7: Ecology

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CHAPTER 1 Introduction to Ecology

Chapter Outline

The lake in this photo looks as though it might be completely lacking in life. Even its name—the Dead Sea—adds to that impression. Located far below sea level, the Dead Sea is much saltier than the ocean. It's too salty for fish, frogs, or other animals to survive. Yet even here, living things thrive. The bottom of the Dead Sea, for example, is carpeted with mats of microorganisms. How do they manage to live in these unusual conditions? How have they adapted to their extreme environment?

All organisms must adapt to their environment in order to survive. This is true whether they live in the highly salty water of the Dead Sea or in a lush tropical rainforest that is bursting with life. Most environments are not as extreme as the Dead Sea. But they all have conditions that require adaptations. In this chapter, you'll read about a wide variety of environments and the organisms that live in them.

1.1 What Is Ecology?

Lesson Objectives

- Define ecology.
- Distinguish between biotic and abiotic factors in the environment.
- Outline levels of organization in ecology.

Lesson Vocabulary

- abiotic factor
- biosphere
- biotic factor
- ecology

Introduction

The science of how living things interact with each other and their environment is called ecology. Ecology is a major branch of life science, but it overlaps with many other fields. For example, it shares data and theories with geography, biology, climatology, and other sciences. In this lesson, you'll learn some of the basic concepts of ecology.

Organisms and Environmental Factors

Organisms are individual living things. They range from microscopic bacteria to gigantic blue whales (see **Figure** 1.1). Despite their great diversity, all organisms have the same basic needs: energy and matter. Energy and matter must be obtained from the environment.

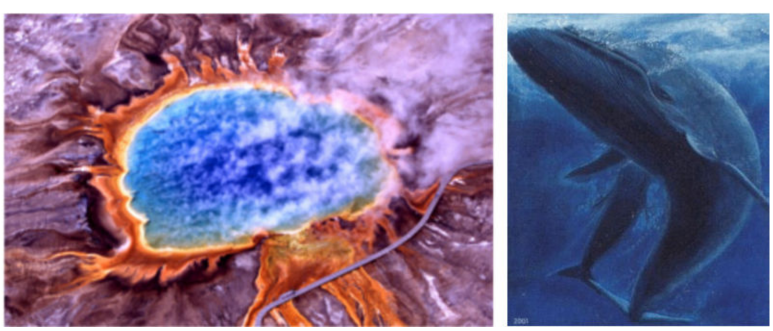


FIGURE 1.1
Organisms show tremendous diversity. Some of the smallest and largest living organisms are pictured here: billions of microorganisms that thrive in this hot spring give it its striking colors (left); blue whales are the largest living organisms (right).

Organisms depend on their environment to meet their needs, so they are greatly influenced by it. There are many factors in the environment that affect organisms. The factors can be classified as either biotic or abiotic.

- Biotic factors are all of the living or once-living aspects of the environment. They include all the organisms that live there as well as the remains of dead organisms.

- Abiotic factors are all of the aspects of the environment that have never been alive. They include factors such as sunlight, minerals in soil, temperature, and moisture.

Levels of Organization in Ecology

Ecologists study organisms and environments at several different levels, from the individual to the biosphere. The levels are depicted in **Figure** 1.2 and described below.

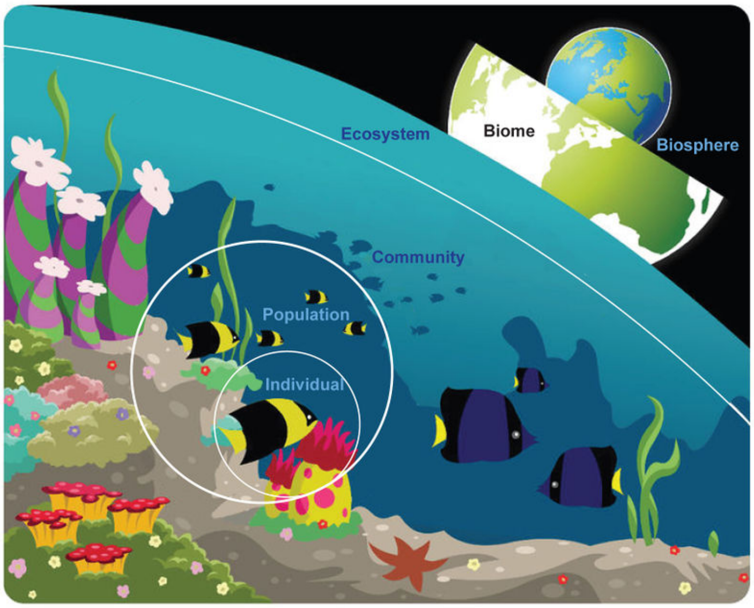
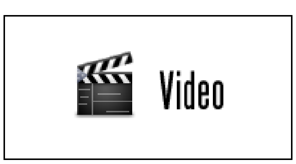


FIGURE 1.2
From individuals to the biosphere, ecology can be studied at several different levels.

- An individual is an organism, or single living thing.
- A population is a group of individuals of the same species that live in the same area. Members of the same population generally interact with each other.
- A community is made up of all the populations of all the species that live in the same area. Populations in a community also generally interact with each other.
- An ecosystem consists of all the biotic and abiotic factors in an area. It includes a community, the abiotic factors in the environment, and all their interactions.
- A biome is a group of similar ecosystems with the same general abiotic factors and primary producers. Biomes may be terrestrial (land-based) or aquatic (water-based).
- The biosphere consists of all the parts of Earth where life can be found. This is the highest level of organization in ecology. It includes all of the other levels below it. The biosphere consists of all the world's biomes, both terrestrial and aquatic.

For a video introduction to the levels of organization in ecology, click on this link: https://www.youtube.com/watch?v=Y5xn1-LB1nE



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Lesson Summary

- Ecology is the science of how living things interact with each other and their environment.
- All organisms depend on their environment for energy and matter and are influenced by their environment. Factors in the environment that can affect organisms include biotic factors and abiotic factors.
- Ecologists study organisms and environments at several different levels. From smallest to largest, they include the individual, population, community, ecosystem, biome, and biosphere.

Lesson Review Questions

Recall

1. What is ecology?
2. Define the biosphere.

Apply Concepts

3. Make an illustrated chart to show the different levels of organization in ecology.

Think Critically

4. Explain why organisms depend on their environment.
5. Compare and contrast biotic and abiotic factors in the environment.

Points to Consider

The population is an important level of organization in ecology. It is also the unit of microevolution.

1. What is a population?
2. How can a population grow?

1.2 Populations

Lesson Objectives

- Define population.
- Identify measures of population size, growth, and structure.
- Describe how the human population grew in the past and is predicted to grow in the future.

Lesson Vocabulary

- age-sex structure
- carrying capacity
- demographic transition
- exponential growth
- logistic growth
- population density
- population distribution
- population growth rate
- population pyramid

Introduction

A population is a group of individuals of the same species that live in the same area. In ecology, how large a population is and how quickly it is growing are often used as measures of a species' health.

Population Size, Growth, and Structure

Population size is the number of individuals in a population. Population size influences the chances of a species surviving or going extinct. If a species' populations become very small, the species may be at risk of going extinct.

Population Density and Distribution

Another sign of a species' state of health is the density of its populations. Population density is the average number of individuals in a population for a given area. Density is a measure of how crowded or spread out the individuals in a population are on average. For example, a population of 100 deer that live in an area of 10 square kilometers has a population density of 10 deer per square kilometer.

Population density is an average measure. Often, individuals in a population are not spread out evenly. Instead, they may live in clumps or some other pattern. How individuals in a population are distributed, or spread throughout their area, is called population distribution. You can see different patterns of population distribution in **Figure** 1.3. Different patterns characterize different species and types of environments, as you can read in the figure.

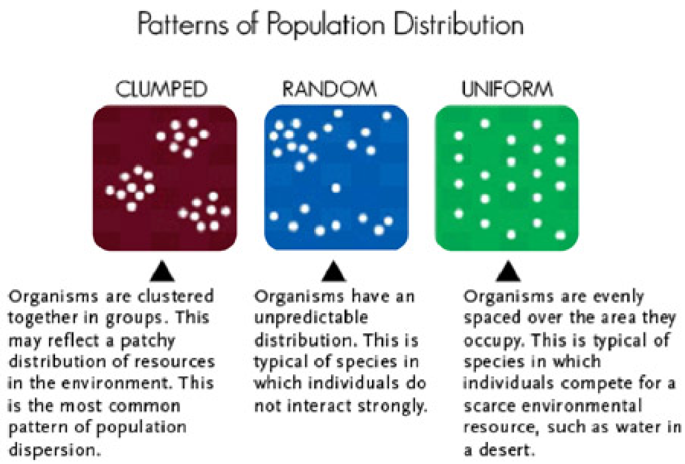

FIGURE 1.3
Patterns of population distribution include clumped, random, and uniform distributions. Each pattern is associated with different types of species or environments.

Population Growth

Whether its populations are growing or shrinking in size may be another indicator of a species' health. Individuals may be added to a population through births and the migration of individuals into the population. Individuals may be lost from a population through deaths and the migration of individuals out of the population.

Populations may show different patterns of growth depending on the conditions. In ideas conditions, a typical population starts out growing slowly. Then, the larger the population becomes, the more quickly it grows. However, it can't continue to grow for very long. Eventually the population size approaches its carrying capacity. Carrying capacity is the largest population size that can be supported in an area without harming the environment. At this point the population stops growing and begins to level off. In the diagram below, which curve, A or B, represents the typically manner for which populations tend to grow? Why?

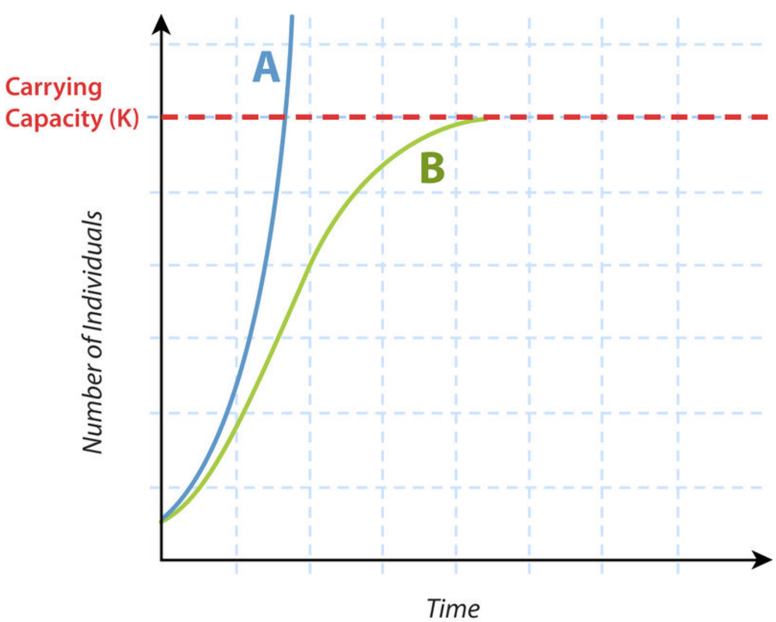

FIGURE 1.4
Curve A represents exponential population growth. Curve B represents logistic population growth.

Lesson Summary

- A population is a group of individuals of the same species that live in the same area.
- Population growth is limited by carry capacity.

Lesson Review Questions

Recall

1. Define population.

Think Critically

2. Compare and contrast the concepts of population density and population distribution.
3. Why does population growth eventually level off, even in ideal conditions?

Points to Consider

A population doesn't exist alone. It is part of a community.

4. What is a community?
5. How might populations in a community interact?

1.3 Communities

Lesson Objectives

- Define community.
- Explain how predation affects predator and prey populations.
- Describe outcomes of intraspecific and interspecific competition.
- Identify three types of symbiotic relationships.

Lesson Vocabulary

- commensalism
- community
- competition
- host
- keystone species
- mutualism
- parasite
- parasitism
- predation
- predator
- prey
- symbiosis

Introduction

A community is the biotic component of an ecosystem. It consists of the populations of all the species that live in the same area. Populations in communities often interact with each other. Community interactions are important factors in natural selection. They help shape the evolution of the interacting species. Types of community interactions include predation, competition, and symbiosis. You'll read about each type of interaction in this lesson.

Predation

Predation is a relationship in which members of one species consume members of another species. The consuming species is called the predator. The species that is consumed is called the prey. In **Figure** 1.5, the wolves are predators, and the moose is their prey.

Predator and Prey Populations

A predator-prey relationship tends to keep the populations of both species in balance. Look at the graph in **Figure** 1.6. As the prey population increases, there is more food for the predators. So after a slight lag time, the predator population also increases. As the number of predators increases, more prey are captured. This causes the prey population to decrease, followed by the predator population decreasing again.

FIGURE 1.5
Pack of wolves preying on a moose

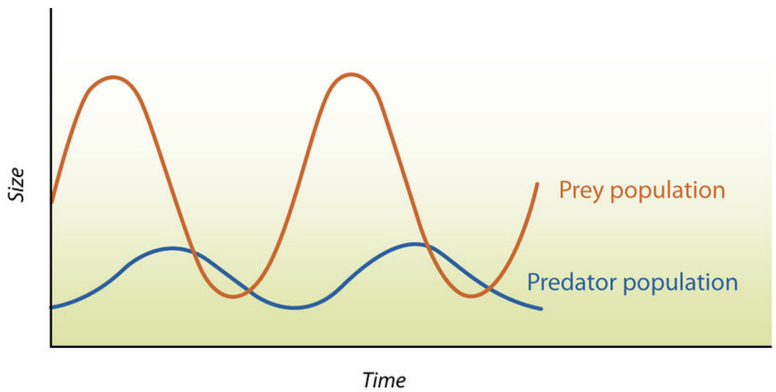

FIGURE 1.6
Predator-Prey populations.

Keystone Species

Some predator species play a special role in their community. They are called keystone species. When the population size of a keystone species changes, the populations of many other species are affected. Prairie dogs, pictured in **Figure** 1.7, are an example of a keystone species. Their numbers affect most of the other species in their community. Prairie dog actions improve the quality of soil and water for plants, upon which most other species in the community depend.

FIGURE 1.7
Prairie dogs are a keystone species in their community.

Adaptations to Predation

Both predators and prey have adaptations to predation that evolve through natural selection. Predator adaptations help them capture prey. Prey adaptations help them avoid predators. A common adaptation in both predator and prey species is camouflage. You can see an example in **Figure** 1.8.

FIGURE 1.8
There is a well-camouflaged frog in this photo. Do you see it?

You can also see some amazing examples in this video: http://www.ted.com/talks/david_gallo_shows_underwater_astonishments?language=en

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Competition

Competition is a relationship between organisms that depend on the same resources. The resources might be food, water, or space. Competition can occur between organisms of the same species or between organisms of different species.

- Competition within a species is called intraspecific competition. It leads to natural selection within the species, so the species becomes better adapted to its environment.
- Competition between different species is called interspecific competition. It might lead to the less well-adapted species going extinct. Or it might lead to one or both species evolving specialized adaptations. For example, competing species might evolve adaptations that allow them to use different food sources. You can see an example in **Figure** 1.9.

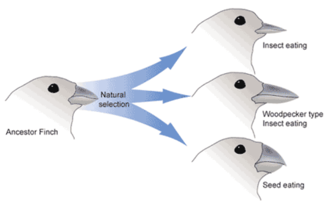


FIGURE 1.9
These species of birds have evolved different types of beaks to exploit different food sources. This allows them to live in the same area without competing for food.

Symbiosis

Symbiosis is a close relationship between two species in which at least one species benefits. For the other species, the relationship may be beneficial, harmful, or neutral. There are three types of symbiosis: mutualism, parasitism, and commensalism.

Mutualism

Mutualism is a symbiotic relationship in which both species benefit. An example of mutualism is pictured in **Figure** 1.10. The clownfish in the photo is hiding among the tentacles of a sea anemone. The tentacles have stingers that can inject poison in the anemone's prey. The clownfish is protected from the stingers by mucus that covers its body.

How do the two species benefit from their close relationship? The anemone provides the clownfish with a safe place to live by keeping away predatory fish. The clownfish also feeds on the remains of the anemone's prey. In return, the clownfish helps the anemone catch food by attracting prey with its bright colors. Its feces also provide nutrients to the anemone.

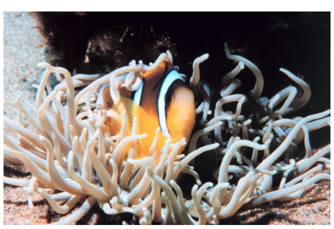


FIGURE 1.10
A clownfish takes refuge among the tentacles of a sea anemone.

Parasitism

Parasitism is a symbiotic relationship in which one species benefits and the other species is harmed. The species that benefits is called the parasite. The species that is harmed is called the host. Many species of animals are parasites, at least during some stage of their life cycle. Most animal species are also hosts to one or more parasites.

A parasite generally lives in or on its host. An example of a parasite that lives in its host is the hookworm. **Figure** 1.11 shows two hookworms living inside a human host's intestines. The hookworms obtain nutrients and shelter from their host, which is harmed by the loss of nutrients and blood.

Some parasites kill their host, but most do not. It's easy to see why. If a parasite kills its host, the parasite may also die. Instead, parasites usually cause relatively minor damage to their host.

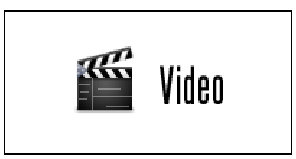
FIGURE 1.11
Hookworm parasites inside their human host's intestines

Commensalism

Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected. An example is the relationship between birds called cattle egrets and cattle (see **Figure** 1.12). Cattle egrets feed on insects. They follow cattle herds around to take advantage of the insects stirred up by the feet of the cattle. The egrets get ready access to food from the relationship, whereas the cattle are not affected.

FIGURE 1.12
A cattle egret "hangs out" near cattle to catch insects stirred up by the cattle's feet.

Review the three types of symbiosis through this Untamed Science video: https://www.youtube.com/watch?v=zSmL2F1t81Q



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Lesson Summary

- A community is the biotic component of an ecosystem. It consists of the populations of all the species that live in the same area.
- Predation is a relationship in which members of one species, called the predator, consume members of another species, called the prey.
- Competition is a relationship between organisms that depend on the same resources. Competition can occur between members of the same species or between members of different species.
- Symbiosis is a close relationship between two species in which at least one species benefits. Types of symbiosis include mutualism, parasitism, and commensalism.

Lesson Review Questions

Recall

1. Define community.
2. Describe two potential outcomes of interspecific competition.
3. Identify three types of symbiosis.

Apply Concepts

4. After a rainy summer and excessive weed growth, a population of mice has doubled in size because of a greater food supply. The main predators of the mice are owls. Predict how the owl population in the same community is likely to change.

Think Critically

5. Explain how camouflage could benefit both predator and prey species.
6. Why do parasites usually not kill their host?

Points to Consider

A community is the biotic component of an ecosystem.

1. What is an ecosystem?
2. What are some examples of ecosystems?

1.4 Ecosystems

Lesson Objectives

- Define ecosystem.
- Describe the role of energy and matter in ecosystems.
- Define niche and habitat, and explain the competitive exclusion principle.

Lesson Vocabulary

- competitive exclusion principle
- ecosystem
- habitat
- niche

Introduction

The focus of study in ecology is often the ecosystem. Ecosystems are units of nature. Each ecosystem consists of all the biotic and abiotic factors in an area and all the ways in which the factors interact. A forest could be an ecosystem, but so could a dead log on the forest floor. Both the forest and the log contain a community of species that interact with each other and with abiotic factors.

Energy and Matter in Ecosystems

Ecosystems need a constant input of energy to supply the needs of their organisms. Most ecosystems get energy from sunlight. A few ecosystems get energy from chemical compounds.

Unlike energy, matter doesn't need to be constantly added to ecosystems. Instead, matter is recycled through ecosystems. Water and elements such as carbon and nitrogen that living things need are used over and over again.

Key Ecosystem Concepts

Two important concepts associated with the ecosystem are niche and habitat.

Niche

Niche is the role that a particular species plays in its ecosystem. This role includes all the ways that the species interacts with the biotic and abiotic factors in the ecosystem. Watch the following video to answer: What is a niche?

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A major aspect of any niche is how the species obtains energy and matter. Look at **Figure** 1.13. The grass in the figure obtains energy from sunlight and uses it to convert carbon dioxide and water to sugar by photosynthesis. The deer in the figure gets matter and energy by consuming and digesting the grass. Each species has a different and distinctive niche.

FIGURE 1.13

The grass and deer fill two different niches in an ecosystem.

Habitat

Another important aspect of a species' niche is its habitat. Habitat is the physical environment in which a species lives and to which it has adapted. Features of a habitat depend mainly on abiotic factors, such as temperature and rainfall. These factors influence the traits of the organisms that live there.

Just One Species Please!

A given habitat may contain many different species. However, each species in the same habitat must have a different niche. Two different species cannot occupy the same niche in the same habitat at the same time. This is called the competitive exclusion principle.

What do you think would happen if two species were to occupy the same niche in the same habitat? The two species would compete for everything they needed in the environment. One species might outcompete and replace the other. Or, both species might evolve different specializations so they can fill slightly different niches.

Lesson Summary

- An ecosystem is a unit of nature. It consists of all the biotic and abiotic factors in an area and all the ways in which they interact.
- Ecosystems need a constant input of energy for their organisms, but matter is recycled through ecosystems.
- Niche is the role that a particular species plays in its ecosystem. Habitat is the physical environment in which a species lives and to which it has adapted. According to the competitive exclusion principle, two different species cannot occupy the same niche in the same habitat at the same time.

Lesson Review Questions

Recall

1. What is an ecosystem?
2. Define niche.

Apply Concepts

3. Two different species of birds live in the same habitat and eat the same foods. What can you conclude about the niches of the two species?

Think Critically

4. Relate the competitive exclusion principle to the concepts of niche, habitat, and competition.

Points to Consider

Similar ecosystems are found in different parts of the world. For example, forests and deserts are found on almost all of Earth's continents.

1. What factors do you think determine where a particular terrestrial ecosystem is found?
2. Think about your own ecosystem. Where else in the world might a similar ecosystem be found?

1.5 References

1. Jim Peaco, National Park Service (left); Postverk Føroya - Philatelic Office (right). http://commons.wikimedia.org/wiki/File:Grand_prismatic_spring_edit.jpg (left); http://commons.wikimedia.org/wiki/File:Faroe_stamp_-402_blue_whale_(Balaenoptera_musculus)_crop.jpg?fastcci_from=1965010 (right) . public domain
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12. Thomas Brown. http://commons.wikimedia.org/wiki/File:Cattle_Egret_(Bubulcus_ibis)_(8592689886).jpg . CC BY 2.0
13. U.S. Fish and Wildlife Service. http://commons.wikimedia.org/wiki/File:Key_deer.gif?fastcci_from=18195 . public domain

CHAPTER 2 Ecosystem Dynamics

Chapter Outline

Sunlight strikes the leaves of this plant. The leaves are like tiny factories. They use the energy in sunlight to manufacture food. Light from the sun is the driving force behind photosynthesis and most of the planet's ecosystems.

2.1 Flow of Energy

Lesson Objectives

- Explain how living things are classified based on the way they obtain energy.
- Show how food chains and food webs model the flow of energy through ecosystems.
- Identify trophic levels, and state how they are related to energy and biomass.

Lesson Vocabulary

- biomass
- chemoautotroph
- chemosynthesis
- consumer
- decomposer
- food chain
- food web
- photoautotroph
- producer
- trophic level

Introduction

Energy is the ability to change or move matter. All living things need energy. They need energy for everything they do, whether it is to move long distances or simply to carry out basic biochemical processes inside cells. Energy enters most ecosystems in the form of sunlight. In a few ecosystems, energy enters in the form of chemical compounds. All ecosystems need a constant input of energy in one of these two forms.

Types of Organisms and Energy

Living things can be classified based on how they obtain energy. Some use the energy in sunlight or chemical compounds directly to make food. Some get energy indirectly by consuming other organisms, either living or dead.

Producers

Producers are living things that produce food for themselves and other organisms. They use energy and simple inorganic molecules to make organic compounds. Producers are vital to all ecosystems because all organisms need organic compounds for energy.

Producers are also called autotrophs. There are two basic types of autotrophs: photoautotrophs and chemoautotrophs.

- Photoautotrophs use energy in sunlight to make organic compounds by photosynthesis. They include plants, algae, and some bacteria (see **Figure** 2.1).
- Chemoautotrophs use energy in chemical compounds to make organic compounds. This process is called chemosynthesis. Chemoautotrophs include certain bacteria and archaea.

FIGURE 2.1
The green streaks in this brilliant blue Guatemalan lake are billions of photosynthetic bacteria.

Consumers

Consumers are organisms that depend on other living things for food. They take in organic compounds by eating or absorbing other living things. Consumers include all animals and fungi. They also include some bacteria and protists.

Consumers are also called heterotrophs. There are several different types of heterotrophs depending on exactly what they consume. They may be herbivores, carnivores, or omnivores.

- Herbivores are heterotrophs that consume producers such as plants or algae. Examples include rabbits and snails.
- Carnivores are heterotrophs that consume animals. Examples include lions and frogs.
- Omnivores are heterotrophs that consume both plants and animals. They include crows and human beings. The grizzly bears pictured in **Figure** 2.2 are also omnivores.

FIGURE 2.2
Grizzly bears eat both plant and animal foods, including grasses, berries, fish, and clams.

Decomposers

Decomposers are heterotrophs that break down the wastes of other organisms or the remains of dead organisms. When they do, they release simple inorganic molecules back into the environment. Producers can then use the inorganic molecules to make new organic compounds. For this reason, decomposers are essential to every ecosystem. Imagine what would happen if there were no decomposers. Organic wastes and dead organisms would pile up everywhere, and their nutrients would no longer be recycled.

FIGURE 2.3
These dung beetles are decomposers. They are feasting on a pile of horse dung (feces).

Modeling the Flow of Energy

Energy flows through ecosystems from producers, to consumers, to decomposers. Food chains and food webs are diagrams that model this flow of energy. They represent feeding relationships by showing who eats whom.

Food Chains

A food chain is a diagram that represents a single pathway through which energy flows through an ecosystem. Food chains are generally simpler than what really happens in nature. That's because most organisms consume and are consumed by more than one species. You can see examples of terrestrial and aquatic food chains in **Figure** 2.4. See if you can construct a food chain of each type by playing the animation at this link: http://www.ecokids.ca/pub/eco_info/topics/frogs/chain_reaction/play_chainreaction.cfm

Food Webs

A food web is a diagram that represents many pathways through which energy flows through an ecosystem. It includes a number of intersecting food chains. Food webs are generally more similar to what really happens in nature. They show that most organisms consume and are consumed by multiple species. You can see an example of a food web in **Figure** 2.5.

Trophic Levels

Each food chain or food web has organisms at different trophic levels. A trophic level is a feeding position in a food chain or web. The trophic levels are identified in the food web in **Figure** 2.5. All food chains and webs have at least two or three trophic levels, but they rarely have more than four trophic levels. The trophic levels are:

1. Trophic level 1 = producers that make their own food
2. Trophic level 2 = primary consumers that eat producers
3. Trophic level 3 = secondary consumers that eat primary consumers

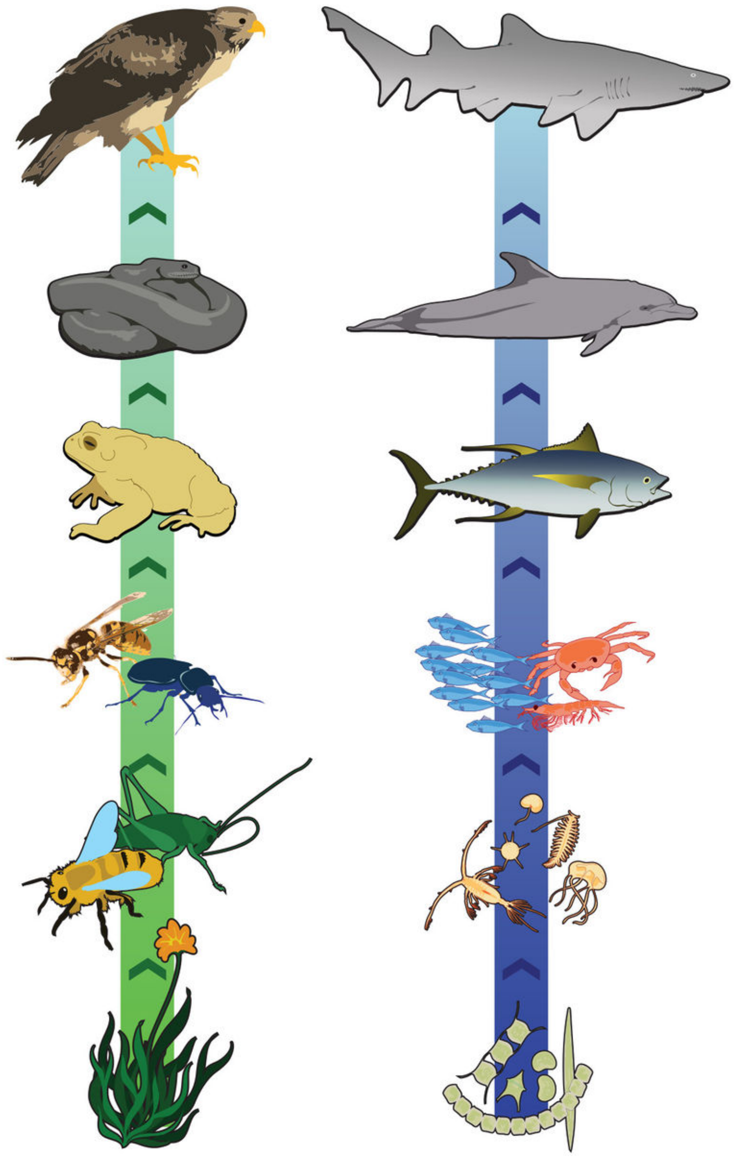


FIGURE 2.4
Terrestrial (left) and aquatic (right) food chains

4. Trophic level 4 = tertiary consumers that eat secondary consumers

Many consumers feed at more than one trophic level. For example, the bivalves in **Figure** 2.5 eat both producers and primary consumers. Therefore, they feed at trophic levels 2 and 3.

Trophic Levels and Energy

Energy is passed up a food chain or web from lower to higher trophic levels. However, only about 10 percent of the energy at one level is passed up the next level. This is represented by the ecological pyramid in **Figure** 2.6. The other 90 percent of energy at each trophic level is used for metabolic processes or given off to the environment as heat. This loss of energy explains why there are rarely more than four trophic levels in a food chain or web. There isn't enough energy left to support additional levels. It also explains why ecosystems need a constant input of energy.

You can learn more about ecological pyramids in this video: http://www.youtube.com/watch?v=wGfOoRrICto .

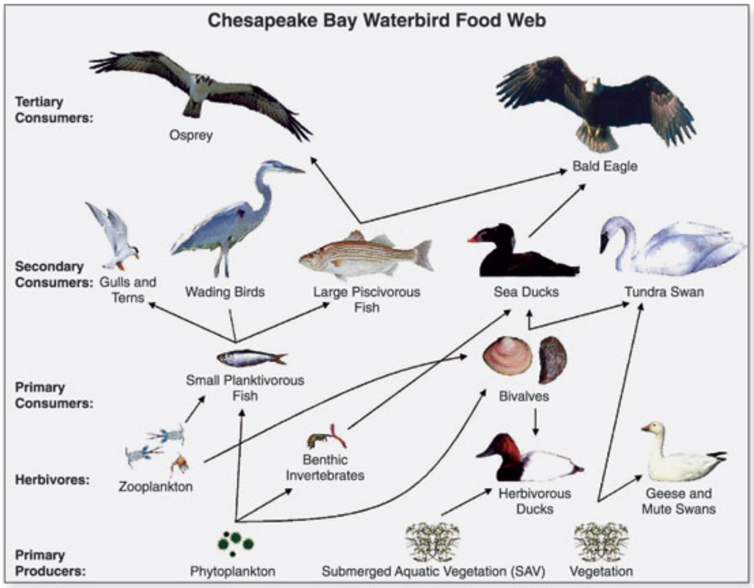
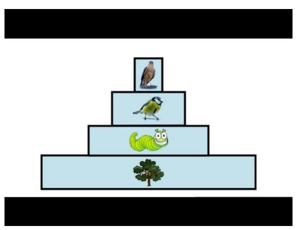


FIGURE 2.5
Food web showing trophic levels



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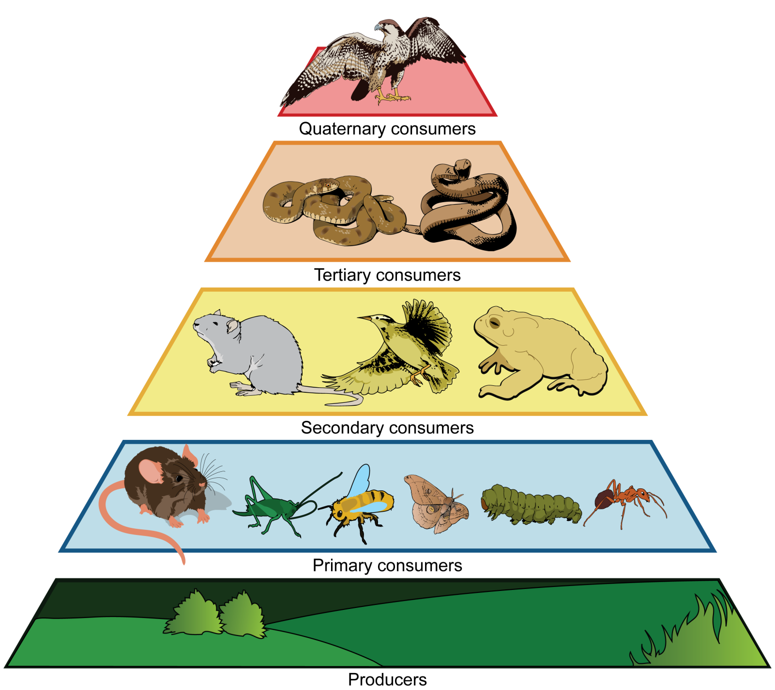


FIGURE 2.6
This ecological pyramid shows how energy and biomass decrease from lower to higher trophic levels.

Trophic Levels and Biomass

Biomass is the total mass of organisms at a trophic level. With less energy at higher trophic levels, there are usually fewer organisms as well. This is also represented in the pyramid in **Figure** 2.6. Organisms tend to be larger in size at higher trophic levels. However, their smaller numbers result in less biomass.

Lesson Summary

- All ecosystems need a constant input of energy in the form of sunlight or chemical compounds. Living things can be classified based on how they obtain energy as producers, consumers, or decomposers.
- Food chains and food webs are diagrams that model the flow of energy through ecosystems. They show who eats whom.
- A trophic level is a feeding position in a food chain or food web. Most food chains and webs have a maximum of four trophic levels. There is less energy and biomass at higher trophic levels.

Lesson Review Questions

Recall

1. Identify three major categories of living things based on how they obtain energy.
2. What is a food chain? Why are food chains simpler than actual feeding relationships in nature?
3. Define trophic level. How does an organism at trophic level 2 obtain energy?

4. At which trophic levels are you consuming when you eat a cheeseburger and French fries?

Think Critically

5. Compare and contrast three types of decomposers.
6. Explain why food chains and webs rarely have more than four trophic levels.

Points to Consider

Energy must constantly be added to an ecosystem for use by organisms. Matter, on the other hand, is continuously recycled through ecosystems.

1. Give an example of a cycle of matter.
2. What role do living things play in this cycle?

2.2 A Closer Look at Photosynthesis

Lesson Objectives

Lesson Vocabulary

- producer
- autotroph
- heterotroph
- photosynthesis
- chloroplast

Introduction

FIGURE 2.7

What can a tiny plant do that you can't do?

This tiny plant can use the energy of the sun to make its own food. You can't make food by just sitting in the sun. Plants are not the only organisms that can get energy from the sun, however. Some protists, such as algae, and some bacteria can also use the energy of the sun to make their own food.

What is Photosynthesis?

If a plant gets hungry, it cannot walk to a local restaurant and buy a slice of pizza. So, how does a plant get the food it needs to survive? Plants are **producers**, which means they are able to make, or produce, their own food. They also produce the "food" for other organisms. Plants are also **autotrophs.** Autotrophs are the organisms that collect the energy from the sun and turn it into organic compounds. So once again, how does a plant get the food it needs to survive?

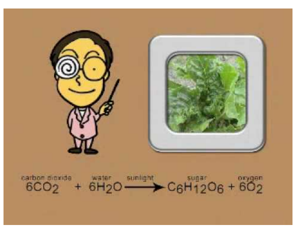
Through photosynthesis. **Photosynthesis** is the process plants use to make their own “food” from the sun’s energy, carbon dioxide, and water. During photosynthesis, carbon dioxide and water combine with solar energy to create **glucose**, a carbohydrate ($C_6H_{12}O_6$), and oxygen.

The process can be summarized as: in the presence of sunlight, carbon dioxide + water $\rightarrow$ glucose + oxygen.

Glucose is a sugar that acts as the "food" source for plants. It can be converted by both plants and animals into a chemical called ATP during cellular respiration. ATP is the energy currency of life.

Actually, almost all organisms obtain their energy from photosynthetic organisms. For example, if a bird eats a caterpillar, then the bird gets the energy that the caterpillar gets from the plants it eats. So the bird indirectly gets energy that began with the glucose formed through photosynthesis. Therefore, the process of photosynthesis is central to sustaining life on Earth. In eukaryotic organisms, photosynthesis occurs in **chloroplasts**. Only cells with chloroplasts—plant cells and algal (protist) cells—can perform photosynthesis. Animal cells and fungal cells do not have chloroplasts and, therefore, cannot photosynthesize. That is why these organisms, as well as the non-photosynthetic protists, rely on other organisms to obtain their energy. These organisms are **heterotrophs.**

The Photosynthesis Song explaining photosynthesis, can be heard at http://www.youtube.com/watch?v=C1_uez5WX1o (1:52).



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Time for Me to Leaf: Tree Chlorophyll Chromatography

Why do leaves change color each fall? This MIT video demonstrates an experiment about the different pigments in leaves. See the video at https://www.youtube.com/watch?v=_v6_5Zxdb68 .

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- All the energy used by living things on Earth came from the process of photosynthesis.
- During photosynthesis, carbon dioxide and water combine with solar energy to create glucose and oxygen.

Lesson Review Questions

1. How is the process of photosynthesis central to sustaining life on Earth?

2. What are the two products produced by photosynthesis?
3. What two raw materials are needed by plants in order to perform photosynthesis?

2.3 Cycles of Matter

Lesson Objectives

- Define biogeochemical cycle.
- Describe the processes of the water cycle.
- Summarize the carbon cycle.
- Outline the nitrogen cycle.

Lesson Vocabulary

- biogeochemical cycle
- carbon cycle
- condensation
- evaporation
- groundwater
- nitrogen cycle
- precipitation
- runoff
- sublimation
- water cycle

Introduction

Where does the water come from that is needed by your cells? What is the source of the carbon and nitrogen that are needed to make your organic molecules? These forms of matter are recycled in an ecosystem. Unlike energy, matter is not lost as it passes through an ecosystem. It just keeps cycling.

Biogeochemical Cycles

The chemical elements and water that are needed by living things keep recycling on Earth. They pass back and forth through biotic and abiotic components of ecosystems. That's why their cycles are called biogeochemical cycles. For example, a chemical element or water might move from organisms (bio) to the atmosphere or ocean (geo) and back to organisms again.

Elements or water may be held for various periods of time in different parts of a biogeochemical cycle.

- An exchange pool is part of a cycle that holds a substance for a short period of time. For example, the atmosphere is an exchange pool for water. It usually holds water (as water vapor) for just a few days.
- A reservoir is part of a cycle that holds a substance for a long period of time. For example, the ocean is a reservoir for water. It may hold water for thousands of years.

The rest of this lesson describes three biogeochemical cycles: water cycle, carbon cycle, and nitrogen cycle.

Water Cycle

Water is an extremely important aspect of every ecosystem. Life can't exist without water. Most organisms contain a large amount of water, and many live in water. Therefore, the water cycle is essential to life on Earth.

Water on Earth is billions of years old. However, individual water molecules keep moving through the water cycle. The water cycle is a global cycle. It takes place on, above, and below Earth's surface, as shown in **Figure** 2.8. During the water cycle, water occurs in three different states: gas (water vapor), liquid (water), and solid (ice). Many processes are involved as water changes state to move through the cycle.

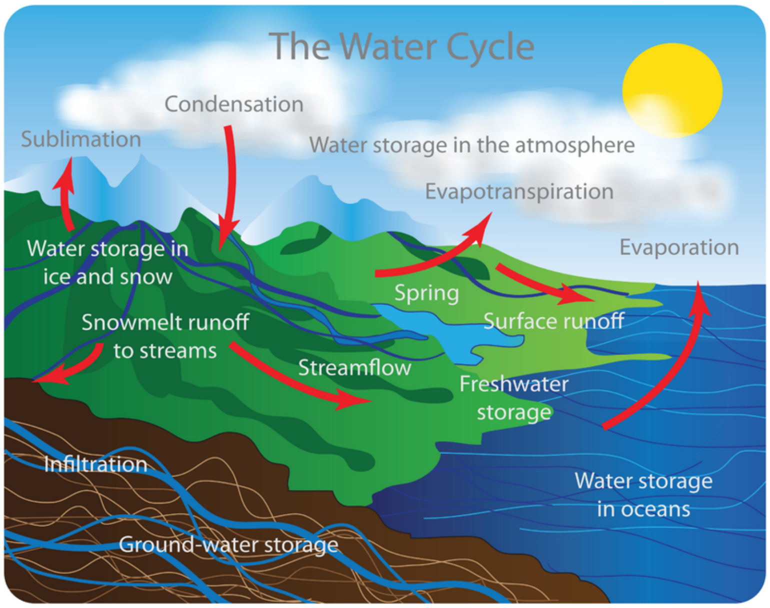

FIGURE 2.8
The water cycle has no beginning or end. It just keeps repeating.

Watch this video for an excellent visual introduction to the water cycle: http://www.youtube.com/watch?v=al-do-HGuIk .

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Evaporation, Sublimation, and Transpiration

Water changes to a gas by three different processes called evaporation, sublimation, and transpiration.

- Evaporation takes place when water on Earth's surface changes to water vapor. The sun heats the water and gives water molecules enough energy to escape into the atmosphere. Most evaporation occurs from the surface of the ocean.
- Sublimation takes place when snow and ice on Earth's surface change directly to water vapor without first melting to form liquid water. This also happens because of heat from the sun.

- Transpiration takes place when plants release water vapor through pores in their leaves called stomata.

Condensation and Precipitation

Rising air currents carry water vapor into the atmosphere. As the water vapor rises in the atmosphere, it cools and condenses. Condensation is the process in which water vapor changes to tiny droplets of liquid water. The water droplets may form clouds. If the droplets get big enough, they fall as precipitation.

Precipitation is any form of water that falls from the atmosphere. It includes rain, snow, sleet, hail, and freezing rain. Most precipitation falls into the ocean. Eventually, this water evaporates again and repeats the water cycle. Some frozen precipitation becomes part of ice caps and glaciers. These masses of ice can store frozen water for hundreds of years or even longer.

Condensation may also form fog or dew. Some living things, like the lizard in **Figure** 2.9, depend directly on these sources of liquid water.

FIGURE 2.9
The thorny devil lizard lives in such a dry environment in Australia that it has a unique specialization for obtaining water. The scales on its body collect dew and channel it to the corners of the mouth, so the lizard can drink it.

Runoff and Groundwater

Precipitation that falls on land may flow over the surface of the ground. This water is called runoff. It may eventually flow into a body of water.

Some precipitation that falls on land soaks into the ground. This water becomes groundwater. Groundwater may seep out of the ground at a spring or into a body of water such as the ocean. Some groundwater is taken up by plant roots. Some may flow deeper underground to an aquifer. An aquifer is an underground layer of rock that stores water. Water may be stored in an aquifer for thousands of years.

Carbon Cycle

The element carbon is the basis of all life on Earth. Biochemical compounds consist of chains of carbon atoms and just a few other elements. Like water, carbon is constantly recycled through the biotic and abiotic factors of ecosystems.

The carbon cycle includes carbon in sedimentary rocks and fossil fuels under the ground, the ocean, the atmosphere, and living things. The diagram in **Figure** 2.10 represents the carbon cycle. It shows some of the ways that carbon moves between the different parts of the cycle. You can see an animated carbon cycle at this link: http://commons.wikimedia.org/wiki/Category:Carbon_cycle#mediaviewer/File:Carbon_Cycle-animated_forest.gif

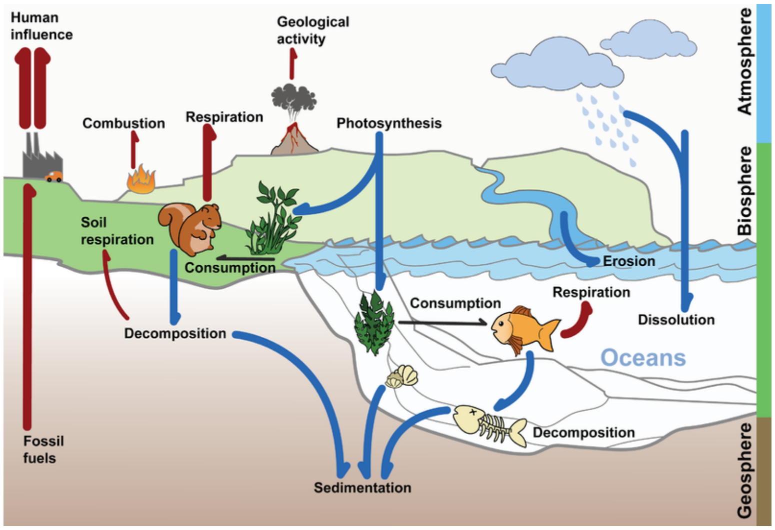

FIGURE 2.10
The Carbon Cycle.

Carbon Reservoirs

Major reservoirs of carbon include sedimentary rocks, fossil fuels, and the ocean. Sediments from dead organisms may form carbon-containing sedimentary rocks. Alternatively, the sediments may form carbon-rich fossil fuels, which include oil, natural gas, and coal. Carbon can be stored in these reservoirs for millions of years. However, if fossil fuels are extracted and burned, the stored carbon enters the atmosphere as carbon dioxide. Natural processes, such as volcanic eruptions, can also release underground carbon from rocks into the atmosphere.

Water erosion by runoff, rivers, and streams dissolves carbon in rocks and carries it to the ocean. Ocean water near the surface dissolves carbon dioxide from the atmosphere. Dissolved carbon may be stored in the deep ocean for thousands of years.

Carbon Exchange Pools

Major exchange pools of carbon include organisms and the atmosphere. Carbon cycles more quickly between these components of the carbon cycle.

- Photosynthesis by plants and other producers removes carbon dioxide from the atmosphere to make organic compounds for living things.
- Cellular respiration by living things releases carbon into the atmosphere or ocean as carbon dioxide.
- Decomposition of dead organisms and organic wastes releases carbon back to the atmosphere, soil, or ocean.

Nitrogen Cycle

Nitrogen is another common element found in living things. It is needed to form both proteins and nucleic acids such as DNA. Nitrogen gas makes up 78 percent of Earth's atmosphere. In the nitrogen cycle, nitrogen flows back and forth between the atmosphere and living things. You can see how it happens in **Figure** 2.11. Several different types of bacteria play major roles in the cycle.

Animals get nitrogen by eating plants or other organisms that eat plants. Where do plants get nitrogen? They can't use nitrogen gas in the air. The only form of nitrogen that plants can use is in chemical compounds called nitrates. Plants absorb nitrates through their roots. This is called assimilation. Most of the nitrates are produced by bacteria that live in soil or in the roots of plants called legumes.

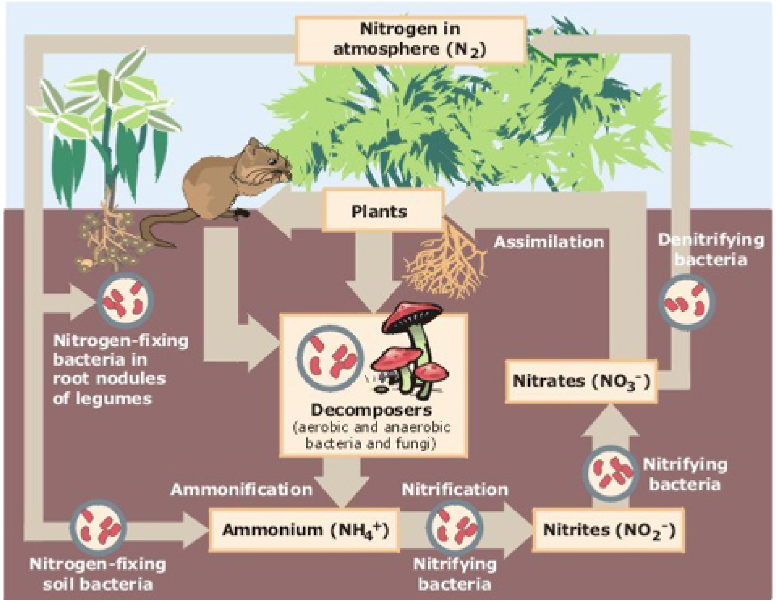

FIGURE 2.11
The nitrogen cycle

- Nitrogen-fixing bacteria change nitrogen gas from the atmosphere to nitrates in soil.
- When organisms die and decompose, their nitrogen is returned to the soil as ammonium ions. Nitrifying bacteria change some of the ammonium ions into nitrates.
- The other ammonium ions are changed into nitrogen gas by denitrifying bacteria.

Lesson Summary

- Water and chemical elements that organisms need keep recycling through biogeochemical cycles. These cycles include biotic and abiotic components of ecosystems.
- The water cycle includes the ocean, atmosphere, ground, and living things. During the water cycle, water keeps changing state by processes such as evaporation, transpiration, condensation, and precipitation.
- The carbon cycle includes photosynthesis, in which plants change carbon dioxide to organic compounds. It also includes cellular respiration, in which living things "burn" organic compounds and release carbon dioxide. Rocks, fossil fuels, and the ocean are also part of the carbon cycle.
- Bacteria play important roles in the nitrogen cycle. They change nitrogen gas and products of decomposition into nitrates, which plants can assimilate. Animals obtain nitrogen by eating plants or other organisms. Still other bacteria return nitrogen gas to the atmosphere.

Lesson Review Questions

Recall

1. What is a biogeochemical cycle?
2. Identify three ways in which water vapor enters the atmosphere in the water cycle.
3. Describe three ways that carbon can enter the ocean in the carbon cycle.
4. What roles do bacteria play in the nitrogen cycle?

Apply Concepts

5. A farmer may plant a field with a legume crop to improve the soil. How does this work?

Think Critically

6. Compare and contrast exchange pools and reservoirs in biogeochemical cycles. Give an example of each from the water and carbon cycles.
7. Explain the role of decomposers in the nitrogen cycle.

Points to Consider

Ecosystem dynamics include more than the flow of energy and recycling of matter. Ecosystems are also dynamic because they change through time.

1. What are some ways ecosystems might change through time?
2. Do you think there are any ecosystems that do not change through time?

2.4 Ecosystem Change

Lesson Objectives

- Define ecological succession.
- Explain how primary succession occurs.
- Explain why secondary succession occurs more rapidly than primary succession.
- Discuss the concept of climax community.

Lesson Vocabulary

- climax community
- ecological succession
- pioneer species
- primary succession
- secondary succession

Introduction

Imagine walking in the forest in **Figure** 2.12. The towering trees have been growing here for hundreds of years. It may seem as though the forest has been there forever. But no ecosystem is truly static. The numbers and types of species in most ecosystems change to some degree through time. This is called ecological succession. Important cases of ecological succession are primary succession and secondary succession.

FIGURE 2.12
An old redwood forest seems unchanging, but even here change happens.

Primary Succession

Primary succession occurs in an area that has never before been colonized by living things. Generally, the area is nothing but bare rock.

Where It Happens

This type of environment could come about when:

- a landslide uncovers bare rock
- a glacier retreats and leaves behind bare rock
- lava flows from a volcano and hardens into bare rock (see **Figure** below)

How It Happens

The first few species to colonize a disturbed area are called pioneer species. In primary succession, pioneer species must be organisms that can live on bare rock. They usually include bacteria and lichens (see **Figure** below). Along with wind and water, the pioneer species help weather the rock and form soil. Once soil begins to form, plants can move in. The first plants are usually grasses and other small plants that can grow in thin, poor soil. As more plants grow and die, organic matter is added to the soil. This improves the soil and helps it hold water. The improved soil allows shrubs and trees to move into the area.

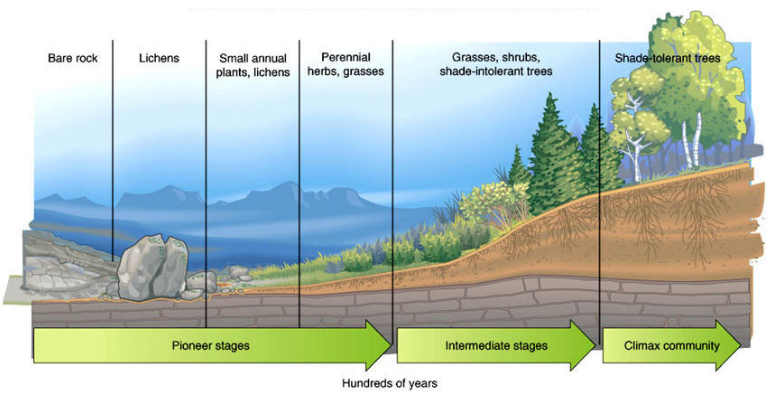

FIGURE 2.13
Primary Succession

Secondary Succession

Secondary succession occurs in a formerly inhabited area that was disturbed. It results from a fire, flood, or human action such as farming. For example, a forest fire might kill all the trees and other plants in a forest, leaving behind only charred wood and soil.

How It Happens

Secondary succession is faster than primary succession. The soil is already in place. After a forest fire, for example, the pioneer species are plants such as grasses and fireweed. You can see a forest in this stage of recovery in **Figure** below. As organic matter from the pioneer species improves the soil, trees and other forest plants will move into the area. You can see the amazing real-world story of secondary succession on Mount St. Helens by watching this short video: http://www.youtube.com/watch?v=4RsMyVavT2Q .

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Does a changing ecosystem ever stop changing? Does its community of organisms ever reach some final, stable state? Scientists used to think that ecological succession always ended at a stable state, called a climax community. Now their thinking has changed. Theoretically, a climax community is possible. But continued change is probably more likely for real-world ecosystems. Most ecosystems are disturbed too often to ever develop a climax community.

Lesson Summary

- Ecological succession is the process in which the numbers and types of species in an ecosystem change over time.
- Primary succession occurs in an area that has never before been colonized. Pioneer species include bacteria and lichens that can grow on bare rock and help make soil.
- Secondary succession occurs in a formerly inhabited area that was disturbed. Soil is already in place, so pioneer species include small plants such as grasses.
- Most ecosystems are disturbed too often to attain a final, stable climax community.

Lesson Review Questions

Recall

1. What is ecological succession?
2. Define climax community, and state why climax communities are unlikely.

Apply Concepts

3. Assume that a flood washed out all of the plants in a large area along the bank of a river. It left behind nothing but soil. How will ecological succession occur in this area?

Think Critically

1. Compare and contrast primary and secondary succession.

Points to Consider

Many ecosystems have changed because of human actions. The human species is responsible for a range of environmental problems.

1. What environmental problems have human actions caused?

2. How have these environmental problems affected living things?

2.5 References

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CHAPTER 3 Biomes and Biodiveristy

Chapter Outline

3.1 Introduction to Biomes and Biodiversity

Lesson Objectives

- Define biome and climate, and explain how biomes are related to climate.
- Outline how climate determines growing conditions for plants and affects the number and biodiversity of plants in a biome.
- Explain how climate is related to biodiversity of biomes and adaptations of organisms.

Introduction

If you look at the two pictures in **Figure 1** below, you will see very few similarities. The picture on the left shows a desert in Africa. The picture on the right shows a rainforest in Australia. What is the most obvious difference between the two places? It could be that the desert does not have any visible plants, whereas the rainforest is densely packed with trees. What causes these two places to be so different? The main reason is climate.

FIGURE 3.1
Sahara Desert in northern Africa (left). Rainforest in northeastern Australia (right).

Biomes and Climate

The two pictures above represent two different types of biomes: deserts and rainforests. A **biome** is a group of similar ecosystems that cover a broad area. Biomes are major subdivisions of the biosphere. They can be classified into two major types:

- **Terrestrial biomes**: biomes on land
- **Aquatic biomes**: biomes in water

Climate is the most important abiotic (non-living) factor affecting the distribution of terrestrial biomes. Climate determines the growing conditions in an area, so it also determines what plants can grow there. Animals depend directly or indirectly on plants, so the type of animals that live in an area also depends on climate.

What Is Climate?

Climate is the average weather in an area over a long period of time, whereas weather is a day to day explanation. Weather and climate are described in terms of factors such as temperature and precipitation. The climate of a particular location depends, in turn, on its latitude (distance from the equator) and altitude (distance above sea level). Other factors that affect an area's climate include its location relative to the ocean or mountain ranges. Temperature and moisture are the two climatic factors that most affect terrestrial biomes.

Temperature

In general, temperature on Earth's surface gets colder as you move from the equator to the poles. Based on temperature, climates can be classified as tropical, temperate, or arctic, as shown in **Figure 2**. Temperature also gets colder from lower to higher altitudes, for example, from the base of a mountain to its peak. This explains why the tops of high mountains in tropical climates may be snow-capped year-round.

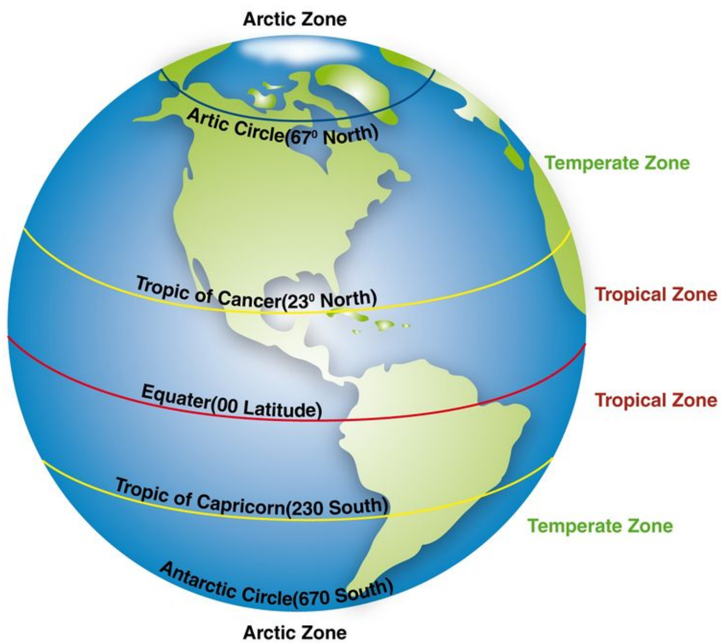

FIGURE 3.2

Major climate zones based on temperature include tropical, temperate, and arctic zones. The tropical zone extends from the Tropic of Capricorn to the Tropic of Cancer. The two temperate zones extend from the tropical zone to the arctic or antarctic circle. The two arctic zones extend from the arctic or antarctic circle to the north or south pole.

The ocean may also play an important role in the temperature of an area. Coastal areas may have milder climates than areas farther inland at the same latitude. This is because the temperature of the ocean changes relatively little from season to season, and this affects the temperature on nearby coasts. As a result, many coastal areas have both warmer winters and cooler summers than inland areas.

Moisture

Based on the amount of water available to plants, climates can be classified on a scale from arid (dry) to humid (wet). The moisture of a biome is determined by both precipitation and evaporation. Evaporation, in turn, depends on heat from the sun. Worldwide precipitation patterns result from global movements of air masses and winds, which are shown in **Figure 3**. For example, warm, humid air masses rise over the equator and are moved north and south by global air currents. The air masses cool and cannot hold as much water. As a result, they drop their moisture as precipitation. This explains why many tropical areas receive more precipitation than other areas of the world.

Distance from the ocean and mountain ranges also influences precipitation. For example, one side of a mountain range near the ocean may receive a lot of precipitation because warm, moist air masses regularly move in from the water. As air masses begin to rise up over the mountain range, they cool and drop their moisture as precipitation. This is illustrated in **Figure 4**.

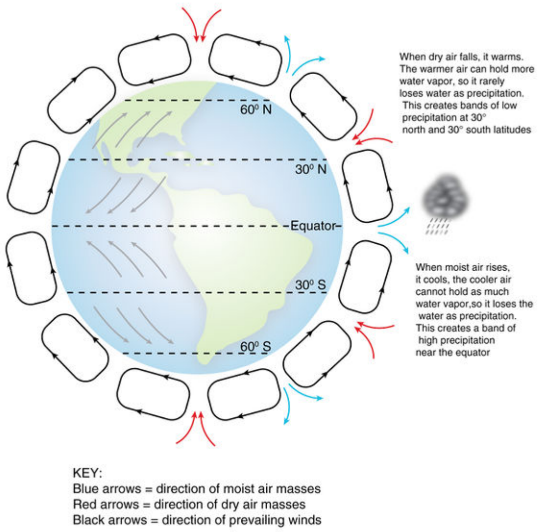

FIGURE 3.3
This model of Earth shows the direction in which air masses typically move and winds usually blow at different latitudes. These movements explain why some latitudes receive more precipitation than others.

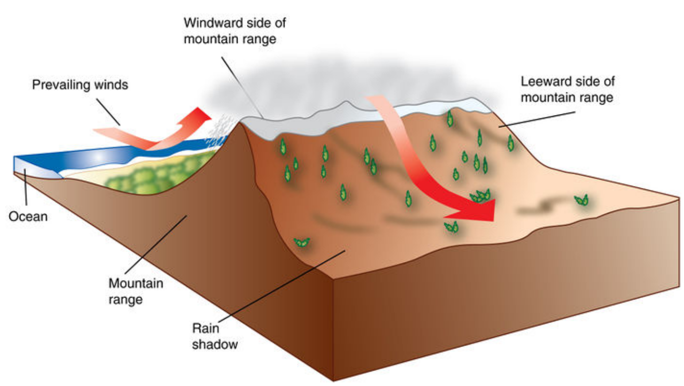

FIGURE 3.4
The windward side of this mountain range has a humid climate, whereas the leeward side has an arid climate. On the windward side, warm moist air comes in from the ocean, rises and cools, and drops its moisture as rain or snow. On the leeward side, the cool dry air falls, warms, and picks up moisture from the land. How has this affected plant growth on the two sides of the mountain range?

By the time the air masses reach the other side of the mountain range, they no longer contain moisture. As a result, land on this side of the mountain range receives little precipitation. Many inland areas far away from the ocean or mountain ranges are also dry. Air masses that have passed over a wide expanse of land to reach the interior of a continent usually no longer carry much moisture.

Plant Growth

Plants are the major producers in terrestrial biomes. Almost all other terrestrial organisms depend on them either directly or indirectly for food. Climate is the major factor affecting the number and diversity of plants that can grow in a terrestrial biome. Plants need air, warmth, sunlight, water, and nutrients to grow.

Plants need soil that contains adequate nutrients and organic matter. Nutrients and organic matter are added to soil when plant litter and dead organisms decompose. In cold climates, decomposition occurs very slowly. As a result, soil in cold climates is thin and poor in nutrients. Soil is also thin and poor in hot, wet climates because the heat and humidity cause such rapid decomposition that little organic matter accumulates in the soil. The frequent rains also leach nutrients from the soil. Thin, poor soil is shown in the left drawing of **Figure 5**. The right drawing shows thick, rich soil. This type of soil is generally found in temperate climates and is best for most plants.

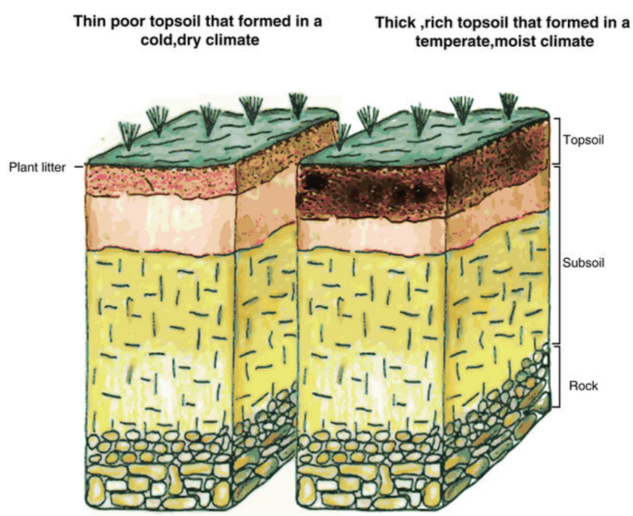

FIGURE 3.5
The soil on the left has a thin layer of topsoil, the part of soil where most plant roots obtain moisture and nutrients. The topsoil is light in color, which means that it is poor in nutrients and organic matter. The soil on the right has a thicker layer of topsoil. Its dark color indicates that the topsoil is rich in nutrients and organic matter.

Biome Biodiversity and Adaptations

Because plants are the most important producers in terrestrial biomes, anything that affects their growth also influences the number and variety of other organisms that can be supported in a biome. Therefore, climate has a major impact on the biodiversity of biomes.

Biodiversity

Biodiversity refers to the number of different species of organisms in a biome (or ecosystem or other ecological unit). Biodiversity is usually greater in warmer biomes. Therefore, biodiversity generally decreases from the equator to the poles. Biodiversity is usually greater in wetter biomes, as well. Remember the desert and rainforest pictured in **Figure 1**? The biodiversity of these two biomes is vastly different. Both biomes have warm climates, but the desert is very dry, and the rainforest is very wet. The desert has very few organisms, so it has low biodiversity. Some parts of the desert may have no organisms, and therefore zero biodiversity. In contrast, the rainforest has the highest biodiversity of any biome on Earth.

A discussion of biodiversity is available at http://www.youtube.com/watch?v=vGxJArebKoc (6:12).

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Adaptations

Plants, animals, and other organisms evolve adaptations to suit them to the abiotic factors in their biome. Abiotic factors to which they adapt include temperature, moisture, growing season, and soil. This is why the same type of biome in different parts of the world has organisms with similar adaptations. For example, biomes with dry climates worldwide have plants with similar adaptations to aridity, such as special tissues for storing water (see **Figure 6**).

FIGURE 3.6

(left) The large hollow leaves of an African aloe plant store water and help the plant survive in its arid biome. (right) Cacti like these are found in arid biomes of North America. They store water in their thick, barrel-like stems.

In biomes with a severe cold or dry season, plants may become dormant during that season of the year. In dormant plants, cellular activities temporarily slow down, so the plants need less sunlight and water. For example, many trees shed their leaves and become dormant during very cold or dry seasons. Animals in very cold or dry biomes also must adapt to these abiotic factors. For example, adaptations to cold include fur or fat, which insulates the body and helps retain body heat.

Changes in ecosystems are discussed at http://www.youtube.com/watch?v=jHWgWxDWhsA (7:47) and http://www.youtube.com/watch?v=5qblwORXwrg (2:26).

MEDIA

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Lesson Summary

- A biome is a group of similar ecosystems that cover a broad area. Climate is the average weather in an area over a long period of time. Climate is the most important abiotic factor affecting the distribution of terrestrial biomes.
- Climate includes temperature and precipitation, and it determines growing season and soil quality. It is the major factor affecting the number and diversity of plants in terrestrial biomes.
- By affecting plants, which are the main producers, climate affects the biodiversity of terrestrial biomes. Plants and other organisms also evolve adaptations to climatic factors in their biomes, including adaptations to extreme cold and dryness.

Review Questions

1. Name three factors that help determine the climate of an ecosystem.
2. List some important factors related to climate that plants need in order to grow?
3. Compare the data for Seattle and Denver in the table below. What factors might explain why Seattle is warmer in the winter than Denver, even though Seattle is farther north?:

TABLE 3.1:

City	Latitude	Altitude	Location	Temperature[1]
Seattle, Washington	48°N	429 ft	Coastal	33°F
Denver, Colorado	41°N	5,183 ft	Interior	15°F

4. Explain how the quality of soil in an area is influenced by climate.

5.Why is biodiversity higher at the equator than it is near the poles?

Points to Consider

Plants and the other organisms in terrestrial biomes are greatly influenced by climate.

- What is the climate like where you live?
- How hot or cold does it get, and how much precipitation usually falls?
- Discuss with your class the climate in your area and how it seems to affect plant growth.
- What plants and animals are naturally found in your part of the country?

Further Reading / Supplemental Links

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- Susan L. Woodward, Biomes of Earth: Terrestrial, Aquatic, and Human-Dominated. Greenwood Press, 2003.

- http://estrellamountain.edu/faculty/farabee/biobk/BioBookcommecosys.html
- http://ridge.icu.ac.jp/gen-ed/biomes.html
- http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/B/Biomes.htmlFurther

3.2 Terrestrial Biomes

- Identify and describe terrestrial biomes.
- Distinguish a desert from a rainforest.
- Provide the characteristics of a tropical grassland.
- Describe the tundra and chaparral.

Lesson Objectives

- Outline the characteristics of the terrestrial biomes.

Lesson Vocabulary

- Tundra
- Temperate and Tropical Forests
- Temperate and Tropical Grasslands
- Chaparral
- Temperate and Tropical Deserts

Introduction

Forest vs. desert. What explains these differences?

If you look at these two pictures, you will see very few similarities. The picture on the left shows a desert in Africa. The picture on the right shows a rainforest in Australia. The desert doesn't have any visible plants, whereas the rainforest is densely packed with trees. Do they have different climates? Does one get more rain than the other?

Survey of Terrestrial Biomes

Terrestrial **biomes** are classified by the **climate** and their **biodiversity**, especially the types of **primary producers**. The world map in **Figure** 3.7 shows where 13 major terrestrial biomes are found.

The following figures summarize the basic features of major terrestrial biomes. As you read about each biome, think about how its biodiversity and types of plants and animals relate to its climate. For example, why do you think there are no amphibians or reptiles in tundra biomes? *(Hint: Amphibians and reptiles cannot maintain a constant body temperature. Instead, they have about the same temperature as their surroundings.)*

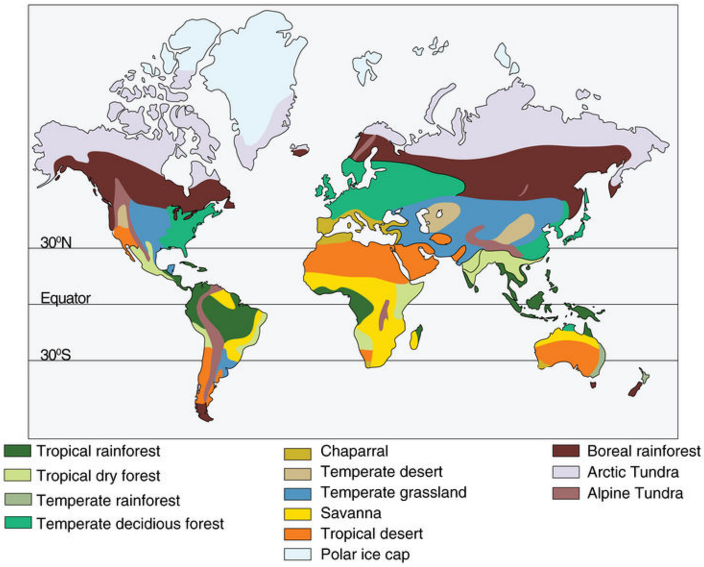
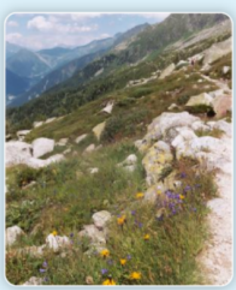


FIGURE 3.7
Worldwide Distribution of Terrestrial Biomes. This map shows the locations of Earth's major terrestrial biomes.

Tundra



Alpine tundra in the Alps Mountains of Switzerland in Europe

Arctic tundra on the northern coast of Alaska in the United States

Other names:
Arctic tundra (high latitudes)
Alpine tundra (high altitudes)

Climate: Arctic, acrid
Growing season: Very short
Soil quality: Very poor

Biodiversity: Very low

Plants: Mosses, grasses, and lichens; few herbaceous plants; no trees.

Animals: Insects; birds (summer only); no amphibians or reptiles; mammals such as rodents, arctic hares, arctic foxes, polar bears; caribou (summer only); mountain goats and chinchillas (alpine tundra only)

Boreal forest in central (inland) Alaska, United States

Boreal Forest

Other names: Taiga, northern conifer forest
Climate: Subarctic, semi-arid
Growing season: Short
Soil quality: Poor

Biodiversity: Low

Plants: Conifers such as cedar, spruce, pine, and fir; mosses and lichens

Animals: Insects; birds (mainly in summer); no amphibians or reptiles; mammals such as rodents, rabbits, minks, raccoons, bears, and moose; caribou (winter only)

Temperate deciduous forest in Pennsylvania, eastern United States

Temperate Deciduous Forest

Other names: Temperate hardwood forest, temperate broadleaf forest
Climate: Temperate, semi-humid
Growing season: Medium
Soil quality: Good

Biodiversity: High

Plants: Broadleaf deciduous trees such as beech, maple, oak, and hickory; ferns, mosses, and shrubs; many herbaceous plants

Animals: Insects, amphibians, reptiles, and birds; mammals such as mice, chipmunks, squirrels, raccoons, foxes, deer, black bears, bobcats, and wolves

Temperate grassland in Nebraska, midwestern United States

Temperate Grassland

Other names: Prairie, outback, pampa, steppe
Climate: Temperate, semi-arid
Growing season: Medium
Soil quality: Excellent

Biodiversity: Medium-high

Plants: Grasses; other herbaceous plants; no trees

Animals: Invertebrates such as worms and insects; amphibians, reptiles, and birds; mammals such as mice, prairie dogs, rabbits, foxes, wolves, coyotes, bison, and antelope; kangaroo (only in Australia)

Chaparral in southern California, United States

Chaparral

Other names: Mediterranean scrub forest
Climate: Temperate, semi-arid
Growing season: Medium
Soil quality: Poor

Biodiversity: Low-medium

Plants: Shrubs and small trees such as scrub oak and scrub pine

Animals: Insects, reptiles, and birds; mammals such as rodents and deer

Desert in southern California, United States

Desert

Climate: Temperate or tropical, arid
Growing season: Varies
Soil quality: Very poor

Biodiversity: None-low

Plants: Plants adapted to dryness, such as cacti, sagebrush, and mesquite; virtually no plants if extremely arid

Animals: Insects, reptiles, and birds; mammals such as rodents and coyotes

Tropical rainforest in Ecuador, South America

Tropical Rainforest

Climate: Tropical, humid
Growing season: Year-round
Soil quality: Excellent

Biodiversity: Very high

Plants: Tall flowering, broadleaf evergreen trees; vines and epiphytes; few plants on forest floor

Animals: Insects, amphibians, reptiles, and birds; mammals such as monkeys, sloths, leopards, jaguars, pigs, and tigers

Elephant grazing in its grassland ecosystem.

Tropical Grassland

Other names: Savanna
Climate: Tropical, semi-arid
Growing season: Year-round
Soil quality: Poor

Biodiversity: Low-medium

Plants: Grasses, scattered clumps of trees

Animals: Insects, reptiles, and birds; mammals such as zebras, giraffes, antelopes, lions, cheetahs, and hyenas

Lesson Summary

- Terrestrial biomes include tundras, temperate forests and grasslands, chaparral, temperate and tropical deserts, and tropical forests and grasslands.

Lesson Review Questions

Explore More

Use this resource to answer the questions that follow.

- **Characteristics of the Earth's Terrestrial Biomes** at http://www.physicalgeography.net/fundamentals/9k.html .

1. What controls the productivity of a biome?

2. How are most terrestrial biomes identified?
3. What determines the animal life that inhabits a biome?
4. Which biome is describe by:
   a. high temperature and high humidity throughout the year.
   b. a moist-cool, transcontinental coniferous forest.
   c. an absence of trees, the presence of dwarf plants, and a ground surface that is wet, spongy, and hummocky.
   d. distinct wet and dry seasons with hot temperatures all year long.

Recall

1. Identify two types of tundra and where they are found.
2. What terrestrial biome has the highest biodiversity? the lowest?
3. In which biome are you most likely to find grasses, zebras, and lions?
4. If you were to design a well-adapted desert animal, what adaptations would you give it to help it survive in its desert biome?

3.3 Aquatic Biomes

- Give an overview of aquatic biomes.
- Explain the factors that are used to define aquatic biomes.
- Distinguish the photic zone from the aphasic zone.
- Summarize adaptations necessary to live in a marine biome.
- Define intertidal zone.

Lesson Objectives

- Outline the characteristics of the aquatic biomes.

Lesson Vocabulary

- aphotic zone
- photic zone
- intertidal zone

Introduction

Do aquatic ecosystems need sunlight?

Of course. The sunlight - in part - allows the diversity of life seen in this ecosystem. If the available sunlight was less, could this ecosystem still thrive? Maybe, but the ecosystem would probably be very different. Sunlight, of course, is necessary for photosynthesis, which brings energy into an ecosystem. So, the availability of that sunlight has a direct impact on the productivity and biodiversity of aquatic ecosystems.

Aquatic Biomes

Terrestrial organisms are generally limited by temperature and moisture. Therefore, terrestrial biomes are defined in terms of these abiotic factors. Most aquatic organisms do not have to deal with extremes of temperature or moisture. Instead, their main limiting factors are the availability of sunlight and the concentration of dissolved oxygen and nutrients in the water. These factors vary from place to place in a body of water and are used to define **aquatic biomes**.

Aquatic Biomes and Sunlight

In large bodies of standing water, including the ocean and lakes, the water can be divided into zones based on the amount of sunlight it receives:

1. The **photic zone** extends to a maximum depth of 200 meters (656 feet) below the surface of the water. This is where enough sunlight penetrates for photosynthesis to occur. Algae and other photosynthetic organisms can make food and support food webs.
2. The **aphotic zone** is water deeper than 200 meters. This is where too little sunlight penetrates for photosynthesis to occur. As a result, food must be made by chemosynthesis or else drift down from the water above.

These and other aquatic zones in the ocean are identified in **Figure** 3.8.

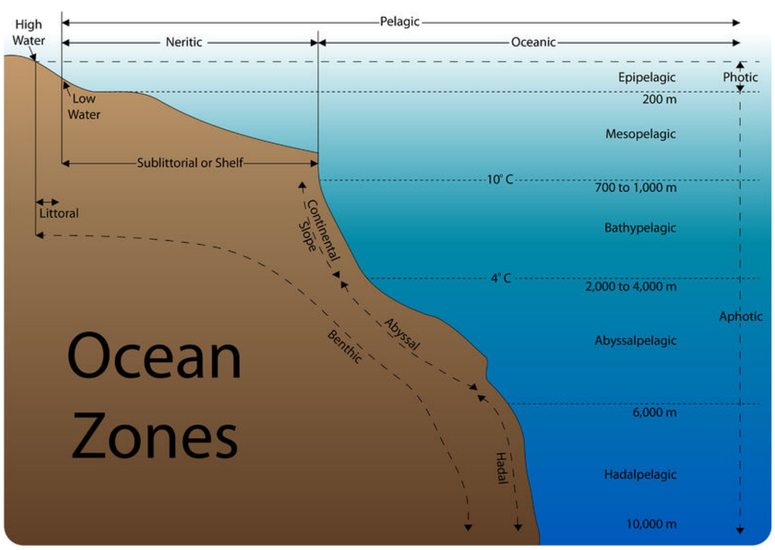


FIGURE 3.8
The ocean is divided into many different zones, depending on distance from shore and depth of water.

Aquatic Biomes and Dissolved Substances

Water in lakes and the ocean also varies in the amount of dissolved oxygen and nutrients it contains:

1. Water near the surface of lakes and the ocean usually has more dissolved oxygen than does deeper water. This is because surface water absorbs oxygen from the air above it.
2. Water near shore generally has more dissolved nutrients than water farther from shore. This is because most nutrients enter the water from land. They are carried by runoff, streams, and rivers that empty into a body of water.

3. Water near the bottom of lakes and the ocean may contain more nutrients than water closer to the surface. When aquatic organisms die, they sink to the bottom. Decomposers near the bottom of the water break down the dead organisms and release their nutrients back into the water.

Marine Biomes

Aquatic biomes in the ocean are called **marine biomes**. Organisms that live in marine biomes must be adapted to the salt in the water. For example, many have organs for excreting excess salt. Two ocean zones are particularly challenging to marine organisms: the intertidal zone and the deep ocean.

The **intertidal zone** is the narrow strip along the coastline that is covered by water at high tide and exposed to air at low tide (see **Figure** 3.9). There are plenty of nutrients and sunlight in the intertidal zone. However, the water is constantly moving in and out, and the temperature keeps changing. These conditions require adaptations in the organisms that live there, such as the barnacles in **Figure** 3.10.

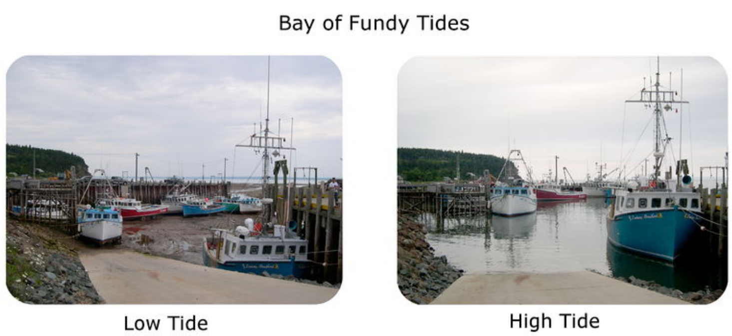


FIGURE 3.9
These pictures show the intertidal zone of the Bay of Fundy, on the Atlantic coast in Maine. Can you identify the intertidal zone from the pictures?

FIGURE 3.10
Barnacles secrete a cement-like substance that anchors them to rocks in the intertidal zone.

Organisms that live deep in the ocean must be able to withstand extreme water pressure, very cold water, and complete darkness. However, even here, thriving communities of living things can be found. Organisms cluster around hydrothermal vents in the ocean floor. The vents release hot water containing chemicals that would be toxic to most other living things. The producers among them are single-celled chemoautotrophs. They make food using energy stored in the chemicals.

Summary

- Aquatic biomes are determined mainly by sunlight and concentrations of dissolved oxygen and nutrients in the water.
- Marine biomes are found in the salt water of the ocean.

Lesson Review Questions

Explore More

Use these resources to answer the questions that follow.

- **The Aquatic Biome** at http://www.ucmp.berkeley.edu/glossary/gloss5/biome/aquatic.html .

1. Aquatic biomes cover about how much of Earth's surface?
2. The aquatic biome can be broken down into two basic regions. What are they?
3. Where in a river would trout be found? Why?
4. Describe the animal life of a coral reef.

Recall

1. How are aquatic biomes defined?
2. What is the photic zone of the ocean?
3. Where does food come from at the bottom of the ocean?

3.4 Biodiversity and Extinction

Lesson Objectives

- Define biodiversity.
- Identify ways organisms are adapted to their environment.
- List benefits of biodiversity to people and ecosystems.
- Describe the sixth mass extinction, and identify its chief causes.
- Identify ways individuals can protect biodiversity.

Lesson Vocabulary

- biodiversity
- exotic species
- habitat loss
- sixth mass extinction

Introduction

It's obvious that living things are important natural resources needed by human beings. After all, other species provide us with all of the food we eat. We couldn't survive without them. But that's far from the only reason that other species are important for human survival. Biodiversity is an important natural resource in and of itself.

Biodiversity

Biodiversity refers to the variety of life and its processes. It includes the variation in living organisms, the genetic differences among them, and the range of communities and ecosystems in which they live. Scientists have identified about 1.9 million species alive today, but they are discovering new species all the time. Many of them live on coral reefs and in tropical rainforests (see **Figure** 3.11). These two ecosystems have some of the greatest biodiversity on the planet.

Organisms have Adaptations that help them Live in the Environment

Each organism has the ability to survive in a specific environment. Dry desert environments are difficult to live in. Desert plants have special stems and leaves to conserve water (**Figure** below). Animals have other ways to live in the desert. The Namib Desert receives only 1.5 inches of rainfall each year. The Namib Desert beetle lives there. How do the beetles get enough water to survive? Early morning fog deposits water droplets. The droplets collect on a beetle's wings and back (**Figure** below). The beetle tilts its rear end up. When the droplet is heavy enough, it slides forward. It lands in the beetle's mouth. There are many other environments that need unique approaches for survival (**Figure** below and below).

FIGURE 3.11
This coral reef (top) and tropical rainforest (bottom) have a tremendous variety of different species.

FIGURE 3.12

FIGURE 3.13

FIGURE 3.14

FIGURE 3.15

Getting Food and Being Food (Or Not)

Organisms must be able to get food and avoid being food. Hummingbirds have long, thin beaks that help them drink nectar from flowers. Some flowers are tubular. Different species of flowers have tubes of different lengths. Different species of hummingbirds have different lengths of beaks. A particular hummingbird species has evolved to feed from one or a few species of flowers.

The battle between needing food and being food plays out in the drama between lions and zebras. When a herd of zebras senses a lion, the animals run away. The zebras' dark stripes confuse the lions. It becomes hard for them to focus on just one zebra. The zebras may get away. But lions are swift and agile. A lion may be able to get a zebra, maybe one that's old or sick.

Importance of Biodiversity

Biodiversity is important to human beings for many reasons.

Ecosystem Services

Biodiversity is important for healthy ecosystems. It generally increases ecosystem productivity and stability. It helps ensure that at least some species will survive environmental change. Biodiversity also provides many other ecosystem services. For example:

- Plants and algae maintain Earth's atmosphere. They add oxygen to the air and remove carbon dioxide when they undertake photosynthesis.
- Plants help protect the soil. Their roots grip the soil and keep it from washing or blowing away. When plants die, their organic matter improves the soil as it decomposes.
- Microorganisms purify water in rivers and lakes. They also decompose organic matter and return nutrients to the soil. Certain bacteria fix nitrogen and make it available to plants.
- Predator species such as birds and spiders control insect pests. They reduce the need for chemical pesticides, which are expensive and may be harmful to human beings and other organisms.
- Animals, like the bee in **Figure** below , pollinate flowering plants. Many crop plants depend on pollination by wild animals.

FIGURE 3.16

Economic Services

For one thing, biodiversity has direct economic benefits. Here are a few of the economic benefits of biodiversity:

- Besides food, diverse living things provide us with many different products. Some examples include dyes, rubber, fibers, paper, adhesives, and timber.
- Living things are an invaluable source of medical drugs. More than half of the most important prescription drugs come from wild species. However, only a fraction of species have yet been studied for their medical potential.
- Certain species may warn us of toxins in the environment. Amphibians are particularly sensitive to toxins because of their permeable skin. Their current high rates of extinction serve as an early warning of environmental damage and danger to us all.
- Wild organisms maintain a valuable pool of genetic variation. This is important because most domestic species have been bred to be genetically uniform. This puts domestic crops and animals at great risk of dying out due to disease.

- Some living things provide inspiration for technology. For example, water strider insects like the one in **Figure** 3.17 have helped engineers develop tiny robots that can walk on water. The robots could be used to monitor water quality, among other useful purposes.

FIGURE 3.17
Water strider insect

Extinction

Extinction is the complete dying out of a species. Once a species goes extinct, it can never return. More than 99 percent of all the species that ever lived on Earth have gone extinct. Five mass extinctions have occurred in Earth's history. They were caused by major geologic and climatic events. The fifth mass extinction wiped out the dinosaurs 65 million years ago.

The Sixth Mass Extinction

Evidence shows that a sixth mass extinction is happening right now. Species are currently going extinct at the fastest rate since the dinosaurs died out. Dozens of species are going extinct every day. If this rate continues, as many as half of all remaining species could go extinct by 2050.

Why are so many species going extinct today? Unlike previous mass extinctions, the sixth mass extinction is due mainly to human actions.

Habitat Loss

The single biggest cause of the sixth mass extinction is habitat loss. A habitat is the area where a species lives and to which it has become adapted. When a habitat is disturbed or destroyed, it threatens all the species that live there with extinction.

More than half of Earth's land area has been disturbed or destroyed by farming, mining, forestry, or the development of cities, suburbs, and golf courses. Habitats that are rapidly being destroyed include tropical rainforests. They are being cut and burned, mainly to clear the land for farming. Half of Earth's mature tropical forests have already been destroyed. At current rates of destruction, they will all be gone by 2090. In the U.S., half of the wetlands and almost all of the tall-grass prairies (see **Figure** 3.18) have already been destroyed for farming.

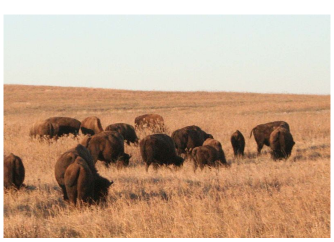


FIGURE 3.18
Bison graze on grasses in a tall-grass prairie nature preserve in Oklahoma.

Other Causes of Extinction

There are several other causes of the sixth mass extinction. Most of them contribute to habitat destruction.

- The burning of fossil fuels has increased the greenhouse effect and caused global climate change. Increasing temperatures are changing basic climate factors of habitats, and rising sea levels are covering them with water. These changes threaten many species.
- Pollution of air, water, and soil makes habitats toxic to many organisms. A well-known example is the near extinction of the peregrine falcon in the mid-1900s due to the pesticide DDT.
- Humans have over-harvested trees, fish, and other wild species. This threatens not only their survival but the survival of all the other species that depend on them.
- Humans have introduced exotic species into new habitats. These are species that are not native to the habitat where they are introduced. They may lack predators in the new habitat so they can out-compete native species and drive them extinct. Exotic species may also carry new diseases, prey on native species, and disrupt local food webs. You can read about an example of an exotic species in **Figure** 3.19.

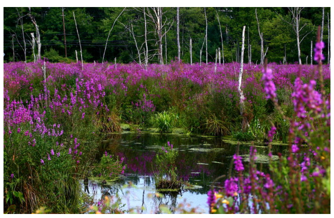


FIGURE 3.19

Purple loosestrife is a European wildflower that was introduced to North America in the early 1800s. It soon spread to take over wetland habitats throughout the U.S. and Canada. Purple loosestrife replaces native wetland plants and threatens native wildlife by eliminating natural foods and cover. It also blocks irrigation systems.

Protecting Biodiversity

Government policies and laws are needed to protect biodiversity. Such actions have been shown to work in the past. For example, peregrine falcons made an incredible recovery after laws were passed banning the use of DDT.

Individuals can also play a role in protecting biodiversity. What can you do? Here are a few suggestions:

- Start a compost pile to recycle organic wastes. Use the compost to enrich yard and garden soil. It will reduce the need for chemical fertilizers and added water.
- Make your backyard welcoming to native wildlife. Plant native plants that will provide food and shelter for native animals such as birds and amphibians. Add a water source, such as a fountain or bird bath.
- Avoid the introduction of exotic species to local habitats.
- Avoid the use of herbicides and pesticides. In addition to killing garden weeds and pests, they may harm native organisms, such as wildflowers, honey bees, and song birds.
- Conserve natural resources, including energy resources. Always reduce, reuse, or recycle.
- Learn more about biodiversity and how to protect it. Then pass on what you learn to others.

Lesson Summary

- Biodiversity refers to the variety of life and its processes. Biodiversity has direct economic benefits. It also increases ecosystem productivity and stability and provides vital ecosystem services.
- Extinction is the complete dying out of a species. Five mass extinctions have occurred in Earth's history, caused by major geologic and climatic events. A sixth mass extinction is happening right now. The single biggest cause of the current mass extinction is habitat loss due to human actions.
- Government policies and laws are needed to protect biodiversity, but individuals can also play a role.

Lesson Review Questions

Recall

1. What is biodiversity?

2. Study the organisms in the photos above. For the aloe vera plant and the beetles, list the adaptations that each has for successful living.

3. Study the organisms in the photos above. For the stoats and the crowned crane, list the adaptations that each has for successful living.

4. Describe two ecosystem services provided by biodiversity.

Apply Concepts

5. How does being well suited for a particular environment lead to biodiversity?

6. Describe one specific change you could make in your life to help protect biodiversity.

Points to Consider

The human species has been incredibly successful. In a relatively short period of time, it has colonized almost all of Earth's terrestrial habitats. Unfortunately, human beings have also impacted Earth, its climate, and its environment. Human actions threaten Earth's valuable biodiversity.

1. What do you think Earth's future may hold?
2. Do you think people will take steps to save Earth for future generations before it's too late?

Explore More

Use the resource below to answer the questions that follow.

- **The Loneliest Animals: Critical Biodiversity** at http://www.youtube.com/watch?v=I7G2rQARCC8 (2:42)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/1496

1. How did so much biodiversity come about?
2. Why is biodiversity important?
3. Why are so many species disappearing now?
4. How many species are disappearing from tropical rainforests each year? Why?

3.5 References

1. Desert: Nicholasink; Rainforest: Tim35. Desert: http://en.wikipedia.org/wiki/Image:Desert1.jpg; Rainforest: http://commons.wikimedia.org/wiki/File:DSC00686Cairns.JPG . Desert: CC-BY-SA 2.0; Rainforest: Public Domain
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6. Aloe: Image copyright paolo airenti, 2012; Cactus: Amante Darmanin. Aloe: http://www.shutterstock.com; Cactus: http://www.flickr.com/photos/amantedar/5699827213/in/photostream/ . Aloe: Used under license from Shutterstock.com; Cactus: CC-BY 2.0
7. CK-12 Foundation. A map showing the locations of Earth's major terrestrial biomes . CC BY-NC 3.0
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9. Dylan Kereluk. The intertidal zone can be identified in by comparing these pictures of high tide and low tide . CC BY 2.0
10. Mo Riza. Barnacles are adapted to the intertidal zone by anchoring to rocks . CC BY 2.0
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13. . Aloe vera plants have fat, waxy leaves that allow them to conserve water.
14. . Aloe vera plants have fat, waxy leaves that allow them to conserve water.
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16. . The Namib Desert Beetle has bumps on its back for collecting water.
17. . The Namib Desert Beetle has bumps on its back for collecting water.
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19. . Stoats change color in the winter, from brown to white, so that they can hide in the snow.
20. . Stoats change color in the winter, from brown to white, so that they can hide in the snow.
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22. . Crowned cranes have plumage that helps them attract a mate.
23. . Crowned cranes have plumage that helps them attract a mate.
24. OliBac. http://commons.wikimedia.org/wiki/File:Bain_de_pollen_bath_of_pollen_(2503875867).jpg . CC BY 2.0
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27. liz west. http://commons.wikimedia.org/wiki/File:Lythrum_salicaria,_purple_loosestrife,_Boxborough,_Massachusetts_2.jpg . CC BY 2.0