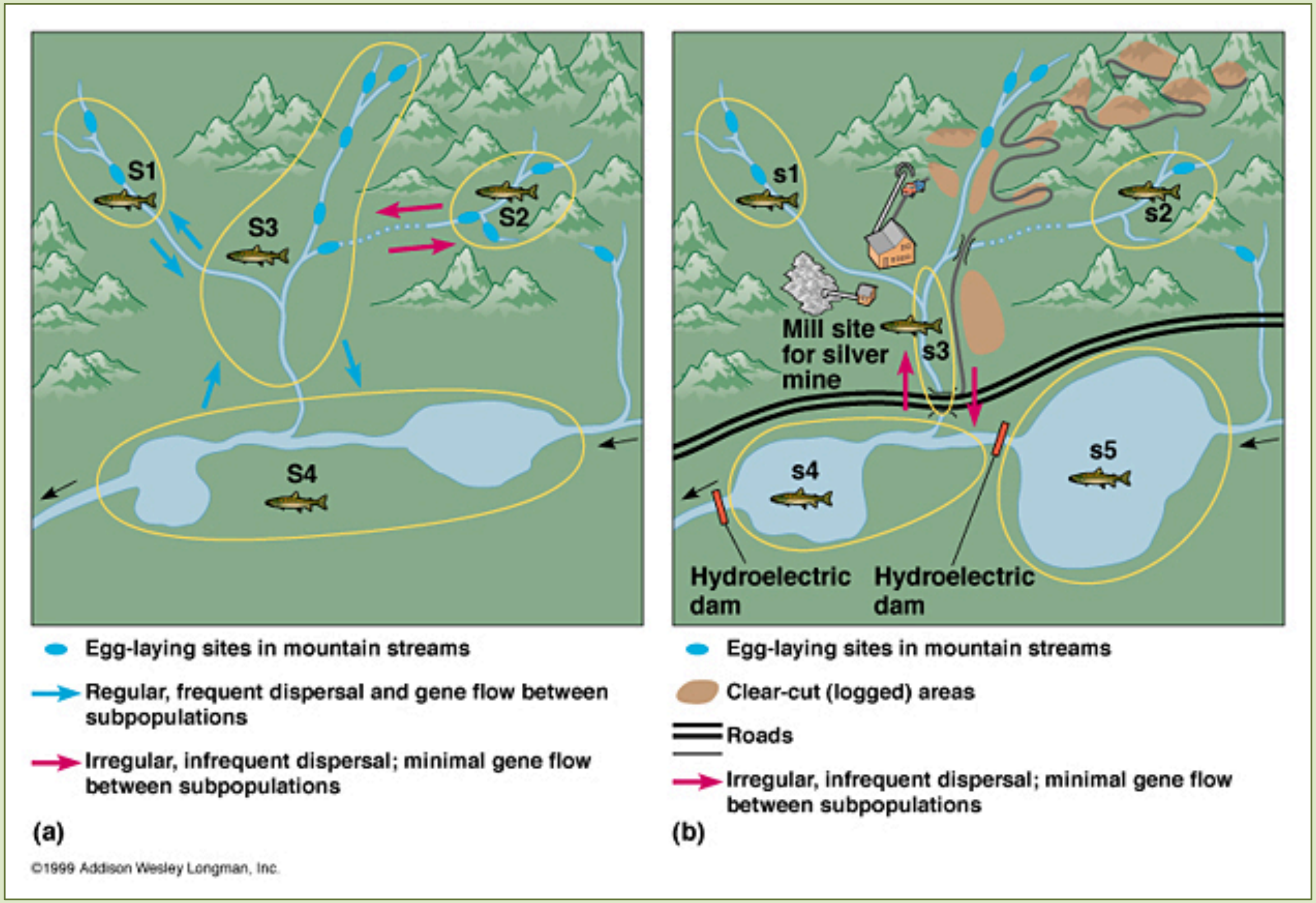
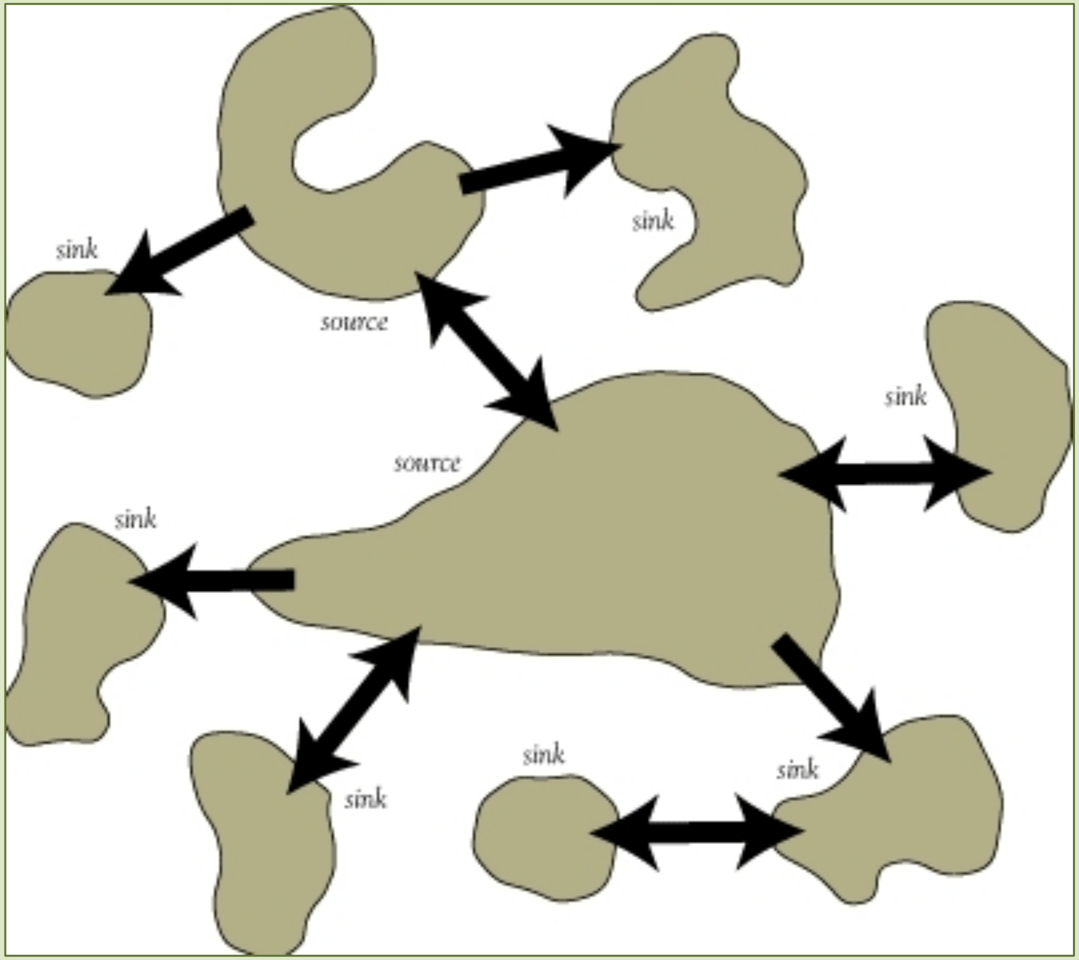


Fig. 9.11, p. 206

A species metapopulation is defined as a set of spatially separated populations, which have some form of migration or mixing behavior among them.



A species metapopulation is defined as a set of spatially separated populations, which have some form of migration or mixing behavior among them. Animal populations are often thought of in the context of metapopulations, but plants are an equally worthy subject, since seed dispersal is tantamount to animal migration in connecting disparate habitat patches. The name metapopulation was first used in 1970 by Levins to describe a population dynamics model for insect pests inhabiting crop growing areas; however, the idea has since been most broadly applied to species in fragmented habitats.



J-Curves and S-Curves

- Exponential growth
  - Starts slowly, then accelerates to carrying capacity when meets environmental resistance

- Logistic growth
  - Decreased population growth rate as population size reaches carrying capacity

Logistic Growth of Sheep in Tasmania

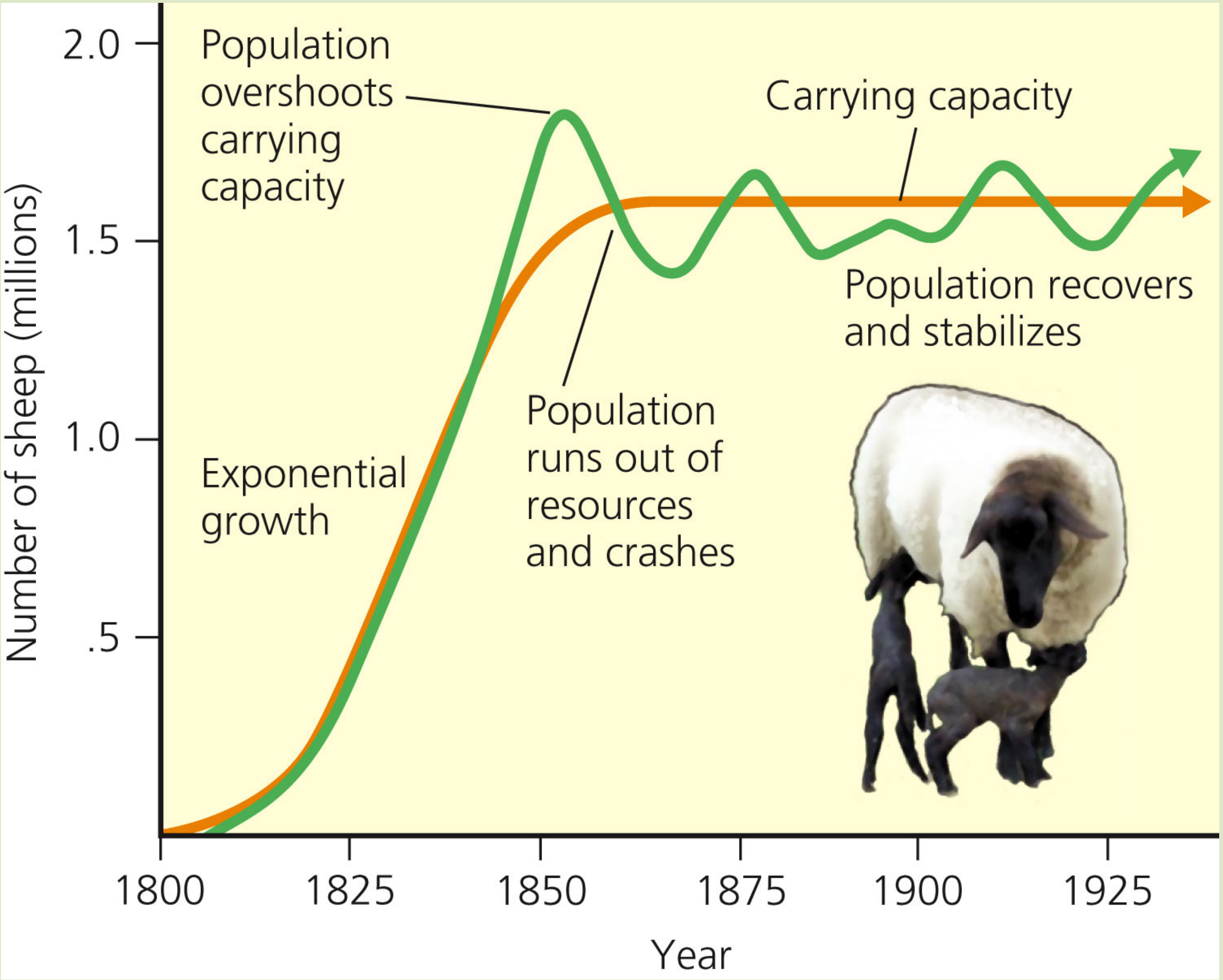


Fig. 5-15, p. 115

Regulation of population size

- Limiting factors
  - **density dependent**
    - competition: food, mates, nesting sites
    - predators, parasites, pathogens
  - **density independent**
    - abiotic factors
      - sunlight (energy)
      - temperature
      - rainfall

Population Cycles for the Snowshoe Hare and Canada Lynx

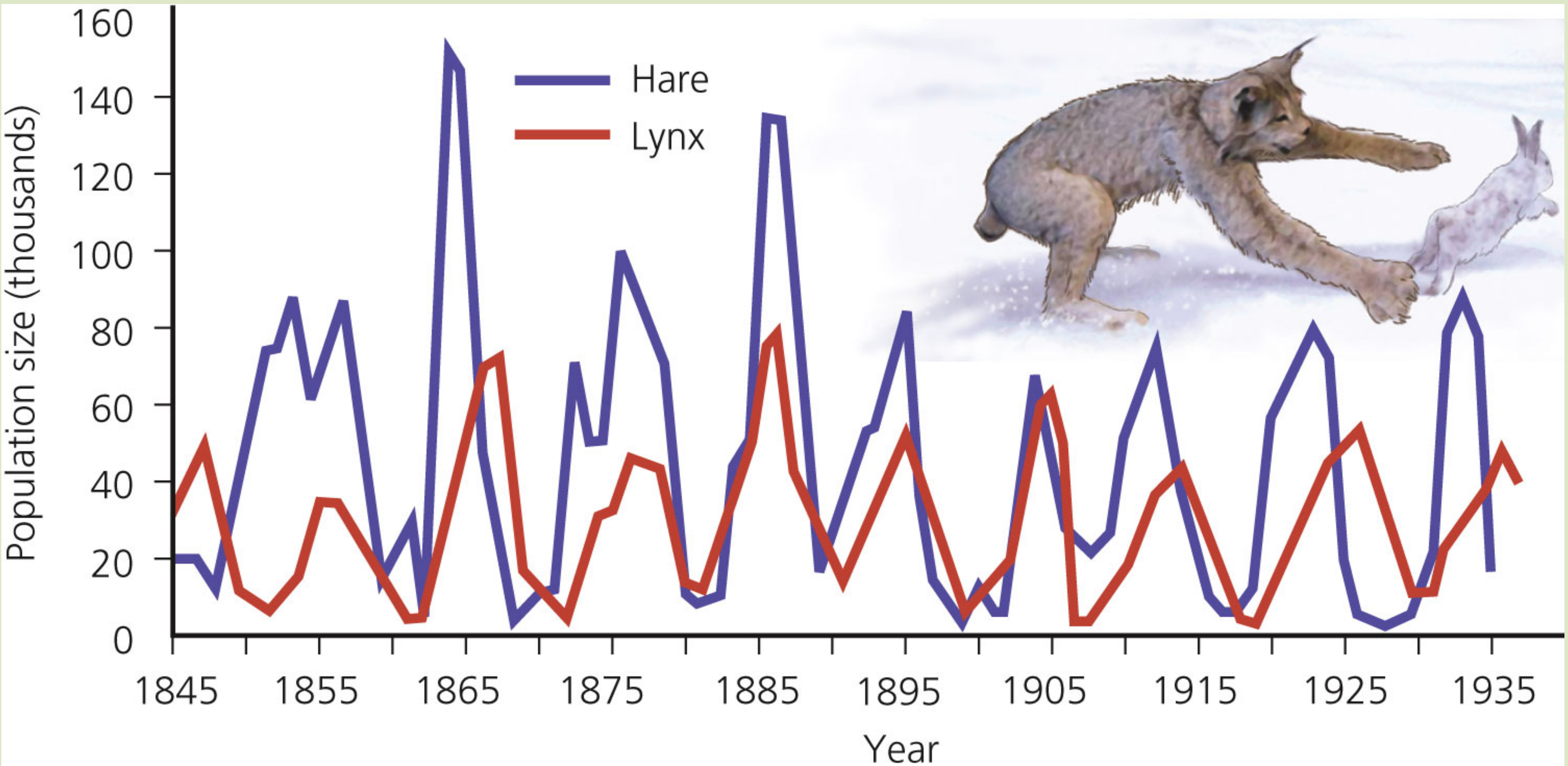


Fig. 5-18, p. 118

Each Species Plays a Unique Role in Its Ecosystem

- **Ecological niche, niche**
  - Pattern of living: everything that affects survival and reproduction
  - Water, space, sunlight, food, temperatures
- **Generalist species**
  - Broad niche: wide range of tolerance
- **Specialist species**
  - Narrow niche: narrow range of tolerance

Specialist Species and Generalist Species Niches

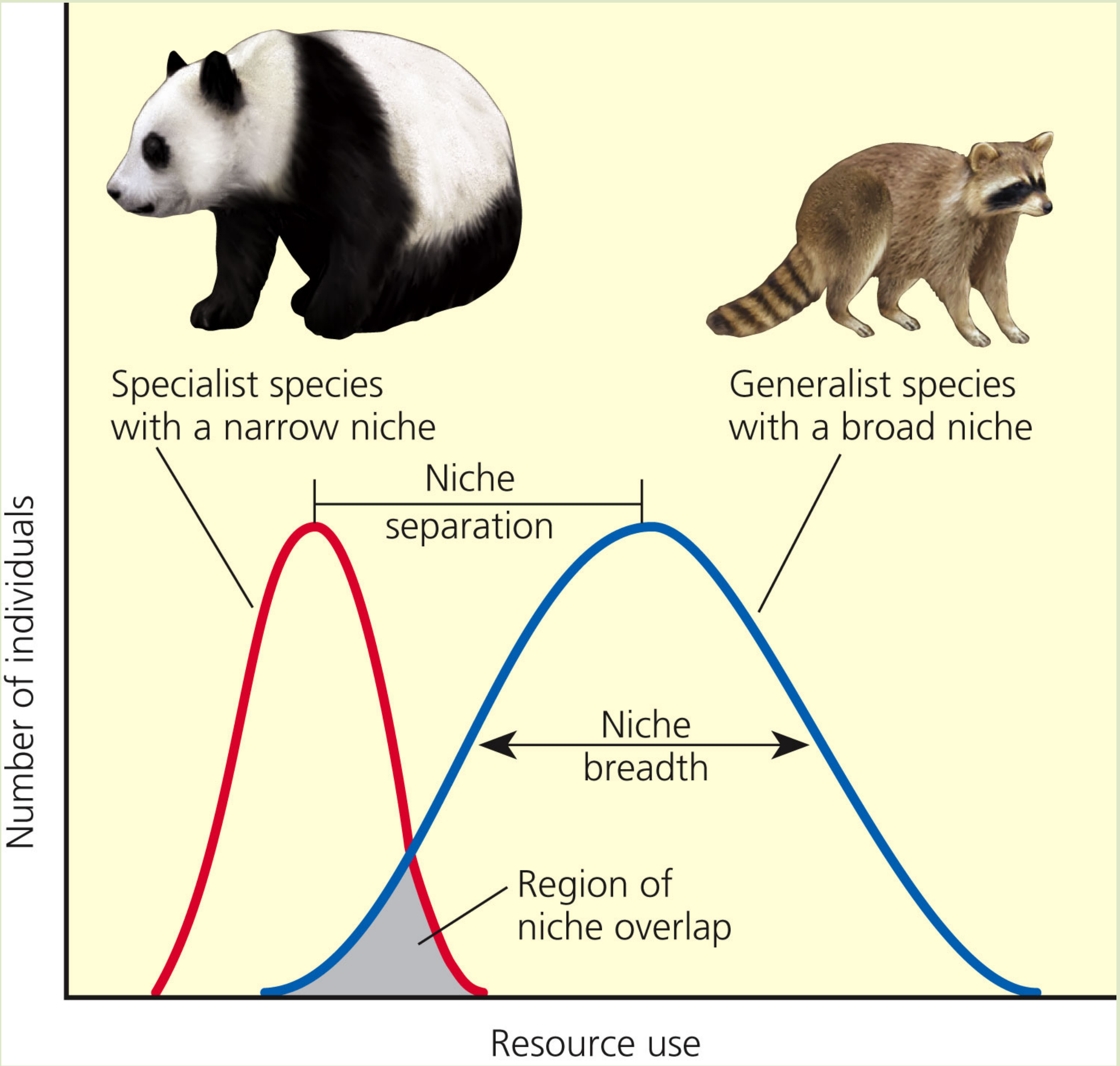
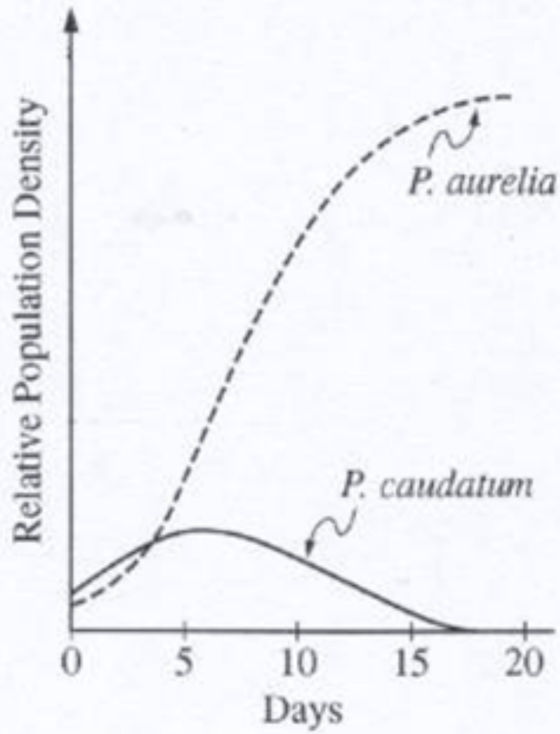


Fig. 4-13, p. 95

In ecology, the competitive exclusion principle, sometimes referred to as Gause's law of competitive exclusion or just Gause's law, is a proposition that states that two species competing for the same resource cannot coexist at constant population values, if other ecological factors remain constant.

78. The graph below shows the results obtained when two species of *Paramecium* were grown together in the same medium.



The graph above best exemplifies

(A) the demographic transition
(B) sustained logarithmic growth
(C) the edge effect
(D) competitive exclusion
(E) the normal distribution

Some Species Feed off Other Species by Living on or in Them

- **Parasitism**

- Parasite is usually much smaller than the host

- Parasite rarely kills the host

- Parasite-host interaction may lead to coevolution

Parasitism: Trout with Blood-Sucking Sea Lamprey

Fig. 5-7, p. 110

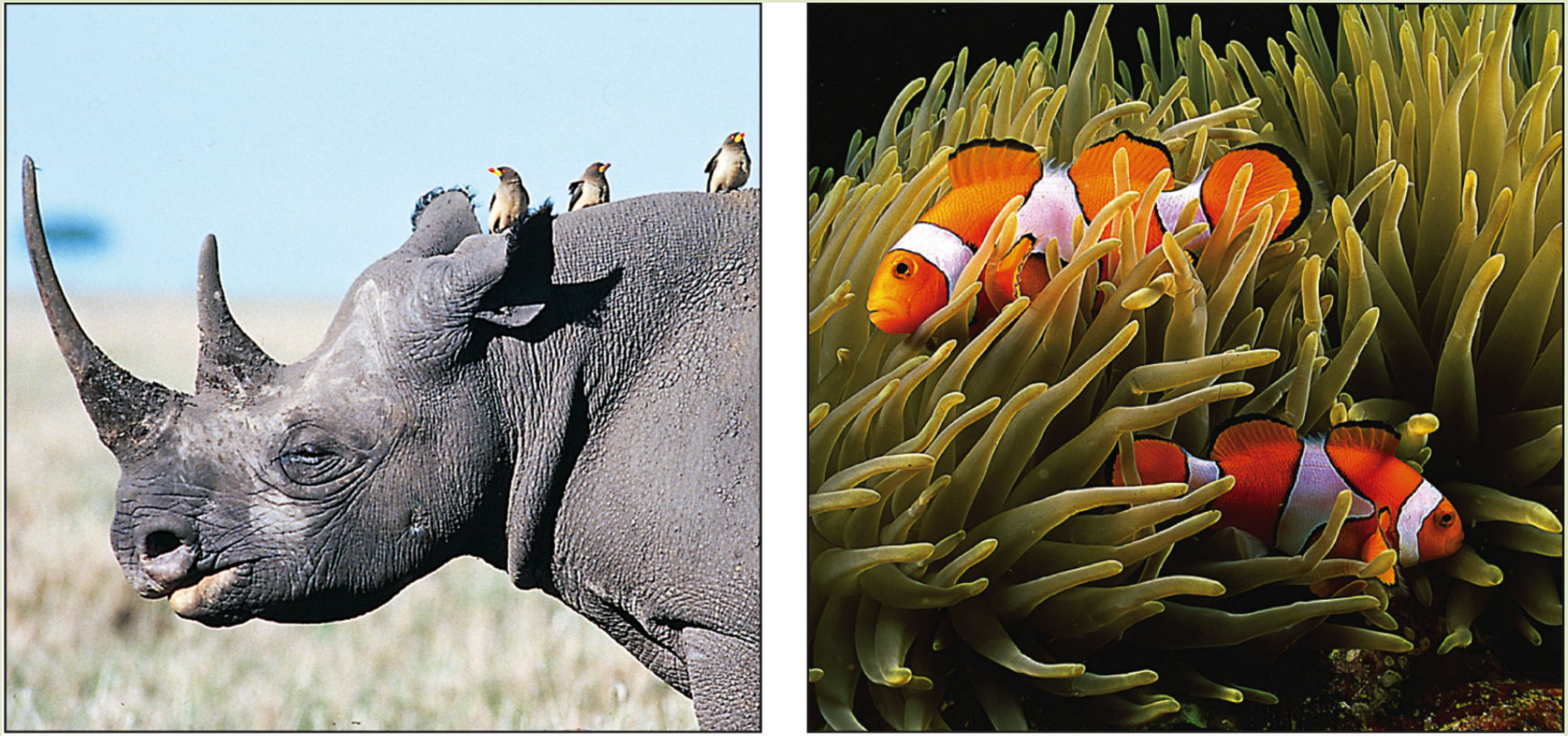
In Some Interactions, Both Species Benefit

- **Mutualism**
- Nutrition and protection relationship
- Gut inhabitant mutualism
- Not cooperation: it' s mutual exploitation

Mutualism: Hummingbird and Flower

Fig. 5-8, p. 110

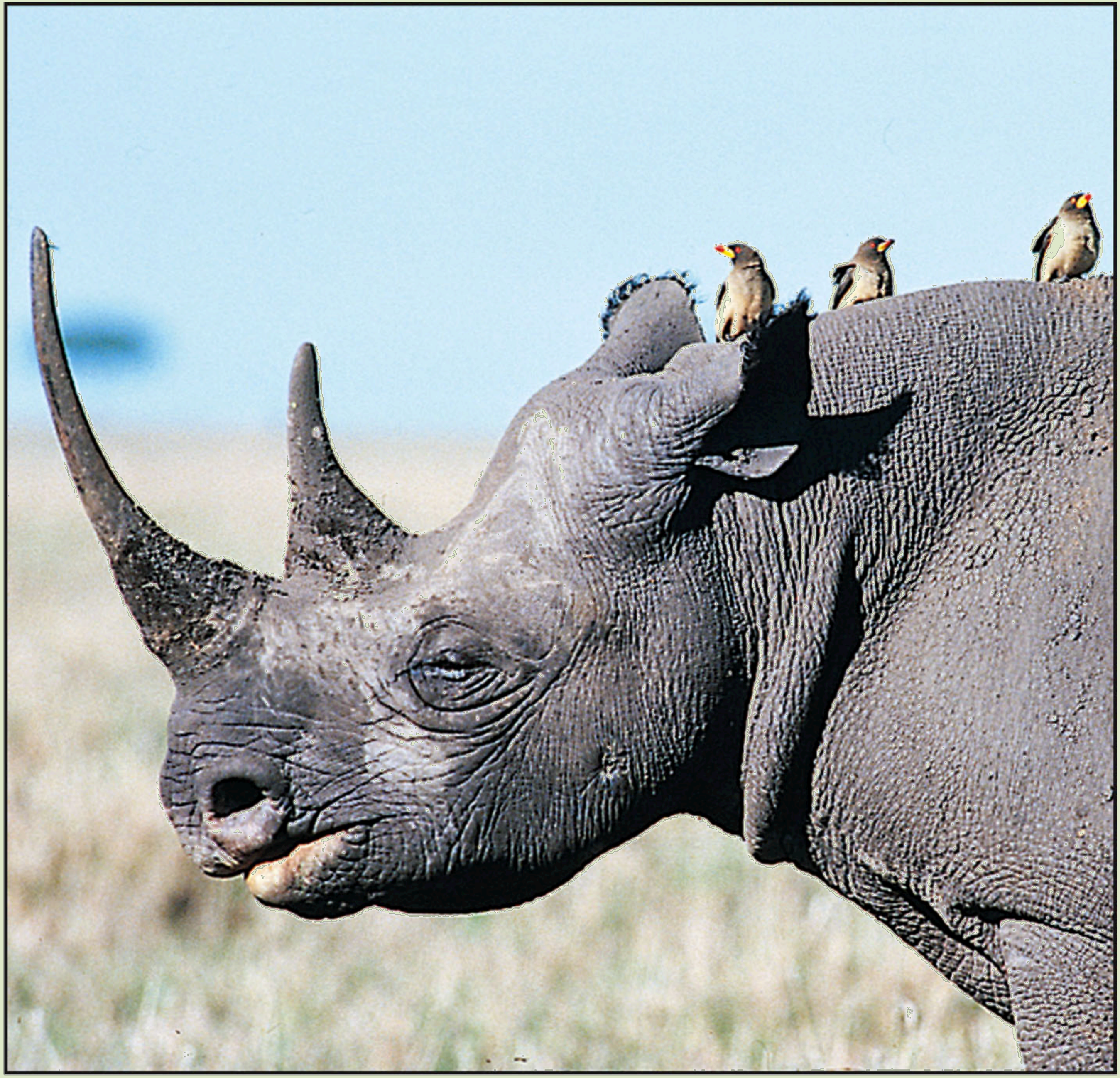
Mutualism: Oxpeckers Clean Rhinoceros; Anemones Protect and Feed Clownfish



(a) Oxpeckers and black rhinoceros

(b) Clownfish and sea anemone

Fig. 5-9, p. 111



(a) Oxpeckers and black rhinoceros

(b) Clownfish and sea anemone

Fig. 5-9b, p. 111

In Some Interactions, One Species Benefits and the Other Is Not Harmed

- **Commensalism**
- Epiphytes
- Birds nesting in trees

Commensalism: Bromiliad Roots on Tree Trunk Without Harming Tree

Fig. 5-10, p. 111

Keystone Species Play Critical Roles in Their Ecosystems

- **Keystone species**: roles have a large effect on the types and abundances of other species

- Pollinators

- Top predators

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: a keystone species
- 1967: endangered species
- 1977: comeback, threatened species

American Alligator

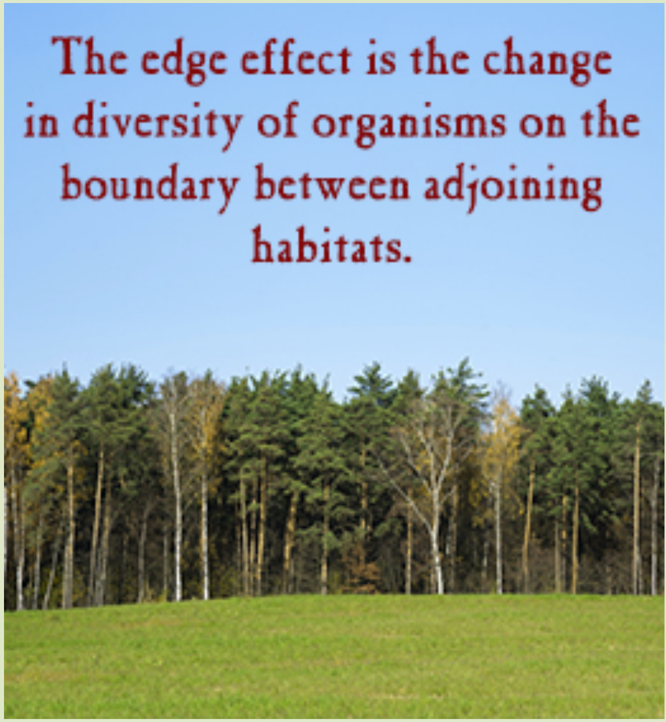
Fig. 4-18, p. 99

Ecotone

...may exist along a broad belt or in a small pocket, such as a forest clearing, where two local communities blend together. The influence of the two bordering communities on each other is known as the edge effect. An ecotonal area often has a higher density of organisms of one species and a greater number of species than are found in either flanking community. Some organisms need a transitional...

Community ecology: Ecotones

...specifically for living in these zones. In many cases, the number of species and the population density are greater within the ecotone than in the surrounding communities, a phenomenon known as the edge effect.

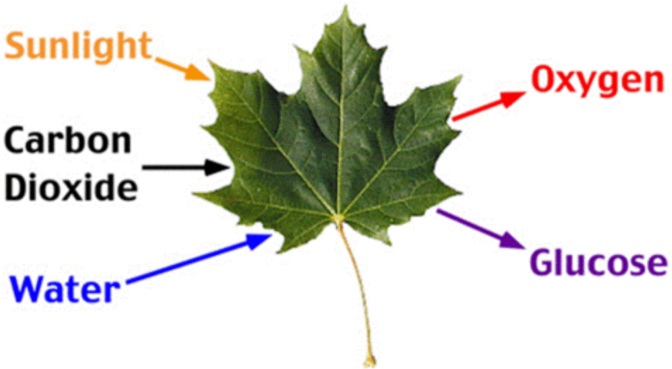


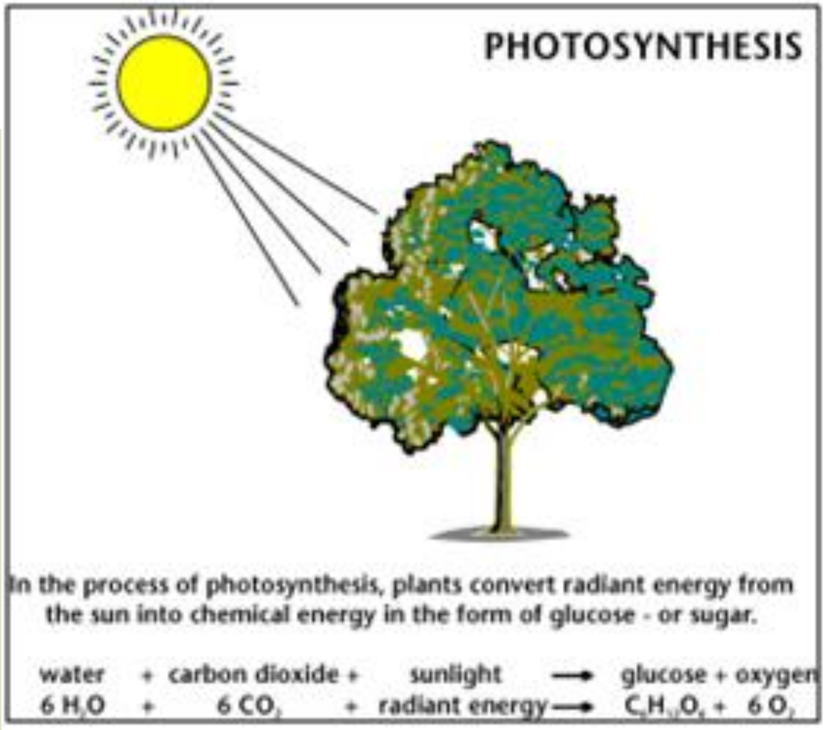
Producers and Consumers Are the Living Components of Ecosystems (3)

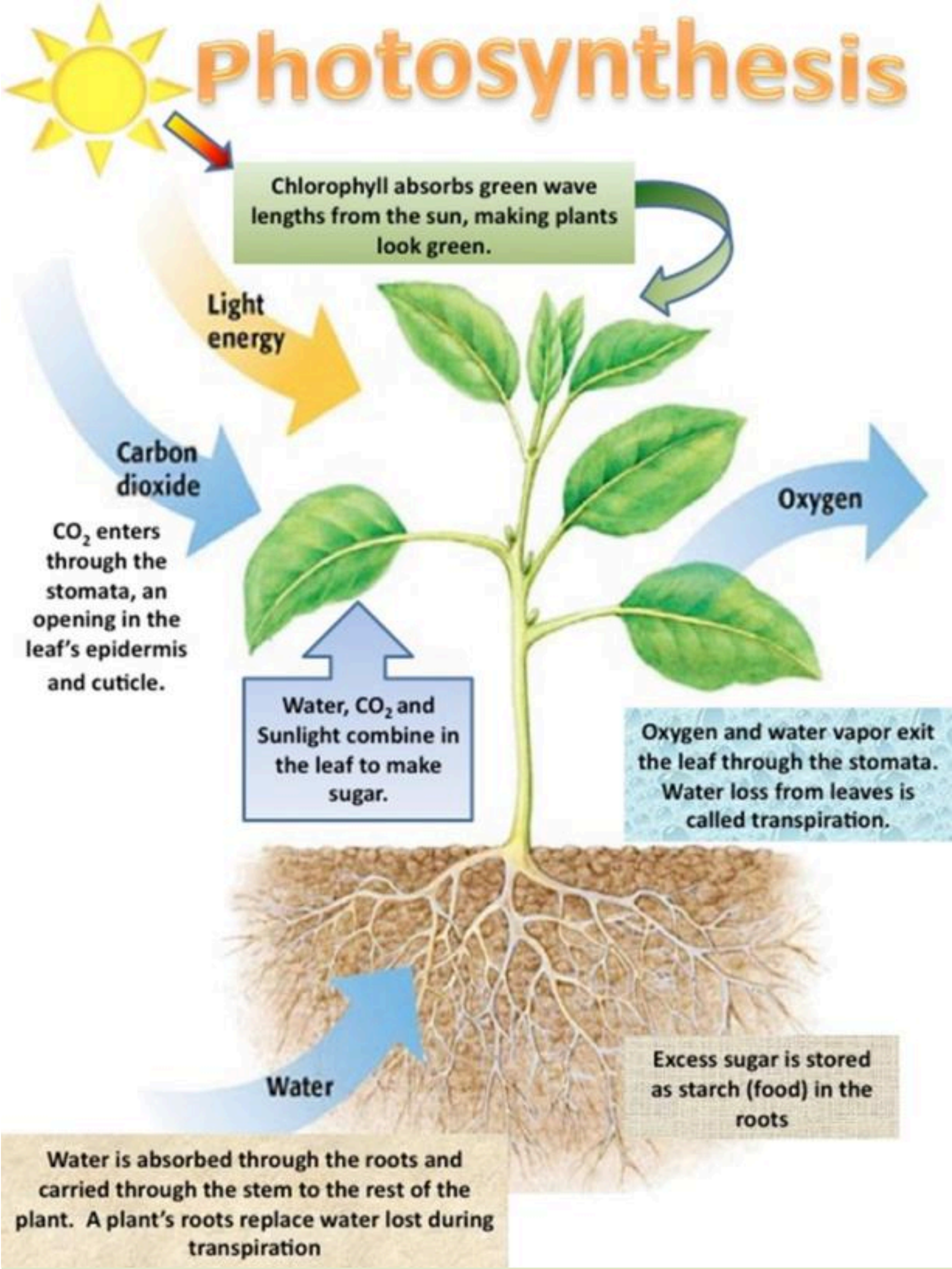
- **Aerobic respiration**
  – Using oxygen to turn glucose back to carbon dioxide and water

- **Anaerobic respiration** = **fermentation**
  – End products are carbon compounds such as methane or acetic acid

INPUTS & OUTPUTS





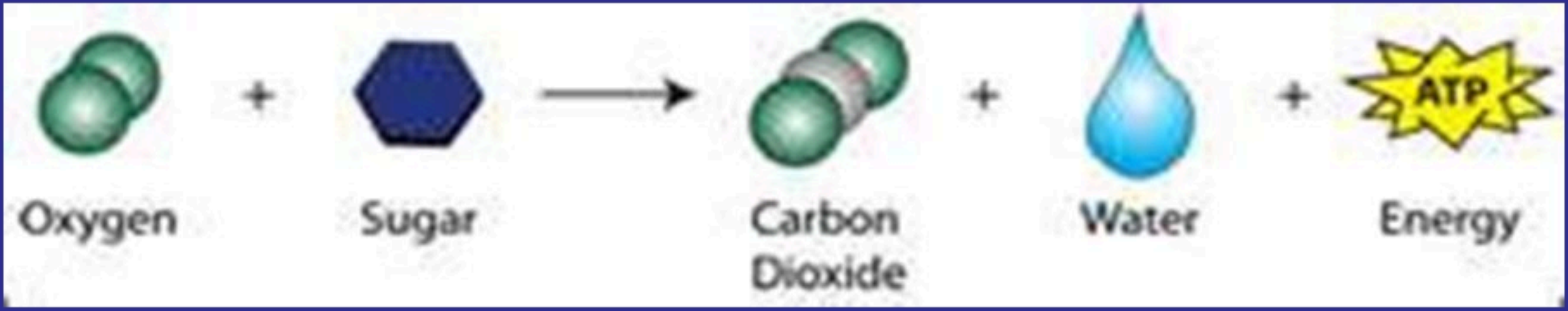


AEROBIC RESPIRATION

- The formula for aerobic cellular respiration is

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (ATP)}$$

- The “word” equation for this is:

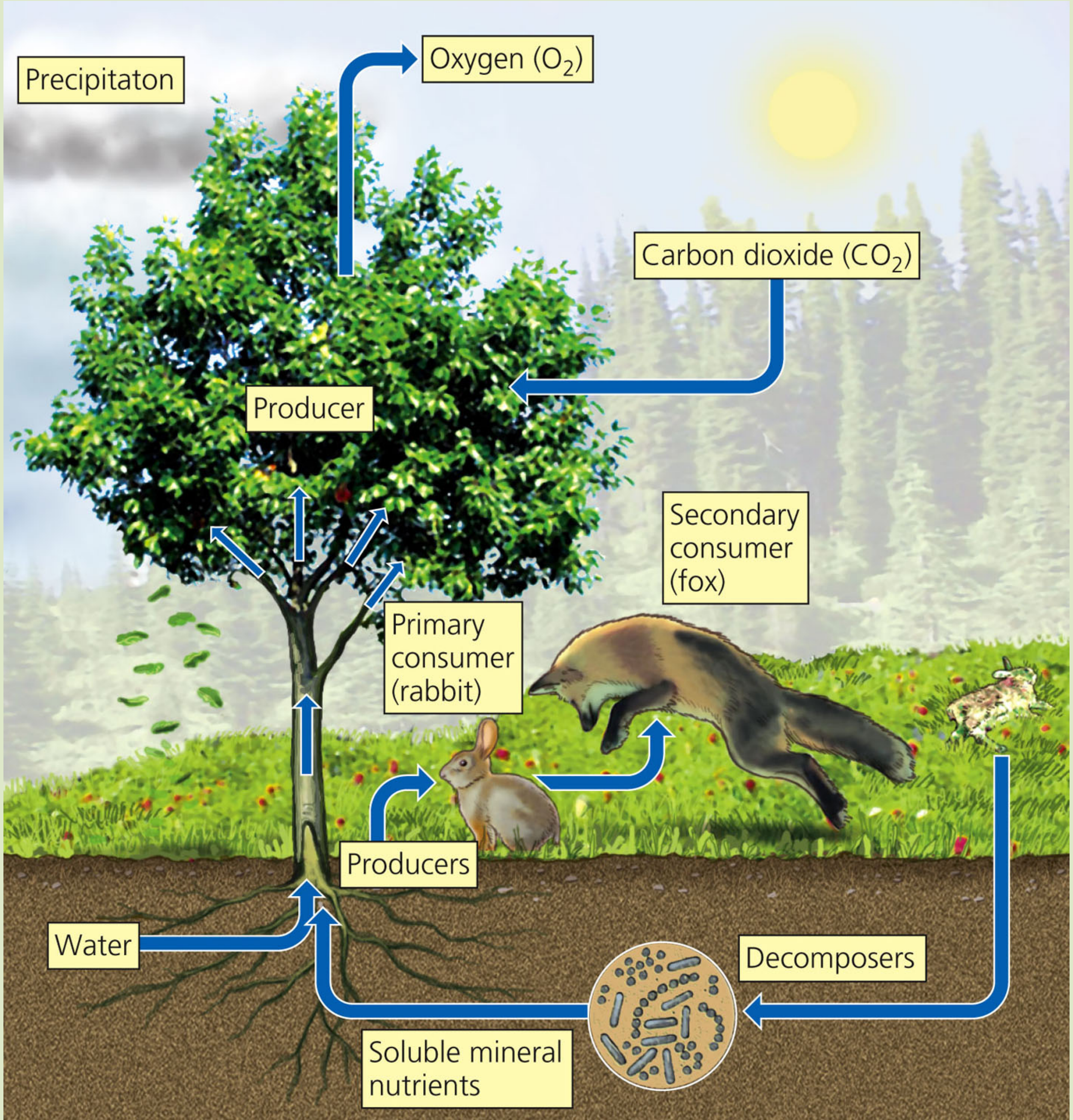


Ecosystems Have Living and Nonliving Components

- Abiotic
  - Water
  - Air
  - Nutrients
  - Rocks
  - Heat
  - Solar energy

- Biotic
  - Living and once living

Major Biotic and Abiotic Components of an Ecosystem



29. Which of the following best illustrates an abiotic component of the environment affecting a biotic component of the environment?

(A) Composted manure is added to agricultural soil during spring tilling.
(B) Coral reefs modify the direction of an ocean current.
(C) Plants release O_2 into the atmosphere during photosynthesis.
(D) Low phosphorus content in soil limits the growth of vegetation.
(E) A thick planting of ground cover reduces soil erosion on a hillside.

34. In a typical forest ecosystem, dead trees and fallen trees are most important because of their role in which of the following?

(A) Providing a valuable source of timber
(B) Providing habitats for wildlife
(C) Contributing to soil erosion
(D) Increasing water runoff
(E) Removing carbon dioxide from the air

Producers and Consumers Are the Living Components of Ecosystems (1)

- **Producers, autotrophs**
  - **Photosynthesis**:
    - CO_2 + H_2O + sunlight → glucose + oxygen
  - **Chemosynthesis**

- **Consumers, heterotrophs**
  - **Primary consumers** = **herbivores**
  - **Secondary consumers**
  - **Tertiary consumers**
  - **Carnivores, Omnivores**

Producers

Fig. 3-7a, p. 59

Consumers

Fig. 3-8a, p. 60

Producers and Consumers Are the Living Components of Ecosystems (2)

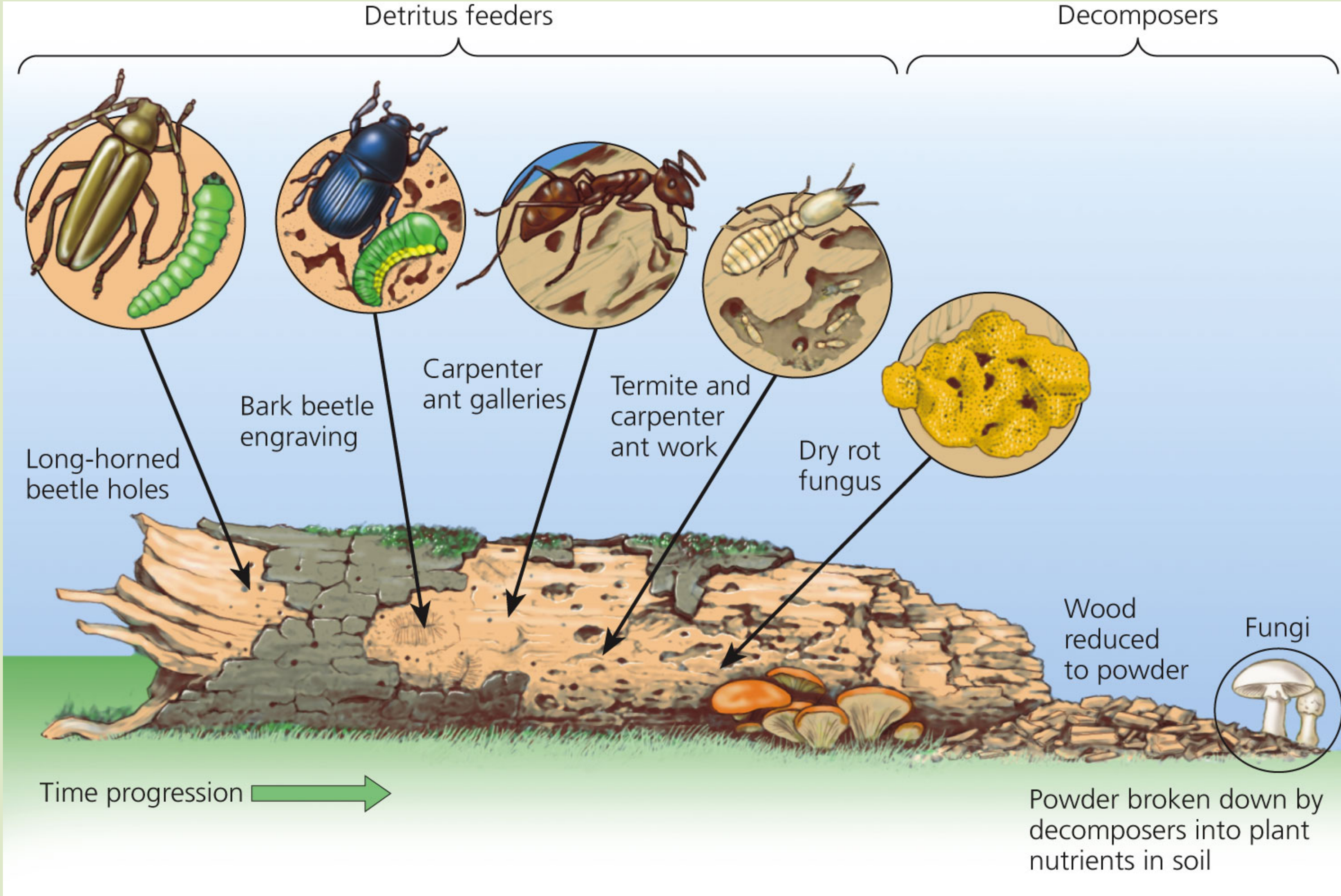
- **Decomposers**
  - Consumers that release nutrients
  - Bacteria
  - Fungi

- **Detritivores**
  - Feed on dead bodies of other organisms
  - Earthworms
  - Vultures

Decomposer

Fig. 3-9a, p. 61

Detritivores and Decomposers



Producers and Consumers Are the Living Components of Ecosystems (3)

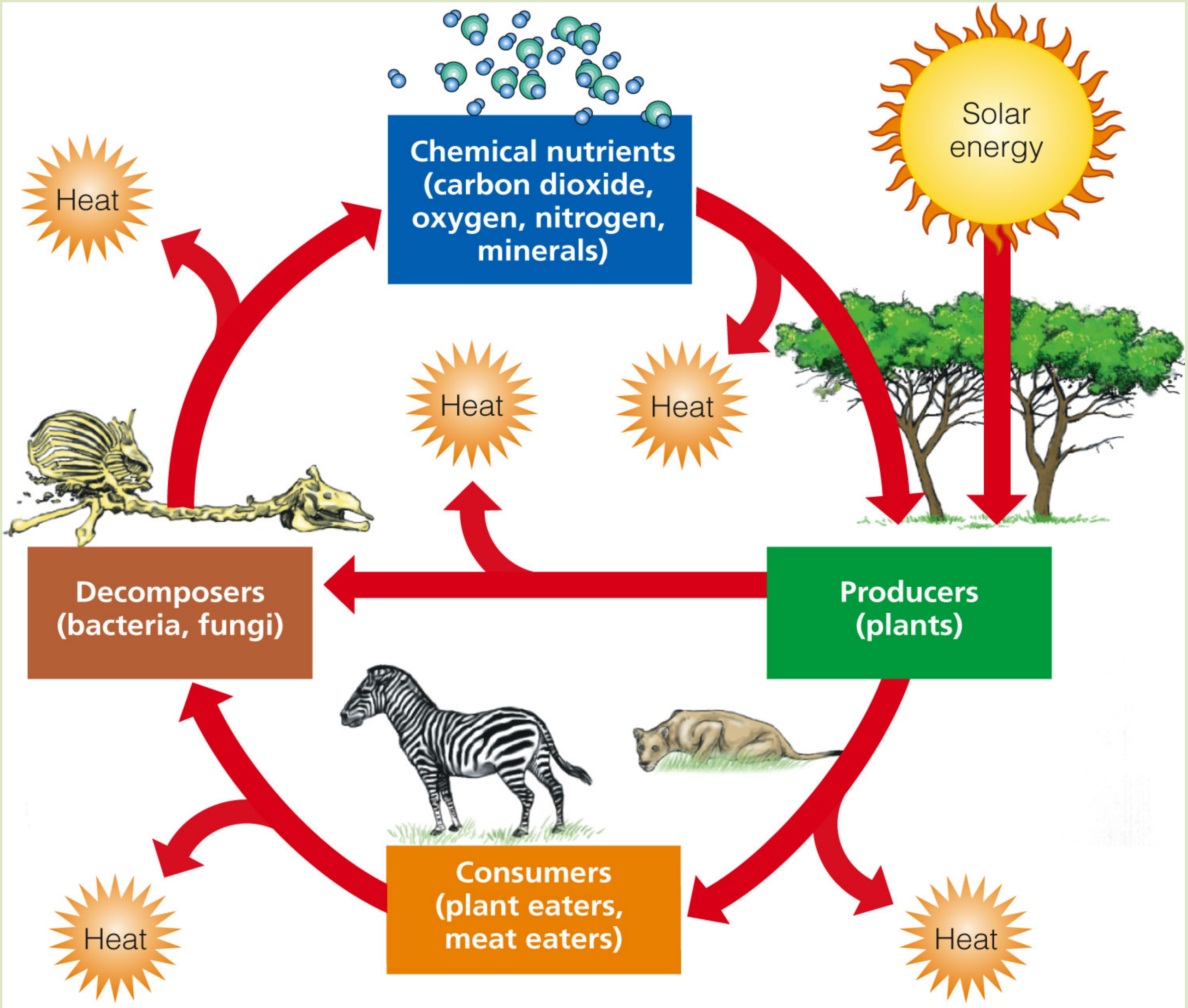
- **Aerobic respiration**
  - Using oxygen to turn glucose back to carbon dioxide and water

- **Anaerobic respiration** = **fermentation**
  - End products are carbon compounds such as methane or acetic acid

Energy Flow and Nutrient Cycling

- One-way energy flow from sun
- Nutrient cycling of key materials

Ecosystem Components



Science Focus: Many of the World's Most Important Species Are Invisible to Us

Microorganisms

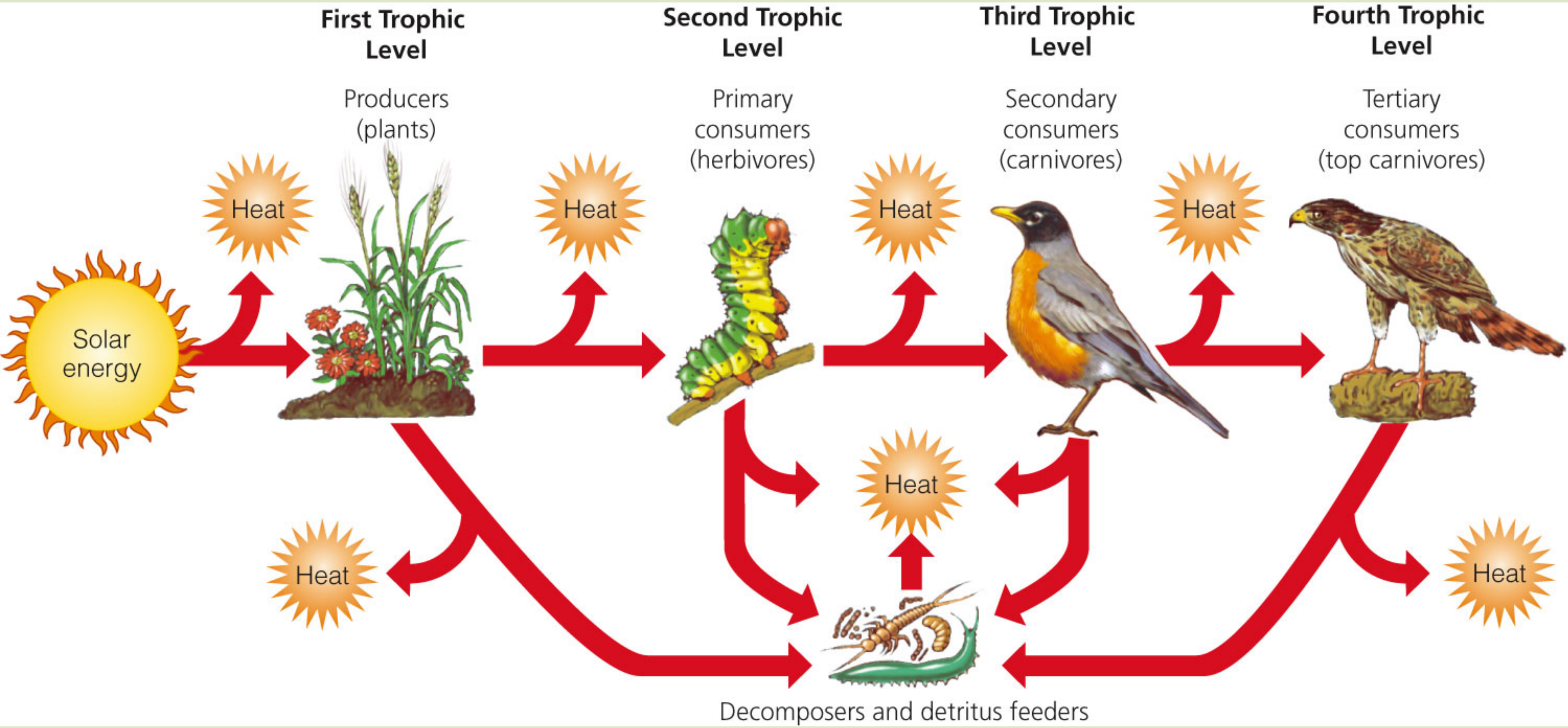
- Bacteria
- Protozoa
- Fungi

Energy Flows Through Ecosystems in Food Chains and Food Webs

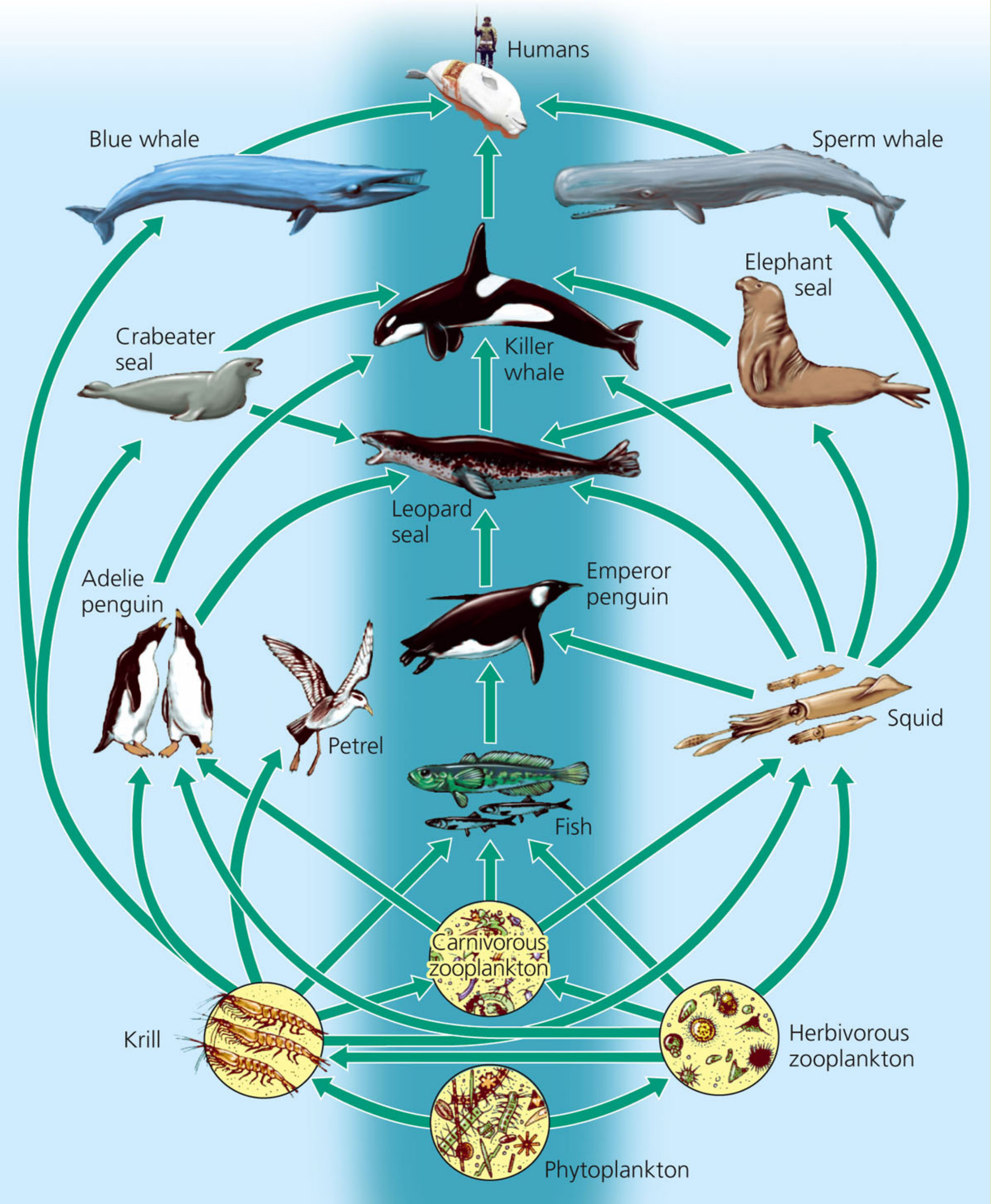
- **Food chain**
  - Movement of energy and nutrients from one **trophic level** to the next
  - Photosynthesis → feeding → decomposition

- **Food web**
  - Network of interconnected food chains

A Food Chain


First Trophic Level
Producers (plants)
Second Trophic Level
Primary consumers (herbivores)
Third Trophic Level
Secondary consumers (carnivores)
Fourth Trophic Level
Tertiary consumers (top carnivores)
Solar energy
Heat
Heat
Heat
Heat
Heat
Heat
Heat
Decomposers and detritus feeders

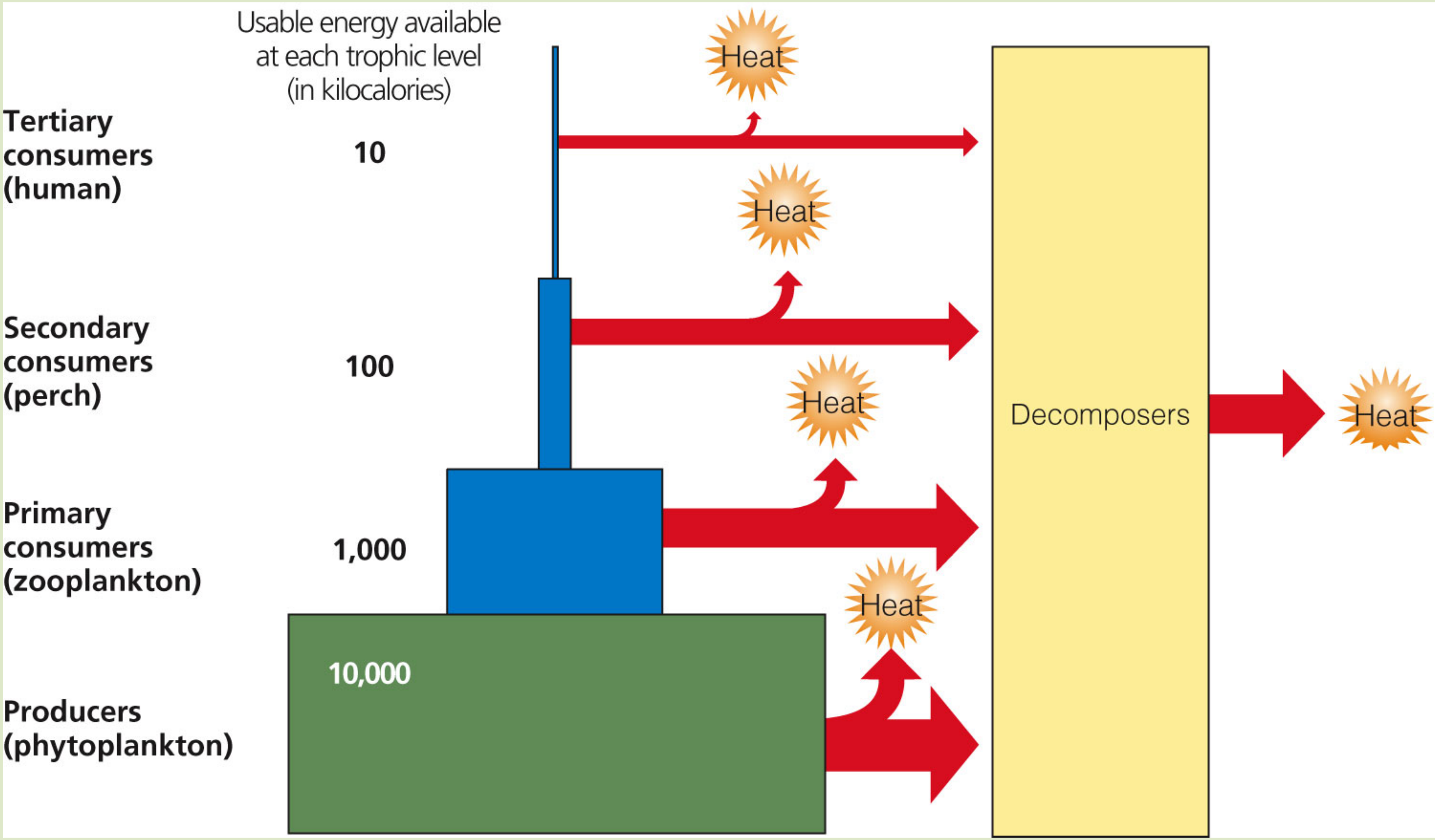
A Food Web


Humans
Blue whale
Sperm whale
Elephant seal
Crabeater seal
Killer whale
Leopard seal
Emperor penguin
Adelie penguin
Petrel
Squid
Fish
Carnivorous zooplankton
Krill
Herbivorous zooplankton
Phytoplankton

Usable Energy Decreases with Each Link in a Food Chain or Web

- **Biomass**
  - Dry weight of all organic matter of a given trophic level in a food chain or food web
  - Decreases at each higher trophic level due to heat loss
- **Pyramid of energy flow**
  - 90% of energy lost with each transfer
  - Less chemical energy for higher trophic levels

Pyramid of Energy Flow



96. Losses of usable energy between successive trophic levels in an ecosystem are best accounted for by which of the following?

(A) The first law of thermodynamics
(B) The second law of thermodynamics
(C) The law of conservation of matter
(D) The process of ecological succession
(E) Limiting factors in the ecosystem

Some Ecosystems Produce Plant Matter Faster Than Others Do

- **Gross primary productivity (GPP)**
  - Rate at which an ecosystem's producers convert solar energy to chemical energy and biomass
  - Kcal/m^2/year
- **Net primary productivity (NPP)**
  - Rate at which an ecosystem's producers convert solar energy to chemical energy, minus the rate at which producers use energy for aerobic respiration
  - Ecosystems and life zones differ in their NPP

46. The net annual primary productivity of a particular wetland ecosystem is found to be 8,000 kcal/m^2 per year. If respiration by the aquatic producers is 12,000 kcal/m^2 per year, what is the gross annual primary productivity for this ecosystem, in kcal/m^2 per year?

(A) 4,000
(B) 8,000
(C) 12,000
(D) 20,000
(E) 96,000

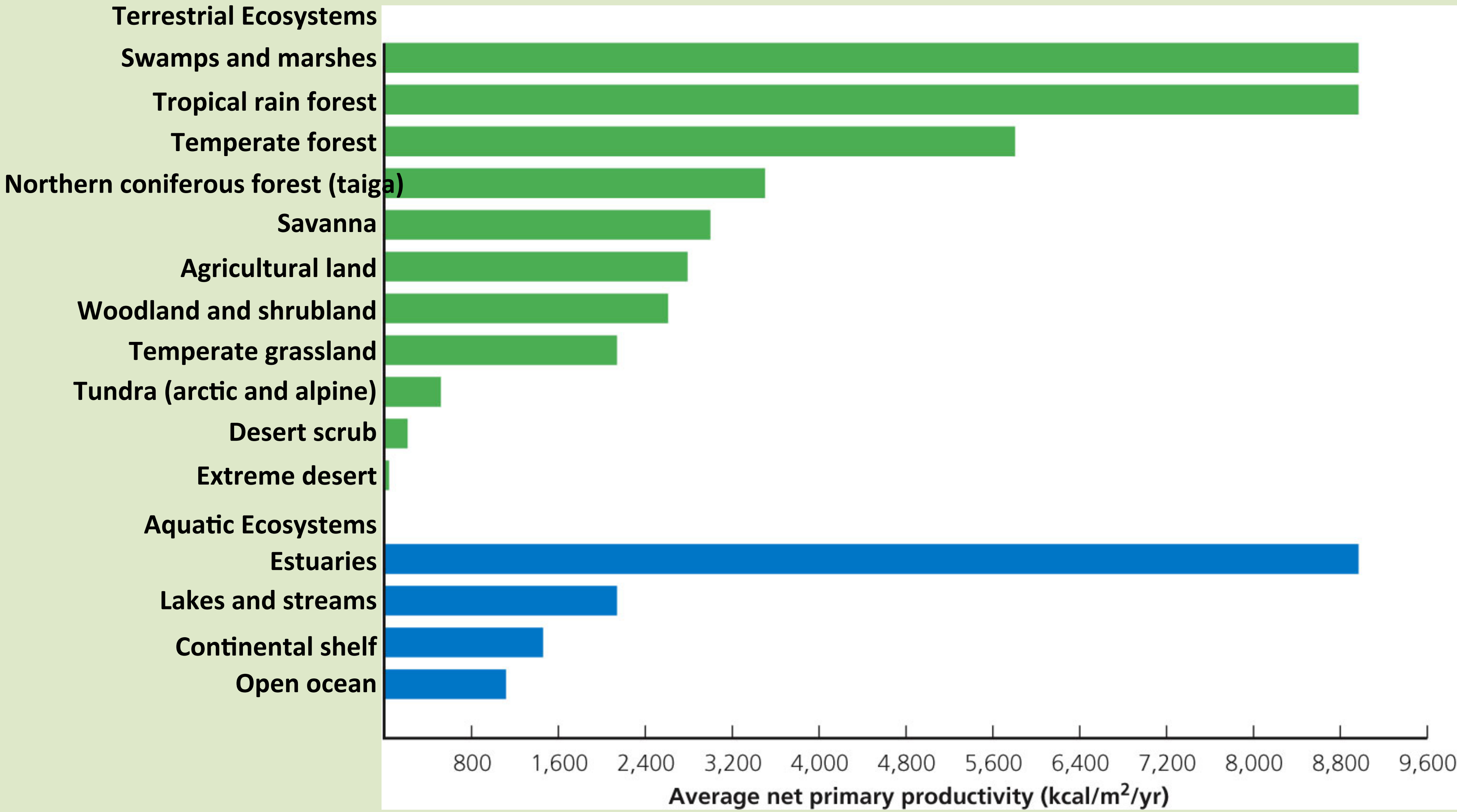

Terrestrial Ecosystems
Swamps and marshes
Tropical rain forest
Temperate forest
Northern coniferous forest (taiga)
Savanna
Agricultural land
Woodland and shrubland
Temperate grassland
Tundra (arctic and alpine)
Desert scrub
Extreme desert
Aquatic Ecosystems
Estuaries
Lakes and streams
Continental shelf
Open ocean
800
1,600
2,400
3,200
4,000
4,800
5,600
6,400
7,200
8,000
8,800
9,600
Average net primary productivity (kcal/m²/yr)

Fig. 3-15, p. 66

The Earth's Major Biomes

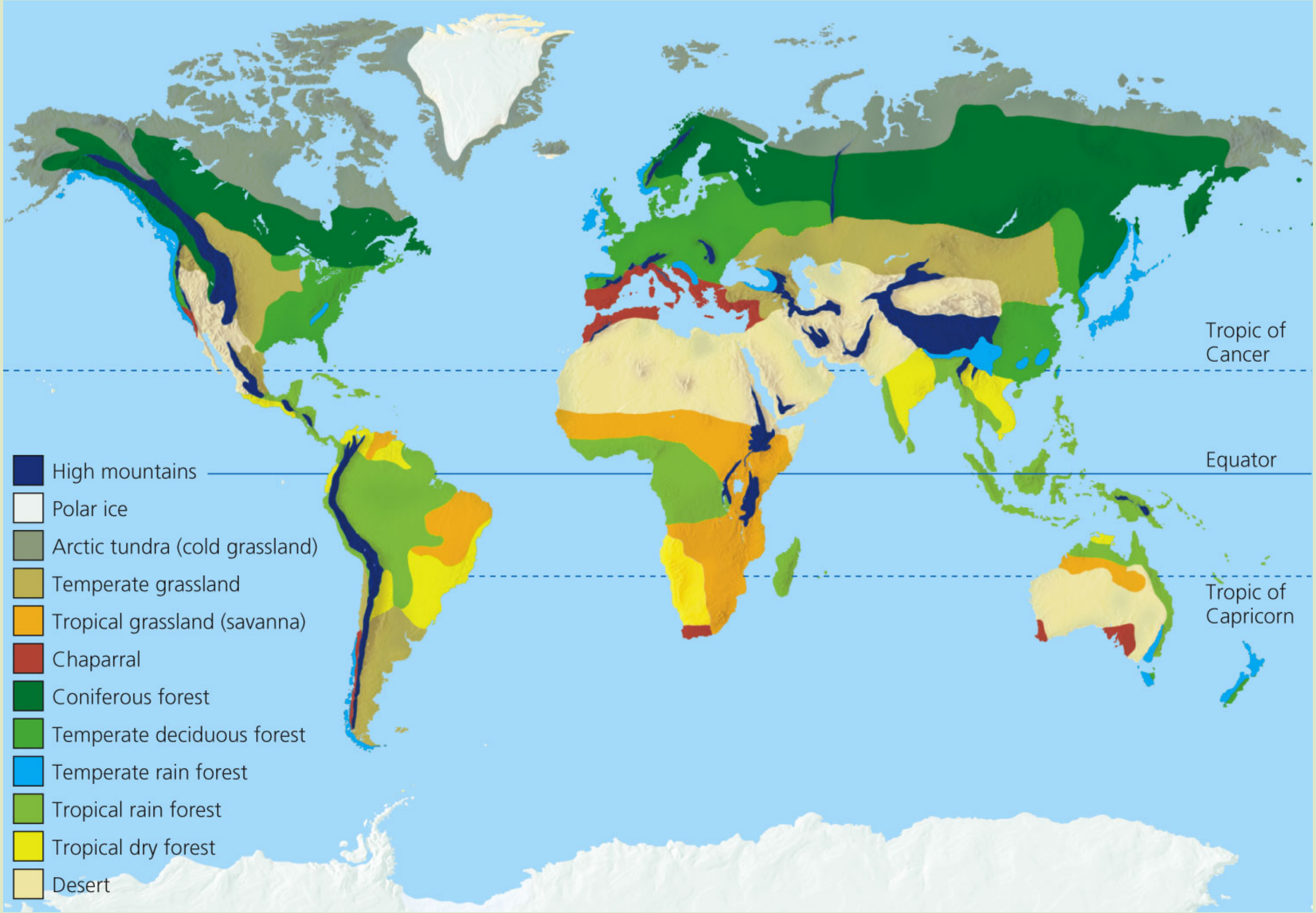


Fig. 7-7, p. 153

22. Which of the following world regions contain the greatest area of rain forest?

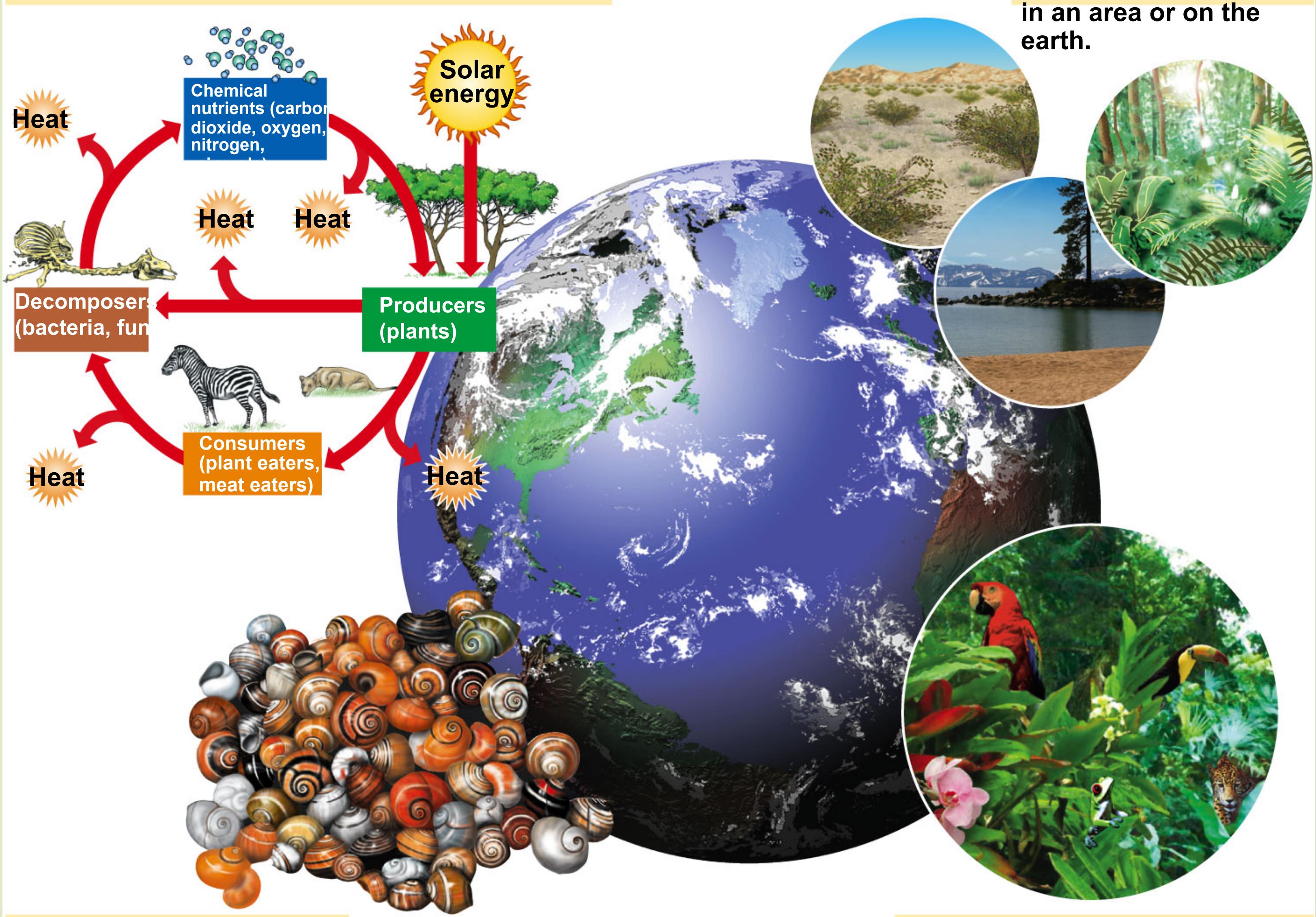
(A) Canada and the United States
(B) Eastern and Western Europe
(C) Russia and China
(D) Australia and New Zealand
(E) Brazil and Indonesia

Natural Capital: Major Components of the Earth's Biodiversity

- Species diversity
- Genetic diversity
- Ecosystem diversity
- Functional diversity
- Biodiversity is an important part of natural capital

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 Diversity The number and abundance of species present in different communities.

Fig. 4-2, p. 82

Species Diversity: Variety, Abundance of Species in a Particular Place (1)

- **Species diversity**

- **Species richness**:
  - The number of different species in a given area

- **Species evenness**:
  - Comparative number of individuals

Species Diversity: Variety, Abundance of Species in a Particular Place (2)

- Diversity varies with geographical location

- The most species-rich communities
  - Tropical rain forests
  - Coral reefs
  - Ocean bottom zone
  - Large tropical lakes

Variations in Species Richness and Species Evenness

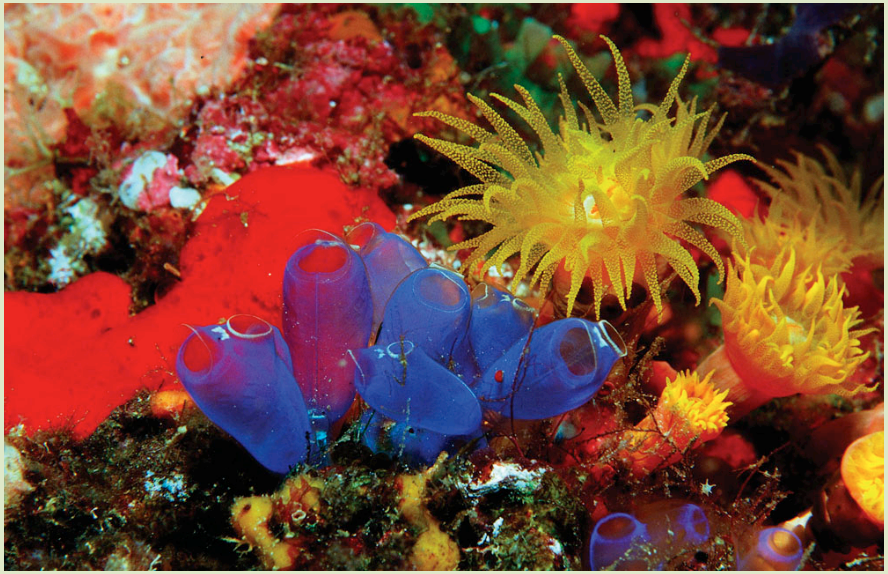


Fig. 4-12, p. 93

55. Which of the following can be used to assess the biological diversity of an area?

(A) Population size of each species and area occupied by each population
(B) Minimum population area and minimum viable population size
(C) Ratio of *r*-strategists to *K*-strategists and life expectancy of *K*-strategists
(D) Number of individuals under fifteen years old and number of individuals over sixty-five years old
(E) Genetic variation within each species and number of species present

85. The consumption of mosquitoes by bats and the control of flooding provided by tropical forests in mountainous areas of Central America are examples of

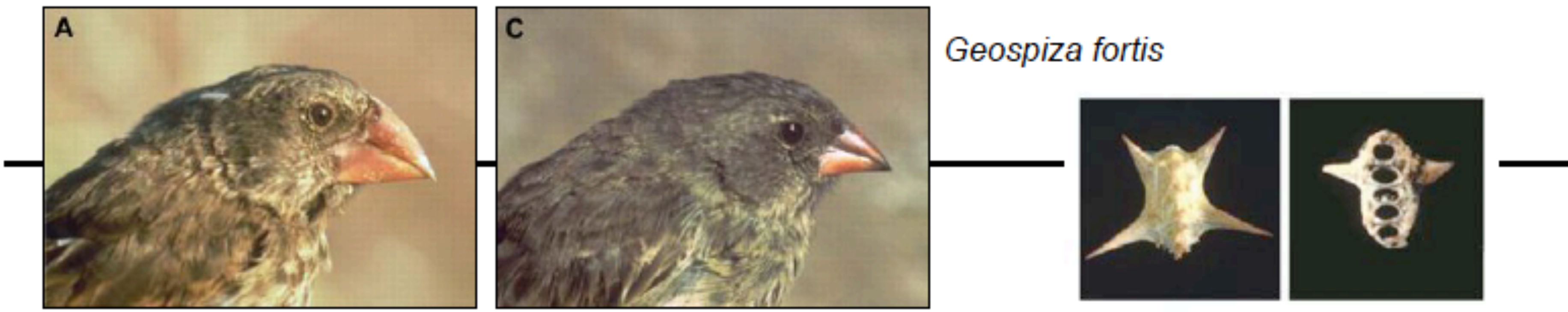
(A) adaptive radiation
(B) ecosystem services
(C) evolution by natural selection
(D) ecological equilibrium
(E) positive feedback loops

44. Five islands, *A*, *B*, *C*, *D*, and *E*, differ only in distance from the mainland, area, and species diversity. Which island would be predicted to have the highest species diversity?

	Island	Distance from Mainland (kilometers)	Area (hectares)
(A)	*A*	50	1×10^2
(B)	*B*	50	1×10^6
(C)	*C*	500	1×10^2
(D)	*D*	1,000	1×10^2
(E)	*E*	1,000	1×10^6

Natural selection...

a difference, on average, in the survival or fecundity of individuals with certain phenotypes compared to individuals with alternative phenotypes



Four tenets of natural selection…

(1) Individuals within populations are variable

(2) Variation is heritable

(3) Organisms differ in their ability to survive and reproduce

(4) Survival & reproduction are non-random

Darwin's Theory of Evolution by Natural Selection

1. More individuals are produced each generation that can survive.
2. Phenotypic variation exists among individuals and the variation is heritable.
3. Those individuals with heritable traits better suited to the environment will survive.
4. When reproductive isolation occurs new species will form.

These are the basic tenets of evolution by natural selection as defined by Darwin.

The following is a quote from Darwin.
"Variation is a feature of natural populations and every population produces more progeny than its environment can manage. The consequences of this overproduction is that those individuals with the best genetic fitness for the environment will produce offspring that can more successfully compete in that environment. Thus the subsequent generation will have a higher representation of these offspring and the population will have evolved."

What about fitness?

Biologists use the word fitness to describe how good a particular genotype is at leaving offspring in the next generation relative to how good other genotypes are at it. So if brown beetles consistently leave more offspring than green beetles because of their color, you'd say that the brown beetles had a higher fitness.

		
Number that survive compared to total	95 %	33 %

The brown beetles have a greater fitness relative to the green beetles.

Biological Evolution by Natural Selection Explains How Life Changes over Time (2)

- **Biological evolution**: how earth's life changes over time through changes in the genetic characteristics of populations
  - Darwin: *Origin of Species*

- **Natural selection**: individuals with certain traits are more likely to survive and reproduce under a certain set of environmental conditions

- Huge body of evidence

Evolution by Natural Selection Works through Mutations and Adaptations (1)

- Populations evolve by becoming genetically different

- Genetic variations
  - First step in biological evolution
  - Occurs through mutations in reproductive cells
  - **Mutations**: random changes in DNA molecules

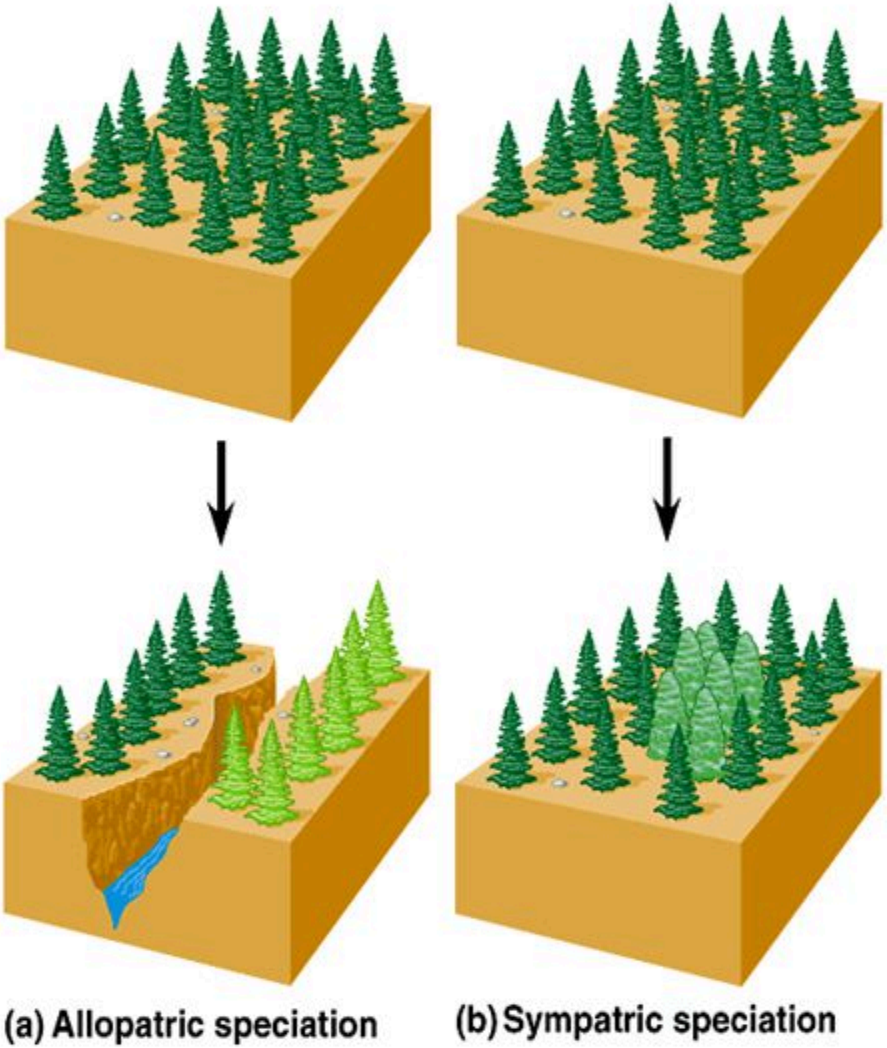
Evolution by Natural Selection Works through Mutations and Adaptations (2)

- **Natural selection**: acts on individuals
  - Second step in biological evolution
  - **Adaptation** may lead to **differential reproduction**
  - Genetic resistance: ability of one or more members of a population to resist a chemical designed to kill it

Allopatric vs. Sympatric Speciation

Allopatric speciation-
Speciation occurs because a given group has been separated from the parent group, usually because of a geographic separation as time goes by.

Sympatric speciation-
speciation occurs even though the two groups are still living in the same area.



MATH + SCIENCE

Genetic drift

Genetic drift — along with natural selection, mutation, and migration — is one of the basic mechanisms of evolution.

In each generation, some individuals may, just by chance, leave behind a few more descendents (and genes, of course!) than other individuals. The genes of the next generation will be the genes of the "lucky" individuals, not necessarily the healthier or "better" individuals. That, in a nutshell, is genetic drift. It happens to ALL populations — there's no avoiding the vagaries of chance.

Earlier we used this hypothetical cartoon. Genetic drift affects the genetic makeup of the population but, unlike natural selection, through an entirely random process. So although genetic drift is a mechanism of evolution, it doesn't work to produce adaptations.

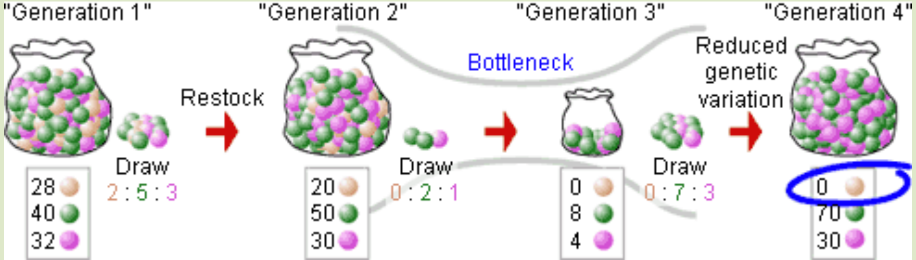
Bottlenecks and founder effects

Genetic drift can cause big losses of genetic variation for small populations.

Population bottlenecks occur when a population's size is reduced for at least one generation. Because genetic drift acts more quickly to reduce genetic variation in small populations, undergoing a bottleneck can reduce a population's genetic variation by a lot, even if the bottleneck doesn't last for very many generations. This is illustrated by the bags of marbles shown below, where, in generation 2, an unusually small draw creates a bottleneck.

Reduced genetic variation means that the population may not be able to adapt to new selection pressures, such as climatic change or a shift in available resources, because the genetic variation that selection would act on may have already drifted out of the population.

Elephant seal- An example of a bottleneck
Northern elephant seals have reduced genetic variation probably because of a population bottleneck humans inflicted on them in the 1890s. Hunting reduced their population size to as few as 20 individuals at the end of the 19th century. Their population has since rebounded to over 30,000 — but their genes still carry the marks of this bottleneck: they have much less genetic variation than a population of southern elephant seals that was not so intensely hunted.



Founder effects
A founder effect occurs when a new colony is started by a few members of the original population. This small population size means that the colony may have:

reduced genetic variation from the original population.
a non-random sample of the genes in the original population.
For example, the Afrikaner population of Dutch settlers in South Africa is descended mainly from a few colonists. Today, the Afrikaner population has an unusually high frequency of the gene that causes Huntington's disease, because those original Dutch colonists just happened to carry that gene with unusually high frequency. This effect is easy to recognize in genetic diseases, but of course, the frequencies of all sorts of genes are affected by founder events.

39. A large forested area is fragmented into small forest tracts separated by agricultural areas. This change will most likely lead to

(A) an increase in the population of top carnivores
(B) an improvement in the dispersal mechanisms of forest species
(C) a more stable regional climate
(D) a decrease in the amount of edge habitat
(E) a decrease in the gene flow within species of the original forest

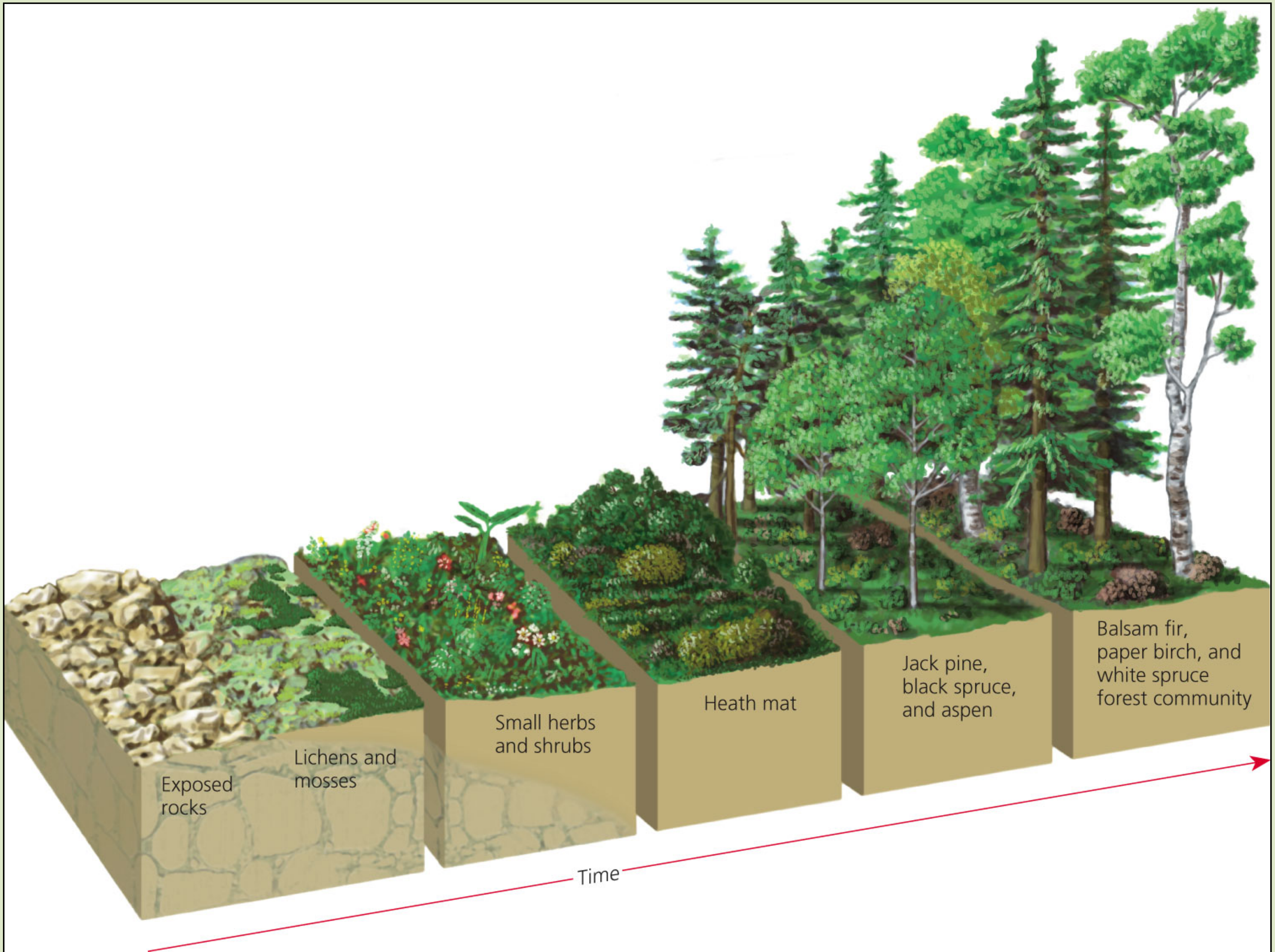
Communities and Ecosystems Change over Time: Ecological Succession

- **Natural ecological restoration**
  - **Primary succession**
  - **Secondary succession**

Some Ecosystems Start from Scratch: Primary Succession

- No soil in a terrestrial system
- No bottom sediment in an aquatic system
- Takes hundreds to thousands of years
- Need to build up soils/sediments to provide necessary nutrients

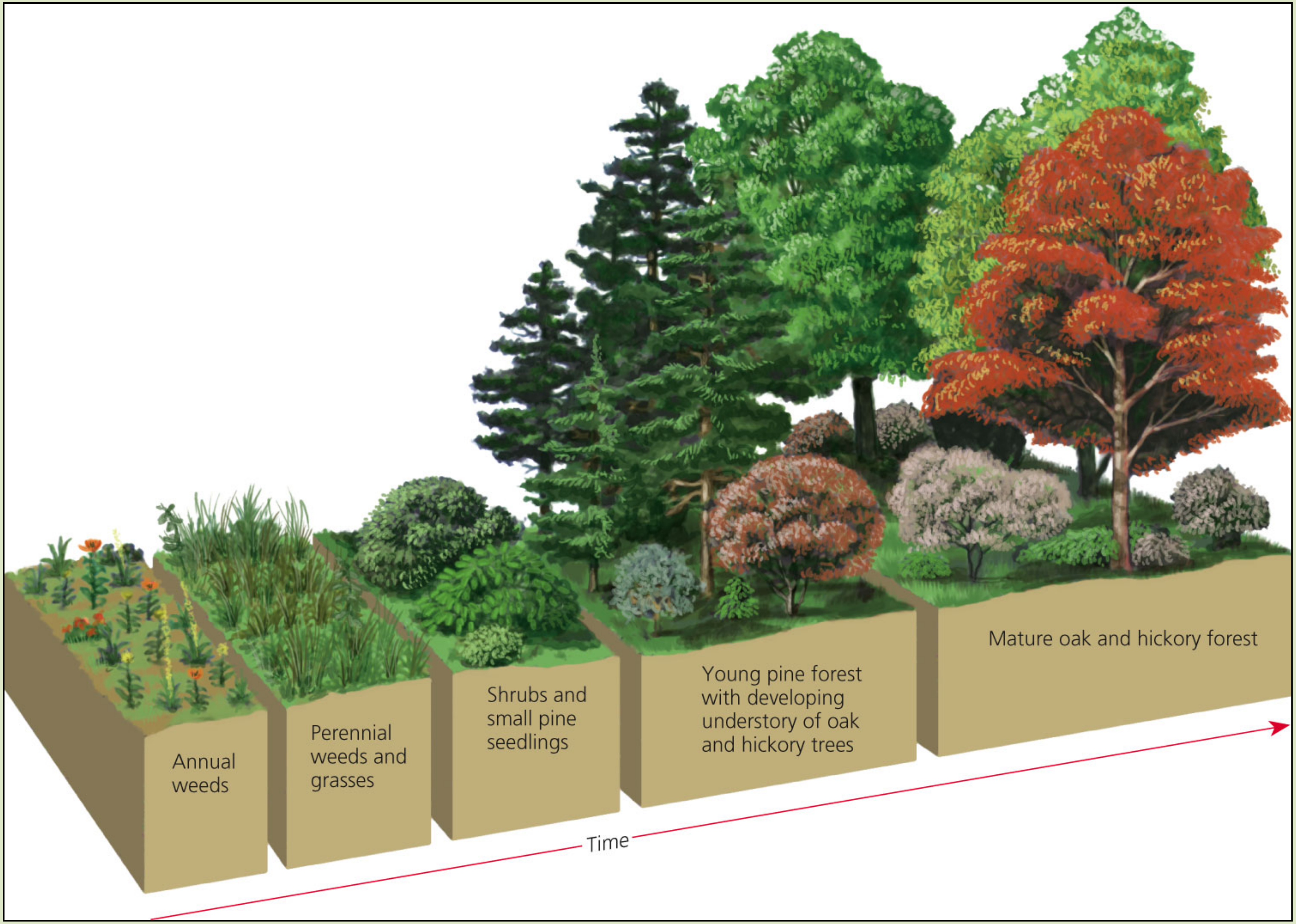
Primary Ecological Succession



Some Ecosystems Do Not Have to Start from Scratch: Secondary Succession (1)

- Some soil remains in a terrestrial system
- Some bottom sediment remains in an aquatic system
- Ecosystem has been
  - Disturbed
  - Removed
  - Destroyed

Secondary Succession- Natural Ecological Restoration of Disturbed Land



Secondary Ecological Succession in Yellowstone Following the 1998 Fire

Some Ecosystems Do Not Have to Start from Scratch: Secondary Succession (2)

- Primary and secondary succession
  - Tend to increase biodiversity
  - Increase species richness and interactions among species
- Primary and secondary succession can be interrupted by
  - Fires
  - Hurricanes
  - Clear-cutting of forests
  - Plowing of grasslands
  - Invasion by nonnative species

Science Focus: How Do Species Replace One Another in Ecological Succession?

- Facilitation
- Inhibition
- Tolerance

Living Systems Are Sustained through Constant Change

- **Inertia, persistence**
  - Ability of a living system to survive moderate disturbances
- **Resilience**
  - Ability of a living system to be restored through secondary succession after a moderate disturbance
- Some systems have one property, but not the other: tropical rainforests

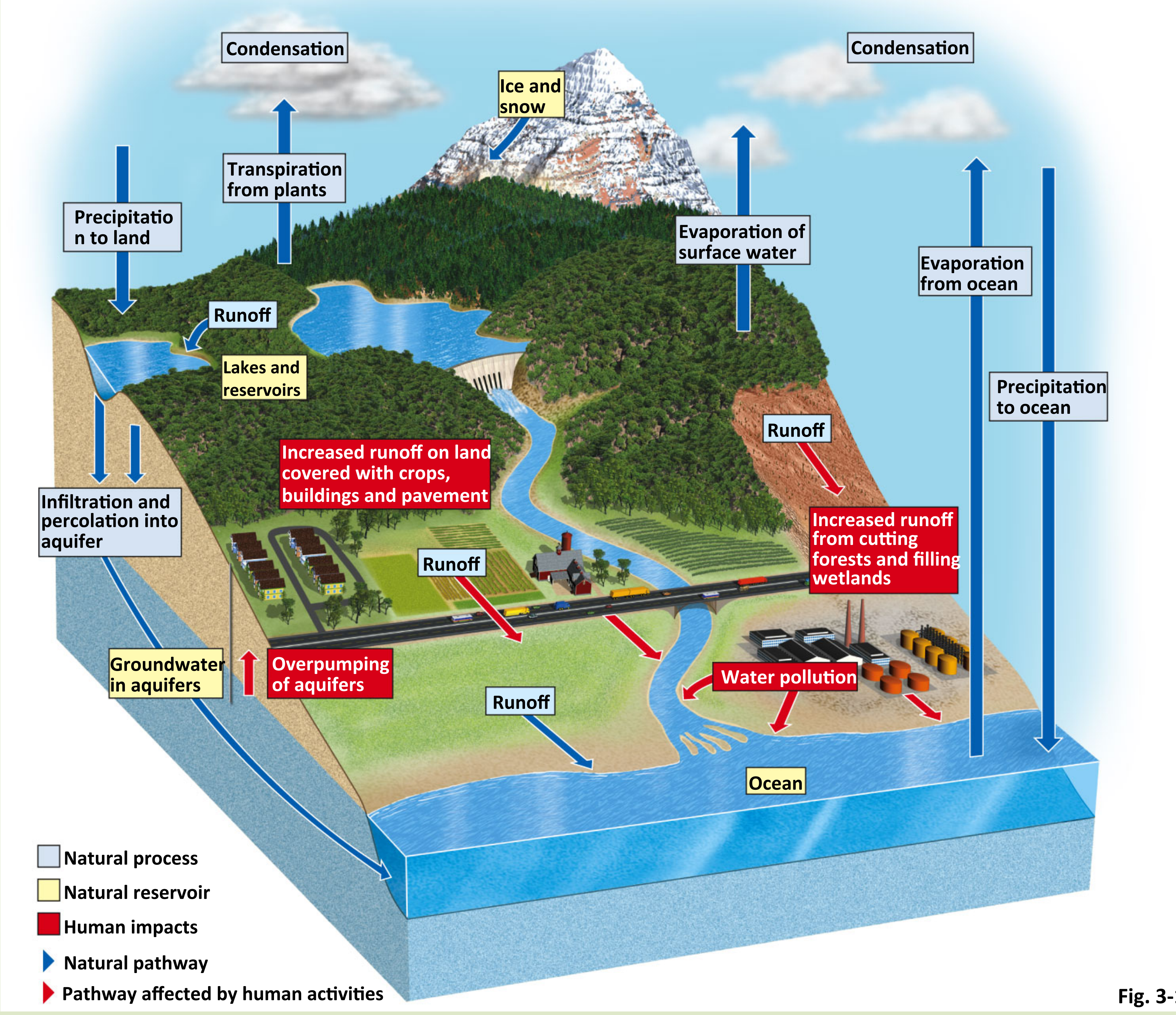

Condensation
Condensation
Ice and snow
Transpiration from plants
Precipitation to land
Evaporation of surface water
Evaporation from ocean
Runoff
Lakes and reservoirs
Precipitation to ocean
Runoff
Increased runoff on land covered with crops, buildings and pavement
Infiltration and percolation into aquifer
Increased runoff from cutting forests and filling wetlands
Runoff
Groundwater in aquifers
Overpumping of aquifers
Water pollution
Runoff
Ocean
Natural process
Natural reservoir
Human impacts
Natural pathway
Pathway affected by human activities

Fig. 3-16, p. 67

59. The process in the hydrologic cycle in which water vapor is released from leaves into the atmosphere is called

(A) infiltration
(B) transpiration
(C) sublimation
(D) reflection
(E) percolation

14. The greatest amount of fresh water is found in which of the following?

(A) The atmosphere
(B) Estuaries
(C) Lakes
(D) Rivers and streams
(E) Polar ice caps and glaciers

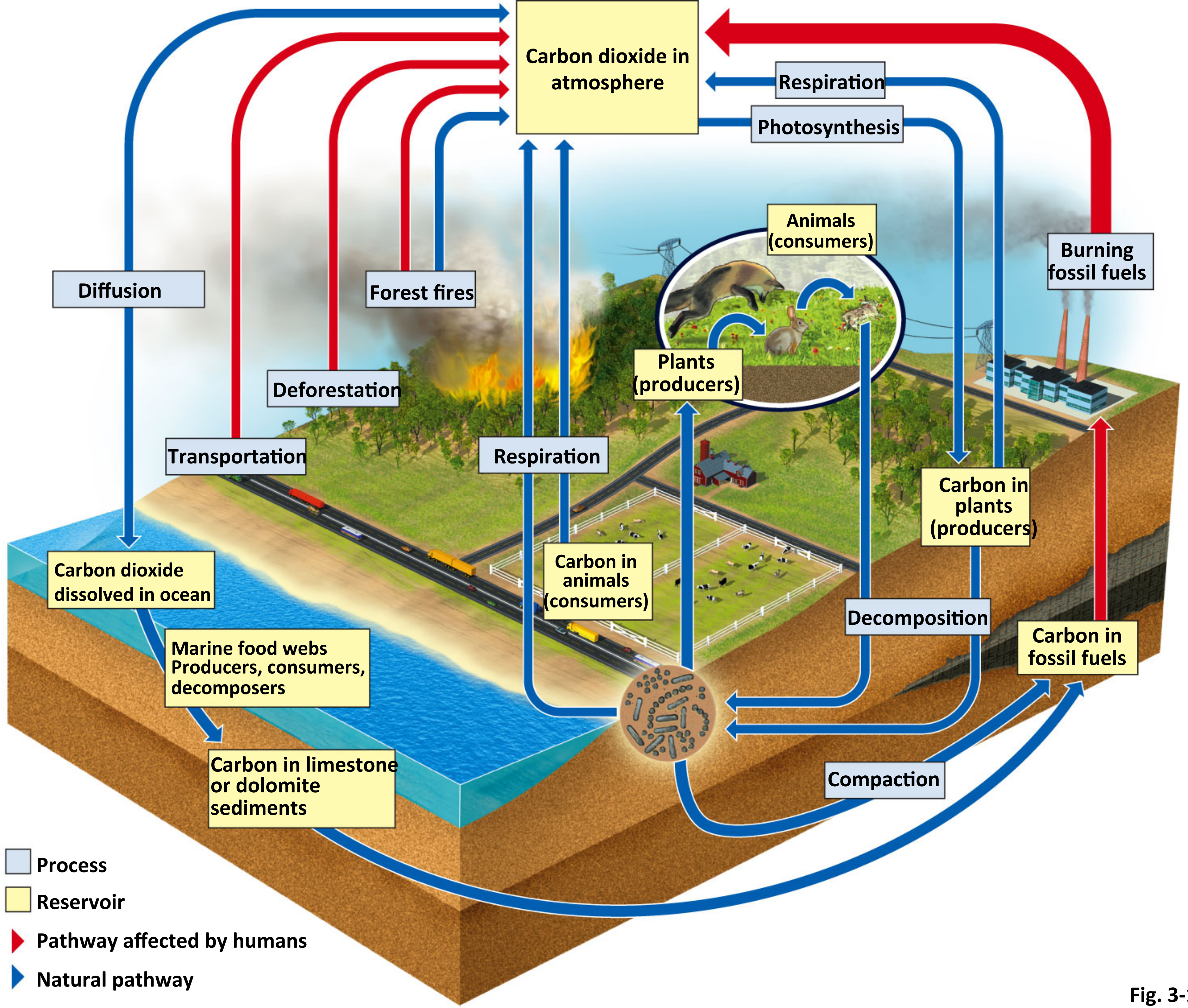

Carbon dioxide in atmosphere
Respiration
Photosynthesis
Diffusion
Forest fires
Deforestation
Transportation
Respiration
Animals (consumers)
Plants (producers)
Burning fossil fuels
Carbon in plants (producers)
Carbon in animals (consumers)
Carbon dioxide dissolved in ocean
Marine food webs Producers, consumers, decomposers
Decomposition
Carbon in fossil fuels
Compaction
Carbon in limestone or dolomite sediments
Process
Reservoir
Pathway affected by humans
Natural pathway

Fig. 3-19, p. 70

15. Which of the following is true of carbon as it cycles in nature?

(A) Carbon dioxide is released during photosynthesis.
(B) Carbon compounds rarely exist in the gaseous state.
(C) Carbon sinks include forests and oceans.
(D) The carbon dioxide concentration in the atmosphere is reduced by cutting trees.
(E) Carbon is concentrated in igneous rocks.

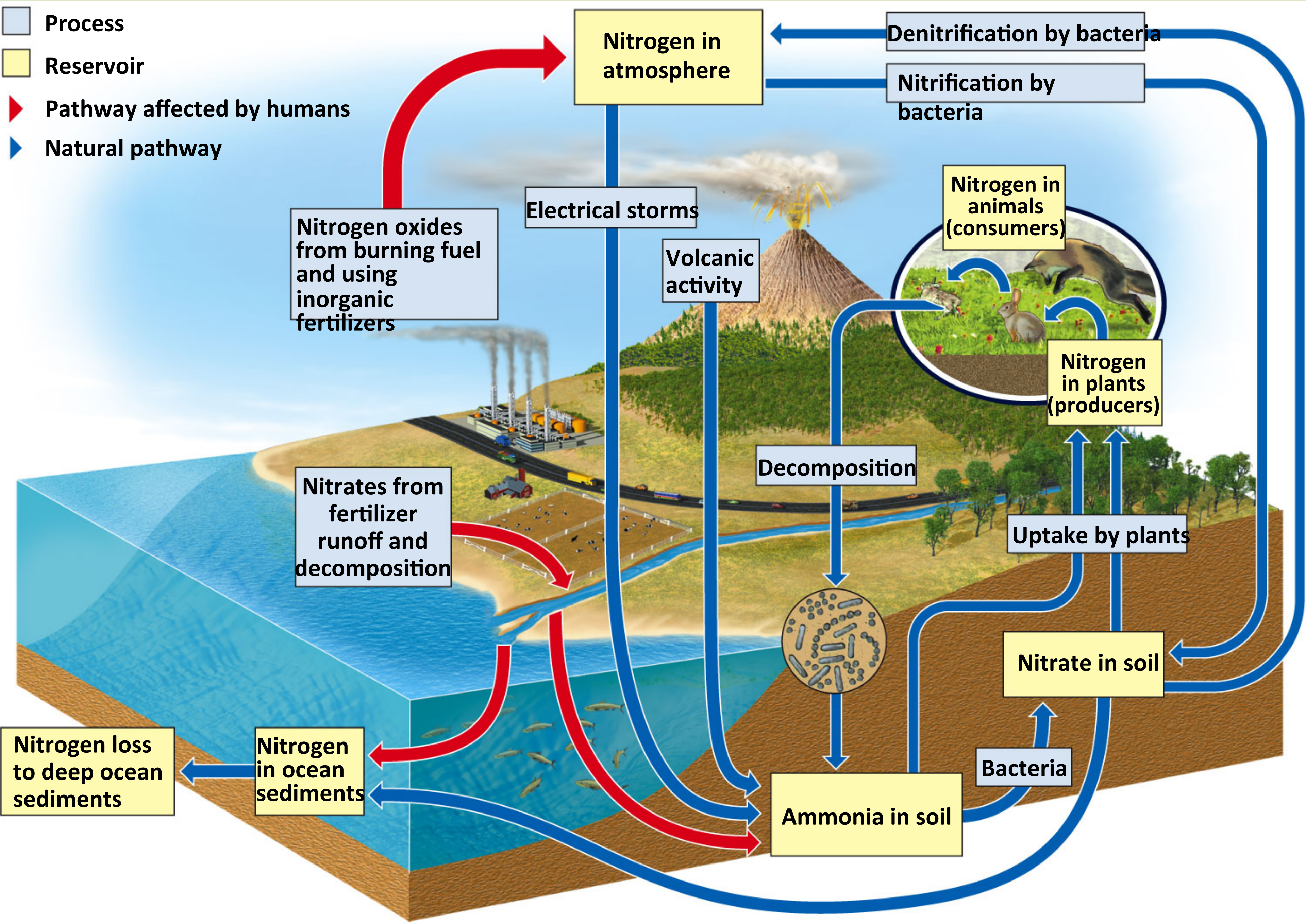

Process
Reservoir
Pathway affected by humans
Natural pathway
Nitrogen in atmosphere
Denitrification by bacteria
Nitrification by bacteria
Nitrogen oxides from burning fuel and using inorganic fertilizers
Electrical storms
Volcanic activity
Nitrogen in animals (consumers)
Nitrogen in plants (producers)
Decomposition
Nitrates from fertilizer runoff and decomposition
Uptake by plants
Nitrate in soil
Bacteria
Ammonia in soil
Nitrogen loss to deep ocean sediments
Nitrogen in ocean sediments

Fig. 3-20, p. 71

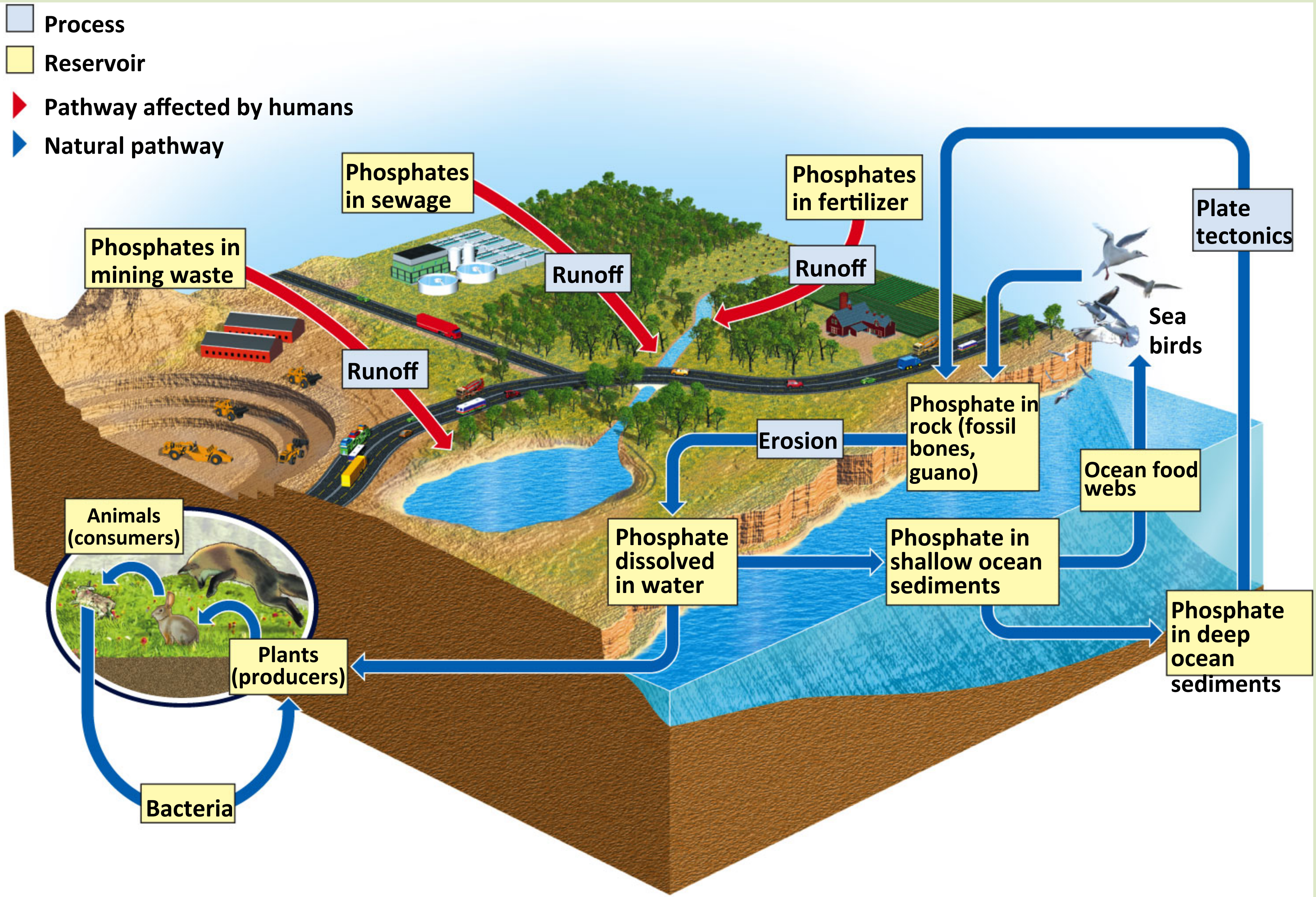

Process
Reservoir
Pathway affected by humans
Natural pathway
Phosphates in sewage
Phosphates in fertilizer
Plate tectonics
Phosphates in mining waste
Runoff
Runoff
Runoff
Sea birds
Phosphate in rock (fossil bones, guano)
Erosion
Ocean food webs
Animals (consumers)
Phosphate dissolved in water
Phosphate in shallow ocean sediments
Phosphate in deep ocean sediments
Plants (producers)
Bacteria

Fig. 3-21, p. 73

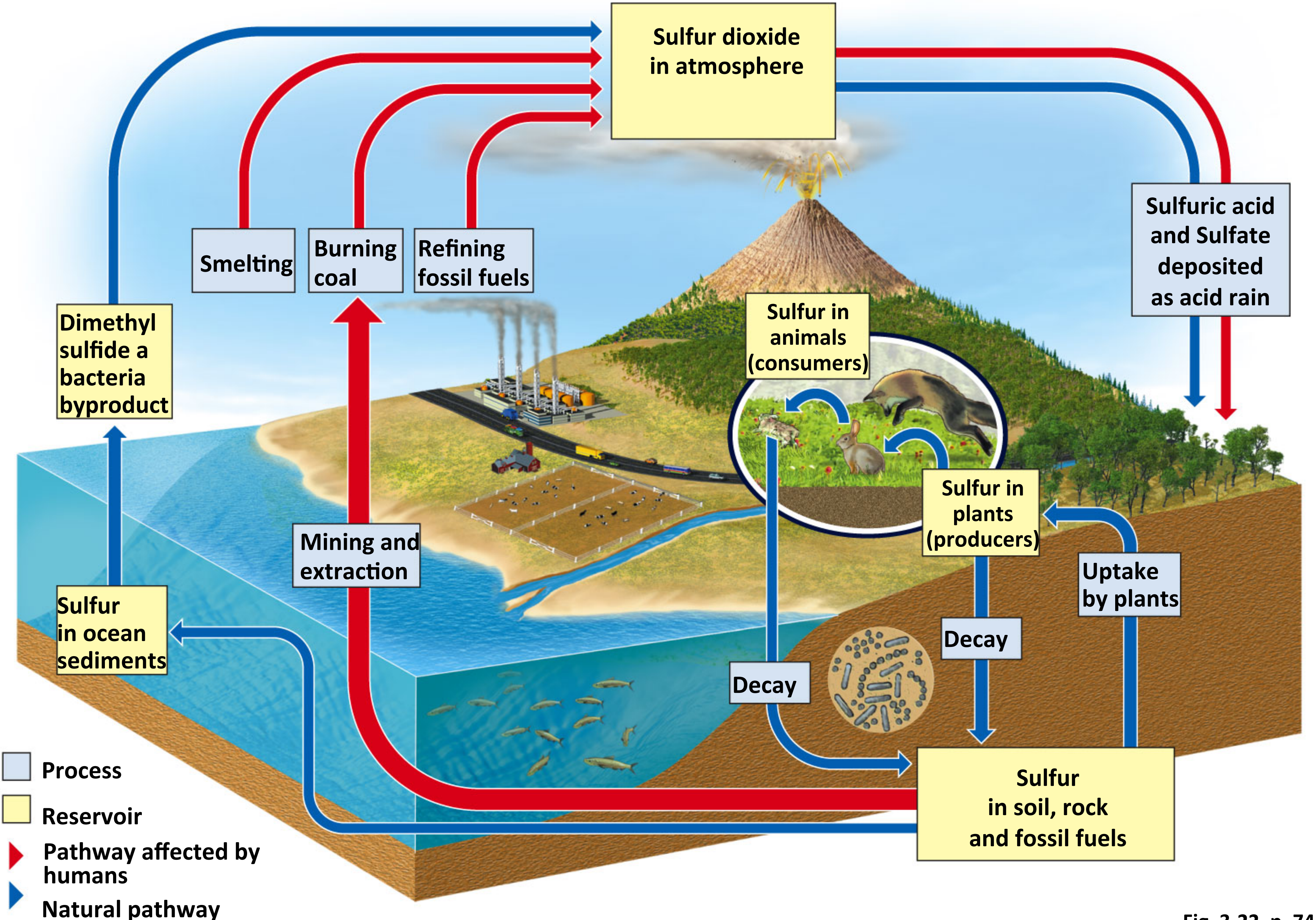

Sulfur dioxide in atmosphere
Sulfuric acid and Sulfate deposited as acid rain
Smelting
Burning coal
Refining fossil fuels
Dimethyl sulfide a bacteria byproduct
Sulfur in animals (consumers)
Sulfur in plants (producers)
Mining and extraction
Uptake by plants
Decay
Decay
Sulfur in ocean sediments
Sulfur in soil, rock and fossil fuels
Process
Reservoir
Pathway affected by humans
Natural pathway

Fig. 3-22, p. 74