Science 10: Ecosystems

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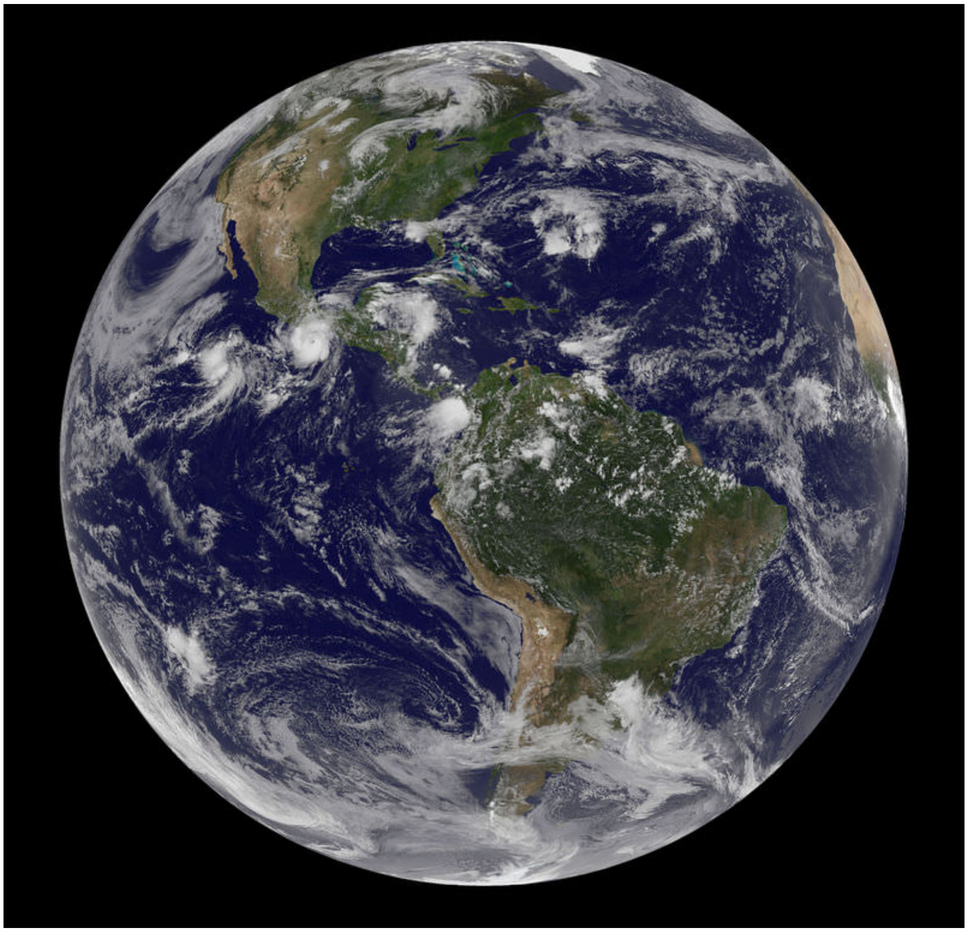
Contents

CONCEPT 1 The Biosphere

- Describe the biosphere and its importance in ecology.
- Distinguish the lithosphere from the hydrosphere and from the atmosphere.
- Discuss the Gaia hypothesis.



Is Earth a living organism?

Most scientists agree that the Earth itself is not a living thing. However, the Earth does have some aspects of life. Some scientists argue that the Earth maintains homeostasis, a stable state, just like a living organisms.

The Biosphere

The highest level of ecological organization is the **biosphere**. It is the part of Earth, including the air, land, surface rocks, and water, where life is found. Parts of the lithosphere, hydrosphere, and atmosphere make up the biosphere. The **lithosphere** is the outermost layer of the Earth's crust; essentially land is part of the lithosphere. The **hydrosphere** is composed of all the areas that contain water, which can be found on, under, and over the surface of Earth. The **atmosphere** is the layer of gas that surrounds the planet. The biosphere includes the area from about 11,000 meters below sea level to 15,000 meters above sea level. It overlaps with the lithosphere, hydrosphere, and atmosphere. Land plants and animals are found on the lithosphere, freshwater and marine plants and animals are found in the hydrosphere, and birds and other flying animals are found in the atmosphere. Of course, there are countless bacteria, protists, and fungi that are also found in the biosphere.

Is the Biosphere Living?

The **Gaia hypothesis** states that the biosphere is its own living organism. The hypothesis suggests that the Earth is self-regulating and tends to achieve a stable state, known as **homeostasis**. For example the composition of our atmosphere stays fairly consistent, providing the ideal conditions for life. When carbon dioxide levels increase in the atmosphere, plants grow more quickly. As their growth continues, they remove more carbon dioxide from the atmosphere. In this way, the amount of carbon dioxide stays fairly constant without human intervention.

For a better understanding of how the biosphere works and various dysfunctions related to human activity, scientists have simulated the biosphere in small-scale models. Biosphere 2 (**Figure** 1.1) is a laboratory in Arizona that contains 3.15 acres of closed ecosystems. Ecosystems of Biosphere 2 are an ocean ecosystem with a coral reef, mangrove wetlands, a tropical rainforest, a savannah grassland and a fog desert. See http://www.b2science.org/ for additional information.

Additional biosphere projects include BIOS-3, a closed ecosystem in Siberia, and Biosphere J, located in Japan.

FIGURE 1.1
Biosphere 2, in Arizona, contains 3.15 acres of closed ecosystem and is a small-scale model of the biosphere.

Summary

- The biosphere is the part of the Earth, including the air, land, surface rocks, and water, where you can find life.
- The Gaia hypothesis states that the biosphere is its own living organism

Explore More

Use the resource below to answer the questions that follow.

- **Biosphere** at http://www.eoearth.org/view/article/150667/

1. What is the biosphere?
2. What is the ecological definition of the biosphere?
3. What is the result of humans releasing carbon dioxide back into the atmosphere?
4. What is the Anthropocene?

Review

1. What is the biosphere?
2. Distinguish between the lithosphere, atmosphere and hydrosphere.
3. Give an example of how Earth is self-regulating.

References

1. Karen (Flickr: DrStarbuck). Biosphere 2 is a laboratory that contains acres of various ecosystems . CC BY 2.0

Concept 2 Introduction to Ecology

- Define ecology.
- Compare field studies to laboratory studies.
- Distinguish between abiotic and biotic factors.

Do organisms live in isolation?

No, organisms are not separated from their environment or from other organisms. They interact in many ways with their surroundings. For example, these deer may be drinking from this stream or eating nearby plants. Ecology is the study of these interactions.

Introduction to Ecology

Life Science can be studied at many different levels. You can study small things like cells. Or you can study big things like a group of animals. You can also study the **biosphere,** which is any area in which organisms live. The study of the biosphere is part of **ecology**, the study of how living organisms interact with each other and with their environment.

Research in Ecology

Ecology involves many different fields, including geology, soil science, geography, meteorology, genetics, chemistry, and physics. You can also divide ecology into the study of different organisms, such as animal ecology, plant ecology, insect ecology, and so on.

Ecologists also study biomes. A **biome** is a large community of plants and animals that live in the same place. For example, ecologists can study the biomes as diverse as the Arctic, the tropics, or the desert (**Figure** 2.1). They may want to know why different species live in different biomes. They may want to know what would make a particular biome or ecosystem stable. Can you think of other aspects of a biome or ecosystem that ecologists could study?

Ecologists do two types of research:

FIGURE 2.1
An example of a biome, the Atacama Desert, in Chile.

1. Field studies.
2. Laboratory studies.

Field studies involve collecting data outside in the natural world. An ecologist who completes a field study may travel to a tropical rainforest to study, count, and classify all of the insects that live in a certain area. Laboratory studies involve working inside, usually in a controlled environment. Sometimes, ecologists collect data from the field, and then they analyze that data in the lab. Also, they use computer programs to predict what will happen to organisms that live in a specific area. For example, they may make predictions about what happens to insects in the rainforest after a fire.

Organisms and Environments

All organisms have the ability to grow and reproduce. To grow and reproduce, organisms must get materials and energy from the environment. Plants obtain their energy from the sun through **photosynthesis**, whereas animals obtain their energy from other organisms. Either way, these plants and animals, as well as the bacteria and fungi, are constantly interacting with other species as well as the non-living parts of their ecosystem.

An organism's environment includes two types of factors:

1. **Abiotic factors** are the parts of the environment that are not living, such as sunlight, climate, soil, water, and air.
2. **Biotic factors** are the parts of the environment that are alive, or were alive and then died, such as plants, animals, and their remains. Biotic factors also include bacteria, fungi and protists.

Ecology studies the interactions between biotic factors, such as organisms like plants and animals, and abiotic factors. For example, all animals (biotic factors) breathe in oxygen (abiotic factor). All plants (biotic factor) absorb carbon dioxide (abiotic factor) and need water (abiotic factor) to survive.

Can you think of another way that abiotic and biotic factors interact with each other?

Summary

- Ecology is the study of how living organisms interact with each other and with their environment.

- Abiotic factors are the parts of the environment that have never been alive, while biotic factors are the parts of the environment that are alive, or were alive and then died.

Explore More

Use the resource below to answer the questions that follow.

- **A Study in Stream Ecology** at USGS http://gallery.usgs.gov/videos/449#.UKWeJId9KSo (6:57)

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/117078

1. What are some of the abiotic factors that scientists monitor when dealing with stream ecosystems?
2. What are some of the biotic factors that scientists monitor when dealing with stream ecosystems?
3. What is a "benchmark" in ecology? Why are they essential?
4. How does water pollution seem to be affecting diversity in some streams?

Review

1. What do ecologists study?
2. In a forest, what are five biotic factors present? Five abiotic factors?
3. What is a biome? Give an example.

References

1. Courtesy of NASA. The Atacama Desert is an example of a biome . Public Domain

CONCEPT 3 What are Biomes?

- Define biome and describe how they are classified.
- Explain what determines the differences among biomes.
- Distinguish terrestrial biomes from aquatic biomes.

Where was this picture taken?

This scene is from Anza-Borrago California Desert Park. However, deserts exist around the globe. You might find a similar picture of a desert in Africa. The desert is one type of biome.

What are Biomes?

Tropical rainforests and deserts are two familiar types of biomes. A **biome** is an area with similar populations of organisms. This can easily be seen with a community of plants and animals. Remember that a **community** is all of the populations of different species that live in the same area and interact with one another. Different biomes, such as a forest (**Figure** 3.1) or a desert, obviously have different communities of plants and animals. How are the plants and animals different in the rainforest than those in the desert? Why do you think they are so different?

The differences in the biomes are due to differences in the **abiotic factors**, especially climate. **Climate** is the typical weather in an area over a long period of time. The climate includes the amount of rainfall and the average temperature in the region. Obviously, the climate in the desert is much different than the climate in the rainforest. As a result, different types of plants and animals live in each biome.

There are into two major groups of biomes:

1. **Terrestrial biomes**, which are land-based, such as deserts and forests.
2. **Aquatic biomes**, which are water-based, such as ponds and lakes.

The abiotic factors, such as the amount of rainfall and the temperature, are going to influence other abiotic factors, such as the quality of the soil. This, in turn, is going to influence the plants that migrate into the ecosystem and thrive

FIGURE 3.1
Tropical rainforest landscape in Hawaii. Notice how the plants are different from those in the desert.

in that biome. Recall that **migration** is the movement of an organism into or out of a population. It can also refer to a whole new species moving into a **habitat**. The type of plants that live in a biome are going to attract a certain type of animal to that habitat. It is the interaction of the abiotic and biotic factors that describe a biome and ecosystem. In aquatic biomes, abiotic factors such as salt, sunlight and temperature play significant roles.

For example, a hot dry biome is going to be completely different from a moderate wet biome. The soil quality will be different. Together, these will result in different plants being able to occupy each biome. Different plants will attract different animals (herbivores) to eat these plants. These animals, in turn, will attract different (carnivores) animals to eat the herbivores. So it is the abiotic factors that determine the biotic factors of an ecosystem, and together these define the biome.

Summary

- A biome is an area with similar climate that includes similar communities of plants and animals.
- Climate influences the types of plants and animals that inhabit a specific biome.

Explore More

Use the resources below to answer the questions that follow.

- **Biomes** at http://www.youtube.com/watch?v=ag5ATGEplbU (7:50)

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/57311

1. Where do tundra biomes primarily occur? How much precipitation do these areas see annually?
2. What areas are best known for having Taiga biomes? What is the temperature range this biome experiences?

3. What is a behavioral adaptation that animals in desert biomes display?
4. List three characteristics of the rainforest.
5. How do the animals of a grassland adapt? Give two examples of animals of the grassland.

Review

1. What is a biome?
2. What causes differences in the biomes?
3. Give two examples of terrestrial biomes.
4. What influence does the soil quality have on a biome?

References

1. Flickr:daveynin. This tropical rainforest has different plants than those found in a desert . CC BY 2.0

CONCEPT 4 Habitat and Niche

- Define habitat and niche.
- Describe the roles of the habitat and niche in an ecosystem.

What is your niche at school?

Are you on the basketball team? Are you a cheerleader? Do you play an instrument in the band? Your niche would be your role or place in the school. Organisms also each have their own niche in the ecosystem. Is an organism a producer or a consumer? How does the organism interact with other organisms? Is the organism involved in any symbiotic relationships?

Habitat and Niche

Niche

Each organism plays a particular role in its ecosystem. A **niche** is the role a species plays in the ecosystem. In other words, a niche is how an organism "makes a living." A niche will include the organism's role in the flow of energy through the ecosystem. This involves how the organism gets its energy, which usually has to do with what an organism eats, and how the organism passes that energy through the ecosystem, which has to do with what eats the organism. An organism's niche also includes how the organism interacts with other organisms, and its role in recycling nutrients.

Once a niche is left vacant, other organisms can fill that position. For example when the Tarpan, a small wild horse found mainly in southern Russia, became extinct in the early 1900s, its niche was filled by a small horse breed, the Konik (**Figure** 4.1). Often this occurs as a new species evolves to occupy the vacant niche.

FIGURE 4.1
The Konik horse.

A species' niche must be specific to that species; no two species can fill the same niche. They can have very similar niches, which can overlap, but there must be distinct differences between any two niches. If two species do fill the same niche, they will compete for all necessary resources. One species will out compete the other, forcing the other species to adapt or risk extinction. This is known as competitive exclusion.

When plants and animals are introduced, either intentionally or by accident, into a new environment, they can occupy the existing niches of native organisms. Sometimes new species out-compete native species, and the native species may go extinct. They can then become a serious pest. For example, kudzu, a Japanese vine, was planted in the southeastern United States in the 1870s to help control soil loss. Kudzu had no natural predators, so it was able to out-compete native species of vine and take over their niches (**Figure** 4.2).

Habitat

The **habitat** is the physical area where a species lives. Many factors are used to describe a habitat. The average amount of sunlight received each day, the range of annual temperatures, and average yearly rainfall can all describe a habitat. These and other **abiotic factors** will affect the kind of traits an organism must have in order to survive there. The temperature, the amount of rainfall, the type of soil and other abiotic factors all have a significant role in determining the plants that invade an area. The plants then determine the animals that come to eat the plants, and so on. A habitat should not be confused with an ecosystem: the habitat is the actual place of the ecosystem, whereas the ecosystem includes both the **biotic** and abiotic factors in the habitat.

Habitat destruction means what it sounds like—an organism's habitat is destroyed. Habitat destruction can cause a population to decrease. If bad enough, it can also cause species to go extinct. Clearing large areas of land for housing developments or businesses can cause habitat destruction. Poor fire management, pest and weed invasion, and storm damage can also destroy habitats. National parks, nature reserves, and other protected areas all preserve habitats.

FIGURE 4.2
Kudzu, a Japanese vine introduced intentionally to the southeastern United States, has out-competed the native vegetation.

FIGURE 4.3
Santa Cruz Island off the California coast has diverse habitats including a coastline with steep cliffs, coves, gigantic caves, and sandy beaches.

Summary

- The role a species plays in the ecosystem is called its niche.
- A habitat is the physical environment in which a species lives.

Explore More

Use the resource below to answer the questions that follow.

- **Competition, Predation, Symbiosis** at http://www.youtube.com/watch?v=D1aRSeT-mQE (3:20)

FIGURE 4.4
The above image shows wetland reeds, another type of habitat.

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1. How do you think rapid changes in the chracteristics of habitats affect the niches of animals occupying that habitat?
2. Do you think rapid or gradual environmental changes have a greater potential to affect an organism's niche? Explain your answer.
3. On a very broad scale, how are the niches of a carnivore and an herbivore in the same geographic area similar? How do they differ?

Review

1. What is a niche?
2. Can two species share the same niche? Why or why not?
3. Name three factors that can be used to describe a habitat.
4. Distinguish between a habitat and an ecosystem.

References

1. Flickr:Free Photo Fun. When the Tarpan horse breed became extinct, the Konik horse breed occupied its n iche in the ecosystem . CC BY 2.0
2. Galen Parks Smith (Wikimedia: GSmith). The Kudzu is a species that has no natural predators and out-com peted existing vines to take over their niches . CC BY 2.5
3. Courtesy of Shane Anderson, NOAA. Santa Cruz Island has a diverse set of habitats . Public Domain
4. Karen Roe. These wetland reeds represent a habitat . CC BY 2.0

CONCEPT 5 Ecosystems

- Define and describe an ecosystem.
- Give examples of biotic and abiotic factors.
- Explain the relationship between producers and consumers.
- Summarize the importance of biogeochemical cycles.

What nonliving things are essential for life?

Living organisms cannot exist without the nonliving aspects of the environment. For example: air, water, and sunlight, which are all nonliving, are all essential to living organisms. Both nonliving and living things make up an ecosystem.

What is an Ecosystem?

Ecology is the study of ecosystems. That is, ecology is the study of how living organisms interact with each other and with the nonliving part of their environment. An **ecosystem** consists of all the nonliving factors and living organisms interacting in the same **habitat**. Recall that living organisms are **biotic factors**. The biotic factors of an ecosystem include all the **populations** in a habitat, such as all the species of plants, animals, and fungi, as well as all the micro-organisms. Also recall that the nonliving factors are called **abiotic factors**. Abiotic factors include temperature, water, soil, and air.

You can find an ecosystem in a large body of fresh water or in a small aquarium. You can find an ecosystem in a large thriving forest or in a small piece of dead wood. Examples of ecosystems are as diverse as the rainforest, the savanna, the tundra, or the desert (**Figure** 5.1). The differences in the abiotic factors, such as differences in temperature, rainfall, and soil quality, found in these areas greatly contribute to the differences seen in these ecosystems. Ecosystems can include well known sites, such as the Great Barrier Reef off the coast of Australia and the Greater Yellowstone Ecosystem of Yellowstone National Park, which actually includes a few different ecosystems, some with geothermal features, such as Old Faithful geyser.

FIGURE 5.1
Desert Botanical Gardens in Phoenix, Arizona.

Ecosystems need energy. Many ecosystems get their energy in the form of sunlight, which enters the ecosystem through **photosynthesis**. This energy then flows through the ecosystem, passed from **producers** to **consumers**. Plants are producers in many ecosystems. Energy flows from plants to the herbivores that eat the plants, and then to carnivores that eat the herbivores. The flow of energy depicts interactions of organisms within an ecosystem.

Matter is also recycled in ecosystems. **Biogeochemical cycles** recycle nutrients, like carbon and nitrogen, so they are always available. These nutrients are used over and over again by organisms. Water is also continuously recycled. The flow of energy and the recycling of nutrients and water are examples of the interactions between organisms and the interactions between the biotic and abiotic factors of an ecosystem.

Summary

- An ecosystem consists of all the living things and nonliving things interacting in the same area.
- Matter is also recycled in ecosystems; recycling of nutrients is important so they can always be available

Explore More

Use the resource below to answer the questions that follow.

- **How Ecosystems Work** at http://www.youtube.com/watch?v=o_RBHfjZsUQ (3:24)

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1497

1. How do land plants generate the energy they need for their metabolic energy? What do they do with excess energy?

2. Where do scavengers in an ecosystem obtain their energy from? How can scavenging be a beneficial strategy for an organism?
3. What is the role of decomposers?
4. What kind of problems can you foresee if every speck of carbon were turned into biomass? Why?
5. Complete this statement: Energy ___________ through an ecosystem, whereas nutrients are ____________.

Review

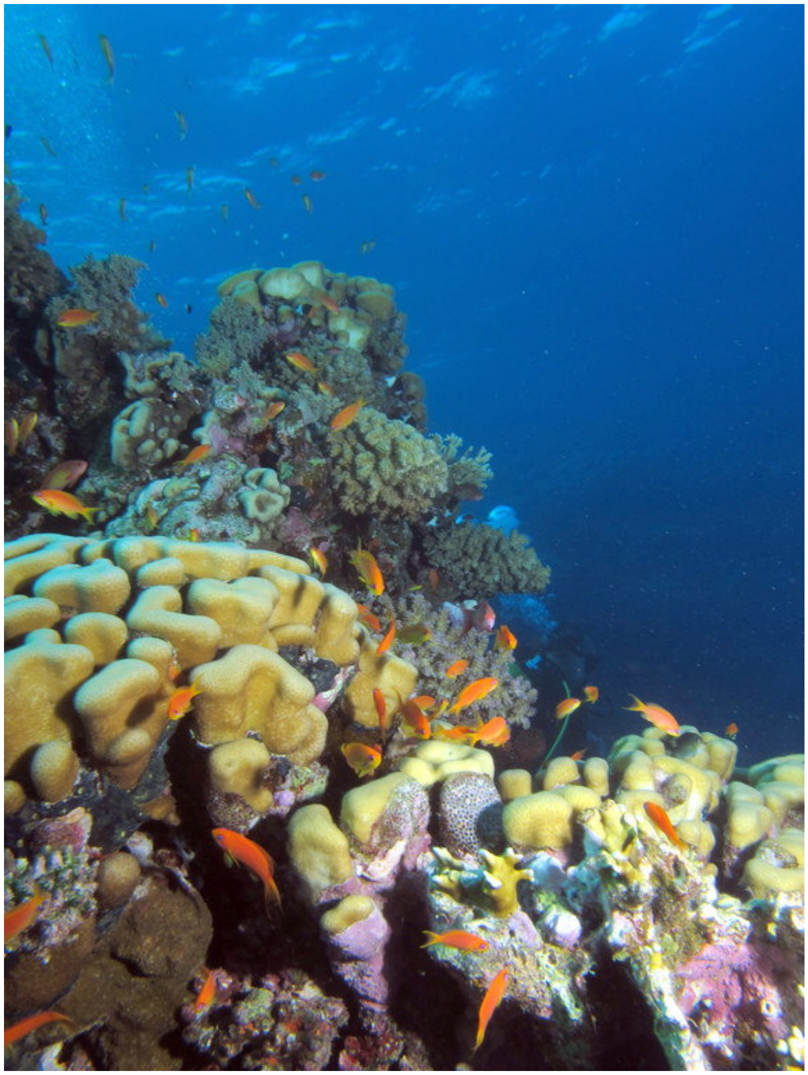
1. Define an ecosystem.
2. Distinguish between abiotic and biotic factors. Give examples of each.
3. Where does the energy come from for many ecosystems?
4. Name two nutrients that are recycled through an ecosystem.

References

1. Kevin Dooley. The Baja desert is an example of an ecosystem . CC BY 2.0

CONCEPT 6 Roles in an Ecosystem

- Define and describe the common roles and relationships of organisms in an ecosystem.



What roles do coral reef organisms have?

Corals are not rocks or plants, but little animals that live in a carbonate shell they create. They have a symbiotic relationship with zooxanthellae, tiny photosynthesizing organisms. The zooxanthellae provide food for the coral and the coral provides a safe home for the zooxanthellae. Together they form the base of a complex ecosystem.

Roles in Ecosystems

There are many different types of ecosystems. Climate conditions determine which ecosystems are found in a particular location. A biome encompasses all of the ecosystems that have similar climate and organisms.

Different organisms live in different types of ecosystems because they are adapted to different conditions. Lizards thrive in deserts, but no reptiles are found in any polar ecosystems. Amphibians can't live too far from the water. Large animals generally do better in cold climates than in hot climates.

Despite this, every ecosystem has the same general roles that living creatures fill. It's just the organisms that fill those niches that are different. For example, every ecosystem must have some organisms that produce food in the form of chemical energy. These organisms are primarily algae in the oceans, plants on land, and bacteria at hydrothermal vents.

Producers and Consumers

The organisms that produce food are extremely important in every ecosystem. Organisms that produce their own food are called **producers**. There are two ways of producing food energy:

- Photosynthesis: plants on land, phytoplankton in the surface ocean, and some other organisms.
- Chemosynthesis: bacteria at hydrothermal vents.

Organisms that use the food energy that was created by producers are named **consumers**. There are many types of consumers:

- **Herbivores** eat producers directly. These animals break down the plant structures to get the materials and energy they need.
- **Carnivores** eat animals; they can eat herbivores or other carnivores.
- **Omnivores** eat plants and animals as well as fungi, bacteria, and organisms from the other kingdoms.

FIGURE 6.1
A llama grazes near Machu Picchu, Peru

Feeding Relationships

There are many types of feeding relationships (**Figure** 6.2) between organisms. A **predator** is an animal that kills and eats another animal, known as its **prey**. **Scavengers** are animals, such as vultures and hyenas, that eat organisms that are already dead. **Decomposers** break apart dead organisms or the waste material of living organisms, returning the nutrients to the ecosystem.

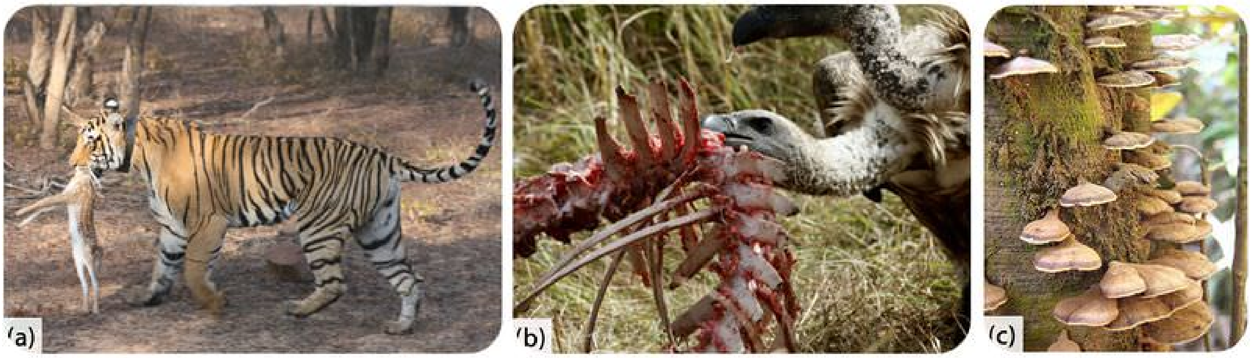


FIGURE 6.2
(a) Predator and prey; (b) Scavengers; (c) Bacteria and fungi, acting as decomposers.

Relationships Between Species

Species have different types of relationships with each other. **Competition** occurs between species that try to use the same resources. When there is too much competition, one species may move or adapt so that it uses slightly different resources. It may live at the tops of trees and eat leaves that are somewhat higher on bushes, for example. If the competition does not end, one species will die out. Each niche can only be inhabited by one species.

Some relationships between species are beneficial to at least one of the two interacting species. These relationships are known as **symbiosis** and there are three types:

- In **mutualism**, the relationship benefits both species. Most plant-pollinator relationships are mutually beneficial. What does each get from the relationship?
- In **commensalism**, one organism benefits and the other is not harmed.
- In **parasitism**, the parasite species benefits and the host is harmed. Parasites do not usually kill their hosts because a dead host is no longer useful to the parasite. Humans host parasites, such as the flatworms that cause schistosomiasis.

Choose which type of relationship is described by each of the images and captions below (**Figure** 6.3).

MEDIA
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URL: https://www.ck12.org/flx/render/embeddedobject/186543

FIGURE 6.3
(a) The pollinator gets food; the plant's pollen gets caught in the bird's feathers so it is spread to far away flowers. (b) The barnacles receive protection and get to move to new locations; the whale is not harmed. (c) These tiny mites are parasitic and consume the insect called a harvestman.

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Summary

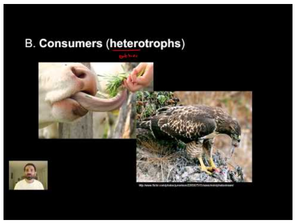
- Herbivores eat plants, carnivores eat meat, and omnivores eat both.
- Predators are animals that eat a prey animal. Scavengers eat organisms that are already dead. Decomposers break down dead plants and animals into component parts, including nutrients.
- Relationships between species can be one of competition or one of symbiosis, in which one or both species benefits. Mutualism, commensalism, and parasitism are the three types of symbiotic relationships.

Review

1. Compare and contrast the two different ways of producing food energy, photosynthesis and chemosynthesis.
2. After a producer produces food energy, follow its path until it ends up being used by another producer.
3. What kind of symbiotic relationship do zooxanthellae and corals have?

Explore More

Use this resource to answer the questions that follow.



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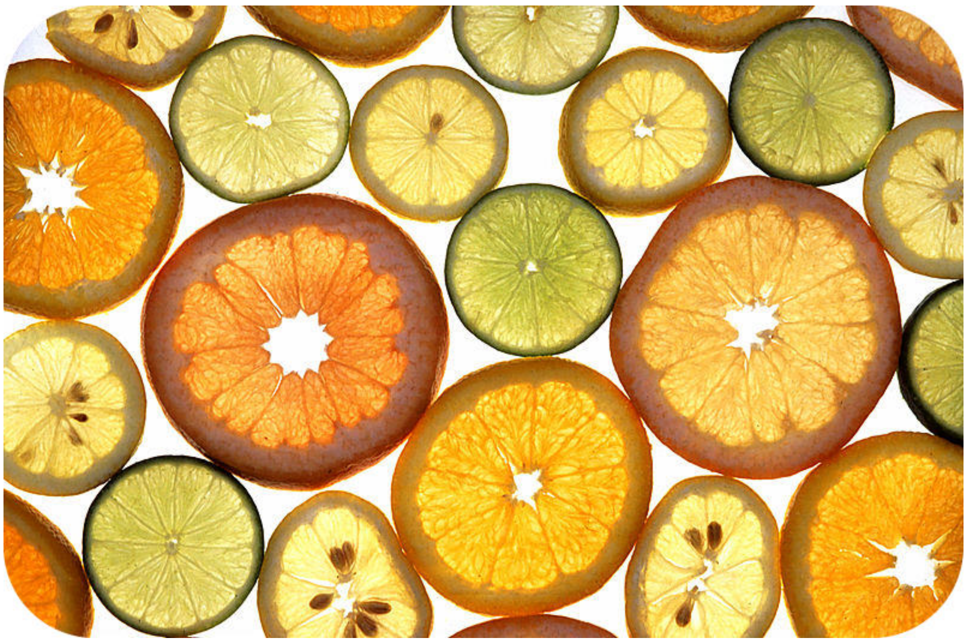
1. What is the science of ecology?
2. What are biotic factors? What are three examples?
3. What are abiotic factors? What are three examples?
4. What is an individual? Give an example.
5. What is a population? Give an example.
6. What is a community? Give an example.
7. What is a population? Give an example.
8. What is an ecosystem? Give an example.
9. What is a biome? Give an example.
10. What is a biosphere? Give an example.
11. What is a niche? What is a habitat?
12. What is the role of producers in an ecosystem?
13. What are consumers? What are three examples?
14. What do decomposers do? Why are they so important?
15. What is symbiosis? What is mutualism? What is commensalism?

References

1. James Christina. A llama grazes near Machu Picchu, Peru . CC BY 2.0
2. (a) Bharat Bolasani; (b) Flickr:DEMOSH; (c) Flickr:Cayce. Examples of predator and prey, scavengers, and decomposers . CC BY 2.0
3. (a) Mike; (b) Image copyright Jan-Dirk Hansen, 2014; (c) Oregon Caves NPS. Examples of mutualism, commensalism, and parasitism . (a) CC BY 2.0; (b) Used under license from Shutterstock.com; (c) CC BY 2.0

Concept 7 Flow of Matter in Ecosystems

- Describe how matter flows through ecosystems.
- Compare and contrast the flow of matter with the flow of energy in ecosystems.



What killed millions of sailors in the 15th through 18th centuries?

Sailors at sea or explorers in polar regions, even Crusaders, who went without fresh food developed scurvy due to the lack of vitamin C in their diets. Without the right nutrients in the right amounts, you can't live — and humans need vitamin C. It wasn't until 1932 that the link between scurvy and a nutrient was made.

Flow of Matter in Ecosystems

The flow of matter in an ecosystem is not like energy flow. Matter enters an ecosystem at any level and leaves at any level. Matter cycles freely between trophic levels and between the ecosystem and the physical environment (**Figure** 7.1).

Nutrients

Nutrients are ions that are crucial to the growth of living organisms. Nutrients such as nitrogen and phosphorous are important for plant cell growth. Animals use silica and calcium to build shells and skeletons. Cells need nitrates and phosphates to create proteins and other biochemicals. From nutrients, organisms make tissues and complex molecules such as carbohydrates, lipids, proteins, and nucleic acids.

What are the sources of nutrients in an ecosystem? Rocks and minerals break down to release nutrients. Some enter the soil and are taken up by plants. Nutrients can be brought in from other regions, carried by wind or water. When one organism eats another organism, it receives all of its nutrients. Nutrients can also cycle out of an ecosystem.

Decaying leaves may be transported out of an ecosystem by a stream. Wind or water carries nutrients out of an ecosystem.

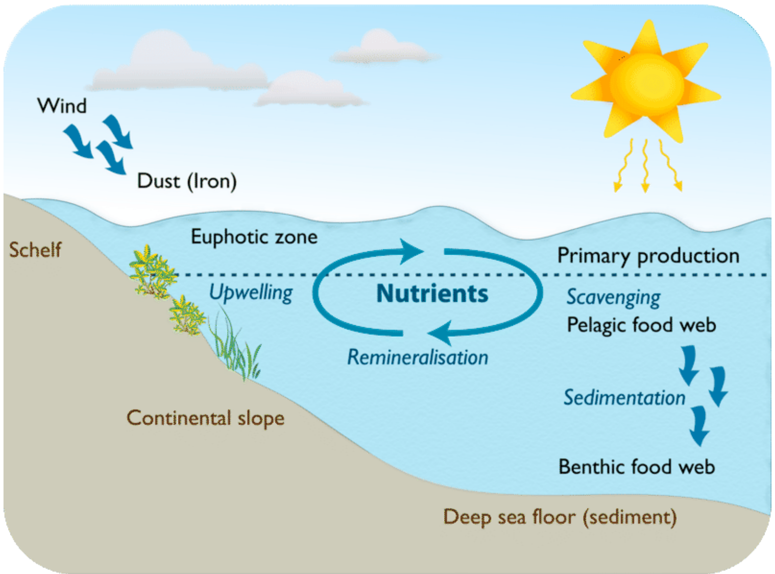


FIGURE 7.1
Nutrients cycle through ocean food webs.

Decomposers play a key role in making nutrients available to organisms. Decomposers break down dead organisms into nutrients and carbon dioxide, which they respire into the air. If dead tissue would remain as it is, eventually nutrients would run out. Without decomposers, life on Earth would have died out long ago.

Summary

- Ions that are crucial to the growth of organisms are known as nutrients.
- Decomposers break down dead organisms into nutrients and gases so that they can be used by other organisms.
- Nutrients can enter or exit an ecosystem at any point and can cycle around the planet.

Review

1. How does the flow of matter differ from the flow of energy through an ecosystem?
2. How do nutrients enter and exit and ecosystem?
3. What would happen to life on Earth if there were no decomposers?

Resources

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Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/186558

References

1. Hana Zavadska. Nutrients cycle through ocean food webs . CC BY-NC 3.0

CONCEPT 8 The Water Cycle

- Define biogeochemical cycle.
- Describe the key features of the water cycle.
- Distinguish condensation from precipitation.
- Distinguish evaporation from transpiration.

Could you be drinking the same water as George Washington?

Water is recycled constantly through the ecosystem. That means any water you drank today has been around for millions of years. You could be drinking water that was once drunk by George Washington, the first humans, or even the dinosaurs.

The Water Cycle

Whereas energy flows through an ecosystem, water and elements like carbon and nitrogen are recycled. Water and nutrients are constantly being recycled through the environment. This process through which water or a chemical element is continuously recycled in an ecosystem is called a **biogeochemical cycle**. This recycling process involves both the living organisms (biotic components) and nonliving things (abiotic factors) in the ecosystem. Through biogeochemical cycles, water and other chemical elements are constantly being passed through living organisms to non-living matter and back again, over and over. Three important biogeochemical cycles are the **water cycle**, **carbon cycle**, and **nitrogen cycle**.

The biogeochemical cycle that recycles water is the water cycle. The water cycle involves a series of interconnected pathways involving both the biotic and abiotic components of the biosphere. Water is obviously an extremely important aspect of every ecosystem. Life cannot exist without water. Many organisms contain a large amount of water in their bodies, and many live in water, so the water cycle is essential to life on Earth. Water continuously moves between living organisms, such as plants, and non-living things, such as clouds, rivers, and oceans (**Figure** 8.1).

The water cycle does not have a real starting or ending point. It is an endless recycling process that involves the oceans, lakes and other bodies of water, as well as the land surfaces and the atmosphere. The steps in the water cycle are as follows, starting with the water in the oceans:

1. Water evaporates from the surface of the oceans, leaving behind salts. As the water vapor rises, it collects and is stored in clouds.
2. As water cools in the clouds, condensation occurs. **Condensation** is when gases turn back into liquids.
3. Condensation creates precipitation. **Precipitation** includes rain, snow, hail, and sleet. The precipitation allows the water to return again to the Earth's surface.
4. When precipitation lands on land, the water can sink into the ground to become part of our underground water reserves, also known as **groundwater**. Much of this underground water is stored in **aquifers**, which are porous layers of rock that can hold water.

Run-off

Most precipitation that occurs over land, however, is not absorbed by the soil and is called **runoff**. This runoff collects in streams and rivers and eventually flows back into the ocean.

Transpiration

Water also moves through the living organisms in an ecosystem. Plants soak up large amounts of water through their roots. The water then moves up the plant and evaporates from the leaves in a process called **transpiration**. The process of transpiration, like evaporation, returns water back into the atmosphere.

Summary

- Chemical elements and water are constantly recycled in the ecosystem through biogeochemical cycles.
- During the water cycle, water enters the atmosphere by evaporation and transpiration, and water returns to land by precipitation.

Explore More

Use the resource below to answer the questions that follow.

- **The Water Cycle** at http://www.youtube.com/watch?v=IncMhop-4Jc (2:48)

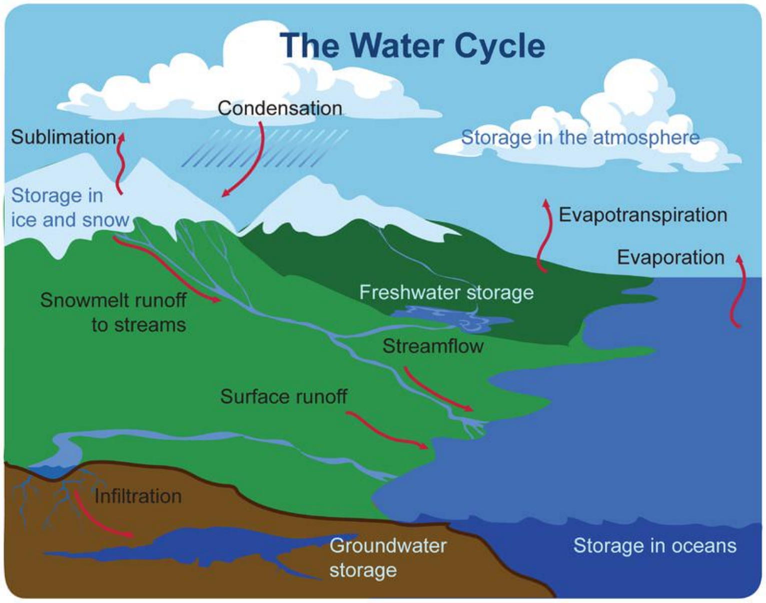

FIGURE 8.1
The water cycle.

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1. What is a fundamental difference between the water cycle and other nutrient cycles?
2. What drives the water cycle? Where does this process primarily occur?
3. What happens to most of the water taken up by plants? How does this compare to most of the water taken up by animals?
4. How does water's role in photosynthesis explain increased biological productivity in areas of heavy precipitation?

Review

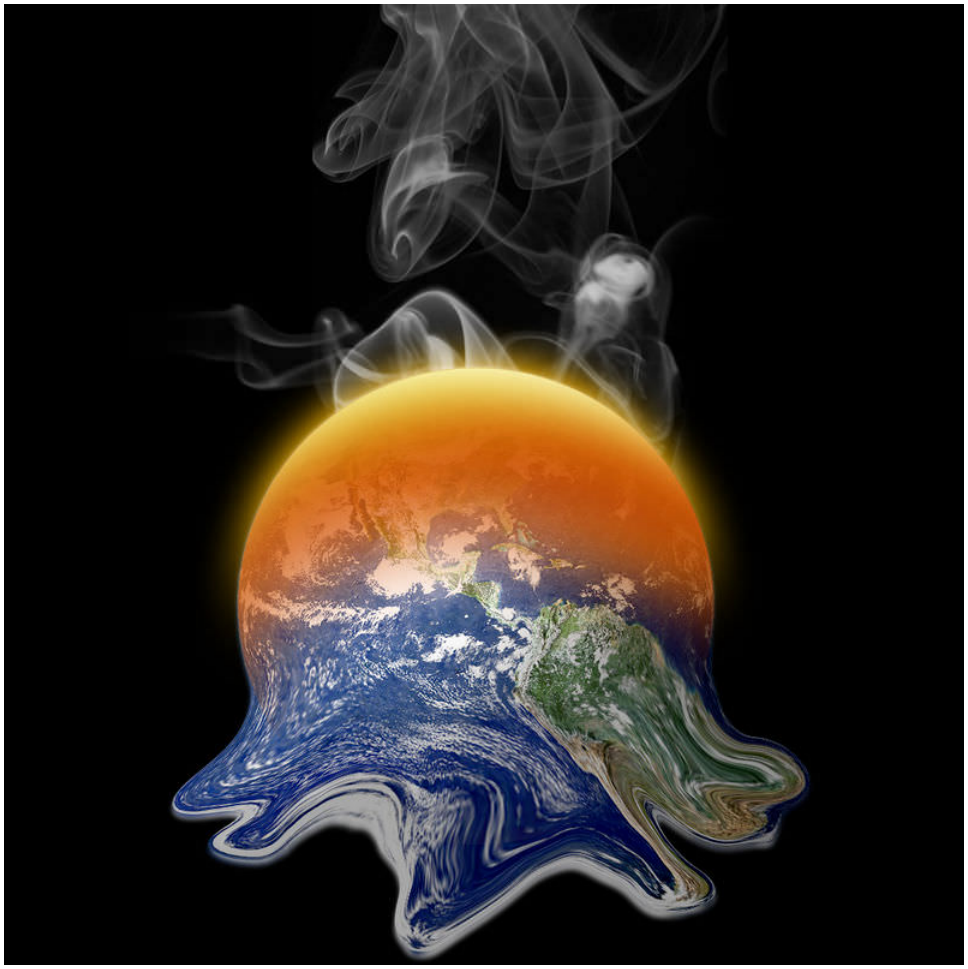
1. What is the water cycle?
2. What are two ways water returns to the atmosphere?
3. How does water get from the atmosphere back to land? What are the various forms of this process?
4. What is the relationship between groundwater and aquifers?

References

1. Mariana Ruiz Villarreal (LadyofHats) for Ck-12 Foundation. The water cycle tracks the flow of water. . CC BY-NC 3.0

CONCEPT 9 The Carbon Cycle

- Describe the key features of the carbon cycle.
- Describe the relationship between photosynthesis and cellular respiration.
- Define fossil fuels.
- Explain the role of fossil fuels in global climate change.



Why is Earth getting warmer?

What happens if carbon is not removed from the atmosphere? The excess carbon dioxide in the atmosphere is contributing to a global rise in Earth's temperature, known as global warming. Where does this carbon dioxide come from? Burning gas to power our cars and burning coal to generate electricity are two main sources of the excess carbon dioxide.

The Carbon Cycle

Carbon is one of the most common elements found in living organisms. Chains of carbon molecules form the backbones of many organic molecules, such as carbohydrates, proteins, and lipids. Carbon is constantly cycling between living organisms and the atmosphere (**Figure** 9.1). The cycling of carbon occurs through the **carbon cycle**.

Living organisms cannot make their own carbon, so how is carbon incorporated into living organisms? In the atmosphere, carbon is in the form of carbon dioxide gas (CO_2). Recall that plants and other producers capture the carbon dioxide and convert it to glucose ($C_6H_{12}O_6$) through the process of **photosynthesis**. Then as animals eat plants or other animals, they gain the carbon from those organisms.

The chemical equation of photosynthesis is $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.

How does this carbon in living things end up back in the atmosphere? Remember that we breathe out carbon dioxide. This carbon dioxide is generated through the process of **cellular respiration**, which has the reverse chemical reaction as photosynthesis. That means when our cells burn food (glucose) for energy, carbon dioxide is released. We, like all animals, exhale this carbon dioxide and return it back to the atmosphere. Also, carbon is released to the atmosphere as an organism dies and decomposes.

Cellular respiration and photosynthesis can be described as a cycle, as one uses carbon dioxide (and water) and makes oxygen (and glucose), and the other uses oxygen (and glucose) and makes carbon dioxide (and water).

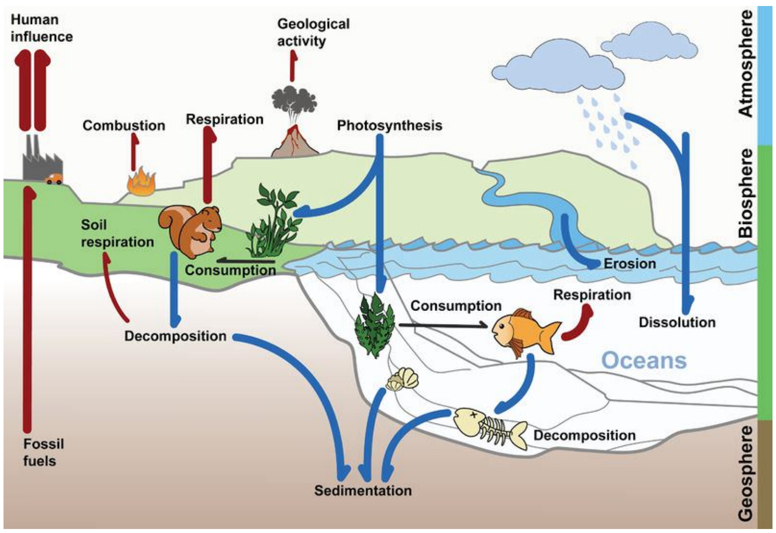


FIGURE 9.1

The carbon cycle. The cycling of carbon dioxide in photosynthesis and cellular respiration are main components of the carbon cycle. Carbon is also returned to the atmosphere by the burning of organic matter (combustion) and fossil fuels and decomposition of organic matter.

Formation of Fossil Fuels

Millions of years ago, there were so many dead plants and animals that they could not completely decompose before they were buried. They were covered over by soil or sand, tar or ice. These dead plants and animals are organic matter made out of cells full of carbon-containing organic compounds (carbohydrates, lipids, proteins and nucleic acids). What happened to all this carbon? When organic matter is under pressure for millions of years, it forms **fossil fuels.** Fossil fuels are coal, oil, and natural gas.

When humans dig up and use fossil fuels, we have an impact on the carbon cycle (**Figure** 9.2). This carbon is not recycled until it is used by humans. The burning of fossil fuels releases more carbon dioxide into the atmosphere than is used by photosynthesis. So, there is more carbon dioxide entering the atmosphere than is coming out of it. Carbon dioxide is known as a **greenhouse gas**, since it lets in light energy but does not let heat escape, much like the panes of a greenhouse. The increase of greenhouse gasses in the atmosphere is contributing to a global rise in Earth's temperature, known as **global warming** or global climate change.

Summary

- During the carbon cycle, animals and plants add carbon dioxide to the atmosphere through cellular respiration, and plants remove carbon dioxide through photosynthesis.
- The burning of fossil fuels releases more carbon dioxide into the atmosphere, contributing to global warming.

FIGURE 9.2
Human activities like burning gasoline in cars are contributing to a global change in our climate.

Explore More

Use the resource below to answer the questions that follow.

- **Organic Carbon and the World Around Us** from USGS http://gallery.usgs.gov/videos/571#.UKWjAId9KSo (7:11)

MEDIA
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1. What are two types of carbon? What type is carbon dioxide (CO_2)? What is an example of the other type?
2. How can carbon aid the spread of toxic substances?
3. Why are the reactivity and binding capabilities of carbon crucial to life?

Review

1. What biological process releases carbon back into the atmosphere?
2. What human activities have thrown the carbon cycle off balance?
3. Why is carbon dioxide a greenhouse gas?
4. What is the outcome of the increase of greenhouse gasses?

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. The carbon cycle tracks the flow of carbon through an ecosystem .
2. Flickr:futureatlas.com (http://futureatlas.com/blog/). Human activities like burning gasoline in cars are contributing to a global change in our climate . CC BY 2.0

CONCEPT 10 The Nitrogen Cycle

- Describe the key features of the nitrogen cycle.
- Define nitrogen fixation.
- Explain assimilation and denitrification.

What can bean plants do that most other plants can't?

No, they don't grow giant stalks to the clouds. Bean plants and other legumes (plants that have their seeds in pods) can use the nitrogen in the air to grow. It takes the help of special bacteria friends in the soil, and this relationship is unique to the legumes.

The Nitrogen Cycle

Like water and carbon, nitrogen is also repeatedly recycled through the biosphere. This process is called the **nitrogen cycle**. Nitrogen is one of the most common elements in living organisms. It is important for creating both proteins and nucleic acids, like DNA. The air that we breathe is mostly nitrogen gas (N_2), but, unfortunately, animals and plants cannot use the nitrogen when it is a gas. In fact, plants often die from a lack of nitrogen even through they are surrounded by plenty of nitrogen gas. Nitrogen gas (N_2) has two nitrogen atoms connected by a very strong triple bond. Most plants and animals cannot use the nitrogen in nitrogen gas because they cannot break that triple bond.

In order for plants to make use of nitrogen, it must be transformed into molecules they can use. This can be accomplished several different ways (**Figure** 10.1).

- Lightning: When lightening strikes, nitrogen gas is transformed into nitrate (NO_3^-) that plants can use.
- **Nitrogen fixation**: Special nitrogen-fixing bacteria can also transform nitrogen gas into useful forms. These bacteria live in the roots of plants in the pea family. They turn the nitrogen gas into ammonium (NH_4^+) (a process called ammonification). In water environments, bacteria in the water can also fix nitrogen gas into ammonium. Ammonium can be used by aquatic plants as a source of nitrogen.
- Nitrogen also is released to the environment by decaying organisms or decaying wastes. These wastes release nitrogen in the form of ammonium.

Ammonium in the soil can be turned into nitrate by a two-step process completed by two different types of bacteria. In the form of nitrate, nitrogen can be used by plants through the process of **assimilation**. It is then passed along to animals when they eat the plants.

Sending Nitrogen back to the Atmosphere

Turning nitrate back into nitrogen gas, the process of **denitrification**, happens through the work of denitrifying bacteria. These bacteria often live in swamps and lakes. They take in the nitrate and release it back to the atmosphere as nitrogen gas.

Just like the carbon cycle, human activities impact the nitrogen cycle. These human activities include the burning of fossil fuels, which release nitrogen oxide gasses into the atmosphere. Releasing nitrogen oxide back into the atmosphere leads to problems like **acid rain**.

Summary

- Gaseous nitrogen is converted into forms that can be used by plants during the process of nitrogen fixation.
- Denitrifying bacteria turn nitrate back into gaseous nitrogen.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **The Nitrogen Cycle** at http://www.teachersdomain.org/asset/lsps07_int_nitrogen/

1. What is the largest source of nitrogen on Earth? How does this nitrogen enter the food web?
2. What kind of relationship exists between nitrogen-fixing bacteria and the plants whose roots they live around?
3. What is assimilation? Describe the "loop" in the Nitrogen Cycle that involves assimilation by animals?
4. At what step in the Nitrogen Cycle do bacteria assimilate nitrogen?

Explore More II

- **The Nitrogen Cycle**

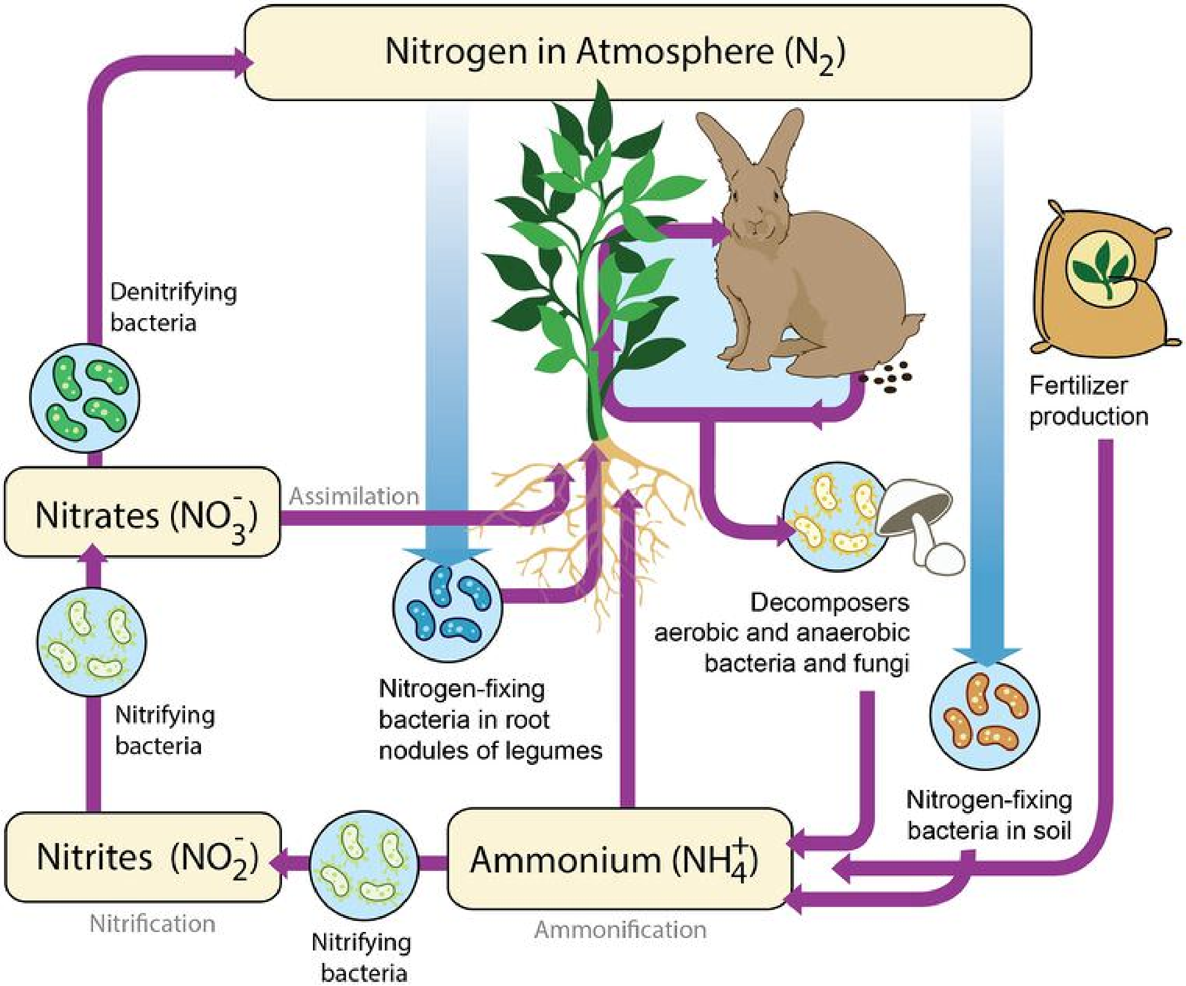


FIGURE 10.1

The nitrogen cycle includes assimilation, when plants absorb nitrogen; nitrogen-fixing bacteria that make the nitrogen available to plants in the form of nitrates; decomposers that transform nitrogen in dead organisms into ammonium; nitrifying bacteria that turn ammonium into nitrates; and denitrifying bacteria that turn nitrates into gaseous nitrogen.

1. What metabolic processes do organisms use nitrogen (N) for?
2. What sorts of molecules are made using nitrogen?

Review

1. How do living organisms use nitrogen?
2. What is nitrogen fixation? Describe how it happens.
3. How is nitrate in the soil converted back to nitrogen gas?
4. How does acid rain form?

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. The nitrogen cycle tracks the flow of nitrogen through an ecosystem . CC BY-NC 3.0

Concept 11 Energy Pyramids

- Define energy and energy pyramid.
- Explain the flow of energy through an ecosystem using an energy pyramid.
- Describe a trophic level.
- Explain the maximum number of trophic levels in an ecosystem.

How much energy could be gained from the warthog?

If the cheetah is successful in capturing the warthog, it would gain some energy by eating it. But would the cheetah gain as much energy as the warthog has ever consumed? No, the warthog has used up some of the energy it has consumed for its own needs. The cheetah will only gain a fraction of the energy that the warthog has consumed throughout its lifetime.

Energy Pyramids

When an herbivore eats a plant, the **energy** in the plant tissues is used by the herbivore. But how much of that energy is transferred to the herbivore? Remember that plants are **producers**, bringing the energy into the ecosystem by converting sunlight into glucose. Does the plant use some of the energy for its own needs? Recall the energy is the ability to do work, and the plant has plenty or "work" to do. So of course it needs and uses energy. It converts the glucose it makes into **ATP** through **cellular respiration** just like other organisms. After the plant uses the energy from glucose for its own needs, the excess energy is available to the organism that eats the plant.

The herbivore uses the energy from the plant to power its own life processes and to build more body tissues. However, only about 10% of the total energy from the plant gets stored in the herbivore's body as extra body tissue. The rest of the energy is used by the herbivore and released as heat. The next consumer on the food chain that eats the herbivore will only store about 10% of the total energy from the herbivore in its own body. This means the carnivore will store only about 1% of the total energy that was originally in the plant. In other words, only about 10% of energy of one step in a food chain is stored in the next step in the food chain. The majority of the energy is used by the organism or released to the environment.

Every time energy is transferred from one organism to another, there is a loss of energy. This loss of energy can be shown in an **energy pyramid**. An example of an energy pyramid is pictured below (**Figure** 11.1). Since there is energy loss at each step in a food chain, it takes many producers to support just a few carnivores in a community.

Each step of the food chain in the energy pyramid is called a **trophic level**. Plants or other photosynthetic organisms (**autotrophs**) are found on the first trophic level, at the bottom of the pyramid. The next level will be the herbivores, and then the carnivores that eat the herbivores. The energy pyramid (**Figure** 11.1) shows four levels of a food chain, from producers to carnivores. Because of the high rate of energy loss in food chains, there are usually only 4 or 5 trophic levels in the food chain or energy pyramid. There just is not enough energy to support any additional trophic levels. **Heterotrophs** are found in all levels of an energy pyramid other than the first level.

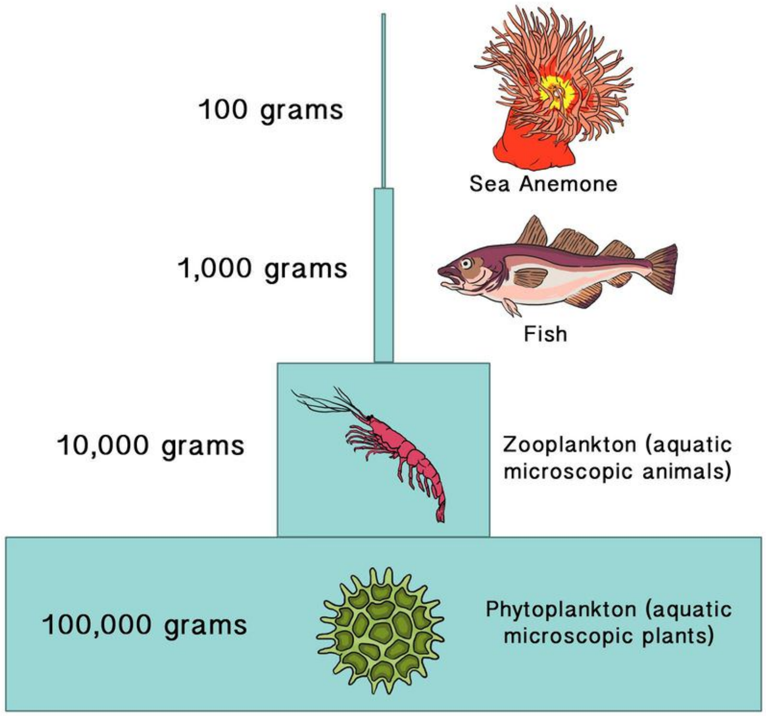


FIGURE 11.1
As illustrated by this ecological pyramid, it takes a lot of phytoplankton to support the carnivores of the oceans. This energy pyramid has four trophic levels, which signify the organisms place in the food chain from the original source of energy.

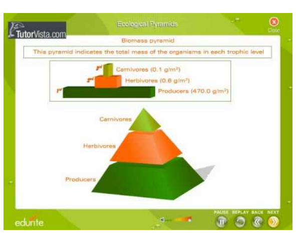
Summary

- As energy is transferred along a food chain, energy is lost as heat.
- Only about 10% of energy of one step in a food chain is stored in the next step in the food chain.

Explore More

Use the resource below to answer the questions that follow.

- **Ecological Pyramids** at http://www.youtube.com/watch?v=NJplkrliUEg (4:03)



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1. What are three types of ecological pyramids? How do their shapes compare?

2. Do you think it would be possible to construct a pyramid where the number of carnivores was more than the number of herbivores? Why or why not?
3. Do you think it would be possible to construct a pyramid where the biomass of carnivores was more than the biomass of herbivores? How does this compare to a numbers pyramid.
4. What consumes energy at each trophic level? How does this contribute to energy loss between trophic levels?

Review

1. When an herbivore eats a plant, what happens to 90% of the energy obtained from that plant?
2. What is a trophic level?
3. Why are the number of trophic levels limited?
4. In a forest community, caterpillars eat leaves, and birds eat caterpillars. Draw an energy pyramid using this information.

References

1. Laura Guerin. This energy pyramid illustrates that many organisms on the bottom are needed to support the top carnivores . CC BY-NC 3.0

CONCEPT 12 Producers

- Explain where all the energy in an ecosystem originates.
- Define photosynthesis and chemosynthesis.
- Describe how energy enters an ecosystem.
- Explain the role of a producer.

Where does all the bear's energy come from?

Bears get their energy from their food. Brown bears eat a varied diet, from nuts and berries to fish and other animals. When bears eat a berry, they are obtaining energy that the plant originally captured from the sun. Even when a bear eats another animal, the energy in that animal ultimately came from eating a producer that captured the sun's energy.

Producers

Energy is the ability to do work. In organisms, this work can be physical work, like walking or jumping, or it can be the work used to carry out the chemical processes in their cells. Every biochemical reaction that occurs in an organism's cells needs energy. All organisms need a constant supply of energy to stay alive.

Some organisms can get the energy directly from the sun. Other organisms get their energy from other organisms. Through **predator-prey relationships**, the energy of one organism is passed on to another. Energy is constantly flowing through a community. With just a few exceptions, all life on Earth depends on the sun's energy for survival.

The energy of the sun is first captured by **producers** (**Figure** 12.1), organisms that can make their own food. Many producers make their own food through the process of **photosynthesis**. The "food" the producers make is the sugar, **glucose**. Producers make food for the rest of the ecosystem. As energy is not recycled, energy must consistently be captured by producers. This energy is then passed on to the organisms that eat the producers, and then to the organisms that eat those organisms, and so on.

Recall that the only required ingredients needed for photosynthesis are sunlight, carbon dioxide (CO_2), and water (H_2O). From these simple inorganic ingredients, photosynthetic organisms produce the carbohydrate glucose ($C_6H_{12}O_6$), and other complex organic compounds. Essentially, these producers are changing the energy from the sunlight into a usable form of energy. They are also making the oxygen that we breathe. Oxygen is a waste product of photosynthesis.

The survival of every ecosystem is dependent on the producers. Without producers capturing the energy from the sun and turning it into glucose, an ecosystem could not exist. On land, plants are the dominant producers. **Phytoplankton**, tiny photosynthetic organisms, are the most common producers in the oceans and lakes. Algae, which is the green layer you might see floating on a pond, are an example of phytoplankton.

There are also bacteria that use chemical processes to produce food. They get their energy from sources other than the sun, but they are still called producers. This process is known as **chemosynthesis**, and is common in ecosystems without sunlight, such as certain marine ecosystems.

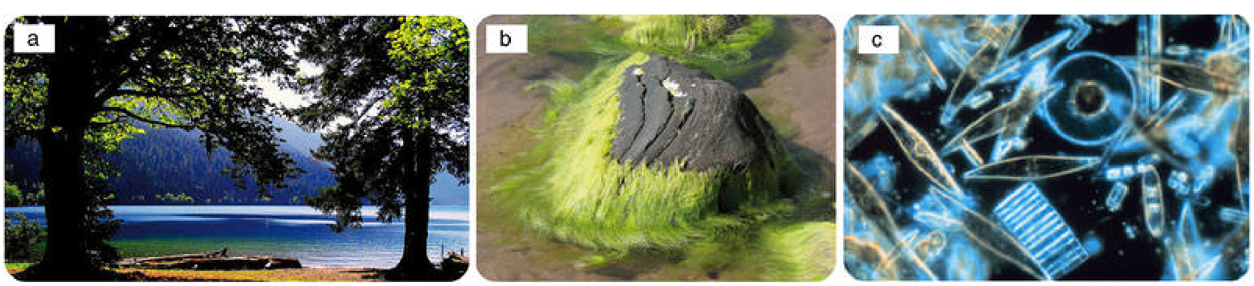


FIGURE 12.1

Producers include (a) plants, (b) algae, and (c) diatoms.

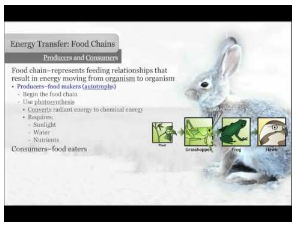
Summary

- With just a few exceptions, all life on Earth depends on the sun's energy for survival.
- Producers make food for the rest of the ecosystem through the process of photosynthesis, where the energy of the sun is used to convert carbon dioxide and water into glucose.

Explore More

Use the resource below to answer the questions that follow.

- **Producers and Consumers** at http://www.youtube.com/watch?v=P0a97kS_3SA (1:59)



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1. Can producers function without sunlight? Why or why not?
2. What are some examples of producers? Why are they called autotrophs?
3. How do some producers use sunlight to make "food"? What other resources do they require?

Review

1. Where does all the "food" in an ecosystem ultimately come from?
2. What is the most common method of producing energy for an ecosystem? What is the energy that is made?
3. What "ingredients" are needed for the process of photosynthesis?
4. Why are producers important to an ecosystem?

References

1. (a) Jan Tik; (b) Flickr:qorize; (c) Courtesy of Prof. Gordon T. Taylor, Stony Brook University/NSF Polar Programs. Producers include plants, algae, and diatoms . (a) CC BY 2.0; (b) CC BY 2.0; (c) Public Domain

CONCEPT 13 Consumers and Decomposers

- Explain the roles of consumers and decomposers in an ecosystem.
- Distinguish herbivores from carnivores and omnivores.
- Classify organisms on the basis of how they obtain energy and describe examples of each.

What is breaking down this leaf?

Notice how this leaf is slowly being broken down. This process can be carried out by fungi and bacteria on the ground. Breaking down old leaves is an important process since it releases the nutrients in the dead leaves back into the soil for living plants to use.

Consumers and Decomposers

Recall that **producers** make their own food through photosynthesis. But many organisms are not producers and cannot make their own food. So how do these organisms obtain their energy? They must get their energy from other organisms. They must eat other organisms, or obtain their energy from these organisms some other way. The organisms that obtain their energy from other organisms are called **consumers**. All animals are consumers, and they eat other organisms. Fungi and many protists and bacteria are also consumers. But, whereas animals eat other organisms, fungi, protists, and bacteria "consume" organisms through different methods.

The consumers can be placed into different groups, depending on what they consume.

- **Herbivores** are animals that eat producers to get energy. For example, rabbits and deer are herbivores that eat plants. The caterpillar pictured below (**Figure** 13.1) is a herbivore. Animals that eat phytoplankton in aquatic environments are also herbivores.
- **Carnivores** feed on animals, either herbivores or other carnivores. Snakes that eat mice are carnivores. Hawks that eat snakes are also carnivores (**Figure** 13.1).

- **Omnivores** eat both producers and consumers. Most people are omnivores, since they eat fruits, vegetables, and grains from plants, and also meat and dairy products from animals. Dogs, bears, and raccoons are also omnivores.

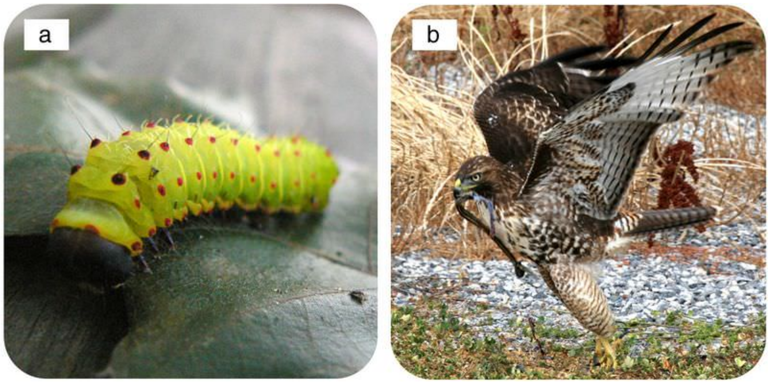

FIGURE 13.1
Examples of consumers are caterpillars (herbivores) and hawks (carnivore).

Decomposers and Stability

Decomposers (**Figure** 13.2) get nutrients and energy by breaking down dead organisms and animal wastes. Through this process, decomposers release nutrients, such as carbon and nitrogen, back into the environment. These nutrients are recycled back into the ecosystem so that the producers can use them. They are passed to other organisms when they are eaten or consumed. Many of these nutrients are recycled back into the soil, so they can be taken up by the roots of plants.

The stability of an ecosystem depends on the actions of the decomposers. Examples of decomposers include mushrooms on a decaying log. Bacteria in the soil are also decomposers. Imagine what would happen if there were no decomposers. Wastes and the remains of dead organisms would pile up and the nutrients within the waste and dead organisms would not be released back into the ecosystem. Producers would not have enough nutrients. The carbon and nitrogen necessary to build organic compounds, and then cells, allowing an organism to grow, would be insufficient. Other nutrients necessary for an organism to function properly would also not be sufficient. Essentially, many organisms could not exist.

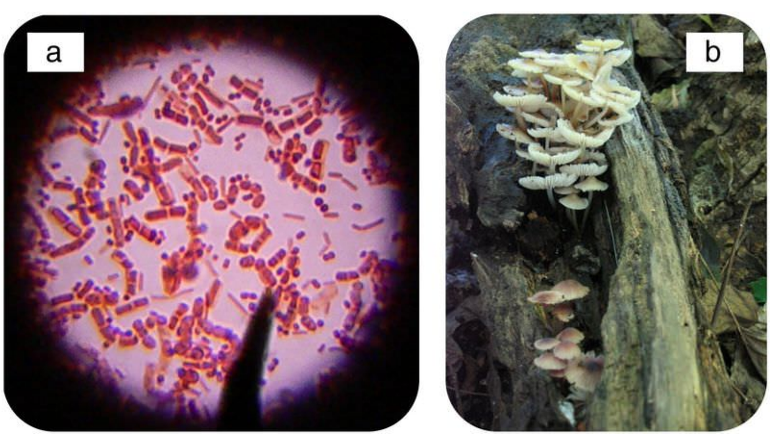

FIGURE 13.2
Examples of decomposers are (a) bacteria and (b) fungi.

Summary

- Consumers must obtain their nutrients and energy by eating other organisms.
- Decomposers break down animal remains and wastes to get energy.
- Decomposers are essential for the stability and survival of an ecosystem.

Explore More

Use the resource below to answer the questions that follow.

- **Decomposers** at http://www.youtube.com/watch?v=Z6V0a_7N1Mw (3:19)

MEDIA

Click image to the left or use the URL below.

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1. What is the role of decomposers in an ecosystem? What is the source of the matter which is decomposed?
2. How do the actions of earthworms improve soil quality? How does this impact the amount of biomass an ecosystem can support?
3. How do gastropods function as decomposers?

Review

1. What is a consumer?
2. What's the term for a consumer that eats both leaves and fish?
3. What are the different types of consumers?
4. Why are decomposers important in the ecosystem?

References

1. (a) Benny Mazur (Flickr: Benimoto); (b) Steve Jurvetson (Flickr: jurvetson). Both caterpillars and hawks are consumers . CC-BY 2.0
2. (a) Umberto Salvagnin (Flickr: kaibara87); (b) Flickr:takomabibelot. Bacteria and fungi are often decomposers . CC BY 2.0

Concept 14 Food Webs

- Distinguish a food chain from a food web.
- Be able to draw and interpret a food web.
- Summarize the roles of producers, herbivores, and carnivores in a food web.

How do the grasshopper and the grass interact?

Grasshoppers don't just hop on the grass. They also eat the grass. Other organisms also eat the grass, and some animals even eat the grasshopper. These interactions can be visualized by drawing a food web.

Food Webs

Energy must constantly flow through an ecosystem for the system to remain stable. What exactly does this mean? Essentially, it means that organisms must eat other organisms. **Food chains** (**Figure** 14.1) show the eating patterns in an ecosystem. Food energy flows from one organism to another. Arrows are used to show the feeding relationship between the animals. The arrow points from the organism being eaten to the organism that eats it. For example, an arrow from a plant to a grasshopper shows that the grasshopper eats the leaves. Energy and nutrients are moving from the plant to the grasshopper. Next, a bird might prey on the grasshopper, a snake may eat the bird, and then an owl might eat the snake. The food chain would be:

plant → grasshopper → bird → snake → owl.

A food chain cannot continue to go on and on. For example the food chain could not be:

plant → grasshopper → spider → frog → lizard → fox → hawk.

Food chains only have 4 or 5 total levels. Therefore, a chain has only 3 or 4 levels for energy transfer.

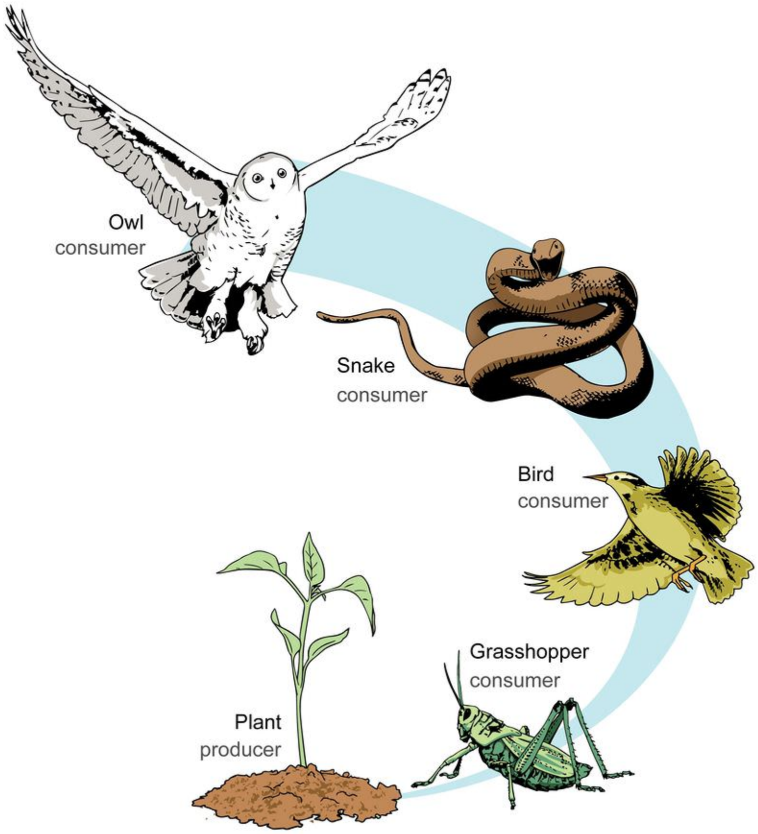


FIGURE 14.1
This food chain includes producers and consumers. How could you add decomposers to the food chain?

In an ocean ecosystem, one possible food chain might look like this: phytoplankton → krill → fish → shark. The **producers** are always at the beginning of the food chain, bringing energy into the ecosystem. Through photosynthesis, the producers create their own food in the form of glucose, but also create the food for the other organisms in the ecosystem. The **herbivores** come next, then the **carnivores**. When these **consumers** eat other organisms, they use the glucose in those organisms for energy. In this example, phytoplankton are eaten by krill, which are tiny, shrimp-like animals. The krill are eaten by fish, which are then eaten by sharks. Could **decomposers** be added to a food chain?

Each organism can eat and be eaten by many different types of organisms, so simple food chains are rare in nature. There are also many different species of fish and sharks. So a food chain cannot end with a shark; it must end with a distinct species of shark. A food chain does not contain the general category of "fish," it will contain specific species of fish. In ecosystems, there are many food chains.

Since feeding relationships are so complicated, we can combine food chains together to create a more accurate flow of energy within an ecosystem. A **food web** (**Figure** 14.2) shows the feeding relationships between many organisms in an ecosystem. If you expand our original example of a food chain, you could add deer that eat clover and foxes that hunt chipmunks. A food web shows many more arrows, but still shows the flow of energy. A complete food web may show hundreds of different feeding relationships.

For more information on food chains, see *A Million Sharks* at https://www.youtube.com/watch?v=QXMTzXaWJyk .

Summary

- A food chain is a diagram that shows feeding interactions in an ecosystem through a single pathway.

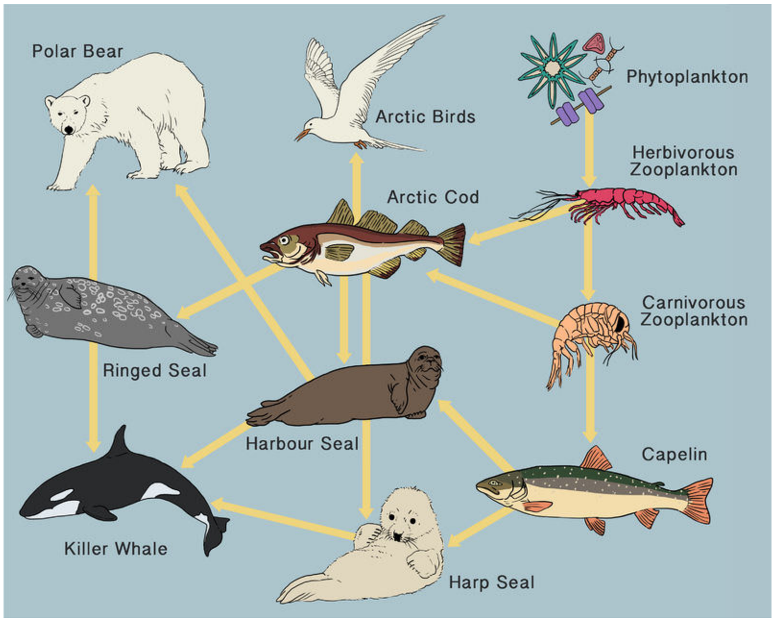


FIGURE 14.2
Food web in the Arctic Ocean.

- A food web is a diagram that shows feeding interactions between many organisms in an ecosystem through multiple intersecting pathways.

Explore More

Use the resource below to answer the questions that follow.

- **Build A Food Web** at http://www.sciencesource2.ca/resources/SS_active_art/active_art/SEinteractive_gr09_ch01_pg31/index.html

1. What do the Loons and Arctic Tern have in common in the food web?
2. What do the Beluga and the sea duck have in common in the food web?
3. What species in the food web feed on zooplankton (animal plankton)?
4. When you build your own food web what must it contain to be healthy? How many healthy food webs could you build?

Review

1. What is the difference between a food chain and a food web?
2. Food chains always begin with what type of organism? Why?
3. What is the herbivore in the following food chain: algae → fish → herons?

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. This food chain includes both producers and consumers, but not decomposers . CC BY-NC 3.0
2. Laura Guerin. This food web displays some feeding relationships found in the Arctic Ocean . CC BY-NC 3.0

CONCEPT 15 Predation

- Define predation.
- Explain the different types of predation.
- Describe how predation affects the community.
- Explain the advantages of camouflage and mimicry.

Can insects hunt for food?

When you think of an animal hunting for its food, large animals such as lions may come to mind. But many tiny animals also hunt for their food. For example, this praying mantis is eating a fly. To eat the fly, the praying mantis first had to catch the fly, which is a form of hunting.

Predation

Predation is another mechanism in which species interact with each other. Predation is when a predator organism feeds on another living organism or organisms, known as **prey**. The predator always lowers the prey's **fitness**. It does this by keeping the prey from surviving, reproducing, or both. **Predator-prey relationships** are essential to maintaining the balance of organisms in an ecosystem. Examples of predator-prey relationships include the lion and zebra, the bear and fish, and the fox and rabbit.

There are different types of predation, including:

- true predation.
- grazing.
- parasitism.

True predation is when a predator kills and eats its prey. Some predators of this type, such as jaguars, kill large prey. They tear it apart and chew it before eating it. Others, like bottlenose dolphins or snakes, may eat their prey whole. In some cases, the prey dies in the mouth or the digestive system of the predator. Baleen whales, for example,

FIGURE 15.1
This lion is an example of a predator on the hunt.

eat millions of plankton at once. The prey is digested afterward. True predators may hunt actively for prey, or they may sit and wait for prey to get within striking distance. Certain traits enable organisms to be effective hunters. These include camouflage, speed, and heightened senses. These traits also enable certain prey to avoid predators.

In **grazing**, the predator eats part of the prey but does not usually kill it. You may have seen cows grazing on grass. The grass they eat grows back, so there is no real effect on the population. In the ocean, kelp (a type of seaweed) can regrow after being eaten by fish.

Predators play an important role in an ecosystem. For example, if they did not exist, then a single species could become dominant over others. Grazers on a grassland keep grass from growing out of control. Predators can be **keystone species**. These are species that can have a large effect on the balance of organisms in an ecosystem. For example, if all of the wolves are removed from a population, then the population of deer or rabbits may increase. If there are too many deer, then they may decrease the amount of plants or grasses in the ecosystem. Decreased levels of **producers** may then have a detrimental effect on the whole ecosystem. In this example, the wolves would be a keystone species.

Prey also have adaptations for avoiding predators. Prey sometimes avoid detection by using camouflage (**Figure** 15.2). **Camouflage** means that species have an appearance (color, shape, or pattern) that helps them blend into the background. **Mimicry** is a related adaptation in which a species uses appearance to copy or mimic another species. For example, a non-poisonous dart frog may evolve to look like a poisonous dart frog. Why do you think this is an adaptation for the non-poisonous dart frog? Mimicry can be used by both predators and prey (**Figure** 15.3).

Parasitism is a type of **symbiotic** relationship and will be described in the *Symbiosis* concept.

FIGURE 15.2
Camouflage by the dead leaf mantis makes it less visible to both its predators and prey. If alarmed, it lies motionless on the rainforest floor of Madagascar, Africa, camouflaged among the actual dead leaves. It eats other animals up to the size of small lizards.

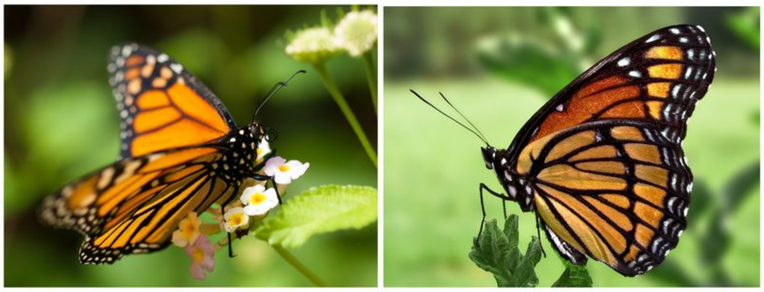


FIGURE 15.3
An example of mimicry, where the Viceroy butterfly (*right*) mimics the unpleasant Monarch butterfly (*left*). Both butterfly species are avoided by predators to a greater degree than either one would be without mimicry.

Summary

- Predation happens when a predator organism feeds on another living organism or organisms, known as prey.
- Predators can be keystone species, a species that can have a large effect on the balance of organisms in an ecosystem.

Explore More

Use the resource below to answer the questions that follow.

- **Best Disguised Predator Fish?** at http://video.nationalgeographic.com/video/stonefish-predation (1:18)

1. What allows the stone fish to sneak up on prey?
2. What does the stone fish eat?
3. Where does the stone fish hide?

Review

1. What is predation?
2. What's the difference between grazing and true predation?
3. What sorts of adaptations do prey have for avoiding predators?
4. Predators can be a keystone species. What does this mean?

References

1. Nick Jewell (Flickr:MacJewell). This lion is an example of a hunting predator . CC BY 2.0
2. Adrian Pingstone (Wikimedia: Arpingstone). This dead leaf mantis is camouflaged by the actual dead leaves . Public Domain
3. Viceroy: James D Rucker; Monarch: William Warby (Flickr:wwarby). The Viceroy butterfly mimics the unpleasant Monarch butterfly . CC BY 2.0

CONCEPT 16 Competition

- Describe competition.
- Describe how competition affects the community.
- Compare intraspecific competition to interspecific competition.
- Summarize the competitive exclusion principle.

What does it mean to compete?

If you are in competition with someone, it usually means you are in a contest for a prize. The prize might just be bragging rights. In nature, the stakes are higher. Organisms must compete for resources necessary for life.

Competition

Recall that **ecology** is the study of how living organisms interact with each other and with their environment. But how do organisms *interact* with each other? Organisms interact with each other through various mechanisms, one of which is competition. **Competition** occurs when organisms strive for limited resources. Competition can be for food, water, light, or space. This interaction can be between organisms of the same species (intraspecific) or between organisms of different species (interspecific).

Intraspecific competition happens when members of the same species compete for the same resources. For example, two trees may grow close together and compete for light. One may out-compete the other by growing taller to get more available light. As members of the same species are usually genetically different, they have different characteristics, and in this example, one tree grows taller than the other. The organism that is better adapted to that environment is better able to survive. The other organism may not survive. In this example, it is the taller tree that is better adapted to the environment.

Interspecific competition happens when individuals of different species strive for a limited resource in the same area. Since any two species have different traits, one species will be able to out-compete the other. One species will be better adapted to its environment, and essentially "win" the competition. The other species will have lower reproductive success and lower population growth, resulting in a lower survival rate. For example, cheetahs and lions feed on similar prey. If prey is limited, then lions may catch more prey than cheetahs. This will force the cheetahs to either leave the area or suffer a decrease in population.

Looking at different types of competition, ecologists developed the **competitive exclusion principle**. The principle states that species less suited to compete for resources will either adapt, move from the area, or die out. In order for two species within the same area to coexist, they may adapt by developing different specializations. This is known as **character displacement**. An example of character displacement is when different birds adapt to eating different types of food. They can develop different types of bills, like Darwin's Finches (**Figure** 16.1). Therefore, competition for resources within and between species plays an important role in **evolution** through **natural selection**.

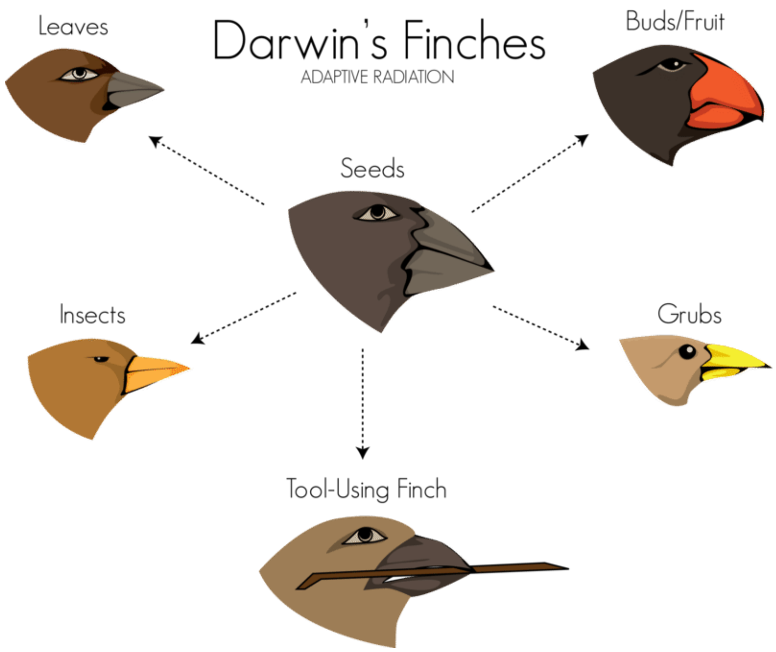


FIGURE 16.1
An example of character displacement, showing different types of bill for eating different types of foods, in Darwin's or Galapagos Finches.

Summary

- Competition, or when organisms strive for limited resources, can be between organisms of the same species (intraspecific) or organisms of different species (interspecific).
- In order for two species within the same area to coexist, they may develop different specializations; this is known as character displacement.

Explore More

Use the resource below to answer the questions that follow.

Anemones Attack at http://shapeoflife.org/video/behavior/cnidarians-anemones-fight (2:49)

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/57317

1. What sort of competition are these anemones displaying?

2. Looking at the size of the sea anemones in this video, are you surprised by the amount of space they they feel they need? Explain your answer.
3. What must be true about the costs in energy of anemone fighting? What would happen to the population if this were not the case?

Review

1. What is the difference between intraspecific and interspecific competition?
2. What is the competitive exclusion principle?
3. How can competition contribute to evolution through natural selection?
4. What has to be true about available resources for competition to exist?

References

1. Christopher Auyeung. These finches exhibit character displacement by adapting to eating different types of fo od . CC BY-NC 3.0

CONCEPT 17 Features of Populations

- Define population.
- List ways in which a population can be described.
- Explain population density and dispersion.
- Explain how population growth is determined.

What is a population?

When you think of the word *population,* you might think of the number of people in your town or city. But humans are not the only species to have populations. Every species has a population. Or many populations. This group of penguins, which are all members of the same species and all living together in the same space, is a population.

What is a Population

A **population** is a group of organisms of the same species, all living in the same area and interacting with each other. Since they live together in one area, members of the same species reproduce together. Ecologists who study populations determine how healthy or stable the populations are. They also study how the individuals of a species interact with each other and how populations interact with the environment. If a group of similar organisms in the same area cannot reproduce with members of the other group, then they are members of two distinct species and form two populations.

Ecologists look at many factors that help to describe a population. First, ecologists can measure the number of individuals that make up the population, known as **population size**. They can then determine the **population density**, which is the number of individuals of the same species in an area. Population density can be expressed as *number per area*, such as 20 mice/acre, or 50 rabbits/square mile.

Ecologists also study how individuals in a population are spread across an environment. This spacing of individuals within a population is called **dispersion**. Some species may be clumped or clustered (**Figure** 17.1) in an area. Others may be evenly spaced (**Figure** 17.2). Still others may be spaced randomly within an area. The population density and dispersion have an effect on reproduction and population size. What do you think the relationship is between population density, dispersion and size?

FIGURE 17.1
Clumped species are closer together. This may allow for easier reproduction.

FIGURE 17.2
A population of cacti in the Sonoran Desert generally shows even dispersion due to competition for water.

Ecologists also study the birth and death rates of the population. Together these give the growth rate (the birth rate minus the death rate), which tells how fast (or slow) the population size is changing. The **birth rate** is the number of births within a population during a specific time period. The **death rate** is the number of deaths within a population during a specific time period. Knowing the birth and death rates of populations gives you information about a population's health. For example, when a population is made up of mostly young organisms and the birth rate is high, the population is growing. A population with equal birth and death rates will remain the same size. Populations that are decreasing in size have a higher death rate than birth rate.

Summary

- A population is a group of organisms of the same species, all living in the same area and interacting with each other.
- Scientists can study many aspects of a population, including density, dispersion, and birth and death rates.

Explore More

Use the resource below to answer the questions that follow.

- **Population Distributions** at http://www.youtube.com/watch?v=BMsmDy-2jbA (3:51)

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/57315

1. Is the distribution of organisms of a species constant with time?
2. What is the most common type of distribution? How does this distribution benefit the species?
3. What factors make a uniform distribution pattern a beneficial strategy for a species?
4. How do chemicals made by organisms help establish and maintain a uniform distribution pattern?
5. What factors contribute to a random distribution pattern? Why do animals not maintain this distribution pattern year round?

Review

1. Define population.
2. What is population dispersion? Describe the possible dispersion patterns for a population.
3. Would all the deer and mice living in a forest be a population? Why or why not?
4. What is the growth rate?

References

1. Liz West. Clumped species are closer together, which allows for easier reproduction . CC BY 2.0
2. User:Wars/Wikimedia Commons. These cacti are dispersed due to competition for water . CC BY 2.5

Concept 18 Population Size

- Describe the factors that regulate population size.

How many penguins are the right number for this beach?

As many as can survive and have healthy offspring! A population will tend to grow as big as it can for the resources it needs. Once it is too large, some of its members will die off. This keeps the population size at the right number.

Populations

Biotic and abiotic factors determine the population size of a species in an ecosystem. What are some important biotic factors? Biotic factors include the amount of food that is available to that species and the number of organisms that also use that food source. What are some important abiotic factors? Space, water, and climate all help determine a species population.

When does a population grow? A population grows when the number of births is greater than the number of deaths. When does a population shrink? When deaths exceed births.

What causes a population to grow? For a population to grow there must be ample resources and no major problems. What causes a population to shrink? A population can shrink either because of biotic or abiotic limits. An increase in predators, the emergence of a new disease, or the loss of habitat are just three possible problems that will decrease a population. A population may also shrink if it grows too large for the resources required to support it.

Carrying Capacity

When the number of births equals the number of deaths, the population is at its **carrying capacity** for that habitat. In a population at its carrying capacity, there are as many organisms of that species as the habitat can support. The carrying capacity depends on biotic and abiotic factors. If these factors improve, the carrying capacity increases. If the factors become less plentiful, the carrying capacity drops. If resources are being used faster than they are being replenished, then the species has exceeded its carrying capacity. If this occurs, the population will then decrease in size.

Limiting Factors

Every stable population has one or more factors that limit its growth. A **limiting factor** determines the carrying capacity for a species. A limiting factor can be any biotic or abiotic factor: nutrient, space, and water availability are examples (**Figure** 18.1). The size of a population is tied to its limiting factor.

FIGURE 18.1

In a desert such as this, what is the limiting factor on plant populations? What would make the population increase? What would make the population decrease?

What happens if a limiting factor increases a lot? Is it still a limiting factor? If a limiting factor increases a lot, another factor will most likely become the new limiting factor.

This may be a bit confusing, so let's look at an example of limiting factors. Say you want to make as many chocolate chip cookies as you can with the ingredients you have on hand. It turns out that you have plenty of flour and other ingredients, but only two eggs. You can make only one batch of cookies, because eggs are the limiting factor. But then your neighbor comes over with a dozen eggs. Now you have enough eggs for seven batches of cookies, but only two pounds of butter. You can make four batches of cookies, with butter as the limiting factor. If you get more butter, some other ingredient will be limiting.

Species ordinarily produce more offspring than their habitat can support (**Figure** 18.2). If conditions improve, more young survive and the population grows. If conditions worsen, or if too many young are born, there is competition between individuals. As in any competition, there are some winners and some losers. Those individuals that survive to fill the available spots in the niche are those that are the most fit for their habitat.

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/183969

FIGURE 18.2
A frog in frog spawn. An animal produces many more offspring than will survive.

Summary

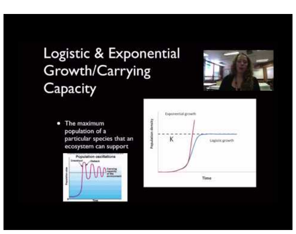
- Biotic factors that a population needs include food availability. Abiotic factors may include space, water, and climate.
- The carrying capacity of an environment is reached when the number of births equal the number of deaths.
- A limiting factor determines the carrying capacity for a species.

Review

1. Why don't populations continue to grow and grow?
2. What happens if a population exceeds its carrying capacity?
3. What happens if a factor that has limited a population's size becomes more available?

Explore More

Use this resource to answer the questions that follow. (Note: that when he says "people," he's really talking about any population of organisms.)



MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/178259

1. Under what circumstances can population growth be exponential?

2. What is carrying capacity?
3. What does reaching the carrying capacity do to population growth?
4. What does carrying capacity depend on?
5. What happens if a population exceeds its carrying capacity?
6. Is the carrying capacity constant? What changes it?
7. What are the two ways to eliminate a pest from your home?
8. Give the definition of density dependent factors that are limiting to population growth.
9. Give four examples and explain them for density dependent factors.
10. How do natural disasters affect the population size in a region?

References

1. Miles Orchinik. Water is the limiting factor on plant population in the desert . CC BY-NC 3.0
2. Image copyright Birute Vijeikiene, 2014. A frog in frog spawn . Used under license from Shutterstock.com

CONCEPT 19 Population Growth Patterns

- Describe factors that affect population growth.
- Distinguish immigration from emigration.
- Compare exponential growth to logistic growth.
- Explain carrying capacity.

What affects population growth in the United States?

One way the population of the United States has grown is through the movement of individuals into the United States from other parts of the world. The same effects can be seen in wildlife populations. Individuals move into a population and increase its size. This is just one of the many factors affecting population growth. Of course, individuals may also move away from a population.

Population Growth

What does population growth mean? You can probably guess that it means the number of individuals in a population is increasing. The **population growth rate** tells you how quickly a population is increasing or decreasing. What determines the population growth rate for a particular population?

Births, Deaths, and Migration

Population growth rate depends on birth rates and death rates, as well as migration. First, we will consider the effects of birth and death rates. You can predict the growth rate by using this simple equation: *growth rate = birth rate - death rate.*

If the birth rate is larger than the death rate, then the population grows. If the death rate is larger than the birth rate, what will happen to the population? The population size will decrease. If the birth and death rates are equal, then the population size will not change.

Factors that affect population growth are:

1. Age of organisms at first reproduction.
2. How often an organism reproduces.
3. The number of offspring of an organism.
4. The presence or absence of parental care.
5. How long an organism is able to reproduce.
6. The death rate of offspring.

For an ecosystem to be stable, populations in that system must be healthy, and that usually means reproducing as much as their environment allows. Do organisms reproduce yearly or every few years? Do organisms reproduce for much of their life, or just part of their life? Do organisms produce many offspring at once, or just a few, or even just one? Do many newborn organisms die, or do the majority survive? All these factors play a role in the growth of a population.

Organisms can use different strategies to increase their reproduction rate. **Altricial** organisms are helpless at birth, and their parents give them a lot of care. This care is often seen in bird species. (**Figure** 19.1). Altricial birds are usually born blind and without feathers. Compared to precocial organisms, altricial organisms have a longer period of development before they reach maturity. **Precocial** organisms, such as the geese shown below, can take care of themselves at birth and do not require help from their parents (**Figure** 19.1). In order to reproduce as much as possible, altricial and precocial organisms must use very different strategies.

FIGURE 19.1

(left) A hummingbird nest with young illustrates an altricial reproductive strategy, with a few small eggs, helpless young, and intensive parental care. (right) The Canada goose shows a precocial reproductive strategy. It lays a large number of large eggs, producing well-developed young.

Migration

Migration is the movement of individual organisms into, or out of, a population. Migration affects population growth rate. There are two types of migration:

1. **Immigration** is the movement of individuals into a population from other areas. This increases the population size and growth rate.

2. **Emigration** is the movement of individuals out of a population. This decreases the population size and growth rate.

The earlier growth rate equation can be modified to account for migration: *growth rate = (birth rate + immigration rate) - (death rate + emigration rate).*

One type of migration that you are probably familiar with is the migration of birds. Maybe you have heard that birds fly south for the winter. In the fall, birds fly thousands of miles to the south where it is warmer. In the spring, they return to their homes. (**Figure** 19.2).

Monarch butterflies also migrate from Mexico to the northern U.S. in the summer and back to Mexico in the winter. These types of migrations move entire populations from one location to another.

FIGURE 19.2
A flock of barnacle geese fly in formation during the autumn migration.

Exponential Growth

Population growth can be described with two models, based on the size of the population and necessary resources. These two types of growth are known as exponential growth and logistic growth. If a population is given unlimited amounts of resources, such as food and water, land if needed, moisture, oxygen, and other environmental factors, it will grow exponentially. **Exponential growth** occurs as a population grows larger, dramatically increasing the growth rate. This is shown as a "J-shaped" curve below (**Figure** 19.3). You can see that the population grows slowly at first, but as time passes, growth occurs more and more rapidly.

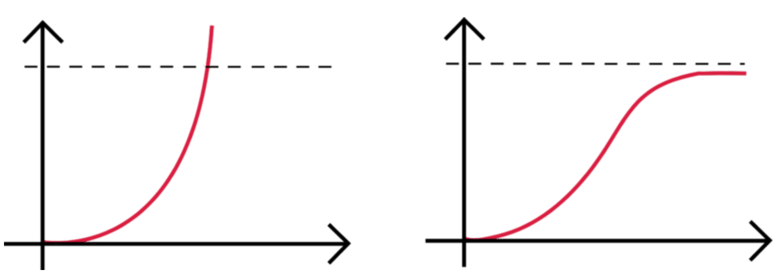


FIGURE 19.3
Growth of populations according to exponential (or J-curve) growth model (*left*) and logistic (or S-curve) growth model (*right*). Time is plotted on the x-axis, and population size is plotted on the y-axis.

In nature, organisms do not usually have ideal environments with unlimited food. In nature, there are limits. Sometimes, there will be plenty of food. Sometimes, a fire will wipe out all of the available nutrients. Sometimes a predator will kill many individuals in a population. How do you think these limits affect the way organisms grow?

Usually, populations first grow exponentially while resources are abundant. But as populations increase and resources become less available, rates of growth slow down and slowly level off, reaching the carrying capacity. The **carrying capacity** is the upper limit to the population size that the environment can support. This type of growth is shown as an "S-shaped" curve below (**Figure** 19.3) and is called **logistic growth.** Why do you think occurs?

Summary

- Population growth rate is affected by birth rates, death rates, immigration, and emigration.
- If a population is given unlimited amounts of food, moisture, and oxygen, and other environmental factors, it will show exponential growth.

Explore More

Use the resource below to answer the questions that follow.

- **Population Growth** at http://www.youtube.com/watch?v=sc4HxPxNrZ0 (2:58)

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/1548

1. How many years did it take the human population to increase from 1 billion to 2 billion? Considering how long it took the human population to reach 1 billion, is this pattern consistent with an exponential growth model?
2. How fast is the human population currently increasing? What kind of growth does this indicate the human population is experiencing currently? Does this rate represent an increase or decrease from previous growth rates?
3. Is our current population level creating problems with available space? Why or why not?

Review

1. List three factors that affect population growth?
2. Compare altricial organisms to precocial organisms.
3. What is the overall equation for growth rate?
4. Does a typical population show exponential growth? Why or why not?
5. Define carrying capacity.

References

1. Hummingbirds: User:Miksmith/Wikipedia; Geese: Courtesy of the U.S. Fish and Wildlife Service. Two reproductive strategies used are altricial strategies with few helpless young and precocial strategies with many well-developed young . Public Domain

2. User:Huhu Uet/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:G%C3%A4nse_Hetlinger_Schanze_04.jpg . CC BY 3.0
3. Laura Guerin. CK-12 Foundation . CC BY-NC 3.0

CONCEPT 20

Limiting Factors to Population Growth

- Give examples of limiting factors to population growth.
- Explain how limiting factors affect population growth.

What happened during the Irish Potato Famine?

In the 1800s, a disease called potato blight destroyed much of the potato crop in Ireland. Since many Irish people depended on potatoes as their staple food, mass starvation and emigration resulted. This caused Ireland's population to dramatically decrease. Lack of food is one factor that can limit population growth.

Limiting Factors to Population Growth

For a population to be healthy, factors such as food, nutrients, water and space, must be available. What happens when there are not resources to support the population? **Limiting factors** are resources or other factors in the environment that can lower the population growth rate. Limiting factors include a low food supply and lack of space. Limiting factors can lower birth rates, increase death rates, or lead to emigration.

When organisms face limiting factors, they show **logistic growth** (S-shaped curve, curve B: **Figure** 20.1). Competition for resources like food and space cause the growth rate to stop increasing, so the population levels off. This flat upper line on a growth curve is the carrying capacity. The **carrying capacity** (K) is the maximum population size that can be supported in a particular area without destroying the habitat. Limiting factors determine the carrying capacity of a population. Recall that when there are no limiting factors, the population grows exponentially. In **exponential growth** (J-shaped curve, curve A: **Figure** 20.1), as the population size increases, the growth rate also increases.

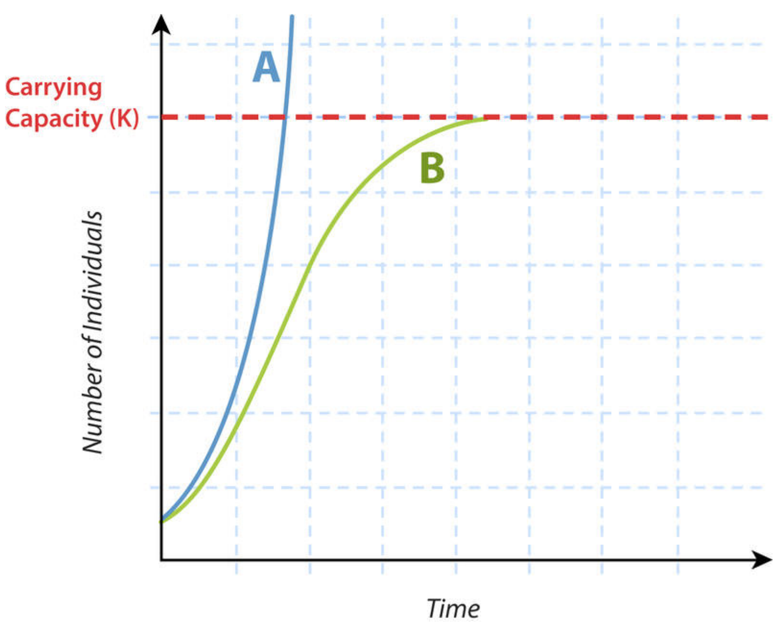


FIGURE 20.1
Exponential and Logistic Growth. Curve A shows exponential growth. Curve B shows logistic growth. Notice that the carrying capacity (K) is also shown.

Food Supply as Limiting Factor

If there are 12 hamburgers at a lunch table and 24 people sit down at a lunch table, will everyone be able to eat? At first, maybe you will split hamburgers in half, but if more and more people keep coming to sit at the lunch table, you will not be able to feed everyone. This is what happens in nature. But in nature, organisms that cannot get food will die or find a new place to live. It is possible for any resource to be a limiting factor, however, a resource such as food can have dramatic consequences on a population.

In nature, when the population size is small, there is usually plenty of food and other resources for each individual. When there is plenty of food and other resources, organisms can easily reproduce, so the birth rate is high. As the population increases, the food supply, or the supply of another necessary resource, may decrease. When necessary resources, such as food, decrease, some individuals will die. Overall, the population cannot reproduce at the same rate, so the birth rates drop. This will cause the population growth rate to decrease.

When the population decreases to a certain level where every individual can get enough food and other resources, and the birth and death rates become stable, the population has leveled off at its carrying capacity.

Other Limiting Factors

Other limiting factors include light, water, nutrients or minerals, oxygen, the ability of an ecosystem to recycle nutrients and/or waste, disease and/or parasites, temperature, space, and predation. Can you think of some other factors that limit populations?

Weather can also be a limiting factor. Whereas most plants like rain, an individual cactus-like *Agave americana* plant actually likes to grow when it is dry. Rainfall limits reproduction of this plant which, in turn, limits growth rate. Can you think of some other factors like this?

Human activities can also limit the growth of populations. Such activities include use of pesticides, such as DDT, use of herbicides, and habitat destruction.

Summary

- Limiting factors, or things in the environment that can lower the population growth rate, include low food supply and lack of space.
- When organisms face limiting factors, they show logistic type of growth (S-curve).

Explore More

Use the resource below to answer the questions that follow.

- **Biotic Potential** at http://www.youtube.com/watch?v=BSVbdaubxxg (2:58)

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/57338

1. What type of growth is characterized by a consistent increase in growth rate? How often is this type of growth actually seen in nature?
2. What factors keep populations from reaching their carrying capacity?
3. How do you think the length of an organism's life span will affect the species' ability to reach carrying capacity?
4. What would the growth equation look like for sessile populations (i.e. populations where individuals are fixed in space)?

Review

1. What is a limiting factor?
2. What are three examples of limiting factors?
3. When organisms face limiting factors, what type of growth do they show?

References

1. Hana Zavadska. Organisms show exponential growth in the absence of limiting factors, while they show logistic growth in the presence of limiting factors . CC BY-NC 3.0

Concept 21 Importance of Biodiversity

- Define biodiversity.
- Discuss the ecological and economic importance of biodiversity.
- Define and discuss biomimicry (bionics).

Why is preserving the rainforest important?

Preserving the rainforest is important for many reasons. But one reason conservation efforts have focused here is that the rainforest is home to more species of insects, amphibians, and birds than anywhere else on the planet. This wide diversity of life is called biodiversity.

Importance of Biodiversity

Biodiversity is a measurement of the amount of variation of the species in a given area. More specifically, biodiversity can be defined as the variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.

A place such as a coral reef has many different species of plants and animals. That means the coral reef is a ecosystem with high biodiversity (**Figure** 21.1). Because of its biodiversity, the rainforest shown above is an ecosystem with extreme importance. Why is biodiversity so important? In addition to maintaining the health and stability of the ecosystem, the diversity of life provides us with many benefits.

Extinction is a threat to biodiversity. Does it matter if we are losing thousands of species each year? The answer is yes. It matters even if we consider not only the direct benefits to humans, but also the benefits to the ecosystems. The health and survival of ecosystems is related to that ecosystem's biodiversity.

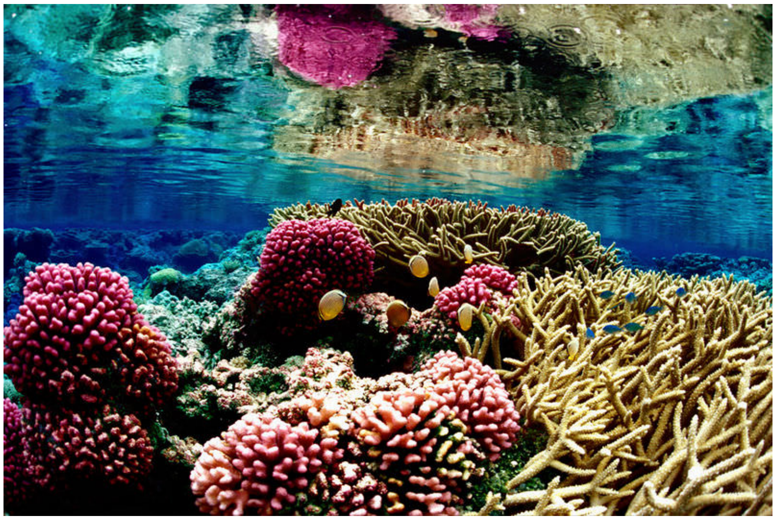


FIGURE 21.1
Coral reefs are one of the biomes with the highest biodiversity on Earth.

Economic Importance

Economically, there are many direct benefits of biodiversity. As many as 40,000 species of fungi, plants, and animals provide us with many varied types of clothing, shelter, medicines and other products. These include poisons, timber, fibers, fragrances, papers, silks, dyes, adhesives, rubber, resins, skins, furs, and more. According to one survey, 57% of the most important prescription drugs come from nature. Specifically, they come from bacteria, fungi, plants, and animals (**Figure** 21.2). But only a small amount of species with the ability to give us medicines have been explored. The loss of any species may mean the loss of new medicines, which will have a direct effect on human health.

FIGURE 21.2
Aspirin originally came from the bark of the white willow tree, pictured here.

Biodiversity and Technology

Nature has inspired many technologies in use today. **Bionics**, also known as biomimetics or biomimicry, uses organisms to inspire technology or engineering projects. By studying animals and their traits, we are able to gain valuable information that we can put to use to help us. For example, rattlesnake heat-sensing pits helped inspire the development of infrared sensors. Zimbabwe's Eastgate Centre (**Figure** 21.3) was inspired by the air-conditioning efficiency of a termite mound (**Figure** 21.4).

FIGURE 21.3
Design of the Eastgate Centre (brown building), in Zimbabwe, which requires just 10% of the energy needed for a conventional building of the same size, was inspired by a biological design.

Ecological Importance

Biodiversity also has many benefits to ecosystems. High biodiversity makes ecosystems more stable. What can happen to an ecosystem if just one species goes extinct? What if that one species was a **producer** or **decomposer**? Would the loss of a producer have an effect on all the organisms that relied on that producer? If a decomposer vanishes, are there other decomposers to fill the void? Maybe the resulting species will adapt. Other species may fill in the **niche** left by the extinct species. But the extinction of one species could have a "domino" effect, resulting in the extinction of other species. This could greatly effect the stability of the whole ecosystem.

One important role of biodiversity is that it helps keep the nutrients, such as nitrogen, in the soil. For example, a diversity of organisms in the soil allows **nitrogen fixation** and nutrient recycling to happen. Biodiversity also allows plants to be pollinated by different types of insects. And of course, different species of fungi are necessary to recycle

FIGURE 21.4
The air-conditioning efficiency of this termite mound was the inspiration for the Eastgate Centre.

wastes from dead plants and animals. These are just a few of the many examples of how biodiversity is important for ecosystems.

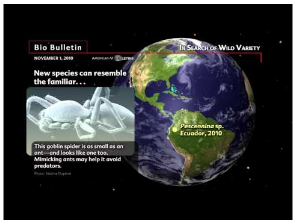
Summary

- Biodiversity is a measurement of the amount of variation of the species in a given area.
- Biodiversity is important because it directly benefits humans and ecosystems.

Explore More

Use the resource below to answer the questions that follow.

- **In Search of Wild Variety** from American Museum of Natural History http://www.youtube.com/watch?v=Pbg_pGZv3CQ (1:52)



MEDIA

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1. As of November 2010, about how many species have been identified on the Earth? How close do scientist feel this number is to the total number of species which exist?
2. In what kinds of locations are new species being found?
3. Can different species be identified by just looking at them? What techniques are scientists using to identify new species?

Review

1. What is biodiversity?
2. What does it mean if a place has high biodiversity?
3. What is an economic impact of biodiversity?
4. How does high biodiversity help the stability of an ecosystem?

References

1. USFWS Pacific. Coral reefs are one of the biomes with the highest biodiversity on Earth . CC BY 2.0
2. User:Willow/Wikimedia Commons. Aspirin is a medicine derived originally from nature . CC BY 2.5
3. Flickr:damien_farrell. Nature has also helped to inspire designs such as the Eastgate Centre . CC BY 2.0
4. Bengt Olof ÅRADSSON. The air-conditioning efficiency of this termite mound was the inspiration for the Eastgate Centre . CC BY 2.5