Biology: Life on Earth

Eighth Edition

Lecture for Chapter 28

How Do Ecosystems Work?

Chapter 28 Opener Biology: Life on Earth, 8/e

Chapter 28 Outline

Section 28.1 Outline

- **28.1 What Are the Pathways of Energy and Nutrients?**

Energy and Nutrient Pathways

- Energy moves in a one-way flow through communities within ecosystems
  - The energy to drive life's activities comes from the sun
  - It is used and transformed in the chemical reactions that power life
  - It is ultimately converted to heat that radiates back into space

Energy and Nutrient Pathways

- Nutrients constantly cycle and recycle within and among ecosystems
  - The molecules of life are built from nutrients obtained from the environment
  - Nutrients change in form and distribution, even moving between ecosystems, but remain on Earth

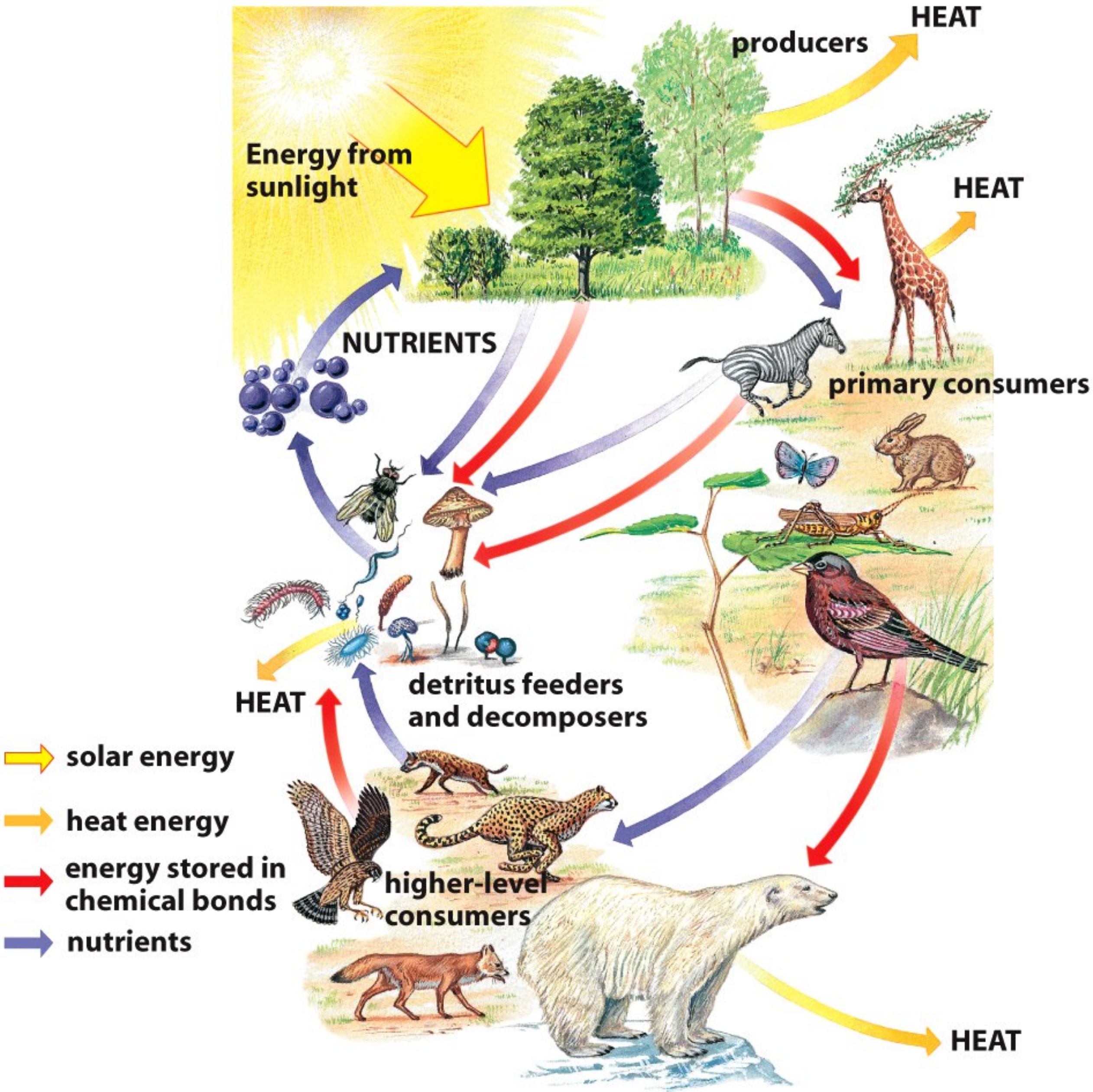

Figure 28-1 Biology: Life on Earth, 8/e

Section 28.2 Outline

- **28.2 How Does Energy Flow Through Communities?**
  - Energy Enters Communities Through Photosynthesis
  - Energy Is Passed from One Trophic Level to Another
  - Energy Transfer Through Trophic Levels Is Inefficient

Energy Entry Via Photosynthesis

- Electromagnetic waves carry energy from the sun to the Earth
  - Most solar energy reaching Earth is reflected or absorbed
  - Only about 1% of total energy is available for photosynthesis
  - Photosynthetic organisms capture only about 3% of this amount

Energy Entry Via Photosynthesis

- Specific wavelengths of sunlight are captured by photosynthetic pigments
  - Solar energy is used in reactions that store energy in chemical bonds of sugar and other high-energy molecules

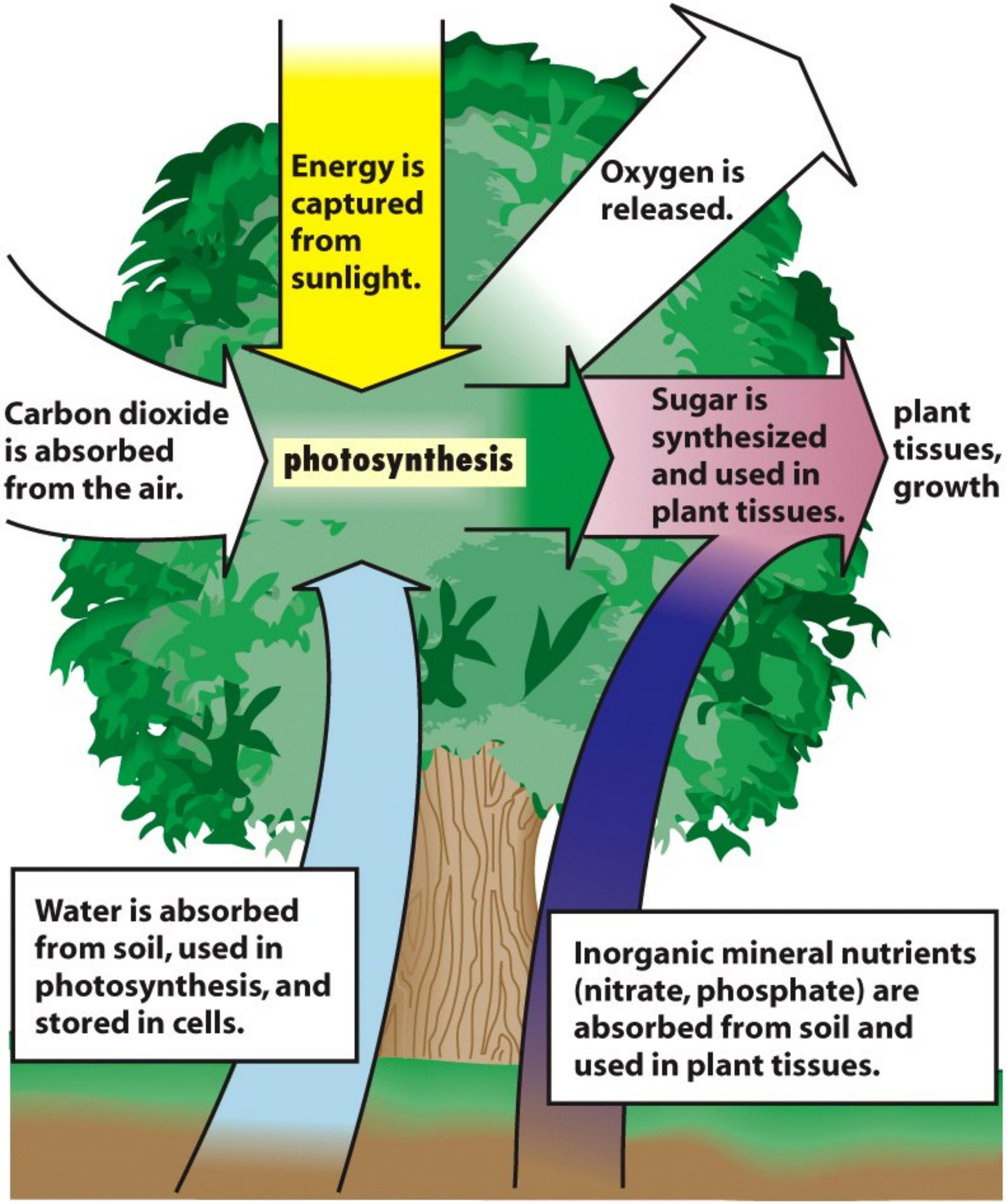

Figure 28-2 Biology: Life on Earth, 8/e

Energy Entry via Photosynthesis

- **Autotrophs** (or **producers**) make their own food using nonliving nutrients and energy from the environment

Energy Entry via Photosynthesis

- Most autotrophs are photosynthetic organisms that obtain their energy from sunlight
- Some bacteria can obtain their energy from nonliving chemicals like hydrogen sulfide (i.e., chemosynthetic organisms)

Energy Entry via Photosynthesis

- **Heterotrophs** (or **consumers**) cannot synthesize their own food, and thus obtain it from producers
  - They acquire energy and nutrients in the molecules that make up other organisms

Energy Entry via Photosynthesis

- **Net primary productivity** is energy that photosynthetic organisms store and make available to the community over time

Energy Entry via Photosynthesis

- Net primary productivity
  - Determines how much life an ecosystem can support
  - Can be measured as the amount of energy (**calories**) or **biomass** (dry weight of organic material) stored or added to the ecosystem per unit area over time

Energy Entry via Photosynthesis

- Productivity of an ecosystem is influenced by
  - The availability of nutrients and sunlight to producers
  - The availability of water
  - Temperature

Energy Entry via Photosynthesis

- The productivity of different ecosystems are compared in **Figure 28-3**, p. 561

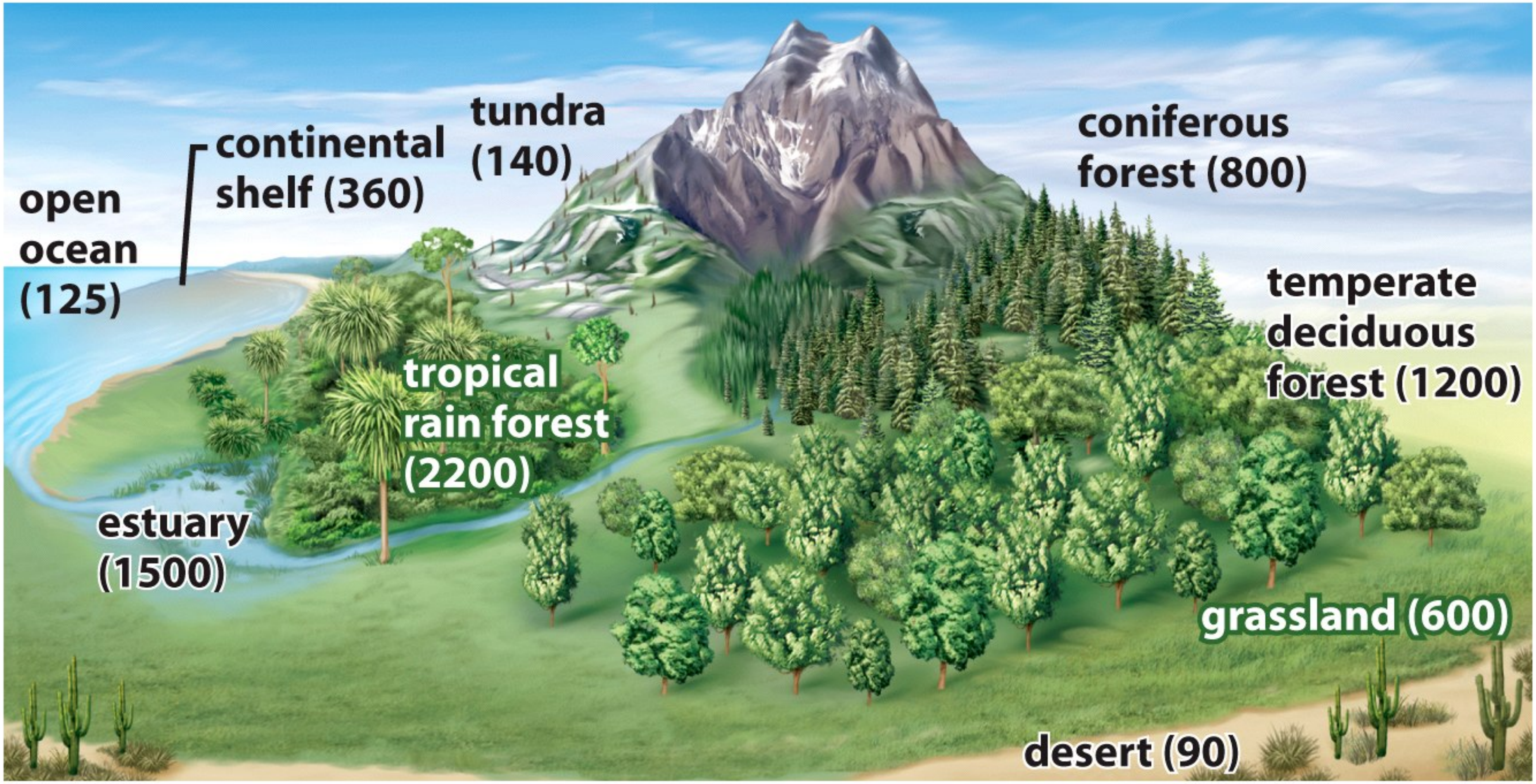

Figure 28-3 Biology: Life on Earth, 8/e

Energy Flow Among Trophic Levels

- Energy flows through a series of **trophic levels** ("feeding levels") in a community
  - The **producers** form the first trophic level, obtaining their energy directly from sunlight

Energy Flow Among Trophic Levels

- Consumers occupy several trophic levels
  - Those that feed directly on producers are called **herbivores** or **primary consumers**

Energy Flow Among Trophic Levels

- Consumers occupy several trophic levels
  - Those that feed on primary consumers are called **carnivores** or **secondary consumers**

Energy Flow Among Trophic Levels

- Consumers occupy several trophic levels
  - Some carnivores eat other carnivores, acting as **tertiary consumers**

Energy Flow Among Trophic Levels

- Some animals are **omnivores**, acting as primary, secondary, and occasionally tertiary consumers at different times
  – Example: humans

Food Chains

- A **food chain** is a linear feeding relationship with just one representative at each trophic level
  - Different ecosystems have radically different food chains
  - Natural communities rarely contain well-defined groups of primary, secondary, and tertiary consumers

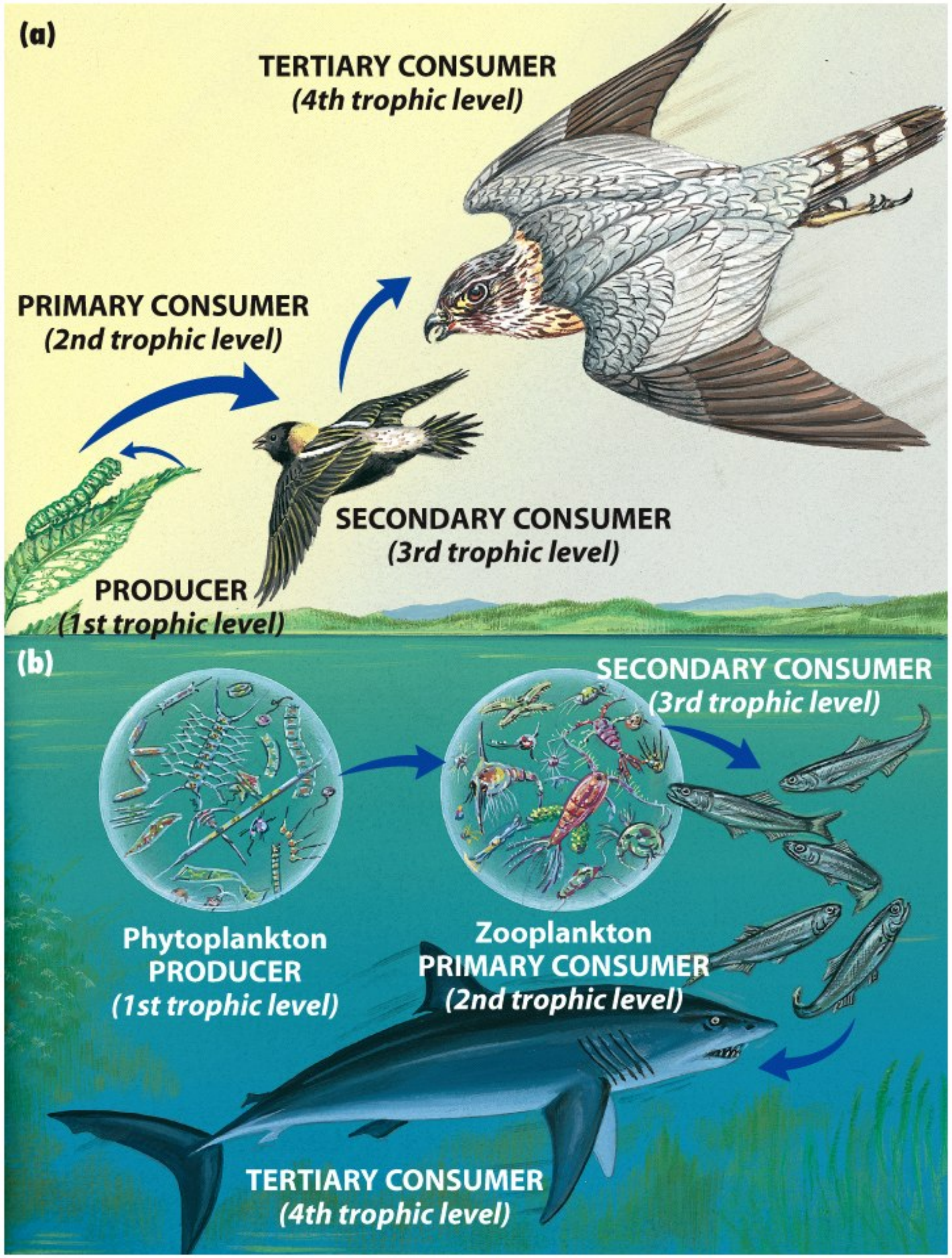

Figure 28-4 Biology: Life on Earth, 8/e

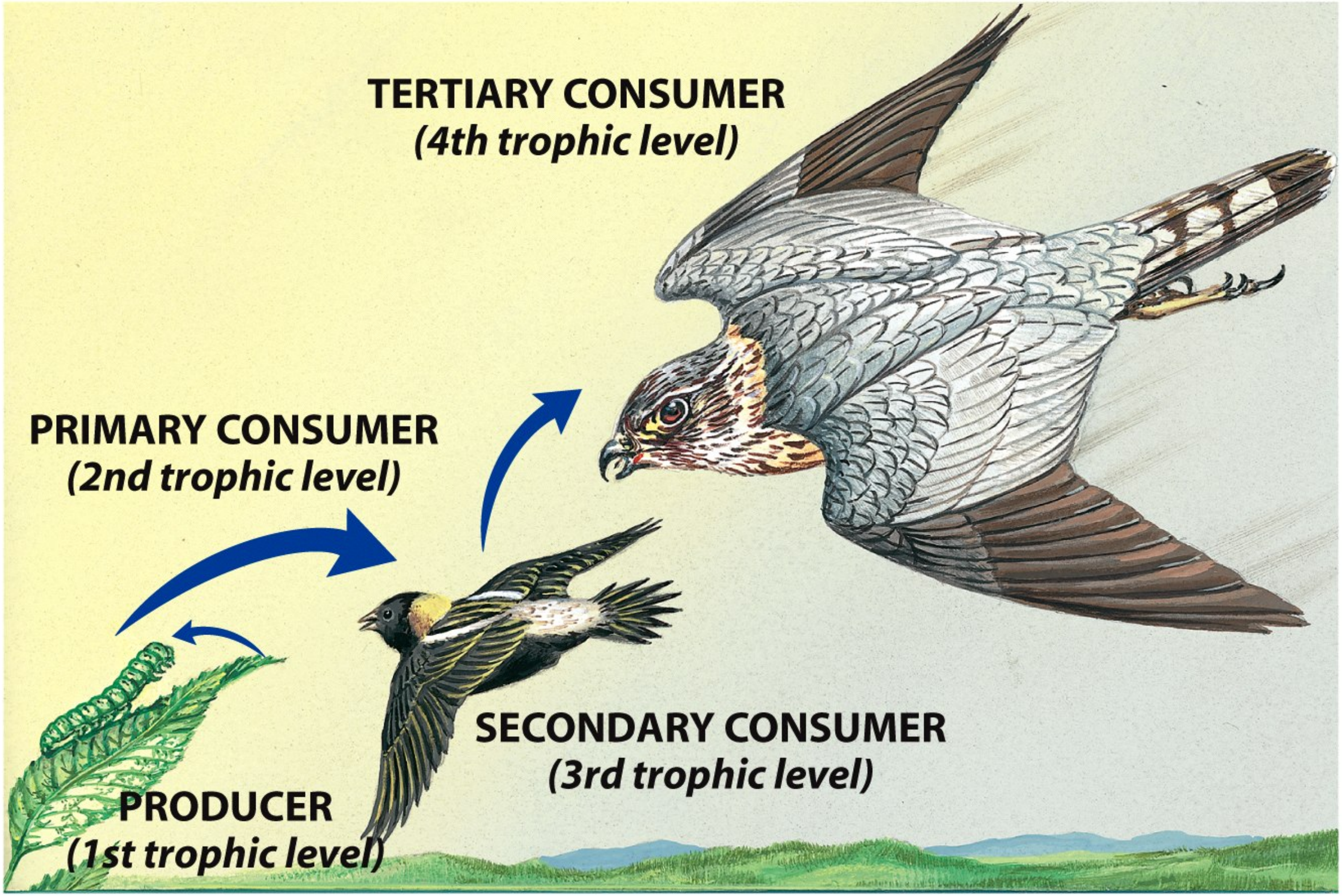

Figure 28-4a Biology: Life on Earth, 8/e

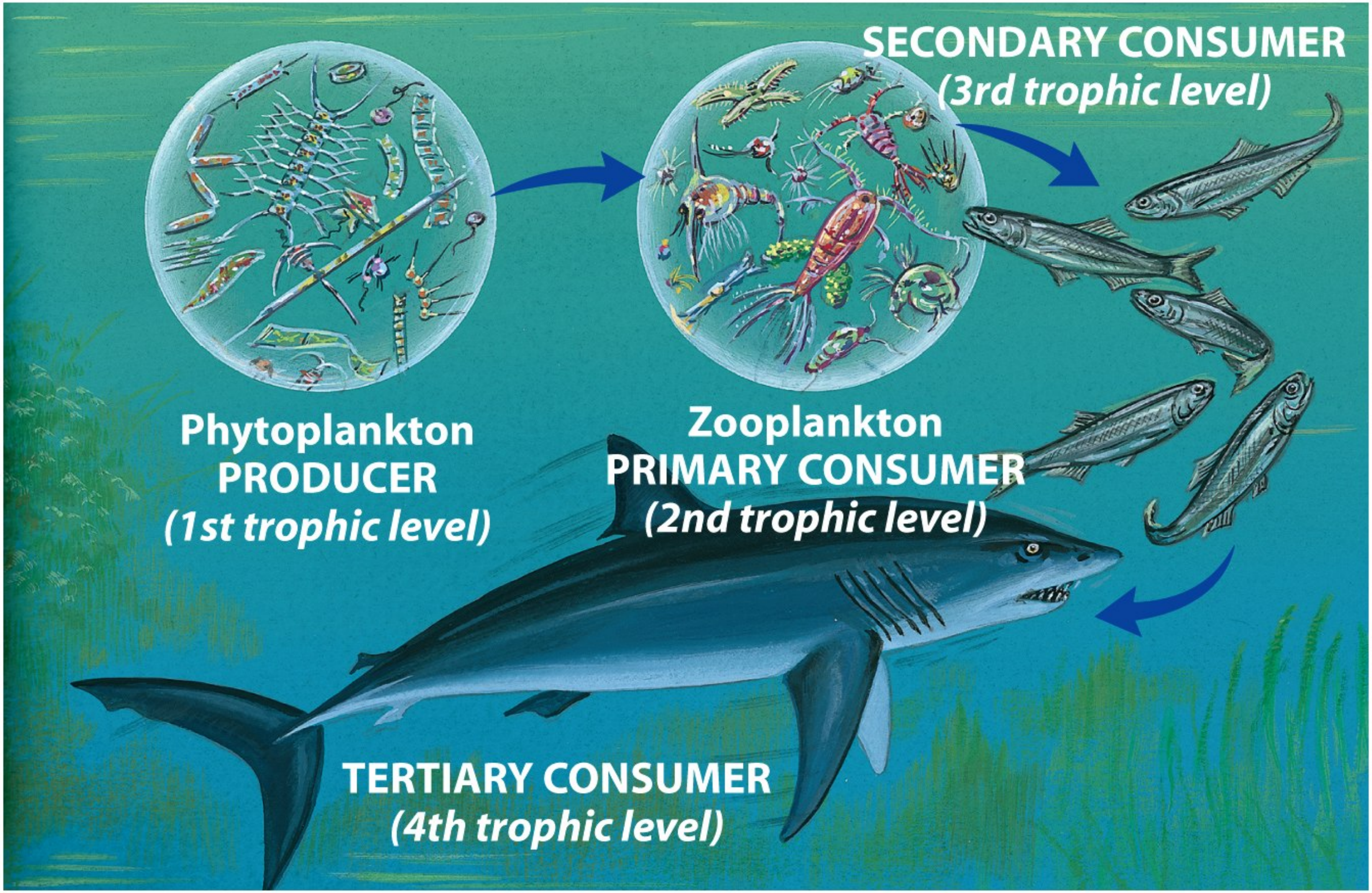

Figure 28-4b Biology: Life on Earth, 8/e

Food Webs

- A **food web** shows the actual feeding relationships in a community, including its many interconnecting food chains

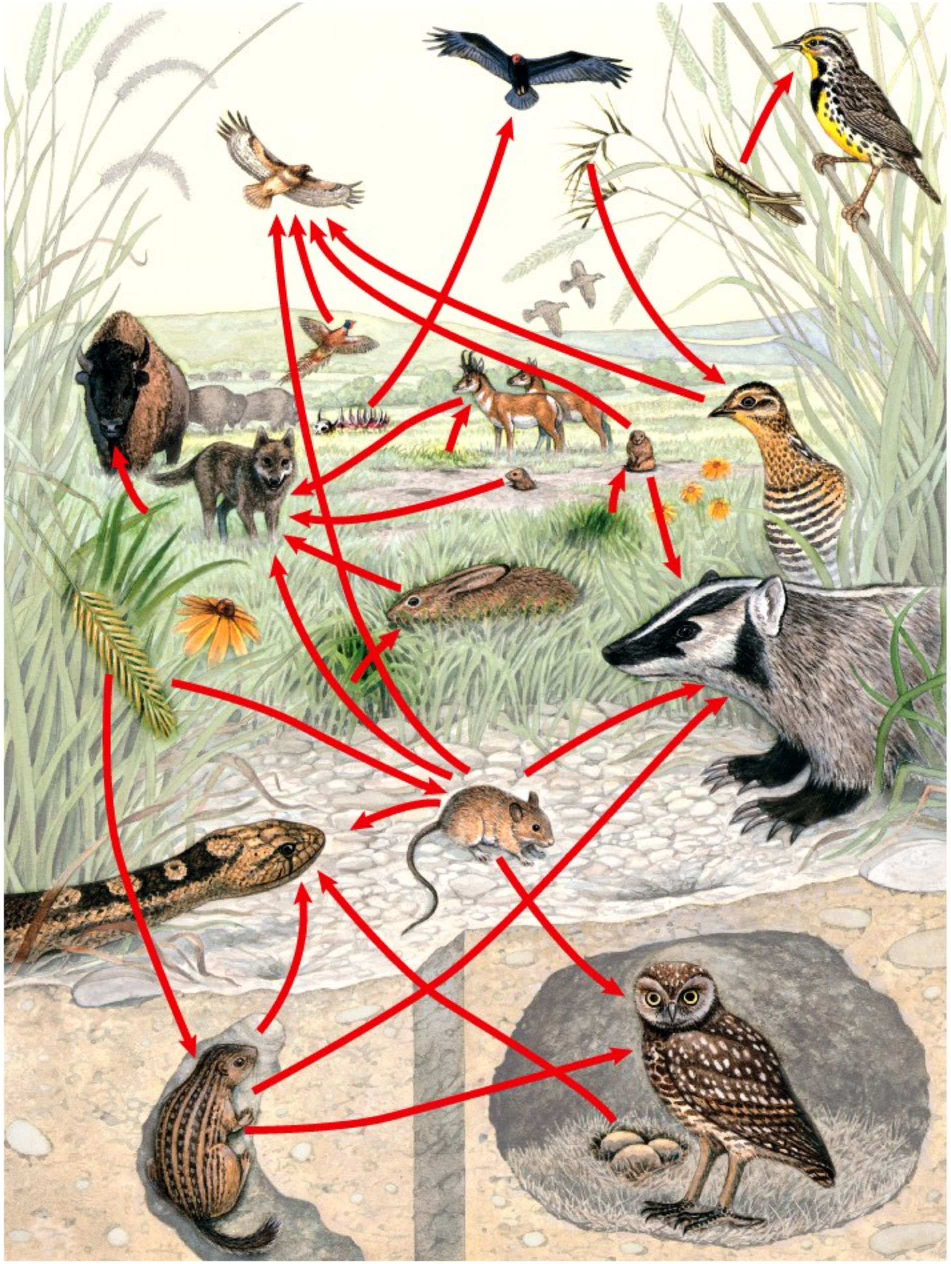

Figure 28-5 Biology: Life on Earth, 8/e

Detritus Feeders and Decomposers

- **Detritus feeders** and **decomposers** release nutrients for reuse

Detritus Feeders and Decomposers

- **Detritus feeders** live on dead organic matter, including the bodies of other organisms, fallen leaves, and wastes

Detritus Feeders and Decomposers

- Detritus feeders
  - Examples: earthworms, protists, pillbugs, and vultures
  - Detritus feeders excrete consumed material in a decomposed state
  - Their excretory products are food for other detritus feeders and **decomposers**

Detritus Feeders and Decomposers

- **Decomposers** digest food outside their bodies by secreting digestive enzymes
  - Are primarily fungi and bacteria
  - They absorb only needed nutrients; the rest are available for other organisms

Detritus Feeders and Decomposers

- Detritus feeders and decomposers convert the bodies of dead organisms into simple molecules
  - They recycle nutrients, making them available again for primary producers
  - If absent, primary productivity stops for lack of nutrients and the community collapses

Energy Transfer Is Inefficient

- Energy transfer through the trophic levels is inefficient
- A small percentage of available energy transfers to the next trophic level because
  - Energy conversion always involves losses as low-grade heat
  - Some of the molecules in organisms cannot be digested or absorbed

Energy Transfer Is Inefficient

- A small percentage of available energy transfers to the next trophic level because
  - Some energy is used by each trophic level for maintenance, repair, movement, etc.
  - Some organisms at each level die without being eaten and pass energy to detritus feeders and decomposers

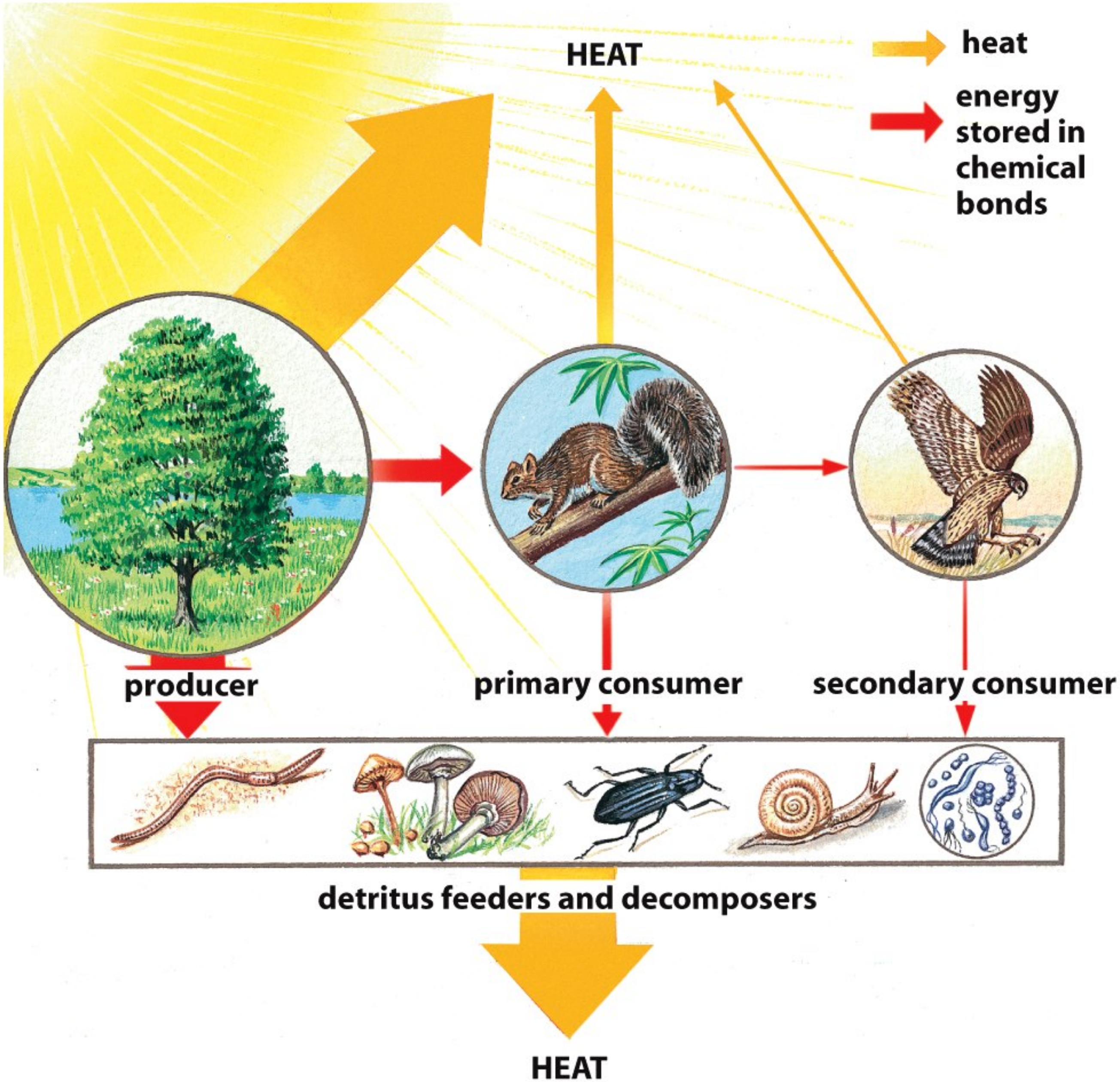

Figure 28-6 Biology: Life on Earth, 8/e

Energy Pyramids

- **Energy pyramids** illustrate energy transfer between trophic levels

Energy Pyramids

- The net energy transfer between trophic levels is roughly 10% efficient
  - An **energy pyramid** represents this, with primary producers on the bottom and higher trophic levels stacked on top

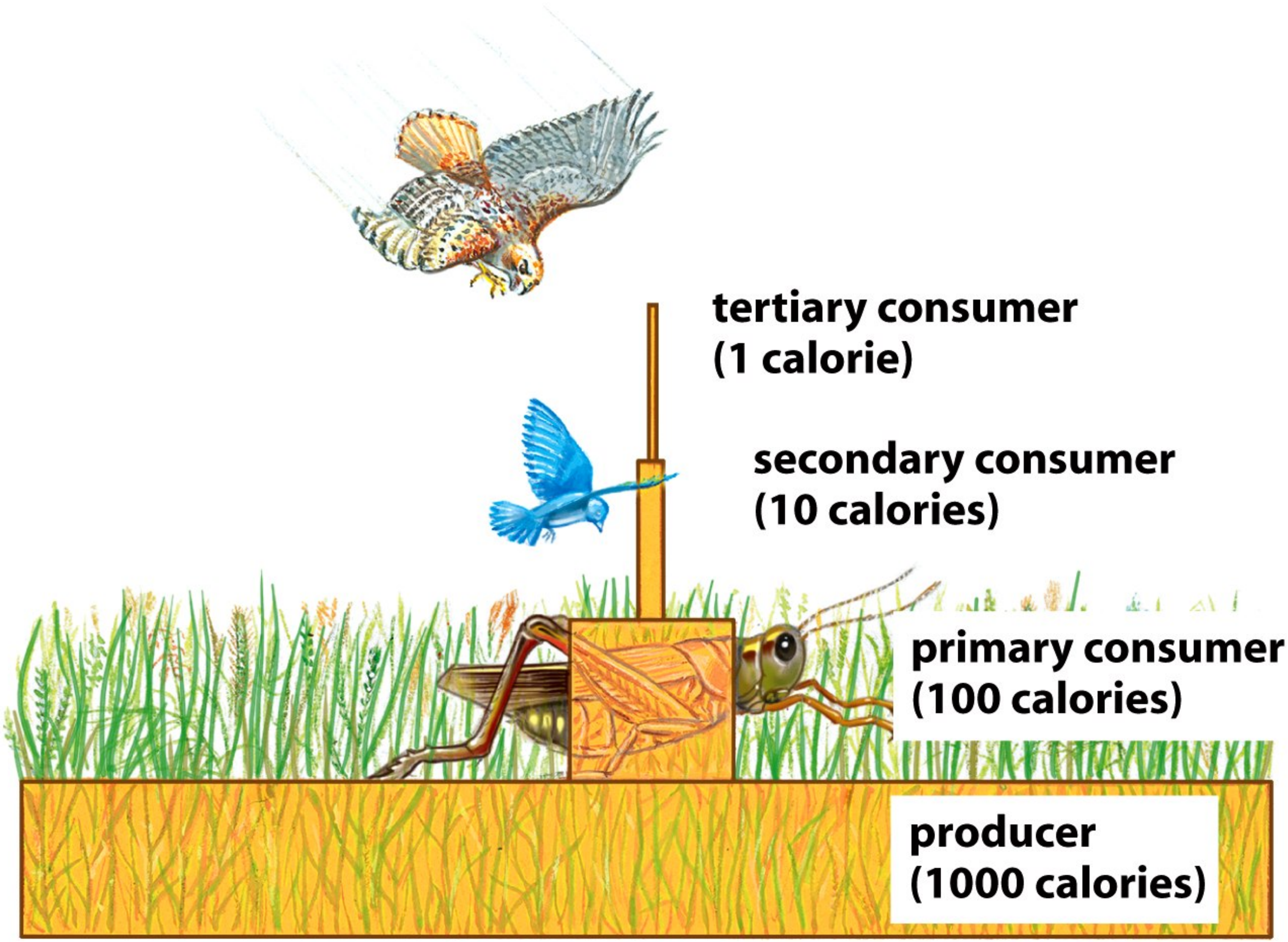

Figure 28-7 Biology: Life on Earth, 8/e

Energy Pyramids

- Sometimes biomass is used as a measure of the energy stored at each trophic level
  - A similar *biomass pyramid* can be constructed

Energy Pyramids

- This pattern of energy transfer has some important ramifications
  - Plants dominate most communities because they have the most energy available to them, followed by herbivores and carnivores
  - We can feed more people directly on grain than on meat from animals fed on grain

Section 28.3 Outline

- **28.3 How Do Nutrients Move Within and Among Ecosystems?**
  - Carbon Cycles Through the Atmosphere, Oceans, and Communities
  - The Major Reservoir for Nitrogen Is the Atmosphere
  - The Phosphorous Cycle Has No Atmospheric Component
  - Most Water Remains Chemically Unchanged During the Hydrologic Cycle

Nutrient Cycles

- *Nutrients* are elements and small molecules that form all the chemical building blocks of life

Nutrient Cycles

- *Macronutrients* are required by organisms in large quantities
  - Examples: water, carbon, hydrogen, oxygen

Nutrient Cycles

- *Micronutrients* are required only in trace quantities
  - Examples: zinc, molybdenum, iron, selenium

Nutrient Cycles

- **Nutrient cycles** (or **biogeochemical cycles**) describe the pathways nutrients follow between communities and the nonliving portions of ecosystems
  - **Reservoirs** are sources and storage sites of nutrients
  - Major reservoirs are usually in the abiotic environment

The Carbon Cycle

- Chains of carbon atoms form the framework of all organic molecules, the building blocks of life

The Carbon Cycle

- Carbon enters communities through capture of CO_2 during photosynthesis
  - Producers on land get CO_2 from the atmosphere
  - Aquatic producers get CO_2 dissolved in the water

The Carbon Cycle

- Primary consumers eat producers and acquire carbon stored in their tissues
  - These herbivores release some of the carbon through respiration as CO_2
  - They store the rest, which may be consumed by higher trophic levels

The Carbon Cycle

- If not eaten, when organisms die their bodies are broken down by detritus feeders and decomposers
- Cellular respiration by organisms releases CO_2 into the atmosphere and oceans

The Carbon Cycle

- **Fossil fuels** are formed when the remains of prehistoric organisms are buried and subjected to high temperatures and pressures for millions of years
  - Burning fossil fuels releases stored energy in hydrocarbons and releases carbon into the atmosphere as CO_2

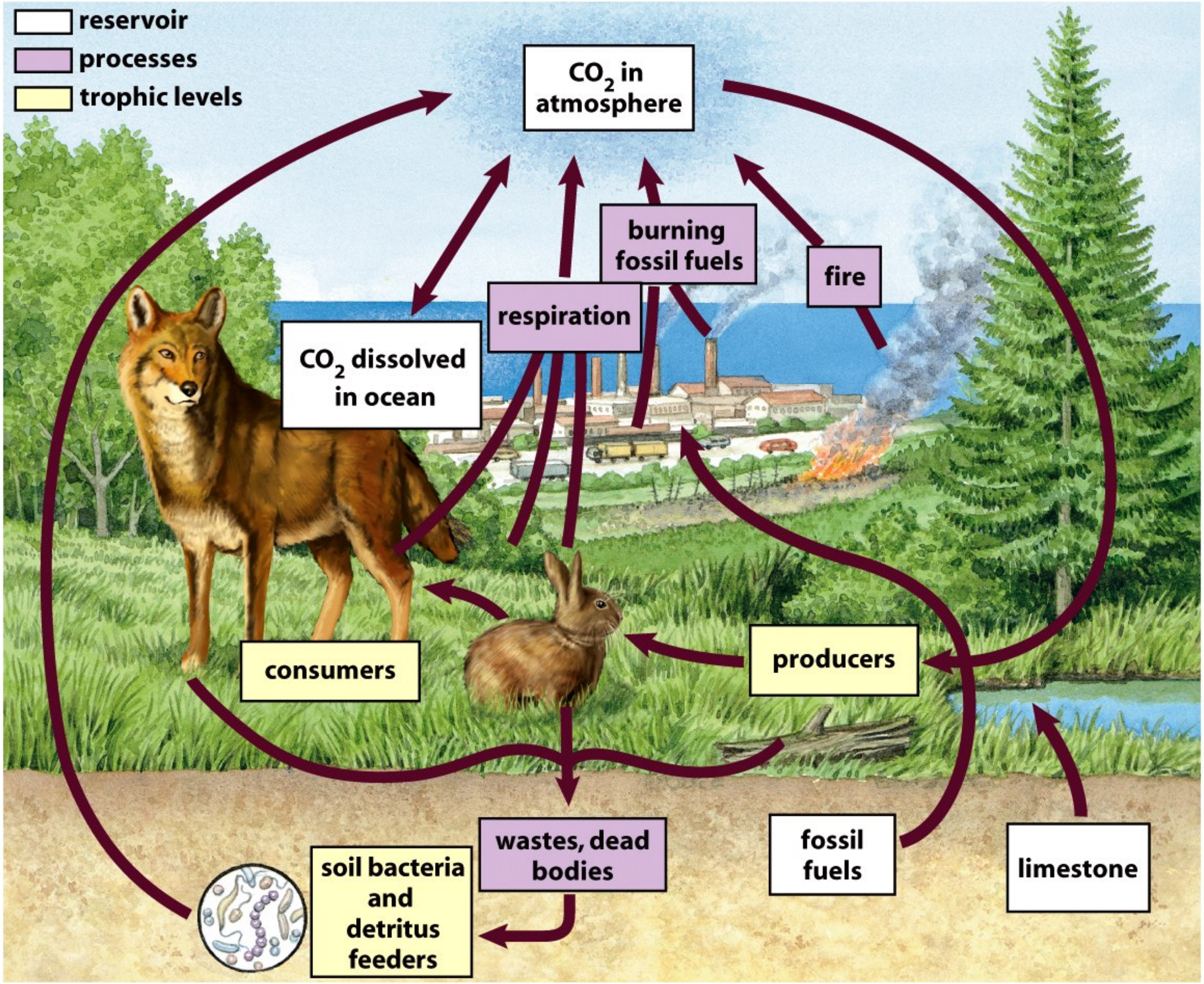

Figure 28-8 Biology: Life on Earth, 8/e

The Nitrogen Cycle

- Nitrogen is a crucial component of proteins, many vitamins, DNA, and RNA
- While nitrogen gas (N_2) makes up 79% of the atmosphere, this form of nitrogen cannot be utilized by plants
- Plants utilize nitrate (NO_3^-) or ammonia (NH_3) as their nitrogen source

The Nitrogen Cycle

- N_2 is converted to ammonia by specific bacteria
  - Some of these bacteria live in water and soil
  - Others live in symbiotic associations with plants called *legumes*

The Nitrogen Cycle

- Primary consumers, detritus feeders, and decomposers obtain nitrogen from their food

The Nitrogen Cycle

- Some nitrogen is released in wastes and dead bodies
- Decomposer bacteria convert this back to nitrate and ammonia in the soil or water, which is then available to plants
- *Denitrifying bacteria* break down nitrate, releasing N_2 back to the atmosphere

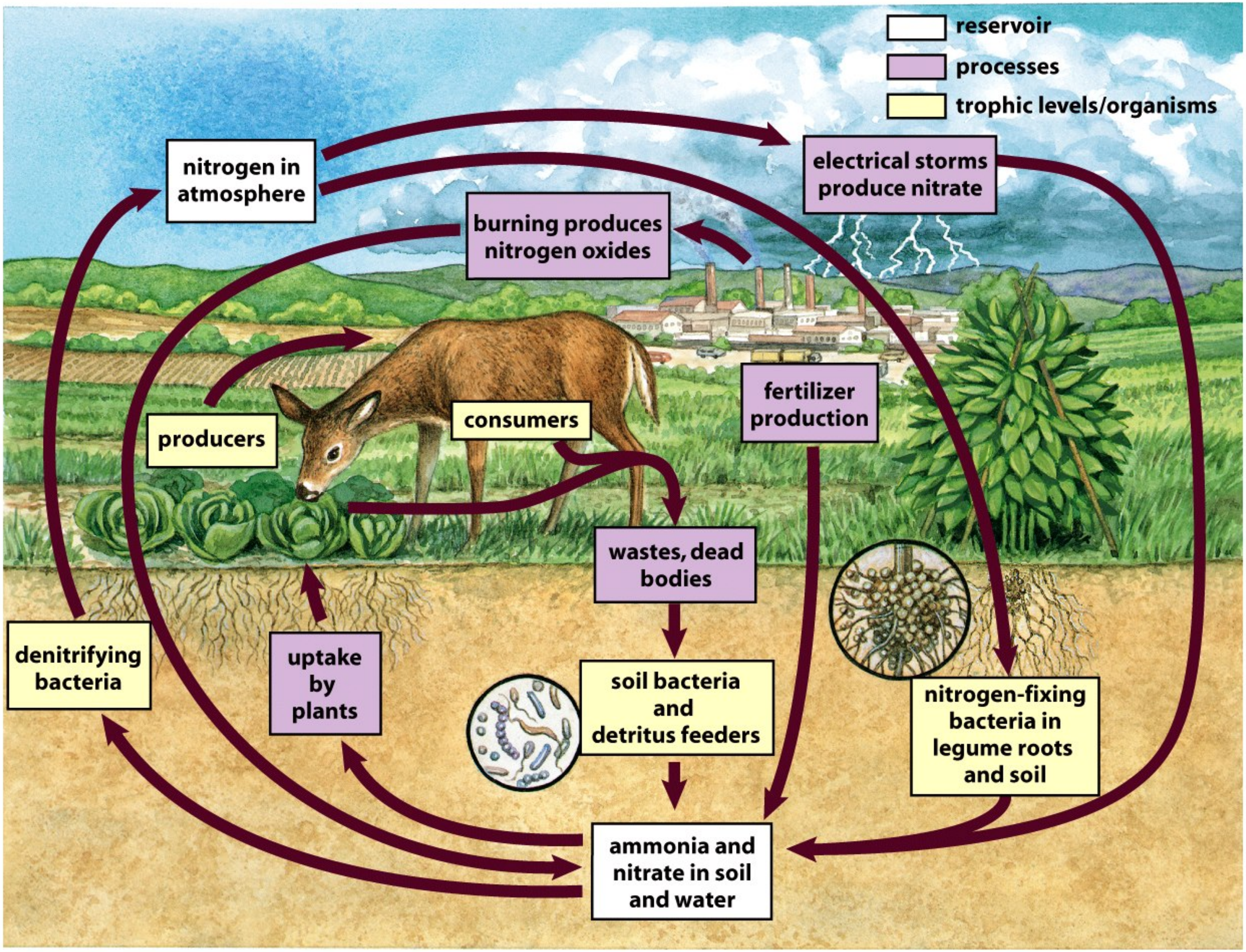

Figure 28-9 Biology: Life on Earth, 8/e

The Nitrogen Cycle

- Human-dominated ecosystems have dramatically altered nitrogen cycles
  - Application of chemical fertilizers may change plant community composition
  - Burning of forests and fossil fuels releases nitrogen that causes habitat acidification

The Phosphorous Cycle

- Phosphorus is a crucial component of ATP and NADP, nucleic acids, and phospholipids of cell membranes

The Phosphorous Cycle

- The major reservoir of the phosphorus cycle is in rock bound to oxygen as phosphate
  - Phosphate in exposed rock can be dissolved by rainwater
  - It is absorbed by autotrophs, where it is incorporated into biological molecules that pass through food webs

The Phosphorous Cycle

- The major reservoir of the phosphorus cycle is in rock bound to oxygen as phosphate
  - At each level, excess phosphorus is excreted and decomposers release phosphate
  - Phosphate may be reabsorbed by autotrophs or reincorporated into rock

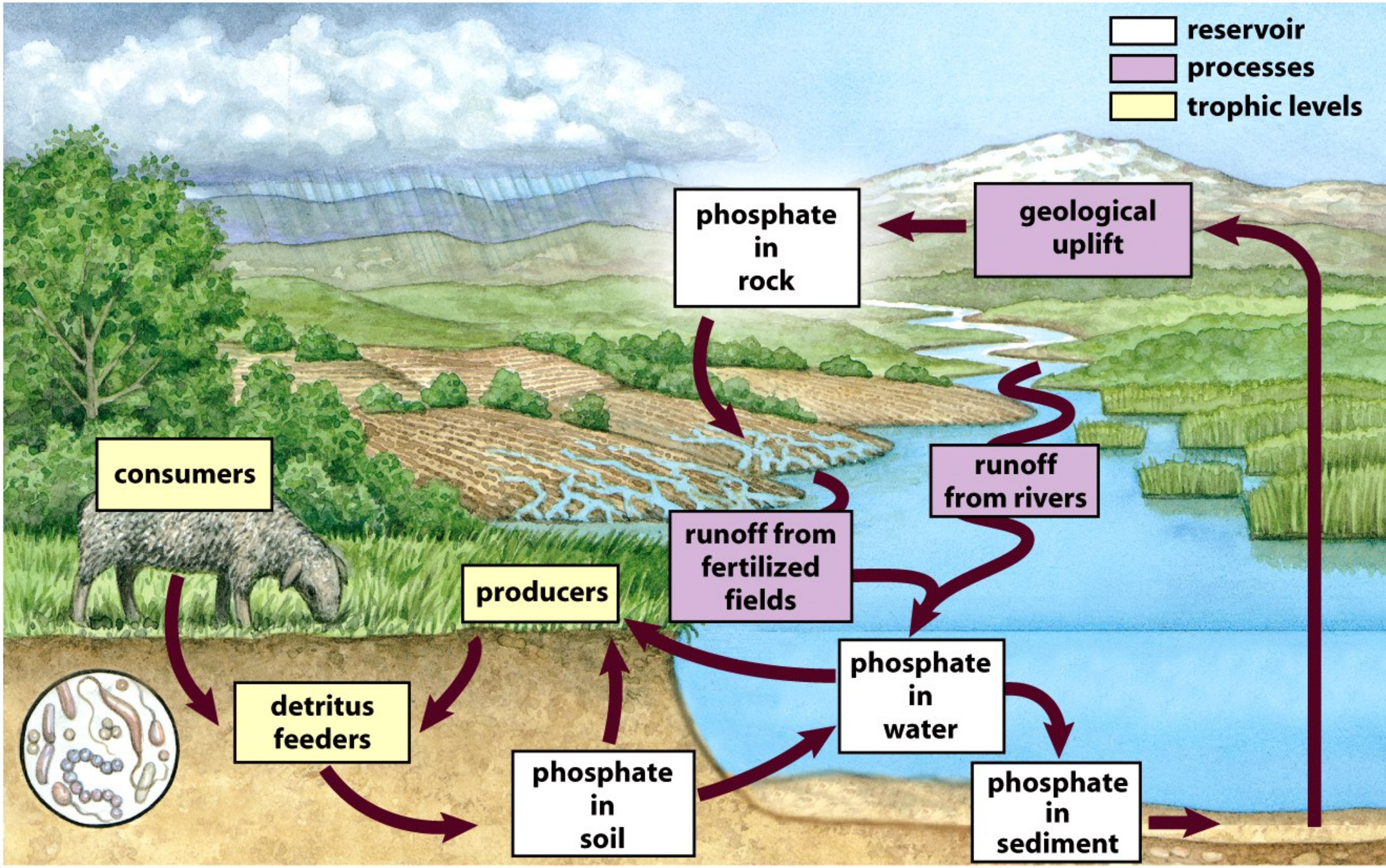

Figure 28-10 Biology: Life on Earth, 8/e

The Phosphorous Cycle

- Phosphate-rich fertilizers are obtained by mining rock
- Soil erosion from fertilized fields carries large quantities of phosphate into lakes, streams, and oceans
  - Stimulates growth of algae and bacteria, disrupting natural community interactions

The Hydrologic Cycle

- Water molecules remain chemically unchanged during the **hydrologic cycle**

The Hydrologic Cycle

- The major reservoir of water is the ocean
  - Contains more than 97% of Earth's water
- Solar energy evaporates water, and it comes back to Earth as precipitation

The Hydrologic Cycle

- Water that has fallen on land takes various paths
  - Some evaporates from the soil, lakes, and streams
  - Some runs off the land back to the ocean
  - A small amount enters underground reservoirs

The Hydrologic Cycle

- Most water evaporates from the surface of the ocean
- Plants absorb water through roots, but most is evaporated back to the atmosphere from leaves

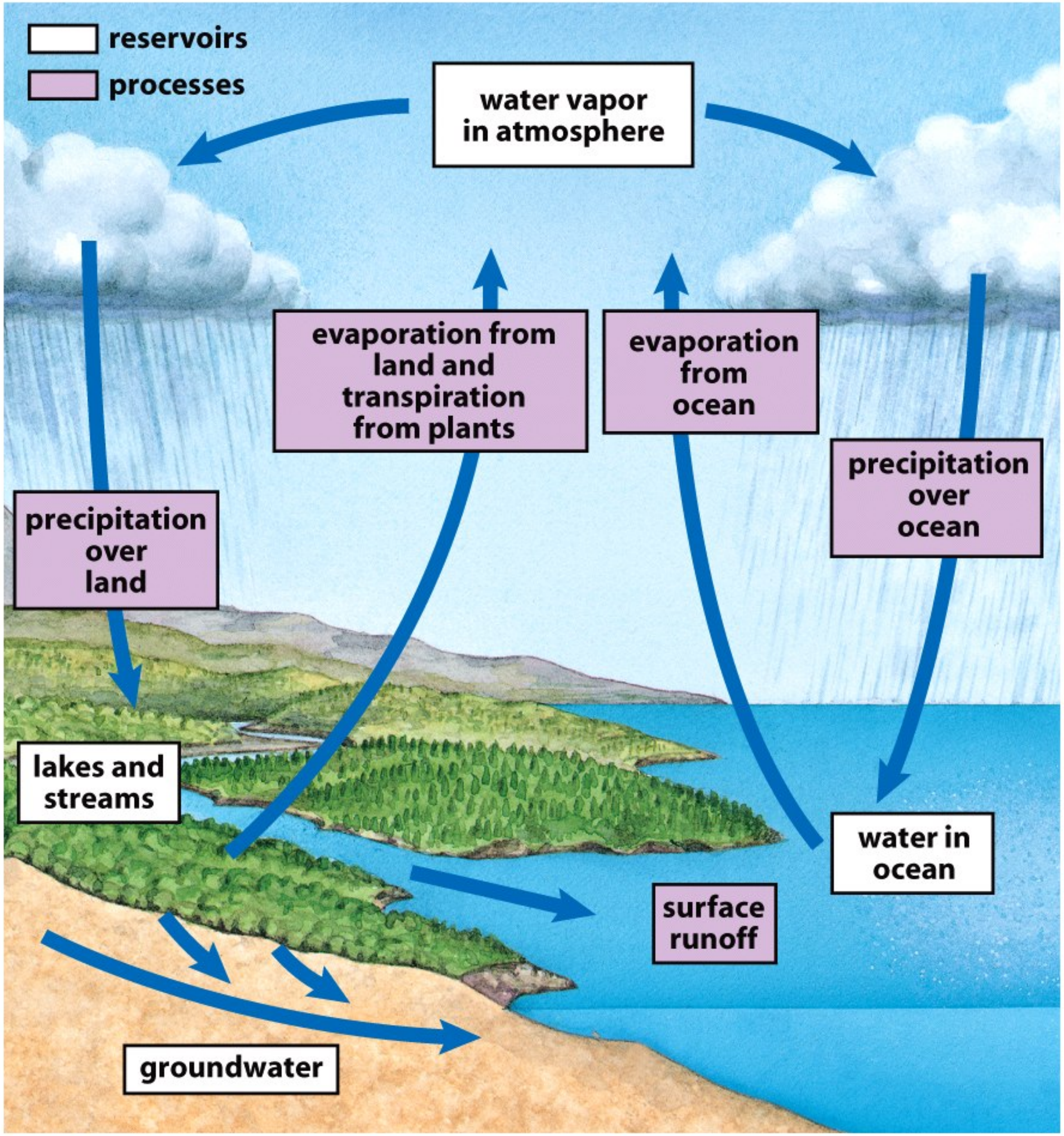

Figure 28-11 Biology: Life on Earth, 8/e

The Hydrologic Cycle

- Consumers get water from their food or by drinking
  - Their bodies are roughly 70% water

The Hydrologic Cycle

- With human population growth, fresh water has become scarce
  - Water scarcity limits crop growth
  - Pumping water from underground aquifers is rapidly depleting many of them

The Hydrologic Cycle

- With human population growth, fresh water has become scarce
  - Contaminated drinking water is consumed by over 1 billion people in developing countries each year, killing millions of children

Section 28.4 Outline

- **28.4 What Causes Acid Rain?**
  - Overloading the Nitrogen and Sulfur Cycles Causes Acid Rain
  - Acid Decomposition Damages Life in Lakes and Forests
  - The Clean Air Act Has Significantly Reduced Sulfur, But Not Nitrogen, Emissions

What Causes Acid Rain?

- Many of our environmental problems are due to our interference with ecosystem function

What Causes Acid Rain?

- We have mined substances that are foreign to natural ecosystems and toxic to many organisms

Figure 28-12 Biology: Life on Earth, 8/e

What Causes Acid Rain?

- We synthesize substances never before found on Earth that are harmful to many forms of life
  - Examples: pesticides and solvents

What Causes Acid Rain?

- Beginning in the Industrial Revolution, we have relied heavily on fossil fuels for heat, light, transportation, industry, and agriculture
- Reliance on fossils fuels leads to two environmental problems
  - Acid rain
  - Global warming

What Causes Acid Rain?

- Acid rain (**acid deposition**) is due to excess industrial production of sulfur dioxide and nitrogen oxides that our natural ecosystems can’t absorb and recycle

Overloaded Cycles

- Sulfur dioxide
  - Released primarily from coal and oil power plants
  - Forms sulfuric acid when it combines with water vapor

Overloaded Cycles

- Nitrogen oxides
  - Released from vehicles, power plants, and industry
  - Combines with water vapor to form nitric acid

Overloaded Cycles

- Days later, and often hundreds of miles from the source, the acids fall
  - Eat away at statues and buildings
  - Damage trees and crops
  - Alter lake communities

Figure 28-13 Biology: Life on Earth, 8/e

Damage from Acid Deposition

- About 25% of lakes and ponds in the Adirondack Mountains are too acidic to support fish

Damage from Acid Deposition

- Fish die because much of the food web that supports them is destroyed,
- Acidification affects clams, snails, crayfish, and insect larvae, followed by amphibians, and finally fish
- The result is a crystal-clear lake—beautiful but dead

Damage from Acid Deposition

- Acid rain decreases productivity of crops and health of wild plants
  - Essential nutrients are leeched from the soils and decomposer organisms are killed
  - Results in weakened plants that are more vulnerable to infection and insect attack

Damage from Acid Deposition

- Acid rain decreases productivity of crops and health of wild plants
  - Example: forests on Mount Mitchell in North Carolina

Figure 28-14 Biology: Life on Earth, 8/e

Damage from Acid Deposition

- Acid rain also increases exposure of organisms to toxic metals which are far more soluble in acidified water

Damage from Acid Deposition

- Aluminum dissolved from rock may inhibit plant growth and kill fish
- Drinking water can be contaminated by lead dissolved in acidic water from solder in old pipes
- Mercury can accumulate in bodies of fish by **biological magnification**

The Clean Air Act

- Amendments to the Clean Air Act in 1990 led to reductions in sulfur dioxide and nitrogen oxide emissions from power plants
- Reduced sulfur emissions have improved air quality and rain acidity in some regions
- However, atmospheric nitrogen compounds have shown a small overall increase, due to increased gasoline burning by automobiles

Section 28.5 Outline

- **28.5 What Is Causing Global Warming?**
  - Interfering with the Carbon Cycle Contributes to Global Warming
  - Greenhouse Gases Trap Heat in the Atmosphere
  - Global Warming Will Have Severe Consequences
  - How Are People Responding to the Threat?

Interfering with the Carbon Cycle

- Between 345–280 million years ago, the bodies of many plants and animals were buried, escaping decomposition

Interfering with the Carbon Cycle

- Over time, these carbon sources were converted to fossil fuels by heat and pressure
- Fossil fuels remained untouched until the beginning of the Industrial Revolution
  - Burning the fuels released it as CO_2 into the air

Interfering with the Carbon Cycle

- Human activities release almost 7 billion tons of carbon (in the form of CO2,) into the atmosphere each year
- About half of this carbon is absorbed into the oceans, plants and soil
- The other half remains in the atmosphere, fueling **global warming**

Interfering with the Carbon Cycle

- Since 1850, atmospheric CO_2 has increased by 36%
  - From 280 ppm to 370 ppm, with a current annual increase of 1.5 ppm
  - 80–85% of this increase in attributable to burning fossil fuels

Interfering with the Carbon Cycle

- **Deforestation** accounts for 15–20% of the added CO_2
  - Occurs principally in the tropics as rain forests are cut and burned

Greenhouse Gases Trap Heat

- CO_2 is a **greenhouse gas**
  - It allows solar energy into the atmosphere, but traps it once it has been converted to heat (the **greenhouse effect**)

Greenhouse Gases Trap Heat

- CO_2 is a **greenhouse gas**
  - Other **greenhouse gases**: methane, chlorofluorocarbons (CFCs), water vapor, and nitrous oxide

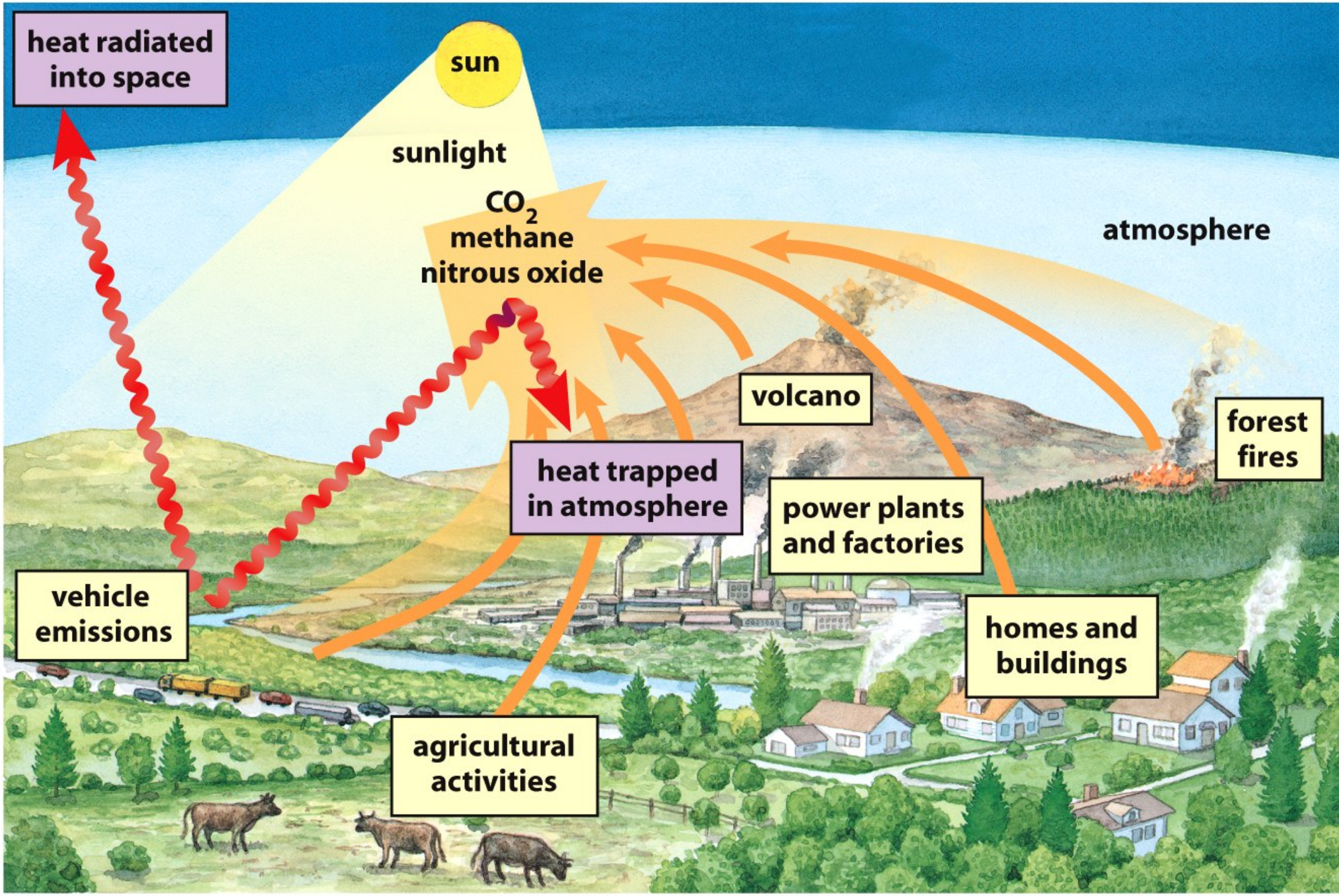

Figure 28-15 Biology: Life on Earth, 8/e

Greenhouse Gases Trap Heat

- Global temperature has increased in parallel with rising atmospheric CO_2 levels
  - Phenomenon called **global warming**

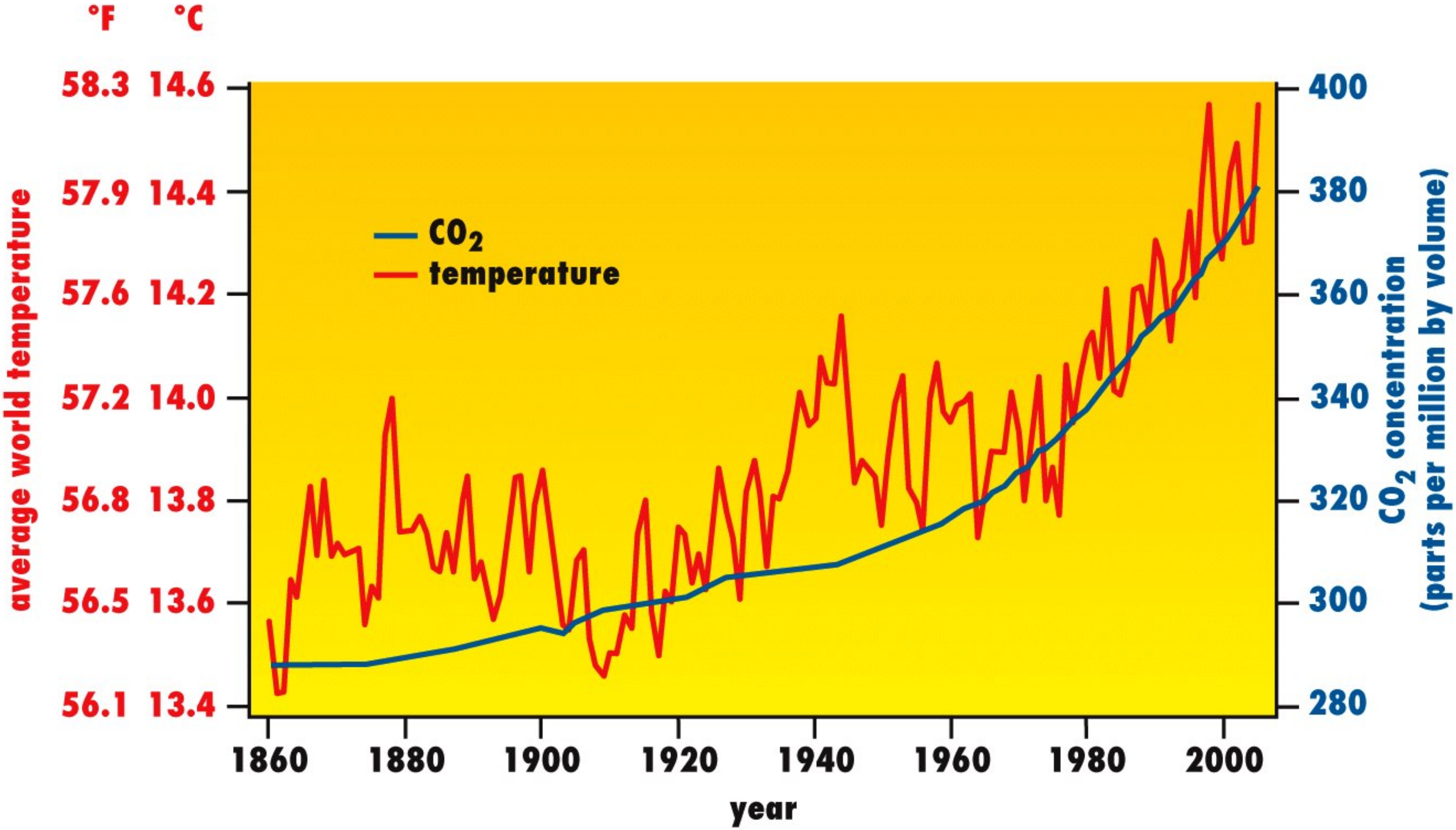

Figure 28-16 Biology: Life on Earth, 8/e

Greenhouse Gases Trap Heat

- Estimates of future climate change predict that average global temperatures will rise from the current average of about 58^{o}F to between 61^{o}F and 66^{o}F

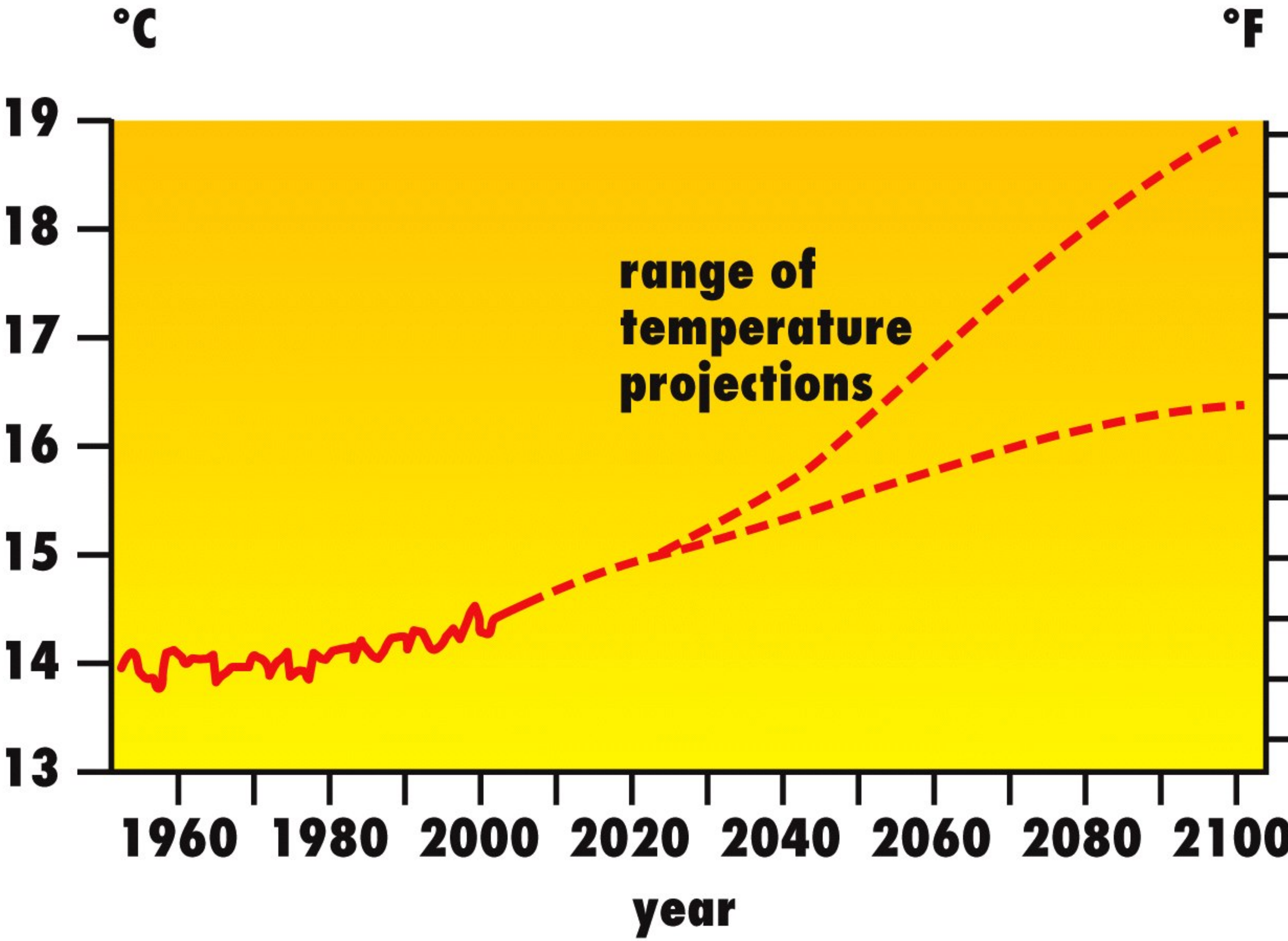

Figure 28-17 Biology: Life on Earth, 8/e

Severe Consequences

- A meltdown is occurring
- Glaciers and ice sheets have been melting at unprecedented rates
  - Rising sea levels will flood many coastal cities and wetlands and may increase hurricane intensity

Figure 28-18 Biology: Life on Earth, 8/e

Severe Consequences

- More extreme weather patterns are predicted
- Warming will alter air and water currents, changing precipitation patterns
  - More severe droughts and greater extremes in rainfall may lead to more frequent crop failures and flooding

Severe Consequences

- Wildlife is impacted
- Forests may suffer loss of species or be replaced by grasslands
- Coral reefs may decline due to warming waters

Severe Consequences

- Studies have documented shifts in species’ ranges towards the poles and advancement of springtime events to earlier dates
- The range of tropical disease-carrying organisms, such as malaria-transmitting mosquitoes may expand

Our Decisions Make a Difference

- The U.S. has only 5% of the world's population but produces 25% of the world's greenhouse emissions

Kyoto Treaty

- Negotiated in 1997 and implemented in 2005
- 35 industrialized countries have pledged to reduce their collective emissions of greenhouse gases to levels 5.2 % below 1990 levels
- 159 countries have ratified the treaty, the U.S. has not

Kyoto Treaty

- Ten U.S. states and many city mayors have pledged to adopt Kyoto-type standards independently
- Although worldwide efforts are essential, our individual choices, collectively, can also have a big impact

Individual Responses

- Use fuel-efficient vehicles, car-pools, and public transportation
- Conserve electricity and support use renewable energy sources

Individual Responses

- Insulate and weatherproof your home
- Recycle
- Support efforts to replace trees both in tropical rain forests and in your community