UNIT 7 CHAPTER 38

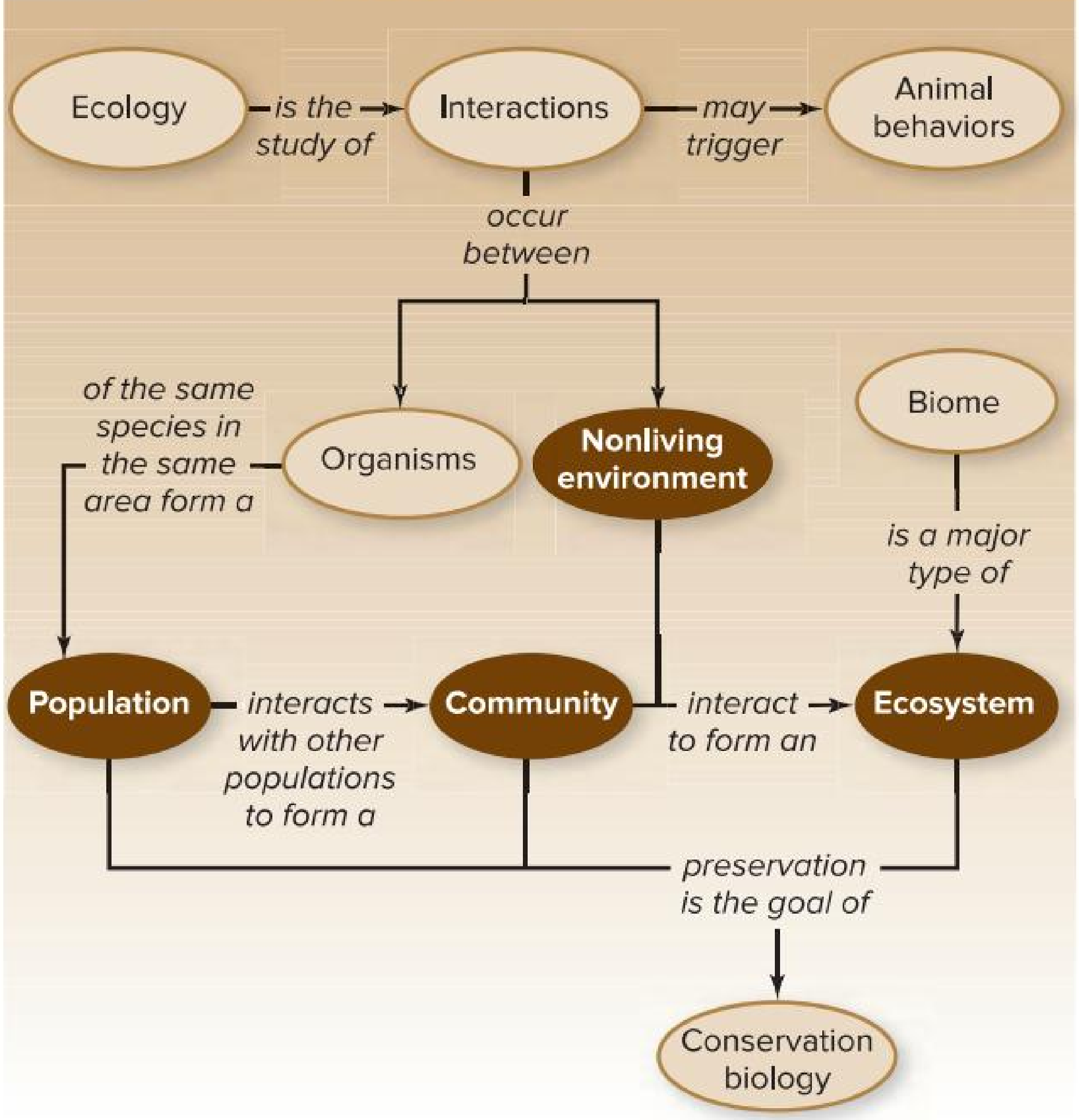
Chapter 38 Communities and Ecosystem

LIU Yang

LEARNING OUTLINE

- 38.1 Multiple Species Interact in Communities
- 38.2 Succession Is a Gradual Change in a Community
- 38.3 Ecosystems Require Continuous Energy Input
- 38.4 Chemicals Cycle Within Ecosystems

SURVEY THE LANDSCAPE
The Ecology of Life



38.1 Multiple Species Interact in Communities

- Chapter 37 described the ecology
inhabit the same area. This chapte
ecosystems.

- **A community is a group of inter**
houses a bustling biotic, or living
microbes.Each community is part
also the abiotic, or nonliving, env
home and way of life. The habit
resources a species requires for it
the niche also includes the temper
conditions where the species lives
chain, are part of the niche as wel

- **Communities usually consist of**
others are microscopic. One on
wasp kills a caterpillar. But an att
complicated. Individuals of differ
another,eat one another,and try to

Figure 38.1 Two Communities. An evergreen forest on land and a kelp forest in the ocean both include populations of multiple species.

38.1 Multiple Species Interact in Communities

A.Many Species Compete for the Same Resources

- **Competition** occurs when organisms vie for the same limited resource, such as shelter, nutrients,water, light, or food.Since neither participant obtains all of the resource that it needs, the effects of competition are negative for both.
- **We saw that competition within a species—for food, mates,breeding sites,and other resources—can limit a population's growth. Likewise, organisms also compete with other species, especially those that occupy a similar niche.**
- **Competition can help shape the species composition of a community.** Consider the competitive exclusion principle, which states that two species cannot coexist indefinitely in the same niche.The two species will compete for the limited resources that they both require,such as food, nesting sites, or soil nutrients. According to the competitive exclusion principle,the species that acquires more of the resources will eventually“win.” The less successful species dies out. **Introduced species sometimes displace native species by competitive exclusion.**

38.1 Multiple Species Interact in Communitiess

A.Many Species Compete for the Same Resources

- Competitive exclusion,however,is not inevitable; coexistence in overlapping niches is also possible. After all, if **interspecific competition**（种间竞争）reduces fitness, then natural selection should favor organisms that avoid competition.Therefore,another possible outcome of competition is **resource partitioning**（资源分配）,in which multiple species use the same resource in a slightly different way or at a different time.For example,multiple species of rock hopper penguins live on islands in the southern Indian Ocean, occupying similar niches:The birds all appear similar,and they all eat similar foods. When researchers tracked penguin movements, however,they found that the populations feed in different places and at different times.Their feeding locations and times reduce competition and therefore improve the reproductive success of all populations.

Figure 38.4 Resource Partitioning. Two species of rockhopper penguins form three populations. All have similar diets, but each feeds at a different time or place.

Photo: ©Enrique R. Aguirre Aves/Oxford Scientific/Getty Images

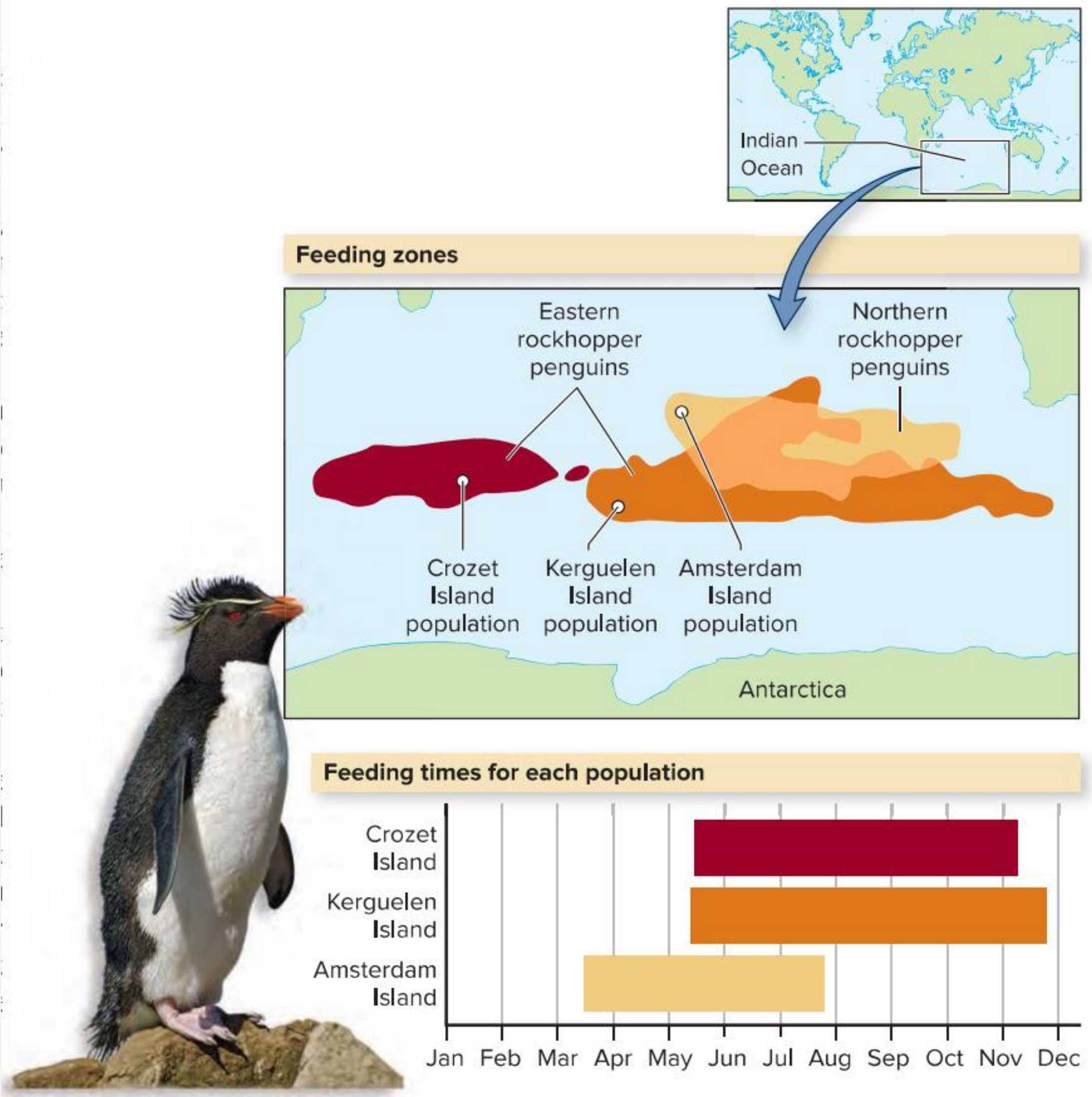


FIGURE IT OUT

1.Which of the following is an example of an ecological community?

a.The many types of microbes living in a human intestine

b.An ant colony

c.The people living in your neighborhood

d.The cells of a platypus

2.Cyanobacteria are photosynthetic bacteria that live in water.Two species,isolated from the same habitat,use different wavelengths oflight in photosynthesis.This is an example of

a.competitive exclusion.

b.resource partitioning.

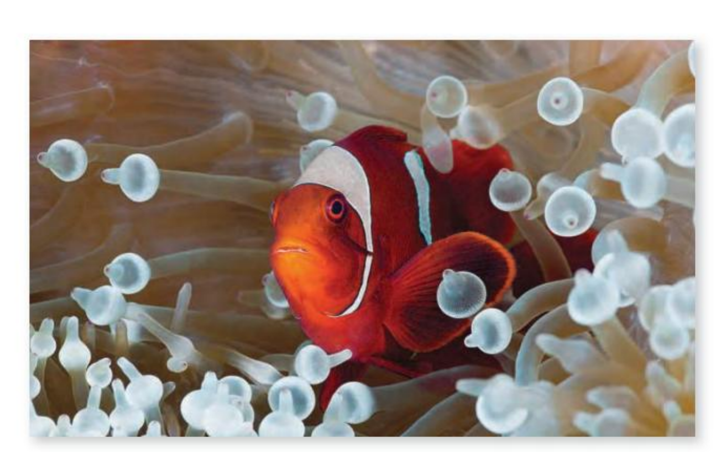
c.commensalism.

d.biomagnification.

38.1 Multiple Species Interact in Communities

B.Symbiotic (共生的) Interactions Can Benefit or Harm a Species

- **In a symbiosis, two species share a close (and often lifelong)relationship in which one typically lives in or on the other.**Th relationship between symbiotic species may take several forms, defined b the effect on each participant.
- **Mutualistic relationships（互利共生关系） are symbioses that improv the fitness of both partners.** The clownfish and the sea anemones are a classic example.Many of the bacteria in our intestines are also mutualistic;these microbes consume nutrients from our food but also produce vitamins and defend us against disease.
- **Commensalism(偏利共生) is a type of symbiosis in which one species benefits but the other is not significantly affected.**The reproductive success of a tree is neither helped nor harmed by the moss plants and lichens that grow on its trunk and branches .
- **In a symbiotic relationship called parasitism(寄生), one species acquires resources at the expense of a living host.**The most familiar parasites are disease-causing bacteria, protists, fungi, and worms. Plants may also be parasites.



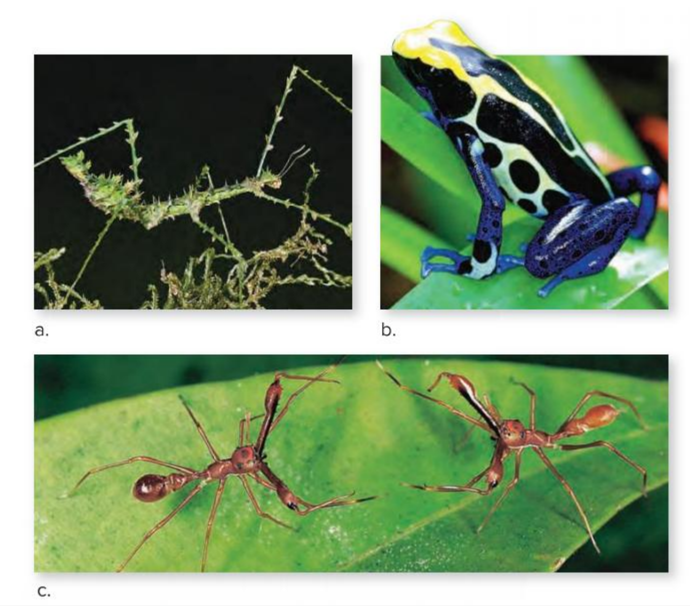
38.1 Multiple Species Interact in Communities

C.Herbivory and Predation Link Species in Feeding Relationships

- All animals must obtain energy and nutrients by eating other organisms, living or dead. **An herbivore** is an animal that consumes plants;a predator is an animal that kills and eats other animals,called prey. As in parasitism,the fitness of the herbivore or predator increases at the expense of the organism being consumed. In some cases, **predator-prey interactions (捕食关系) are directly responsible for fluctuations in an animal's population size.**
- **Natural selection favors plant defenses against herbivores**, which may eat leaves, roots, stems,flowers, fruits,or seeds.The loss of leaf and root tissue reduces the plant's ability to carry out photosynthesis; consumption of flowers or immature fruits and seeds compromises the plant's reproductive success.Some plants pecies deter herbivores with thorns, milky sap,or distasteful or poisonous chemicals.The spicy hot chemicals in chili peppers,for example,discourage attack by both fungi and small mammals.**At the same time,many herbivores have adaptations that correspond to the plant's defenses.**The caterpillars of monarch butterflies,for example,tolerate the noxious chemicals in milkweed plants.

38.1 Multiple Species Interact in Communities

C.Herbivory and Predation Link Species in Feeding Relationships



- Likewise,**predation exerts strong selective pressure on prey animals**, which often have adaptations that help them avoid being eaten. **Camouflage and warning coloration**（伪装和警示色） are two examples.An interesting variation on the theme of warning coloration is mimicry（模仿）, in which different species develop similar appearances.
- Besides camouflage and warning coloration, **prey species may also have hard shells, pincers, stingers, or other defensive adaptations.**And prey animals also have a repertoire（本领） of **defensive behaviors**,including stotting（弹跳）, fleeing, fighting, releasing noxious chemicals,or forming a tight group.
- **Only those predators that can defeat prey defenses will livelong enough to reproduce and care for their young**.Acute senses, agility, sharp teeth,and claws are common among predators.**Camouflage is adaptive in predators as well as prey.Hunting in groups** is a behavioral adaptation that helps predators capture large prey.

38.1 Multiple Species Interact in Communities

D.Closely Interacting Species May Coevolve（共同进化）

- **Some connections between species are so strong that the species directly influence one another's evolution.**In coevolution, agenetic change in one species selects for subsequent changes in the genome of another species.Of course,all interacting species in one community have the potential to influence one another,and they are all“evolving together.”
- One example of coevolution is the relationship between lodge pole pines and birds called crossbills that eat the trees’seeds .In areas with crossbills,the pine trees produce large seed cones with thick, protective scales. The birds,however,have a corresponding adaptation: Their bills are large stin forest regions where pines have thick cones.
- Flowering plants and insects have also coevolved.As described in chapter 24,a plant may rely on one insect species for pollination,and the insect may eat nectar（花蜜） from only that plant.

FIGURE IT OUT

1.When researchers experimentally excluded stream insects called caddis flies from submerged ceramic tiles,algae growth on the tiles was much higher than when caddis flies were present.This experiment tested the effects of ___on community structure.

a.predation b.herbivory c.camouflage d.mutualism

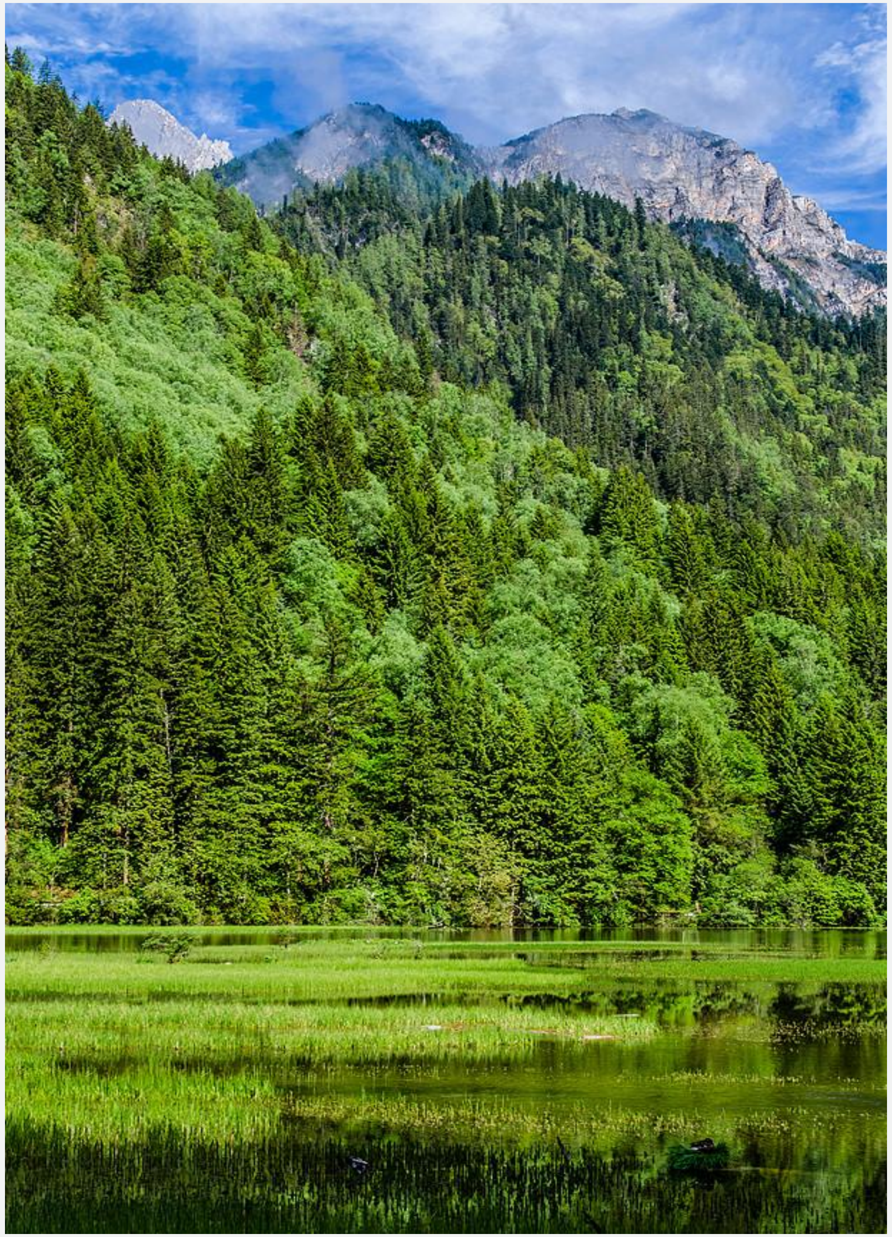
2.Some types of crabs live in clumps of coral.The crab defends its home,protecting the coral from sea stars and other predators.The interaction between crabs and corals is an example of

a.resource partitioning. b.competitive exclusion. c.commensalism. d.mutualism.

38.2 Succession Is a Gradual Change in a Community

- From oceans to mountaintops, many species share each habitat. One way to measure **species richness**（物种丰富度） is simply to count the species occupying a habitat. A patch of prairie,for instance,may contain about 100 plant species,whereas an equal-sized area of desert might house only 6 types of plants.In this example,the prairie has greater species richness than the desert.
- But two communities with the same species richness may not be equally diverse. **Species evenness**（物种均匀度）, or relative abundance, describes the proportion of the community that each species occupies.In our patch of prairie,for example,suppose that one type of plant accounts for 90% of the individuals in the community,with 99 species making up the remaining 10%. Because one species has such high relative abundance,that community is less diverse than one in which,say,each of the 100 species makes up1% of the community.
- **Succession（演替）is a gradual change in a community's species composition**. Ecologists define two major types of succession:primary and secondary.
- **Primary succession occurs in an area where no community previously existed.**When a volcano erupts,for example, lava（熔岩） may obliterate（抹杀） existing life,a little like suddenly replacing an intricate painting with a blank canvas.
- In contrast to primary succession,**secondary succession occurs where a community is disturbed but not destroyed.**Because some soil and life remain, **secondary succession occurs faster than primary succession.** Fires,hurricanes,and agriculture commonly trigger secondary succession.

38.2 Succession Is a Gradual Change in a Community



38.2 Succession Is a Gradual Change in a Community

- **Primary and secondary succession share a common set of processes. The first plants to arrive are usually opportunistic,with rapid reproduction and efficient dispersal.** These early colonists often alter the physical conditions in ways that enable other species to become established.**The new arrivals,in turn,continue to change the environment.** Some early colonists do not survive the new challenges, **further altering the community.** When pine trees invade a site,for example,they simultaneously shade out lower-growing plants while attracting species that grow or feed on pines.**Later in succession, the dominant species are usually long-lived,late-maturing,equilibrium species that are strong competitors in a stable environment.** A century ago,ecologists hypothesized that primary and secondary succession would eventually lead to a so-called **climax community**（顶级群落）,which is a community that remains fairly constant.We now know,however,that few (if any)communities ever reach true climax conditions.In the Pacific Northwest,for example,old-growth forests are500 to 1000 years old,yet they are still changing in their structure and composition.Major disturbances such as fire,disease,and severe storms can leave a mark that lasts for centuries.On a smaller scale,pockets of local disturbance,such as the area affected when a large tree blows over,create a patchy distribution of successional stages across a landscape.
- **Succession is not limited to land;it occurs in aquatic communities as well.** Wetlands often host spectacularly diverse assemblages of plants and animals that rely on the interface between land and water. Eventually,the wetland fills in completely and becomes dry land.

FIGURE IT OUT

A large tree falls over in an old-growth forest,allowing light to reach a formerly shaded area.A few weeks later,what types of rooted plants will dominate the open patch?

a.Lichens and mosses

b.Herbs and weeds

c.Large shrubs

d.Oak trees

38.3 Ecosystems Require Continuous Energy Input

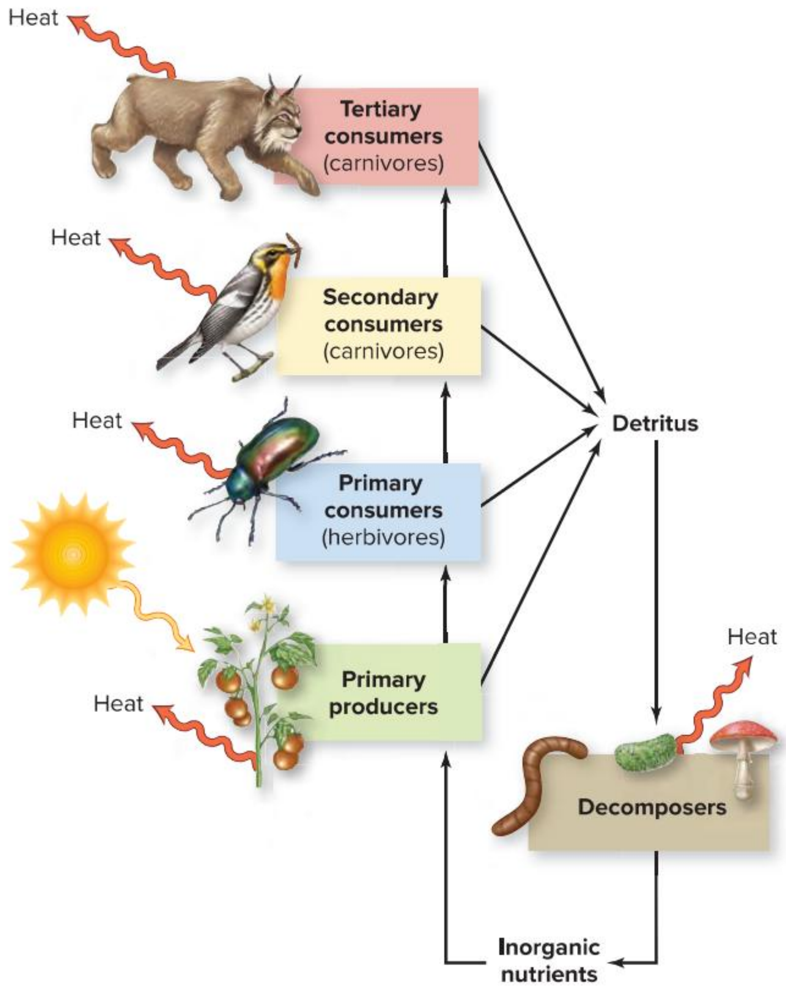


Figure 38.13 **Trophic Levels.** Producers are at the base of the food chain; consumers occupy the other trophic levels. All organisms contribute detritus (wastes and dead bodies) to the ecosystem. Decomposers are microbes that return the nutrients to their inorganic form, which producers absorb.

A. Food Webs Depict the Transfer of Energy and Atoms

- **Many energy and nutrient transfers occur in the context of food chains and food webs.A food chain is a linear sequence of feeding relationships**:A beetle eats a plant,a bird eats the beetle,and so on. Each organism's trophic level describes its position in the food chain.
- **Trophic levels（营养级） are defined relative to the ecosystem's energy source.The first trophic level in any food chain is a primary producer.A primary producer,or autotroph** (“self-feeder”), is any organism that can use energy,CO_2,H_2O,and other inorganic substances to produce all the organic material it requires. For most ecosystems,the energy source is sunlight. Plants, algae, cyanobacteria,and some other microorganisms are primary producers that use photosynthesis **to trap solar energy in the bonds of organic chemicals such as glucose.**Nevertheless,a few ecosystems rely on energy sources other than sunlight. For example, some bacteria and archaea are primary producers that can **extract energy from inorganic chemicals such as iron or manganese.**

38.3 Ecosystems Require Continuous Energy Input

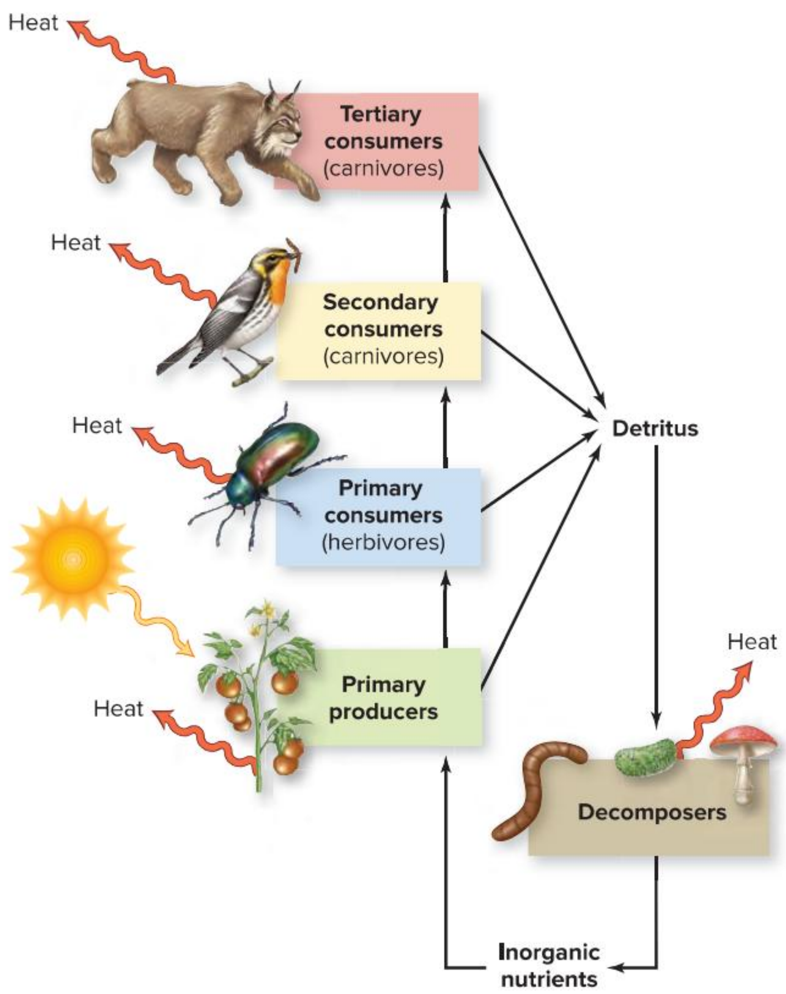


Figure 38.13 Trophic Levels. Producers are at the base of the food chain; consumers occupy the other trophic levels. All organisms contribute detritus (wastes and dead bodies) to the ecosystem. Decomposers are microbes that return the nutrients to their inorganic form, which producers absorb.

A. Food Webs Depict the Transfer of Energy and Atoms

- **All of the other trophic levels consist of consumers, or heterotrophs ("other eaters")**, which obtain energy either from producers or from other consumers. **The primary consumers are always herbivores,which eat the primary producers. Secondary consumers are carnivores (meat-eaters) that eat primary consumers,and tertiary consumers eat secondary consumers.**

- **All organisms leave behind detritus consisting of dead tissue and organic wastes such as feces.** Scavengers（食腐动物） are animals that eat this material. Vultures, crows, raccoons, flies, earth-worms,and many other animals are scavengers. **Decomposers（分解者）**, such as many fungi and bacteria,**are microbes that complete there cycling process**;they secrete enzymes that digest the remaining organic molecules in detritus（腐殖质）.**As they do so,they fuel their own growth and reproduction, but they also return carbon, nitrogen, phosphorus, and other inorganic nutrients to the environment.**Without these crucial microbes,dead bodies and organic wastes would tie up all useful nutrients,and ecosystems would grind to a halt.This chapter's Apply It Now box describes how **we employ decomposers in community wastewater treatment facilities.**

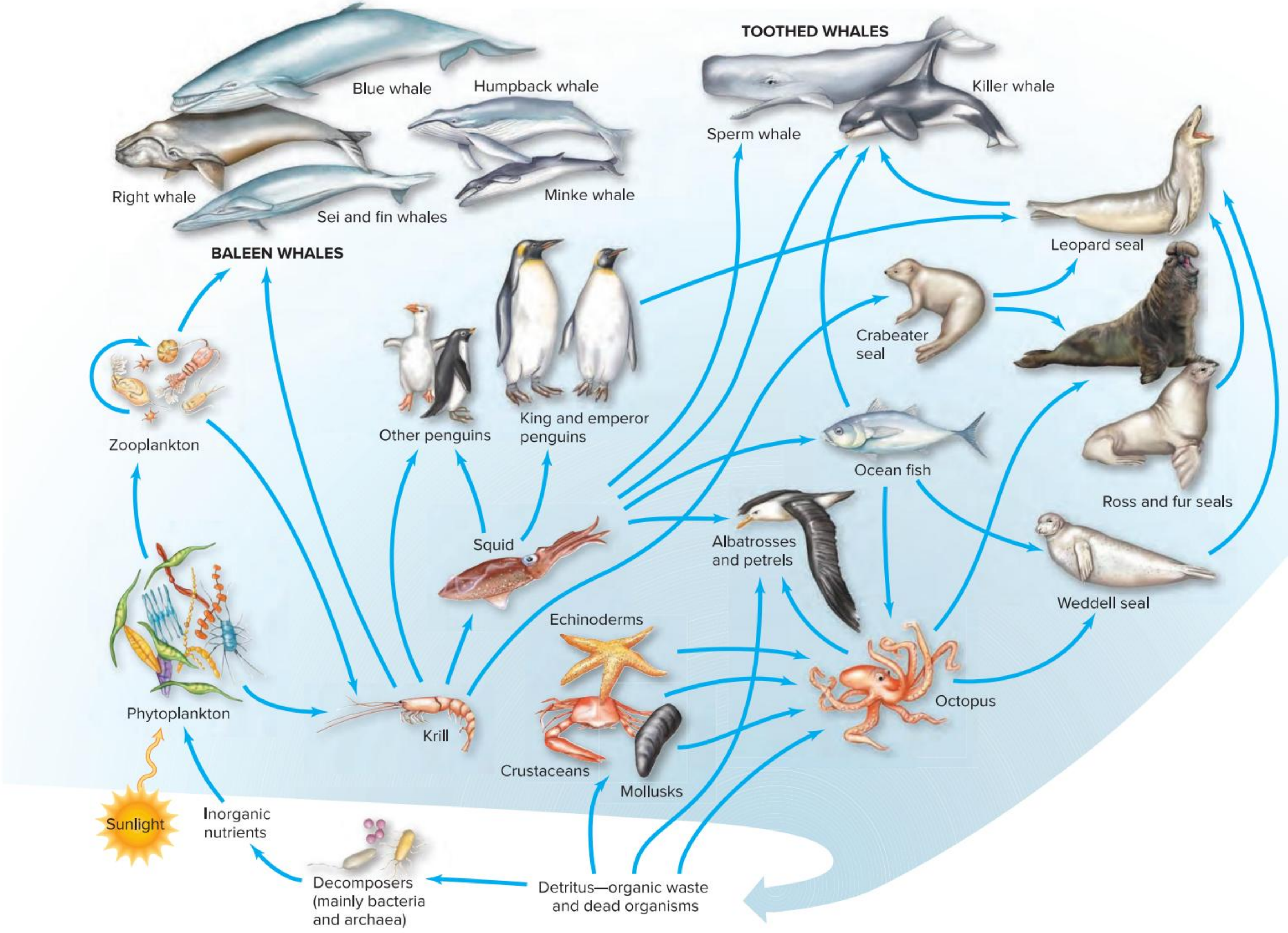


Figure 38.14 **Antarctic Web of Life.** The interactions among Antarctic residents form a complex network. Note that producers, consumers, and scavengers are all present, and that decomposers release inorganic nutrients that producers can use. For simplicity, heat is not illustrated.

FIGURE IT OUT

1. When you eat a carrot,you are acting as a(n)

a.heterotroph and primary consumer. **b.autotroph and herbivore.**

c.heterotroph and secondary consumer. **d.autotroph and primary producer.**

2 （T/F）

Autotrophs and decomposers have opposite roles in ecosystems.

3 （T/F）

Autotrophs are more critical to ecosystem function than decomposers.

3 （T/F）

A food chain is a network of interconnected food webs.

38.3 Ecosystems Require Continuous Energy Input

B. A Keystone Species（关键种） Has a Pivotal Role in the Community

- **Sometimes,many species in a community depend on one type of organism.**A kelp forest,for example, houses snails,shrimps,fishes,and many other species. Sea urchins（海胆） devour the kelp,and otters（海獭）eat sea urchins. Because otters keep sea urchins in check,their presence is critical to the entire community. The sea otter is a keystone species:**It makes up a small portion of the community by weight,yet its influence on community diversity is large. Note that keystone does not simply mean essential.**The grasses in a prairie are not keystone species because they make up the bulk of the community.

- **How do ecologists identify keystone species? One strategy is to measure what happens to a community after artificially removing each species,one at a time.** Using this method,researchers discovered that sea stars are keystone predators that maintain species diversity in tide pools.The sea stars normally prey on diverse invertebrates. Removing sea stars, however,allowed mussels and barnacles to take over,crowding out algae and other invertebrates.Without the keystone predator,the tide pools lost 7out of 15 species,and the community collapsed.

- **Many keystone species are predators,but mutualists may also be keystone species.**For example, mycorrhizal fungi（菌根真菌） help coniferous trees acquire nutrients from soil, and they produce underground fruiting bodies that small rodents eat.Owls and other predators hunt these small mammals.The fungi are considered keystone species because their small biomass is disproportionate to their enormous influence on community structure.

38.3 Ecosystems Require Continuous Energy Input

C.Heat Energy Leaves Each Food Web

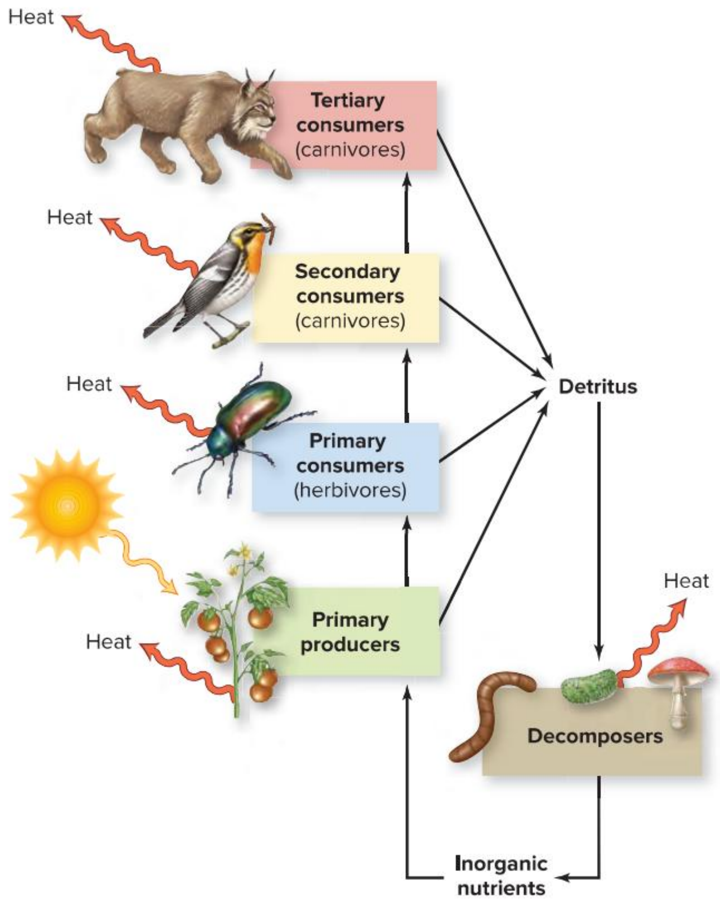


Figure 38.13 Trophic Levels. Producers are at the base of the food chain; consumers occupy the other trophic levels. All organisms contribute detritus (wastes and dead bodies) to the ecosystem. Decomposers are microbes that return the nutrients to their inorganic form, which producers absorb.

- The total amount of energy that is trapped,or "fixed,"by all autotrophs in an ecosystem is called **gross primary production**（初级生产总量）. Autotrophs use much of this energy in respiration,generating ATP for their own growth, maintenance, and reproduction. As they do so, they lose heat energy (the second law of thermodynamics explains this loss).**The remaining energy in the producer level** is called **net primary production**（净初级生产量）;**it is the amount of energy available for consumers to eat.**
- **Primary production varies widely across ecosystems on land,depending largely on temperature and moisture. In aquatic ecosystems,the availability of inorganic nutrients such as phosphorus is more important.**
- **Consumers also produce heat energy in every metabolic reaction.** Because of these inefficiencies, only a small fraction of the potential energy in one trophic level fuels the growth and reproduction of organisms at the next trophic level. **On average, about one tenth of the energy at one trophic level is available to the next rank in the food chain .** The"**10% rule**"provides a convenient estimate,but it ignores the fact that food quality varies widely.The transfer efficiency from one trophic level to the next actually ranges from about 2%to 30%. Eventually,as organic molecules pass from trophic level to trophic level,all of the stored energy leaves the food web in the form of heat.Thus,**energy flows through an ecosystem in one direction:from source (usually the sun), through organisms,to heat.For the ecosystem to persist,it must have a continual supply of energy.**If the energy source goes away,so does the ecosystem.

38.3 Ecosystems Require Continuous Energy Input

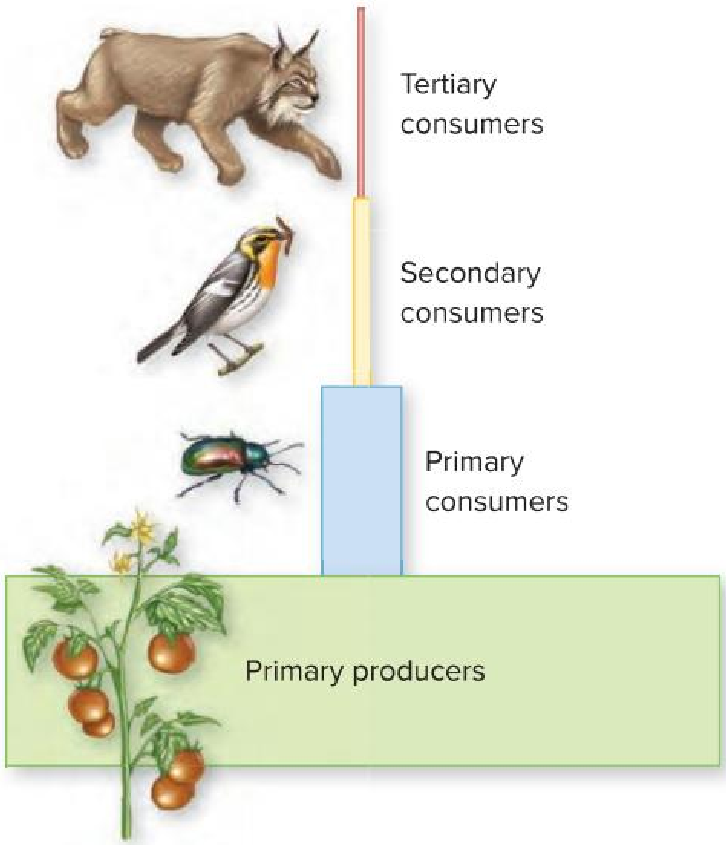


Figure 38.15 Pyramid of Energy. Each block depicts the amount of energy stored in each trophic level. This example assumes that an average of 10% of the energy in any trophic level is available to the next.

C.Heat Energy Leaves Each Food Web

- **A pyramid of energy** represents each trophic level as a block whose size is directly proportional to the energy stored in biomass per unit time.Because **every organism loses heat to the environment,the energy pyramid explains why food chains rarely extend beyond four trophic levels.**

- The loss of energy at each trophic level suggests a way to maximize the benefit we get from crops we grow for food.**The most energy available in an ecosystem is at the producer level.The lower we eat on the food chain,the more people we can feed.**

38.3 Ecosystems Require Continuous Energy Input

D.Harmful Chemicals May Accumulate in the Highest Trophic Levels

- The shape of the energy pyramid has another consequence for ecosystems.I**n biomagnification(生物放大), a chemical becomes most concentrated in organisms at the highest trophic levels.**
- **Biomagnification happens for pollutants and other chemicals that share two characteristics. First,they dissolve in fat. Animals eliminate water-soluble chemicals in their urine but retain fat-soluble chemicals in fatty tissues.Second,chemicals that biomagnify are not readily degraded.** A highly degradable chemical would not persist long enough in the environment to ascend food chains.Mercury is a persistent pollutant that illustrates biomagnification.Coal-fired power plants and mines release this element into the air and water. Moreover,many household products contain mercury that enters water, air, or soil via sewage treatment plants and incinerators. Imagine mercury entering water from a nearby power plant.Bacteria in the sediments soon convert the mercury into a fat-soluble form called methylmercury（甲基汞）.Its concentration in the water is initially low.But methylmercury that enters an organism’s body is not eliminated in urine or other watery wastes.As one animal eats another,all of the methylmercury stored in the prey ends up in the predator. Each predator eats many prey,so the mercury accumulates in the predator's tissues.In organisms at the fourth level of the food chain,mercury concentrations may be100,000 times greater than at the base of the food web.High levels of mercury have prompted health professionals to recommend that people limit their consumption of long-lived,carnivorous fish such as shark and tuna（金枪鱼）. Minamata release in Japan(日本水俣病).

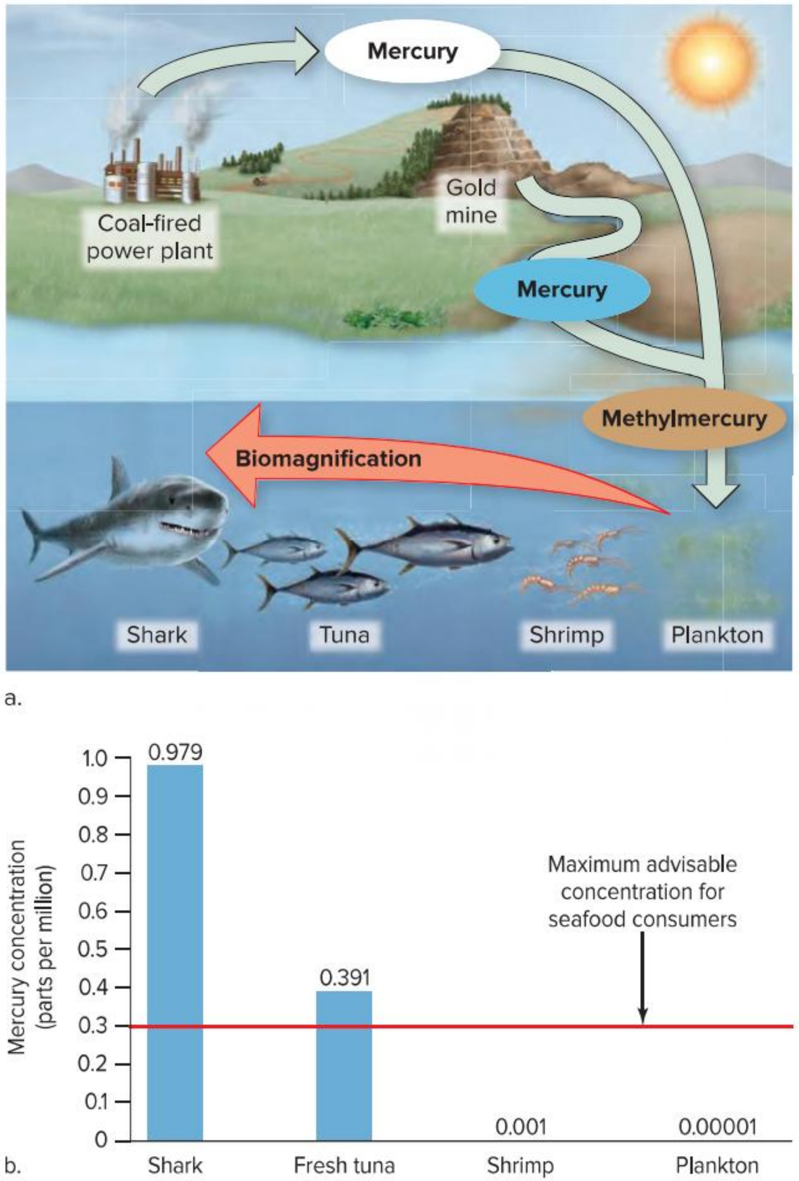


Figure 38.17 Biomagnification. (a) Power plants and gold mines are among the main sources of mercury pollution. Mercury is converted to methylmercury in sediments; after entering the food chain, the methylmercury concentration increases with each successive trophic level. (b) Concentrations of mercury in shark meat, tuna, and shrimp vividly illustrate biomagnification.

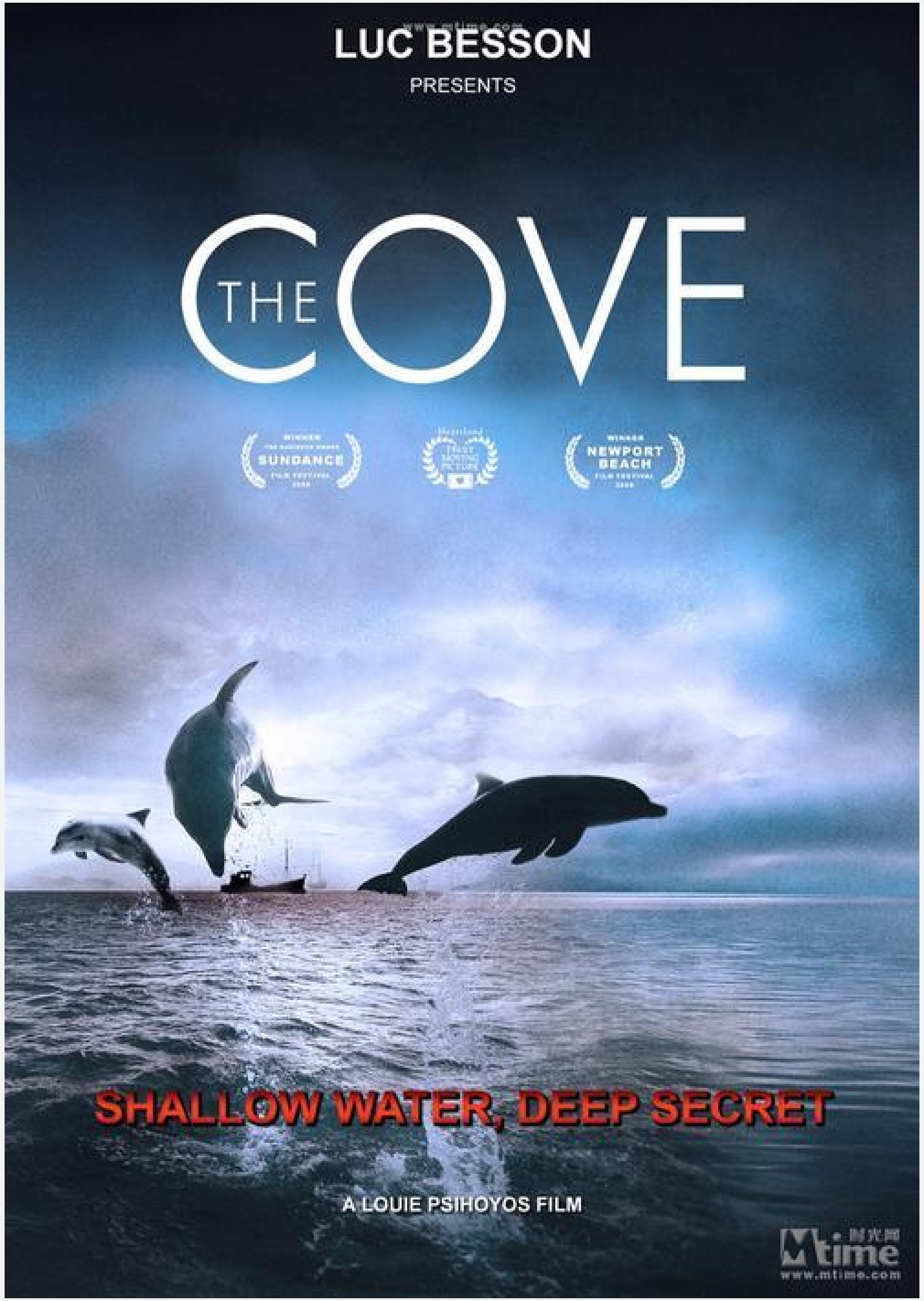


FIGURE IT OUT

1.In a prairie,which trophic level should have the highest biomass?

a.Predatory birds b.Grasses c.Seed-eating rodents d.Soil fungi that decompose organic matter

2.Refer to the food web in figure 38.14. If krill were to disappear from the ecosystem,what species would most likely become more abundant?

a.Phytoplankton b.Penguins c.Squid d.Toothed whales

3.Consult the food web in figure 38.14.Assuming the 10% rule is correct, about how many kilograms of krill would it take to support one 40-kilogram emperor penguin?

a.4 kg b.400 kg c.4000 kg d.40000kg

4. WRITE IT OUT

What are the two characteristics that pollutants and other chemicals share in Biomagnification ?

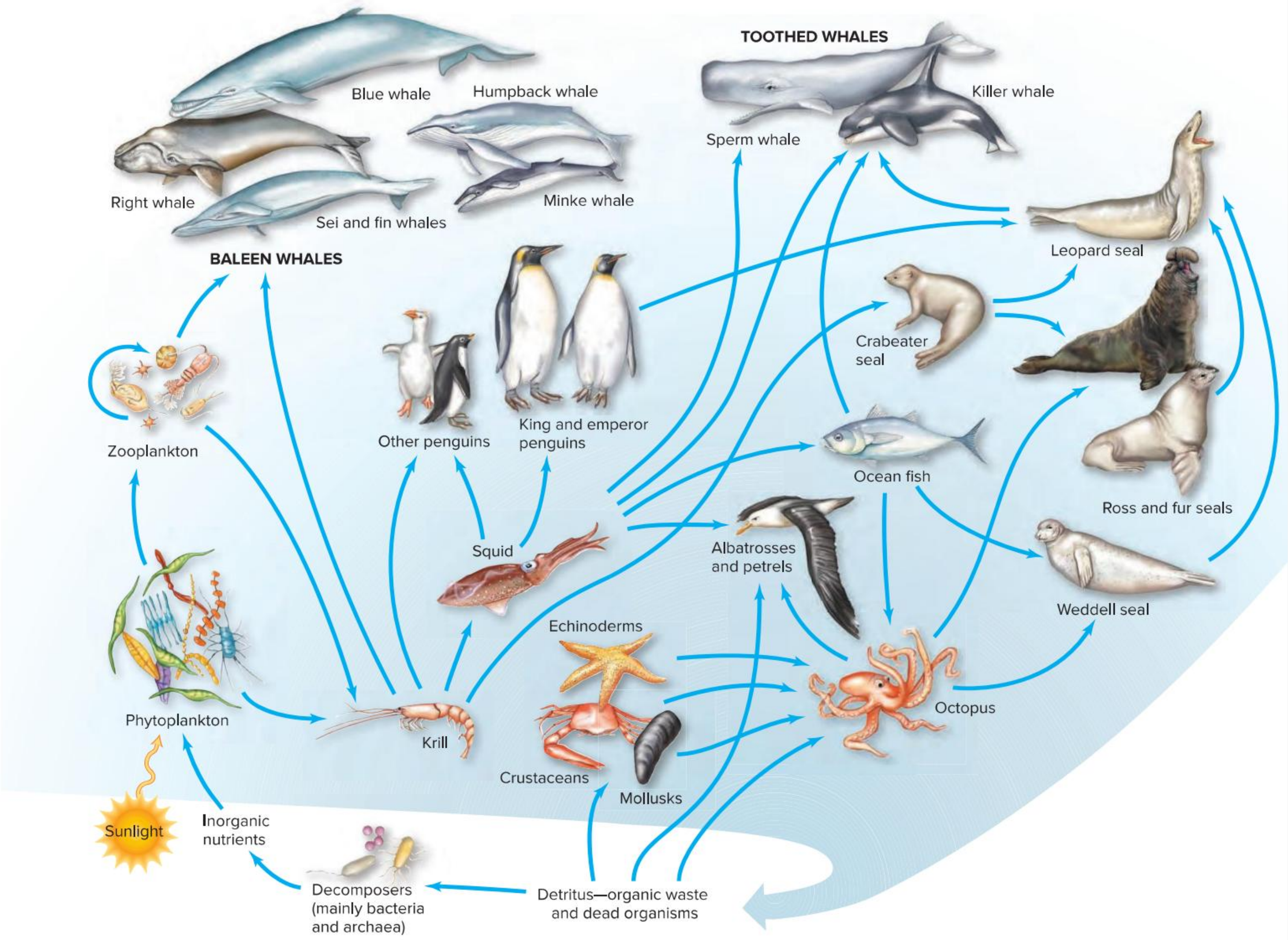


Figure 38.14 **Antarctic Web of Life.** The interactions among Antarctic residents form a complex network. Note that producers, consumers, and scavengers are all present, and that decomposers release inorganic nutrients that producers can use. For simplicity, heat is not illustrated.

38.4 Chemicals Cycle Within Ecosystems

- Energy flows in one direction,but all life must use the elements that were present when Earth formed. **In biogeochemical cycles,interactions of organisms and their environment continuously recycle these elements.**If not for this worldwide recycling program, supplies of essential elements would have been depleted as they became bound in the bodies of organisms that lived eons ago.
- **Whatever the element,all biogeochemical cycles have features in common**(figure 38.18).Each element is distributed among four major storage reservoirs: organisms, the atmosphere, water,and rocks and soil. Depending on the reservoir, the element may combine with other elements and form a solid,liquid,or gas.

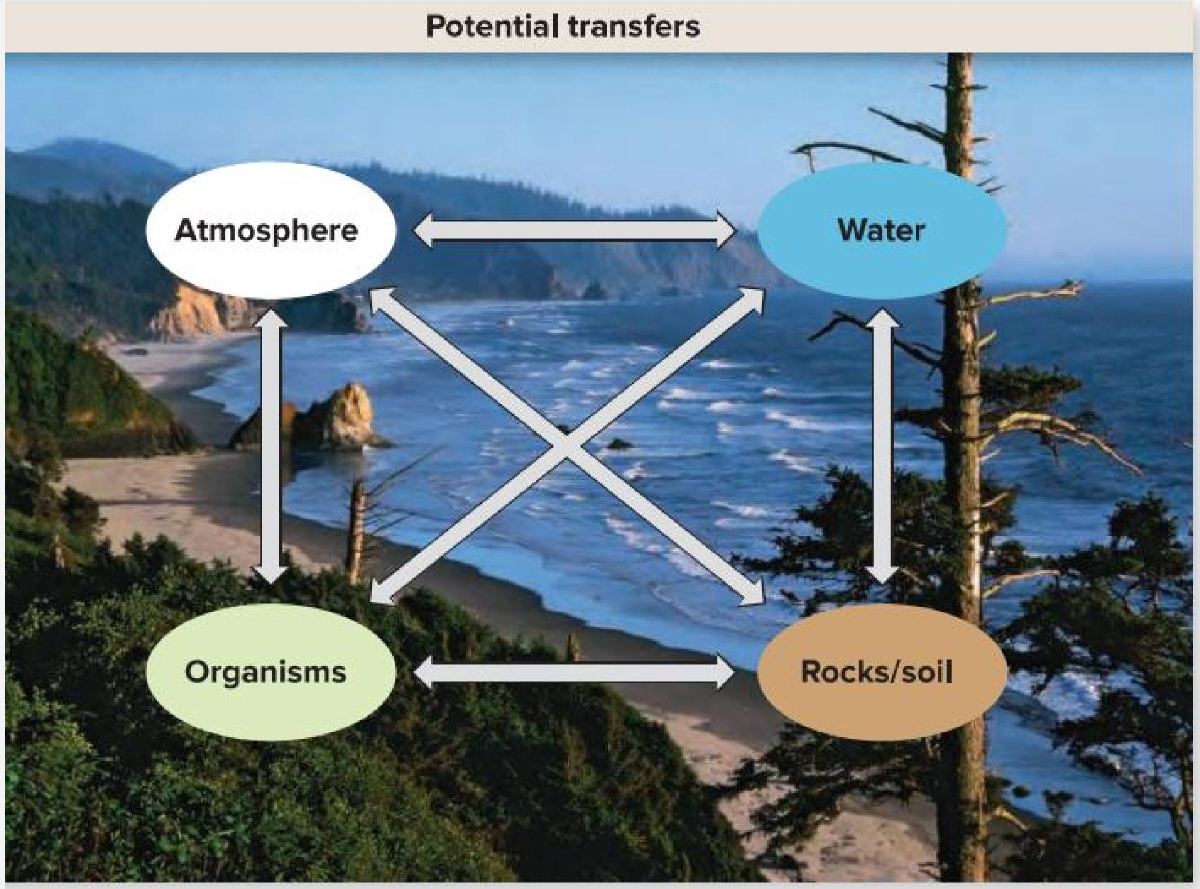


Figure 38.18 Biogeochemical Cycle. Water and inorganic nutrients cycle among four basic storage reservoirs: the atmosphere, water, organisms, and rocks and soil. A coastal ecosystem illustrates all four.

Photo: ©Corbis RF

38.4 Chemicals Cycle Within Ecosystems

A.Water Circulates Between the Land and the Atmosphere

- Water covers much of Earth's surface,primarily as oceans but also as lakes, rivers, streams, ponds, swamps, snow, and ice. Water also occurs below the land surface as groundwater.
- **The main processes that transfer water among these major storage compartments are evaporation,precipitation,runoff,and percolation**.The sun's heat evaporates water from land and water surfaces (step 1).Water vapor rises on warm air currents,then cools and forms clouds (step 2).If air currents carry this moisture higher or over cold water, more cooling occurs,and the vapor condenses into water droplets that fall as rain, snow,or other precipitation (step 3).Some of this precipitation falls on land, where it may run along the surface.Streams unite into rivers that lead back to the ocean (step 4),where the sun's energy again heats the surface,continuing the cycle.Rain and melted snow may also soak (percolate)into the ground, restoring soil moisture and groundwater (step 5). This underground water feeds the springs that support many species.Spring water evaporates or flows into streams,linking groundwater to the overall water cycle.

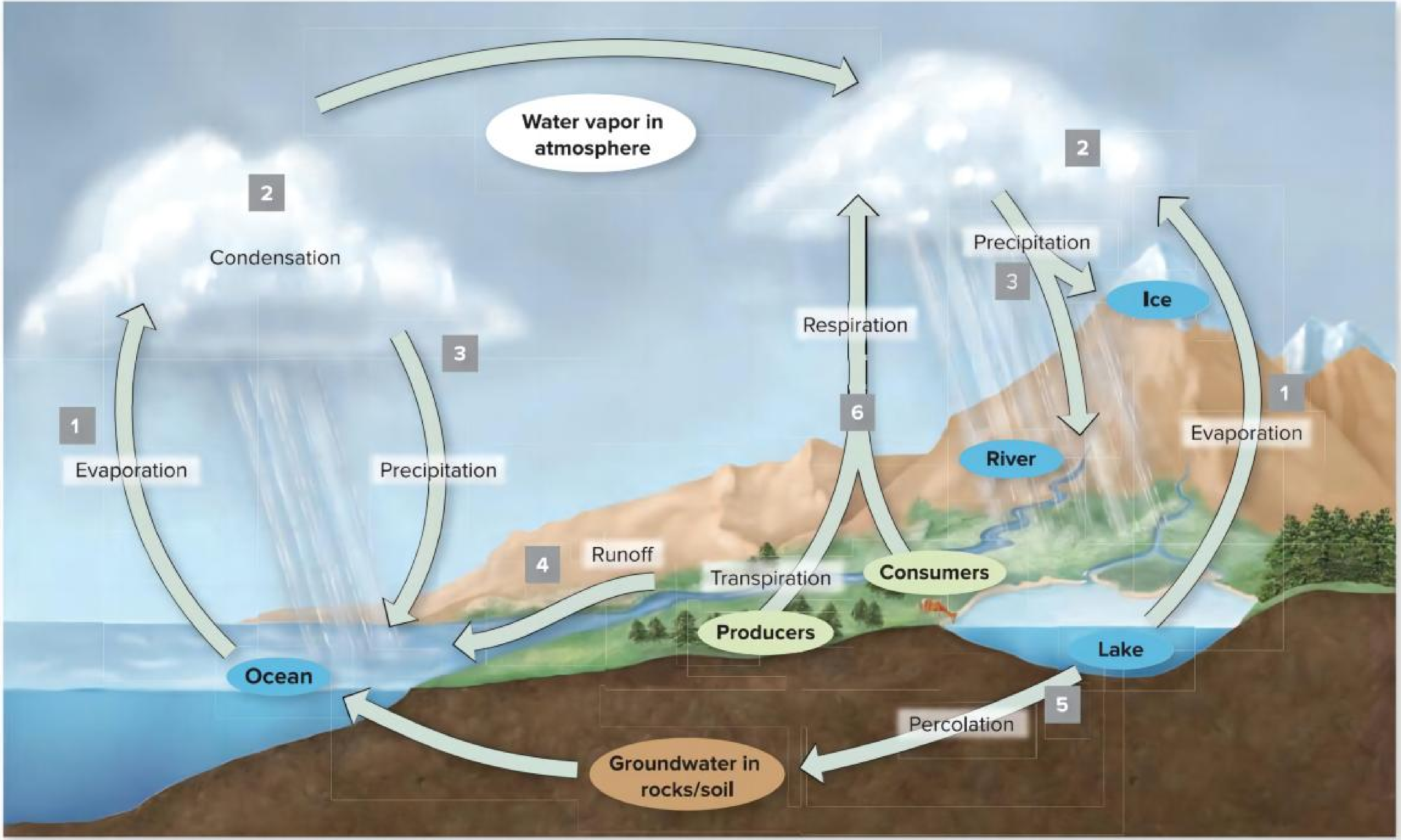


Figure 38.19 **The Water Cycle.** Water falls to Earth as precipitation. Organisms use some water, and the remainder evaporates, runs off into streams and the ocean, or enters the ground. Transpiration and respiration return water to the environment.

38.4 Chemicals Cycle Within Ecosystems

B.Autotrophs Obtain Carbon as CO_2

- **Carbon is a part of all organic molecules,and organisms continually exchange it with the atmosphere.Autotrophs absorb atmospheric CO_2 and use photosynthesis to produce organic compounds,**which they incorporate into their tissues(step 1).**Cellular respiration releases carbon back to the atmosphere as CO_2** (step 2).**Dead organisms and wastes contribute organic carbon to soil or water**(step 3). **Bacteria and fungi decompose these organic compounds and release CO_2 to the soil, air,and water as they respire** (step 4).Some types of archaea also participate in the carbon cycle by metabolizing organic compounds and releasing methane (CH_4)into the atmosphere. Most of these microbes live in anaerobic habitats such as wetlands,marine sediments,and the intestines of humans, cattle,and other animals.The exchange of carbon between organisms and the environment is relatively rapid, but more stable pools of carbon also exist.A substantial fraction of soil carbon consists of persistent, decay-resistant organic matter called humus(腐殖质). Limestone（石灰石）consists mostly of the calcium carbonate exoskeletons and shells of ancient sea inhabitants.In addition,**fossil fuels such as coal and oil formed long ago from the remains of dead organisms**(step 5).**When these fuels burn**(step 6), carbon returns to the atmosphere as CO_2.Decades of accumulation of CO_2 and other greenhouse gases in the atmosphere are likely responsible for Earth's gradually warming climate.**One of the largest reservoirs of carbon is the ocean.$CO_2$from the atmosphere dissolves in ocean water.** Most of the dissolved gas reacts with the water to form **carbonic acid(H_2CO_3)**. **Some of this carbon reacts with calcium to form calcium carbonate, which precipitates into sediments on the ocean floor** (step 7).These sediments are one of the major stable repositories of carbon.

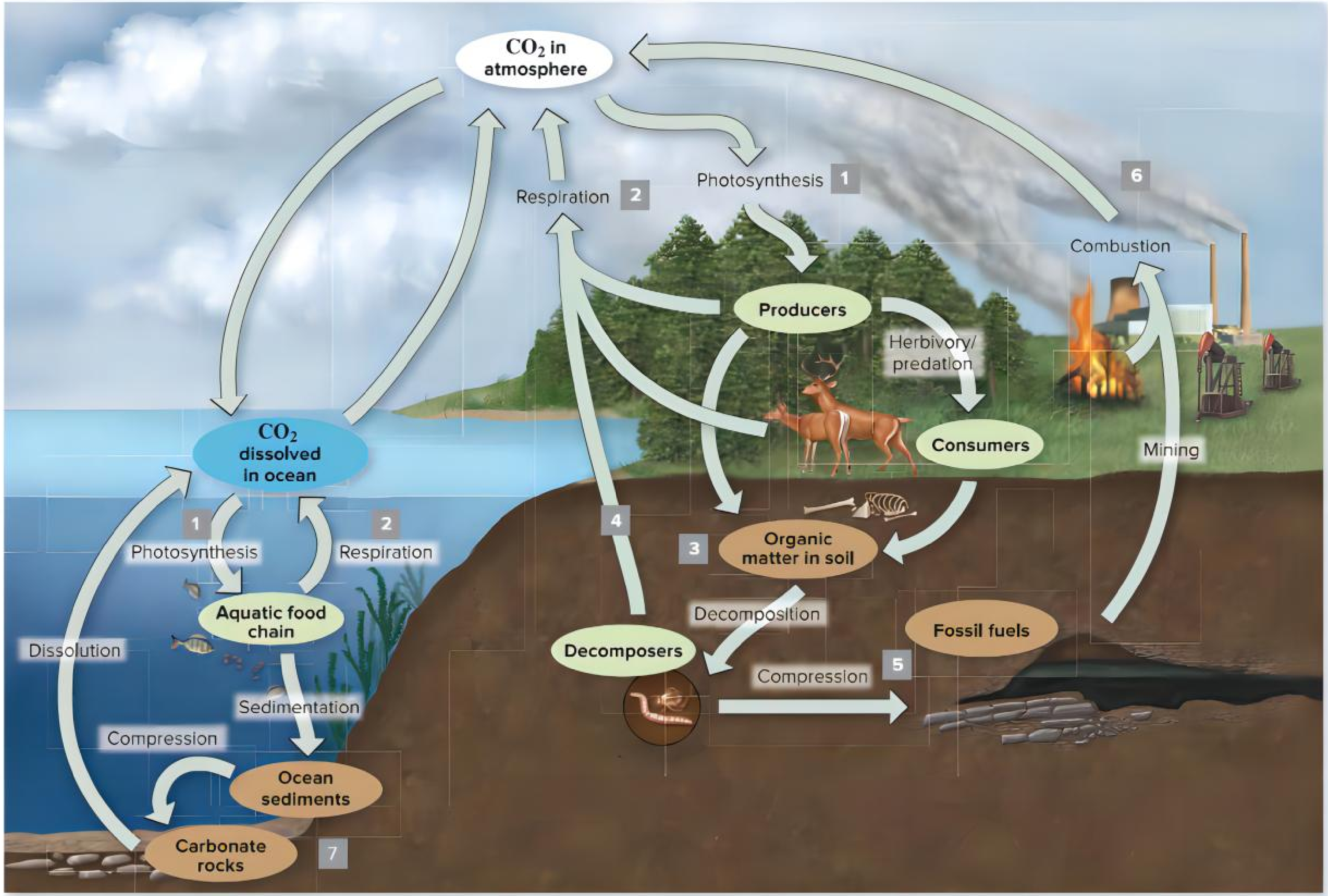


Figure 38.20 **The Carbon Cycle.** Carbon dioxide (CO_2) in the air and water enters ecosystems through photosynthesis and then passes along food chains. Respiration and combustion return carbon to the abiotic environment. Carbon can be retained for long periods in carbonate rocks and fossil fuels. The archaea that produce methane (CH_4) are omitted from the cycle for simplicity.

38.4 Chemicals Cycle Within Ecosystems

C.The Nitrogen Cycle Relies on Bacteria

- Nitrogen is an essential component of proteins,nucleic acids,and other biochemicals in living cells.Although the atmosphere is about 78%nitrogen gas (N_2),most organisms cannot use this form of nitrogen.The nitrogen cycle therefore depends on **nitrogen fixation**,the process by which some bacteria and archaea convert N_2 into ammonium ions, NH_4^+(step 1).Examples of nitrogen-fixing bacteria include Rhizobium,which lives in nodules on the roots of legume plants such as beans,peas,and clover.Many farmers alternate nonlegume crops,with legumes to enrich the soil with biologically fixed nitrogen.In addition,farmers often boost plant growth by applying nitrogen fertilizers to their fields (step 2).Fertilizer production relies on an industrial-scale form of nitrogen fixation.**Nitrogen can also occur in the form of nitrate (NO_3^-).**In a process called **nitrification**（硝化作用）,bacteria and archaea convert ammonium to nitrate (step 3).This process occurs both in soil and in the ocean.In addition,**the combustion of fossil fuels** such as coal,oil,and natural gas **releases NO_2gas and other nitrogen oxides into the atmosphere** (step 4).These compounds dissolve in precipitation;in soil,they are converted to nitrate.Excess nitrogen deposition from the atmosphere may be altering some low-nitrogen ecosystems.**Plants and other autotrophs can absorb either ammonium or nitrate and incorporate it into the organic molecules that make up their own bodies** (step 5).**Consumers then acquire the nitrogen by eating the producers** (step 6),and so on up the food chain.**Decomposers release some ammonia when they decay the dead bodies and wastes** (step 7).
- Yet another group of microbes completes the cycle.**Indenitrification,bacteria and archaea return nitrogen to the atmosphere as they convert nitrate to N_2**(step 8).This process are called **denitrification**（反硝化作用）,which is a form of anaerobic respiration, occurs where O_2 is scarce,such as wetlands, water-saturated soils, groundwater, and ocean sediments.

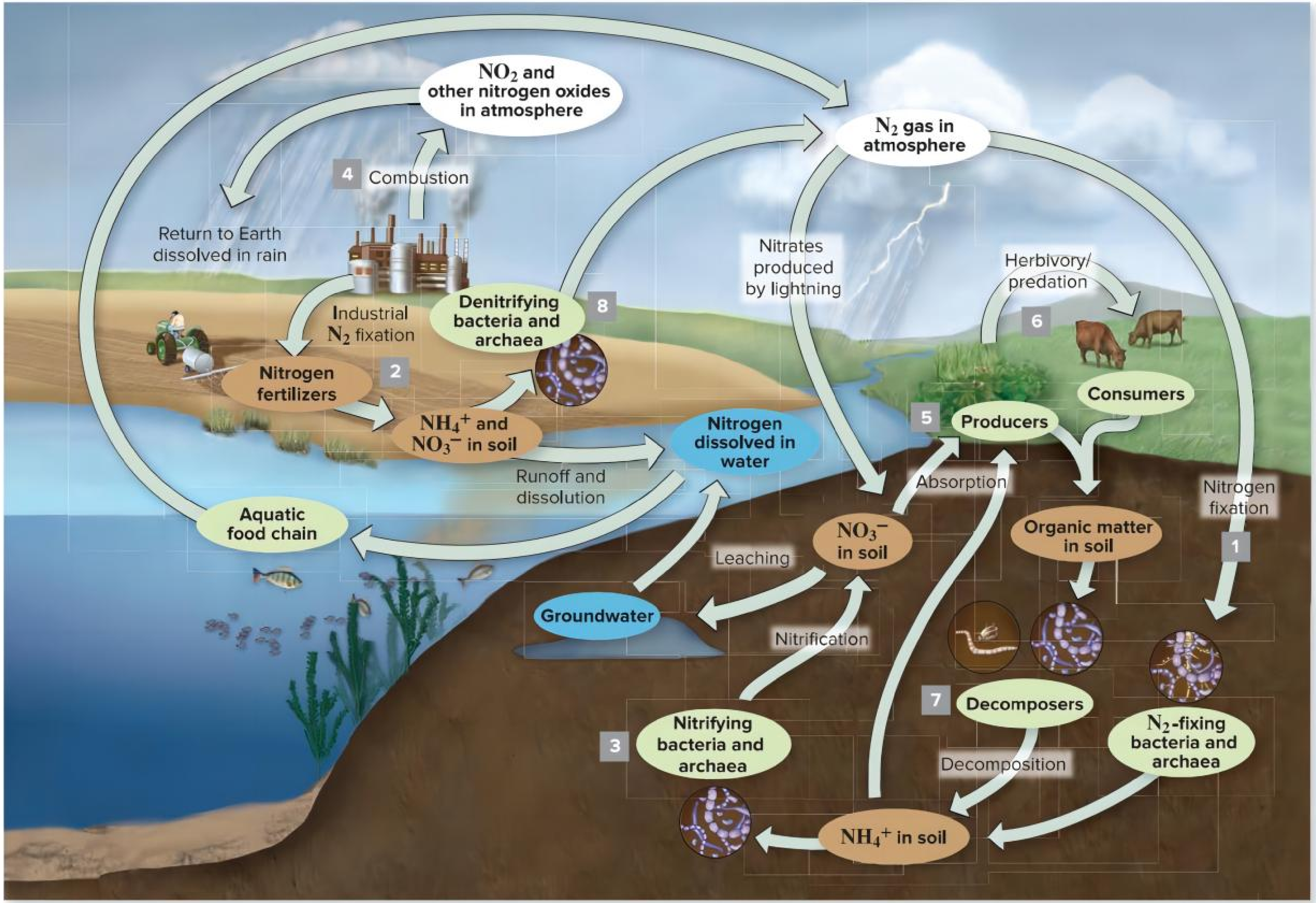


Figure 38.21 **The Nitrogen Cycle.** Nitrogen-fixing bacteria and archaea convert atmospheric nitrogen gas (N_2) to ammonium ions (NH_4^+), which plants can absorb. Nitrogen returns to the abiotic environment in urine and during the decomposition of organic matter. Bacteria and archaea convert ammonium to nitrate, NO_3^- (another form plants can use). Microbes also convert nitrate to N_2, completing the cycle.

38.4 Chemicals Cycle Within Ecosystems

D.The Phosphorus Cycle Begins with the Erosion of Rocks

- Phosphorus occurs in nucleic acids,ATP,and membrane phospholipids ;in vertebrates,this element is also a major component of bones and teeth.
- Unlike in the carbon and nitrogen cycles,the atmosphere plays little role in the phosphorus cycle. Instead, the main storage reservoirs for phosphorus are marine sediments and rocks. As **phosphate-rich rocks erode,they gradually release phosphate ions (PO_4^{-3})into water** (step 1).
- Many soils,however,are relatively low in phosphorus;a deficiency of this element often limits plant growth. **Humans therefore mine phosphate rocks to produce plant fertilizers**(step 2). However,too much phosphorus can damage an ecosystem.
- **Autotrophs absorb phosphorus,often with the help of mycorrhizal fungi** (step 3).**Consumers move the element throughout the food web** (step 4), and **decomposers eventually return inorganic phosphates to soil and water** (step 5).**Much of the phosphate,however,joins the sediments raining down onto the ocean floor** (step 6).**After many millions of years,geological uplift returns some of this underwater sedimentary rock to the land**(step 7).

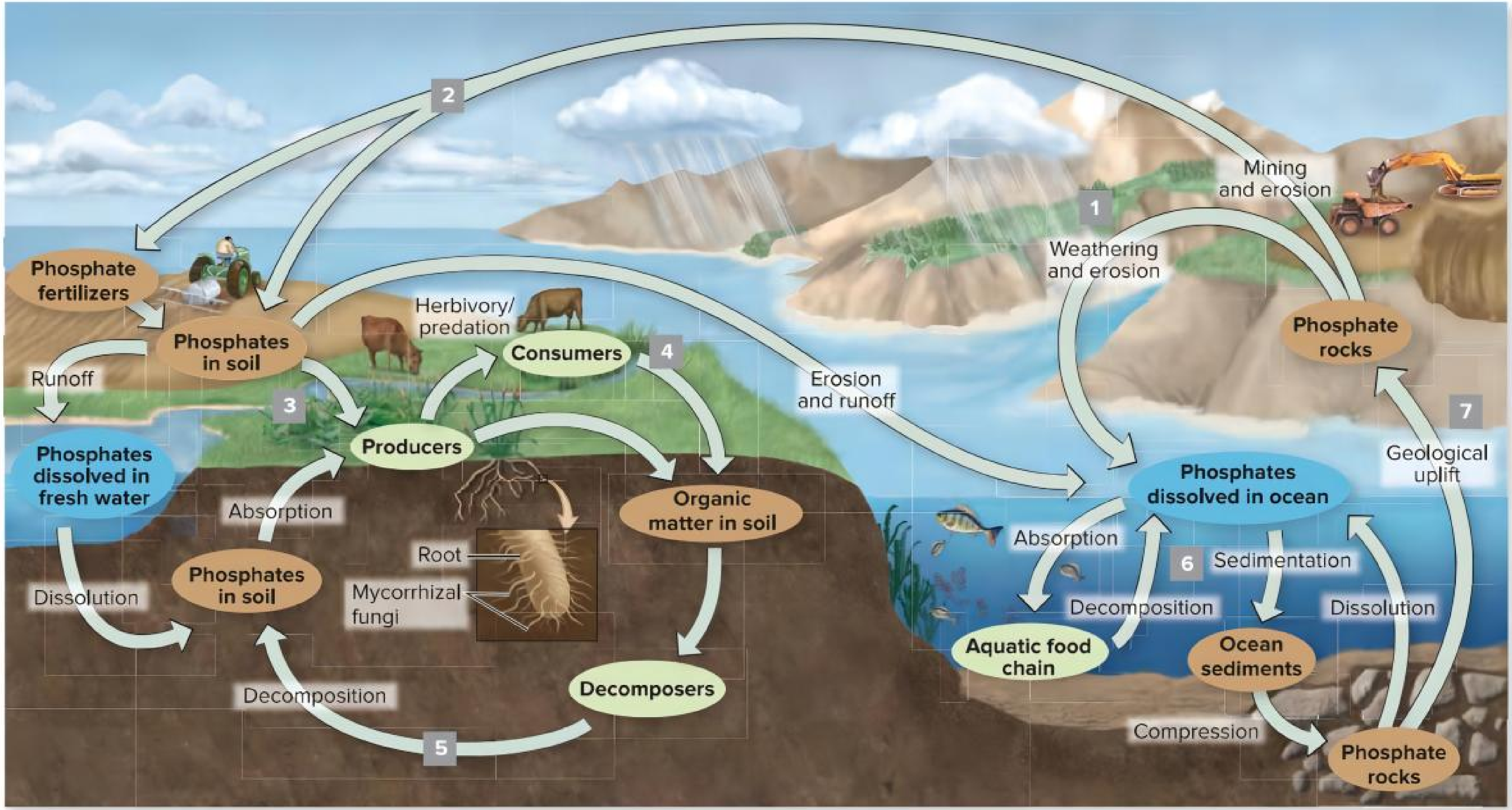


Figure 38.22 **The Phosphorus Cycle.** As phosphate-rich rocks erode, they release phosphorus that plants can absorb and pass to the rest of the food chain. Decomposers return phosphorus to the abiotic environment. Fertilizers have increased phosphorus availability to both terrestrial and aquatic organisms.

38.4 Chemicals Cycle Within Ecosystems

E.Excess Nitrogen and Phosphorus Cause Problems in Water

- Nitrogen and phosphorus are essential to life;in fact,deficiencies of these nutrients typically limit the growth of algae and other primary producers in aquatic ecosystems.Extra nutrients can therefore alter the ecological balance in water.
- For example,sewage and fertilizers carry nitrogen and phosphorus into waterways.In a process called eutrophication（富营养化）, these nutrients trigger the rapid growth of algae and other phytoplankton.in the water .At first,photosynthesis by these producers releases O_2into the upper water column.But when they die, their bodies sink from the surface to deeper waters, where microbes decompose their dead bodies. Cellular respiration by the decomposers depletes dissolved O_2 in the water.Without O_2, most fish and other animals cannot survive. Eutrophication is therefore associated not only with algae blooms but also with massive fish kills. Moreover,some algae release toxins.

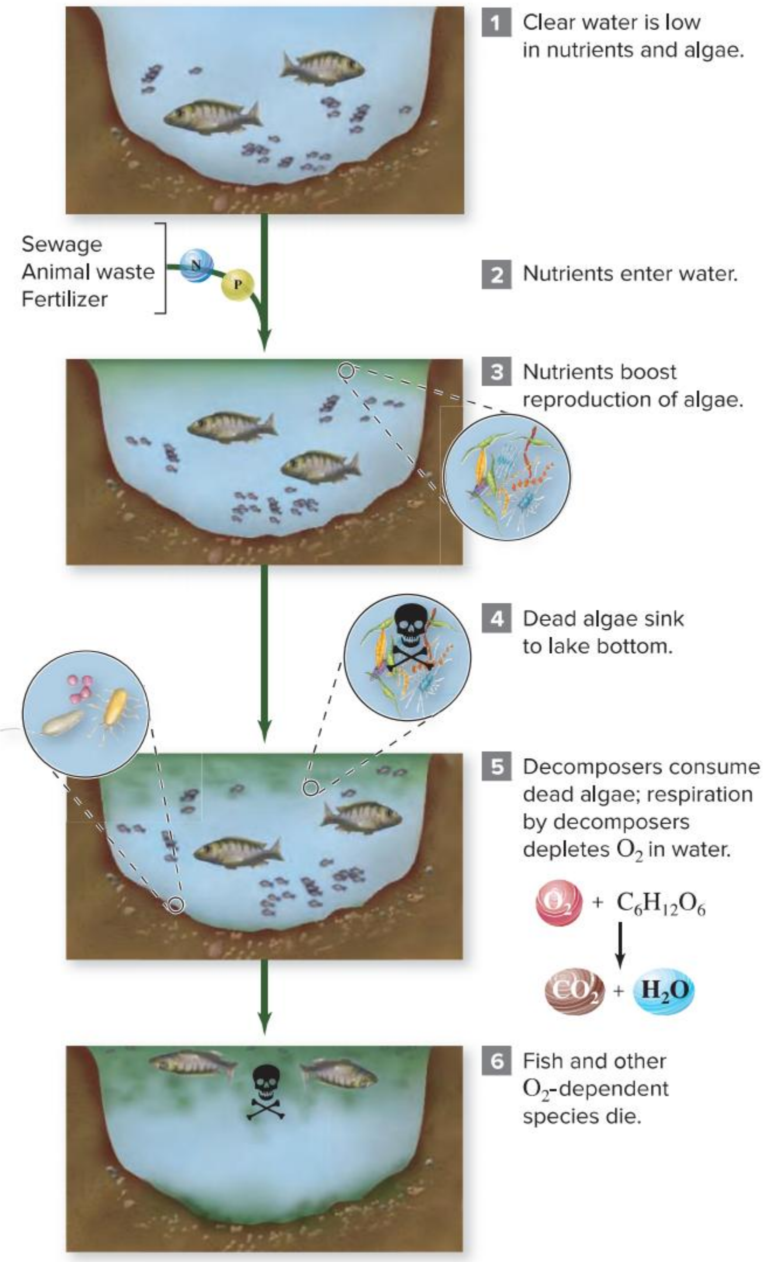


Figure 38.23 Eutrophication. Excess nitrogen and phosphorus trigger algae blooms. After the algae die, decomposers consume their bodies and deplete dissolved oxygen in the water.

38.4 Chemicals Cycle Within Ecosystems

F.Terrestrial and Aquatic Ecosystems Are Linked in Surprising Ways

- **Sometimes,nutrients in an ecosystem can come from unexpected sources**.Consider,for example,a mountain stream in Alaska.The eggs of Alaska salmon hatch in the stream bed,and over the next year or so, the hatchlings develop into juveniles as they make their way to the mouths of their home rivers. As they trans-form into adults,their bodies adjust to seawater,and the fish swim into the Pacific Ocean.They spend as many as 4 years in the ocean,eating crustaceans and small fish.During this portion of their life cycle,the salmon(and their prey)ultimately rely on nutrients that well up from the ocean bottom.
- Eventually,the fully grown salmon readjust to fresh water and swim upstream,back to the same waters where they hatched.As they make their way to their home streams to spawn,their bodies carry nutrients from the ocean to the heart of Alaska.Bears and eagles feast on the salmon,and decomposers consume there mains.The nutrients they release support the growth of algae,which form the foundation of the stream's food chain.Moreover,the bears and eagles may carry their prey away from the stream.The salmon's nutrients—originally from the ocean—end up fertilizing faraway grasses and trees.The adult salmon therefore form a link between the biogeochemical cycles of the ocean and the land.

Figure 38.24 Fish Feast. Sockeye salmon contain nutrients from the sea; a brown bear carries these nutrients from water to land.

(fish): ©Jeff Mondragon/Alamy; (bear): ©Digital Vision/Getty Images RF

FIGURE IT OUT

1.Which cycle relies the least on decomposers?

a.Carbon cycle

b.Phosphorus cycle

c.Water cycle

d.Nitrogen cycle

HOME WORK

Describe the biogeochemical cycle of water/carbon/nitrogen/phosphorus.