(Text from Modern Biology, Holt, Rinehart, and Winston)

Chapter Eighteen (Introduction to Ecology)

SECTION ONE: INTRODUCTION TO ECOLOGY

Ecology is the study of the interactions between organisms and the living and nonliving components of their environment.

INTERDEPENDENCE: A KEY THEME IN ECOLOGY

Organisms and Their Environments

All organisms interact with other organisms in their surroundings and the nonliving portion of their environment. Their survival depends on these interactions. The **interdependence** or *interconnectedness* of organisms refers to the fact that all organisms need another for survival, and that each organism plays an important role in nature.

Interdependence can be seen through the relationship between plants and animals. Plants provide oxygen for the animals, and animals provide carbon dioxide gas for the plants.

Effects of Interdependence

As a result of interdependence, any change in the environment can spread through the network of interactions and affect organisms that appear far removed from the change. The removal of any organism will undoubtedly affect the others.

For example, the spraying of poisonous pesticides on leaves can be harmful to birds such as robins. Since robins do not eat leaves, this may seem to be unrelated. However, leaves sprayed with the chemicals eventually fall to the ground and become leaf litter. This leaf litter is ingested by earthworms, and the poison becomes stored in their bodies. Eating a number of these earthworms will be fatal to a robin.

ECOLOGICAL MODELS

By using **ecological models**, ecologists represent the components of an ecological system so as to make it easier to study. A model may be physical, conceptual, or mathematical. Models are used to help plan and evaluate solutions to environmental problems.

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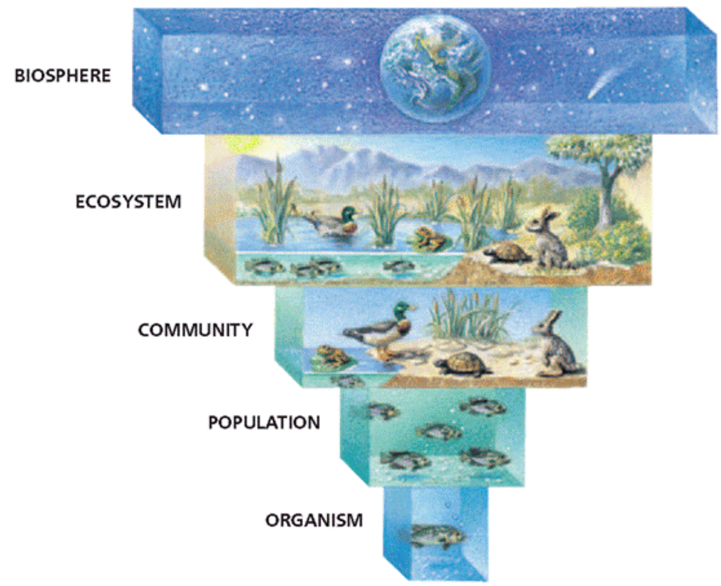
LEVELS OF ORGANIZATION



As previously discussed, scientists recognize a hierarchy of different levels of organization within organisms. Likewise, ecologists recognize a hierarchy of organization in the environment. Although a complete study of ecology would look at all levels, for practical reasons, ecologists often focus their research on one level of organization while realizing that each level is influenced at another.

The Biosphere

The broadest level of organization is the **biosphere**, the thin volume of Earth and its atmosphere that supports life. All organisms are found within the biosphere. This extends to the deepest part of the ocean and about 5 to 6 miles above Earth's surface.

Ecosystems

The biosphere is composed of smaller units called **ecosystems**, which include all of the organisms and the nonliving environment found in a particular place. For example, all the organisms living in a pond are part of their ecosystem. Also, the levels of dissolved oxygen in the pond, the pH, supply of nitrogen, and level of sunlight received are part of the ecosystem.

Communities, Populations, and Organisms

A **community** is all the interacting organisms living in an area. Although a community is more exclusive than an ecosystem, it is still very complex and may contain thousands of species. Below this level is the **population** level, where the focus is on the members of a single species that are living in one place at one time. The simplest level of organization in ecology is that of the organism.

SECTION 1 REVIEW

1. Explain why interdependence is an important theme in ecology.
2. Describe one example of the effects of interdependence upon organisms in their environment.
3. Why are models used so often in the science of ecology?
4. How does a population differ from a community?
5. Define the term *biosphere*.
6. List the five main levels of organization in ecology.

CRITICAL THINKING

7. Assuming wolves eat deer, how could a disease that kills a large portion of the wolf population affect the mice population in a forest ecosystem?
8. Why is the amount of sunlight important to the animals in an ecosystem?
9. Would bacteria that inhabit a cave deep inside Earth be considered part of the biosphere? Explain.

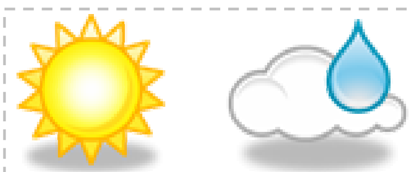
SECTION TWO: ECOLOGY OF ORGANISMS

The place where an organism lives is its **habitat**.

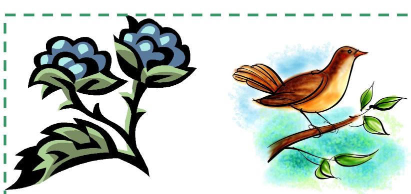
ECOSYSTEM COMPONENTS

Ecologists separate the environmental factors that influence an organism into biotic and abiotic factors. The living components of the environment are called **biotic factors**, and include all living things that affect the organism. The nonliving factors, **abiotic factors**, are the physical and chemical characteristics of the environment.

<u>Biotic and Abiotic Factors</u>



Abiotic Factors



Biotic Factors

Abiotic factors include temperature, humidity, pH, salinity, oxygen concentration, availability of nitrogen, precipitation, and amount of sunlight. The importance of each factor varies in each environment. Abiotic and biotic factors are changed by the organisms living in the environment – for example, the availability of nitrogen can reduce the speed of growth for plants, and plants affect nitrogen availability.

Additionally, abiotic factors vary from place to place and over time. Temperature is an example of a changing abiotic factor, as it varies from hour to hour, from season to season, and from place to place.

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ORGANISMS IN A CHANGING ENVIRONMENT

Each organism is able to survive within a limited range of environmental conditions. For example, an organism could be able to function only within a certain temperature range. By measuring how efficiently an organism performs at different temperatures, this range can be determined. A **tolerance curve** is a graph of performance versus values of an environmental variable.

Acclimation

Some organisms can adjust their tolerance to abiotic factors through the process of **acclimation**. For example, goldfish raised at different temperatures will have different tolerance curves.

Control of Internal Conditions

Since the environment fluctuates in several ways, organisms must be able to cope with such changes to survive. **Conformers** are organisms that do not regulate their internal conditions; they change as their external environment changes. Cold-blooded creatures such as reptiles could be considered conformers, since their temperature changes as the external temperature changes. **Regulators** are organisms that use energy to control some of their internal conditions to keep them in the optimal range over a variety of environmental conditions. Warm-blooded creatures such as mammals and birds exert energy to keep their interior temperature constant, and are regulators.

Escape From Unsuitable Conditions

Some species can survive unfavorable environmental conditions by escaping from them temporarily. Desert species are often inactive during the day and active during the night in order to avoid the high temperatures during the daytime. A longer-term strategy is to enter a state of **dormancy**, reduced activity, during periods of unfavorable conditions. Another strategy is to move to a more favorable habitat, called **migration**.

THE NICHE

Species do not use or occupy their entire habitat at once. The specific role of a species within its environment is its **niche**, which includes the range of conditions that the species can tolerate, the resources it uses, and other interactions with its environment. For example, a squirrel can fill a niche by scattering seeds throughout a forest.

Generalists are species with broad niches that can tolerate a range of conditions and use a variety of resources. One such organism is the Virginia opossum, which is scattered across most of the United States. The opossum feeds on almost anything. In contrast, **specialists** have narrow niches. One example is the giant panda, who feeds almost exclusively on bamboo.

SECTION 2 REVIEW

1. Distinguish between biotic and abiotic factors.
2. Explain how migration allows organisms to cope with a changing environment.
3. What does a tolerance curve indicate about an organism?
4. How does an organism's niche differ from its habitat?
5. Give examples of a generalist and a specialist not mentioned in the text above.

CRITICAL THINKING

6. Why do different species never occupy exactly the same niche?
7. If some of the resources in a habitat are destroyed, which would be more likely to survive, a generalist species or a specialist species? Explain.
8. A small rodent species and a bird species are adapted to cold temperatures. How might each species survive a major temperature increase?

SPECIES THREE: ENERGY TRANSFER

PRODUCERS

Autotrophs, which include plants and some kinds of protists and bacteria, manufacture their own food. Since autotrophs can convert energy into organic molecule, they are called **producers**. Most producers are photosynthetic, using solar energy to power the production of food. However, some autotrophic bacteria instead use the process of **chemosynthesis**, using energy stored in inorganic molecules to produce carbohydrates.

Measuring Productivity

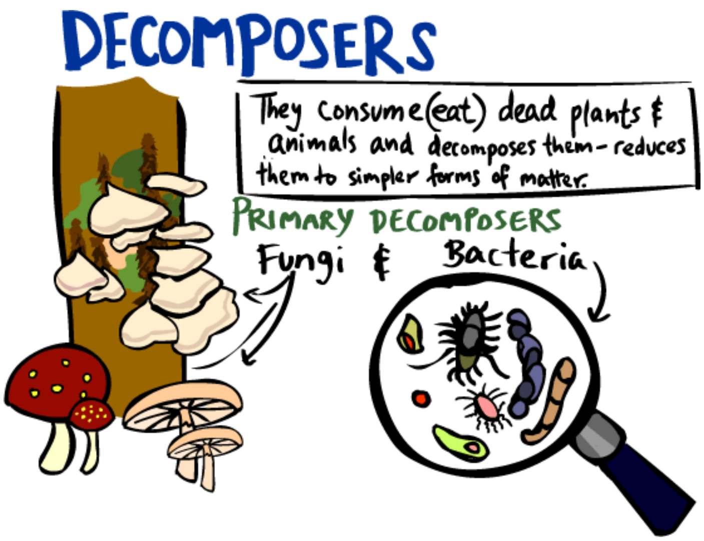
Gross primary productivity is the rate at which producers in an ecosystem capture the energy of sunlight by producing organic compounds. The organic material produced in an ecosystem is **biomass**, which is added to an ecosystem by producers.

Only energy stored in biomass is available to other organisms in the ecosystem. Ecologists measure the rate at which biomass accumulates in units of energy per unit area per year or in units of dry organic mass per unit area per year. This rate is the **net primary productivity**, and equals gross primary productivity minus the rate of respiration in producers.

Net primary productivity varies according to three factors – light, temperature, and precipitation. Generally, an increase in any of these variables usually leads to a productivity increase for terrestrial ecosystems. In aquatic ecosystems, productivity is usually determined by light and the availability of nutrients.

CONSUMERS

Heterotrophs cannot manufacture their own food, and obtain energy by eating other organisms or organic wastes. They are **consumers**, obtaining energy by consuming organic molecules made by other organisms. They can be grouped according to the type of food they eat. **Herbivores** eat producers, and **carnivores** eat other consumers. **Omnivores** eat both producers and consumers.



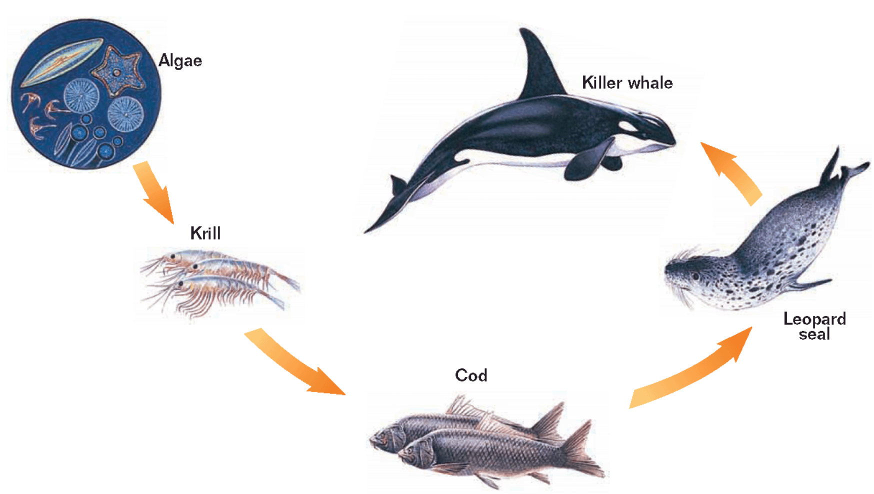
Detritivores are consumers that feed on waste, or *detritus* – this includes organisms that have recently died, fallen leaves, and animal wastes. Many bacteria and fungi are detritivores that cause decay by breaking down complex molecules into simpler molecules. They are specifically called **decomposers**. Some of the molecules released during decay are absorbed by the decomposers, and some are returned to the soil or water. Decomposition recycles chemical nutrients by making them available to the autotrophs in the ecosystem.

ENERGY FLOW

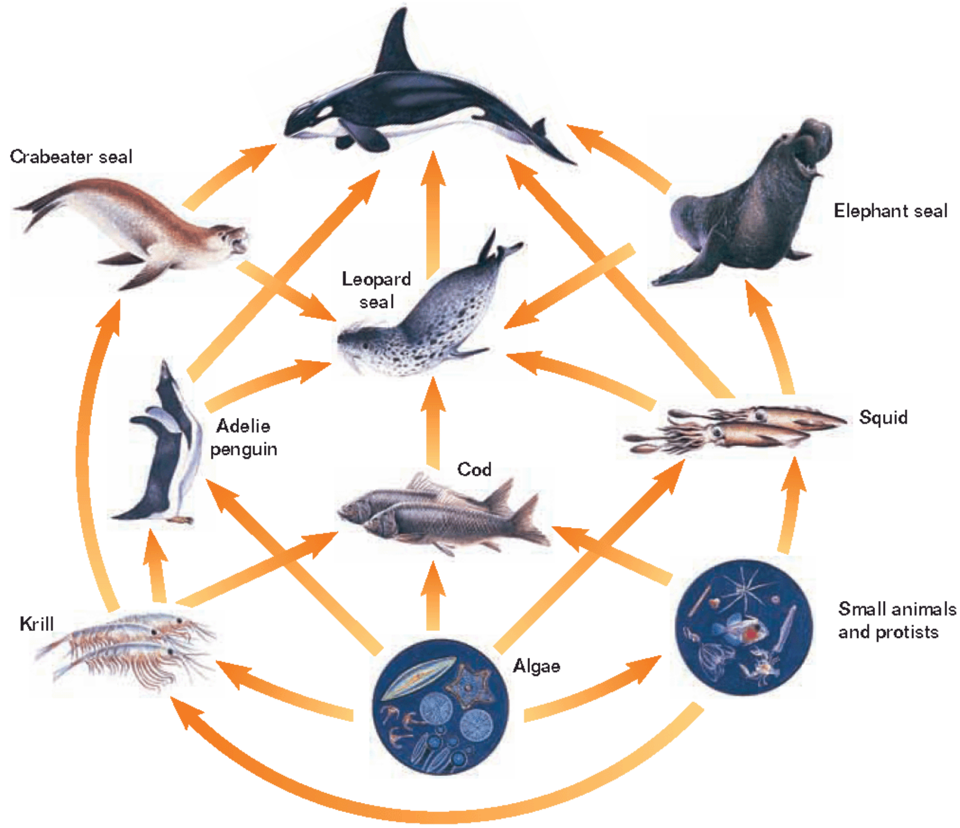
Energy flows through an ecosystem as one organism eats another. An organism's **trophic level** indicates the organism's position in a sequence of energy transfers. For example, producers belong to the first trophic level, herbivores belong to the second level, and predators belong to the third level.

Food Chains and Food Webs

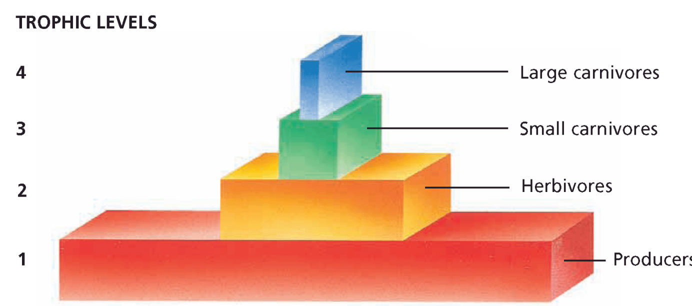
A **food chain** is a single pathway of feeding relationships among organisms in an ecosystem that results in energy transfer. A food chain may begin with algae, which are producers. The food chain will then continue to krill, which consume the algae. Next, the krill are eaten by the cod, the cod are eaten by the leopard seal, and the leopard seal is eaten by the killer whale.



Usually, the feeding relationships in an ecosystem are too complex to be modeled by a single food chain. Many consumers eat more than one type of food, and more than one species of consumer may feed on the same organism. Many food chains interlink to become a **food web**.



Energy Transfer



The pyramid shape of the diagram at right indicates the low percentage of energy transfer from one level to the next. Generally, 10 percent of the total energy consumed in one trophic level is incorporated into the organisms in the next.

Since some of the organisms in a trophic level escape being eaten, they become food from decomposers when they die. The energy contained in their bodies would not pass to a higher trophic level. Even when an organism is eaten, some of the molecules in its body are not in a form that the consumer can break down – such as fur and hooves. Also, the energy that prey use for cellular respiration cannot be used by predators to synthesize new biomass. Finally, all energy transfer result in energy lost as heat.

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Limitations of Trophic Levels

The low rate of energy transfer between trophic levels explains why ecosystems rarely contain more than a few trophic levels. With only 10 percent of the energy available at one level passed on to the next, there is not enough energy in the top trophic level to support more levels.

Organisms at the lowest trophic level are usually much more abundant than organisms at the highest level, since they contain more energy and can support more individuals.

SECTION 3 REVIEW

1. How do producers and consumers obtain energy?
2. Name five types of consumers.
3. What important role do decomposers play in an ecosystem?
4. How does a food chain differ from a food web?
5. Give two reasons for the low rate of energy transfer within ecosystems.
6. Explain why food chains usually do not exceed three to four levels.

CRITICAL THINKING

7. Describe the probable effects on an ecosystem if all the plants were to die. What if all the decomposers were to die?
8. A student has modeled a terrestrial ecosystem with seven trophic levels. Is this number reasonable? Explain.
9. Explain why the same area can support a greater number of herbivores than carnivores.

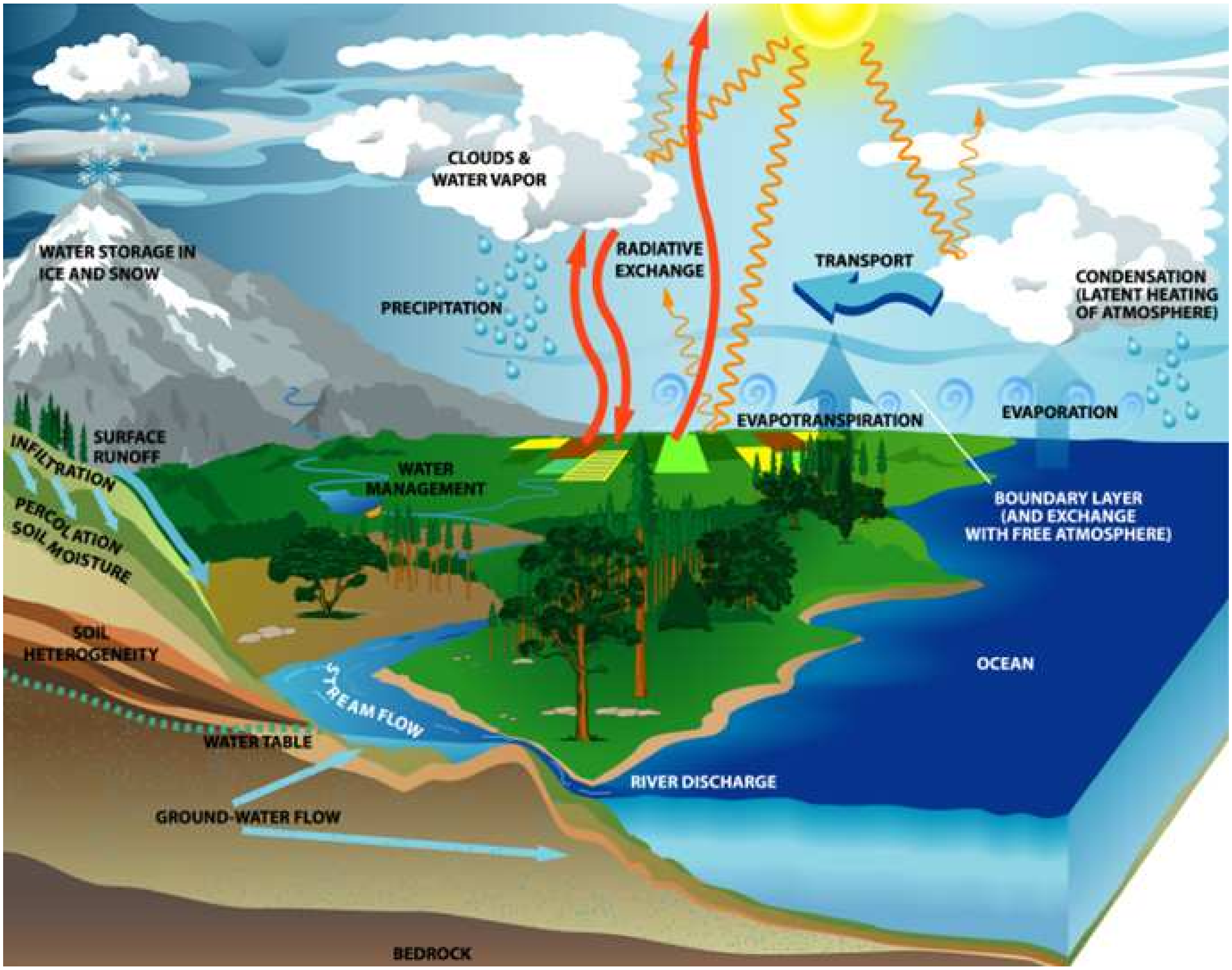
SECTION FOUR: ECOSYSTEM RECYCLING

THE WATER CYCLE

The availability of water is crucial to life as we know it. Very little of the available water on Earth is trapped within living things at any given time. Bodies of water contain a substantial percentage of Earth's water. The atmosphere also contains water. Water in soil or in underground formations of porous rock is known as **groundwater**.

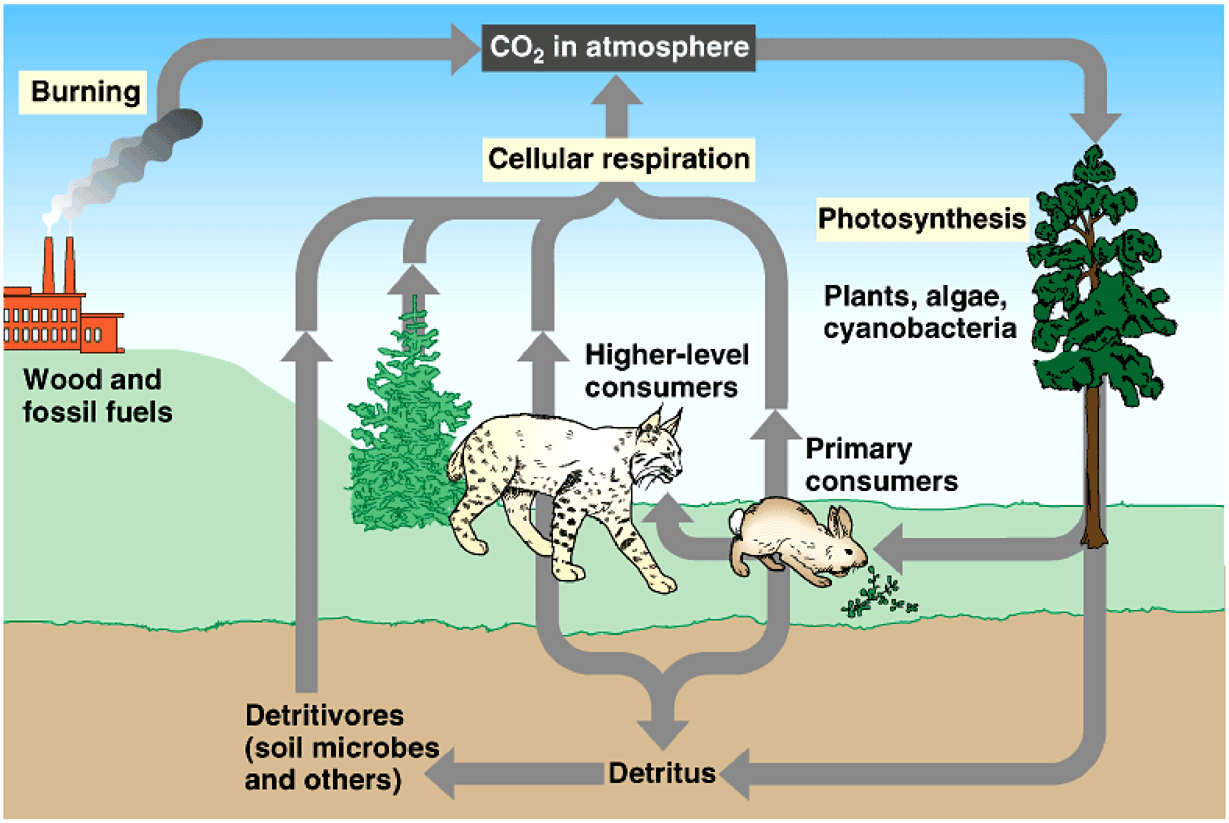
The movement of water between these reservoirs is known as the **water cycle**. Important processes in the cycle are evaporation, transpiration, condensation, precipitation, and percolation.

Evaporation and transpiration add water as vapor to the atmosphere. Heat causes water to evaporate from bodies of water, from the soil, and from the bodies of living things. Water leaves the atmosphere through precipitation.



THE CARBON CYCLE

Photosynthesis and cellular respiration form the basis of the short-term **carbon cycle**. In photosynthesis, plants and other autotrophs use carbon dioxide, along with water and solar energy, to make carbohydrates. Both autotrophs and heterotrophs use oxygen to break down carbohydrates during cellular respiration. The byproducts of cellular respiration (carbon dioxide and water) are released. Decomposers release carbon dioxide into the atmosphere when breaking down organic compounds. Additionally, fossil fuels formed from organic remains contribute to the carbon cycle. When these fossil fuels are burned, carbon dioxide returns to the atmosphere.



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Human Influences on the Carbon Cycle

The concentration of atmospheric carbon has risen in the last 150 years due to humans burning fossil fuels and other organic matter. Additionally, when forests are cleared for agricultural purposes, there is less vegetation to absorb carbon dioxide from the atmosphere.

NITROGEN CYCLE

The complex pathway that nitrogen follows in an ecosystem is called the **nitrogen cycle**. Although nitrogen gas makes up about 78 percent of the atmosphere, most plants can use nitrogen only in the form of nitrogen. The process of converting nitrogen gas into nitrate is called **nitrogen fixation**.

Most organisms rely on **nitrogen-fixing bacteria** to transform nitrogen gas into a usable form. These bacteria live inside swellings on the roots of some kinds of plants. These plants supply carbohydrates for the bacteria, and the bacteria produce usable nitrogen for the plant. Additional nitrogen is released into the soil.

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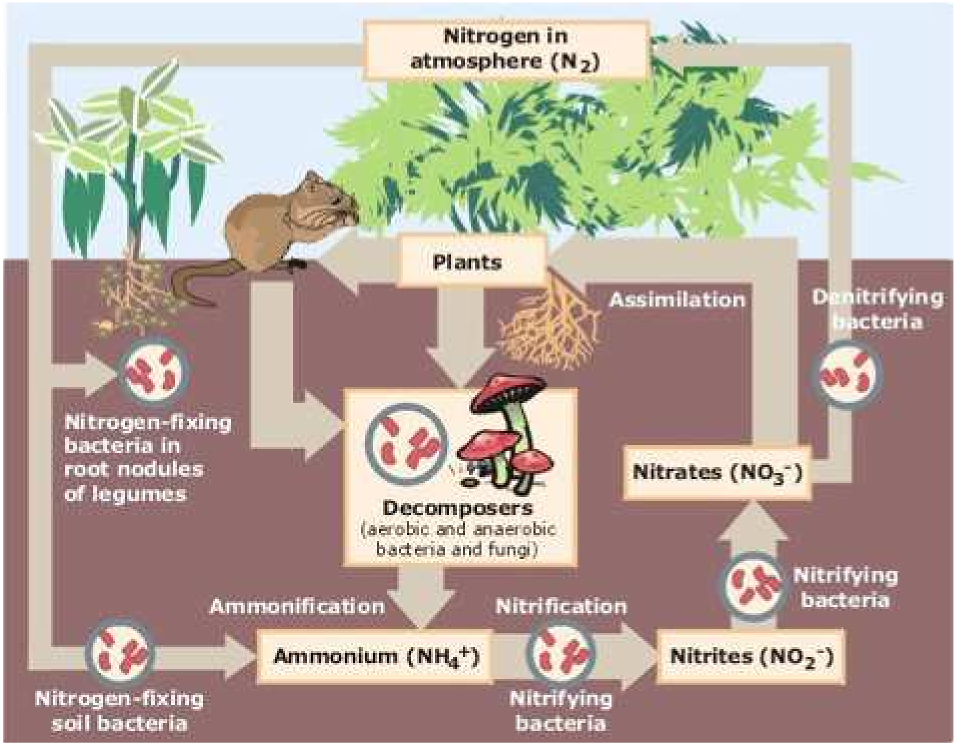

Recycling Nitrogen

The bodies of dead organisms contain nitrogen, mainly in proteins and nucleic acids. Urine and dung also contain nitrogen. Decomposers break down this material and release the nitrogen they contain as ammonia, which becomes ammonium in soil. This process is known as **ammonification**. Through this process, nitrogen is made available to other organisms.

Soil bacteria take up ammonium and oxidize it into nitrites and nitrates in a process called **nitrification**. The erosion of nitrate-rich rocks also release nitrates into an ecosystem. Nitrogen is returned to the atmosphere through **denitrification**. Denitrification occurs when anaerobic bacteria break down nitrates and release nitrogen gas into the atmosphere.

PHOSPHORUS CYCLE

Phosphorus is an element needed by animals to form bones, teeth, and molecules such as DNA and RNA. Plants get the phosphorus they need from soil and water, whereas animals get their phosphorus by eating plants or other animals. The **phosphorus cycle** is the movement of phosphorus from the environment to organisms and then back to the environment. This cycle does not normally occur in the atmosphere, since phosphorus rarely occurs as a gas.

When rocks erode, small amounts of phosphorus dissolve as phosphate in soil and water. Plants absorb phosphorus in the soil through their roots. Phosphorus is also added to soil and water when excess phosphorus is excreted in wastes from organisms and when organisms die and decompose. Some phosphorus used in fertilizer washes off the land into streams and groundwater.

SECTION 4 REVIEW

1. Identify four major biogeochemical cycles.
2. Through what process does most water vapor enter the atmosphere?
3. Outline the steps of the carbon cycle.
4. Describe the role of decomposers in the nitrogen cycle.
5. Identify the sources of phosphorus in the phosphorus cycle.

CRITICAL THINKING

6. How might the removal of vegetation affect oxygen levels in the atmosphere?
7. Identify the role of bacteria in the carbon, nitrogen, and phosphorus cycles.
8. Explain the statement that nutrients cycle, but energy flows.

CHAPTER HIGHLIGHTS

Section 1: Introduction to Ecology

- Species interact with both other species and their nonliving environment.
- Interdependence is a theme in ecology, and states that one change can affect all species in an ecosystem.
- Ecological models help to explain the environment.
- Ecology is usually organized into five levels: organism, population, community, ecosystem, and biosphere.

Section 2: Ecology of Organisms

- Both biotic, or living, factors and abiotic, or nonliving, factors influence organisms. Examples of nonliving things are climate, sunlight, and pH.
- A niche is a way of life, or a role in an ecosystem.
- Some species survive unfavorable environmental conditions by becoming dormant or by migrating.

Section 3: Energy Transfer

- Most producers are photosynthetic and make carbohydrates by using energy from the sun.
- Consumers obtain energy by eating other organisms and include herbivores, omnivores, carnivores, detritivores, and decomposers.
- Decomposers feed on dead organisms and wastes, which releases the nutrients back into the environment.

- A single pathway of energy transfer is a food chain. A network showing all paths of energy transfer is a food web.
- Ecosystems contain only a few trophic levels because there is a low rate of energy transfer between each level.

Section 4: Ecosystem Recycling

- Key processes in the water cycle are evaporation, transpiration, and precipitation.
- Photosynthesis and cellular respiration are the two main steps in the carbon cycle.
- Nitrogen-fixing bacteria are important in the nitrogen cycle because they change nitrogen gas into a usable form of nitrogen for plants.
- Phosphorus moves form phosphate deposited in rock, to the soil, to living organisms, and finally to the ocean.