Student Edition

Inspire Biology

McGraw Hill Education

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Phenomenon: The Long-snouted Seahorse

The long-snouted seahorse, *Hippocampus guttulatus*, is found in shallow marine water. It is in the class Actinopterygii, which are ray-finned fishes. Seahorses and other ray-finned fishes have fins that are supported by thin, spinelike rays. Most fishes alive today are ray-finned fishes.

Fun Fact

The genus of seahorse, *Hippocampus*, comes from the Greek word *hippos*, meaning *horse*, and *kampos*, meaning *sea monster.*

FRONT COVER: Raimundo Fernandez Diez/Moment Open/Getty Images.
BACK COVER: Raimundo Fernandez Diez/Moment Open/Getty Images

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STEM

McGraw-Hill is committed to providing instructional materials in Science, Technology, Engineering, and Mathematics (STEM) that give all students a solid foundation, one that prepares them for college and careers in the 21st century.

Welcome to

Inspire Biology

Explore Our Phenomenal World

The Inspire High School Series brings phenomena to the forefront of learning to engage and inspire students to investigate key science concepts through their three-dimensional learning experience.

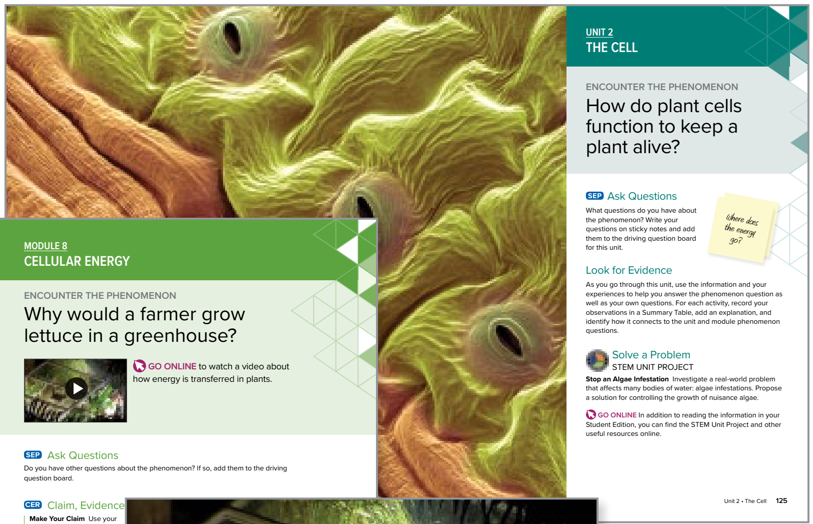
Start exploring now!

Inspire Curiosity • Inspire Investigation • Inspire Innovation

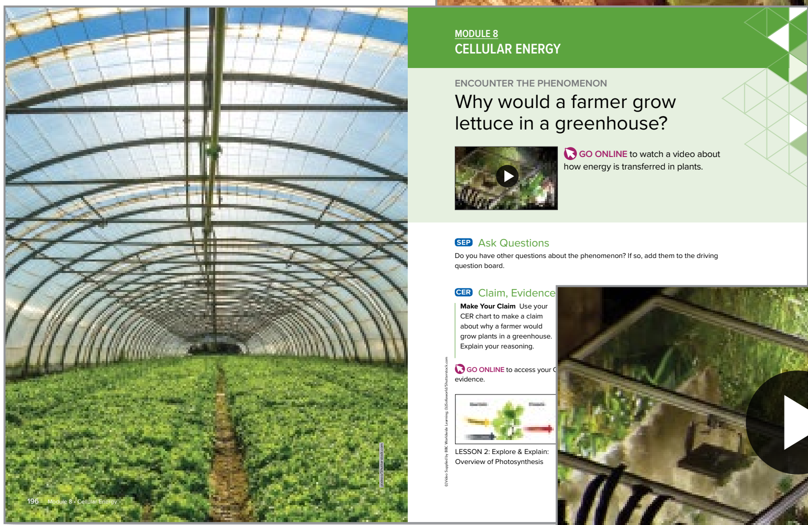
Owning Your Learning

1 Encounter the Phenomenon

Every day, you are surrounded by natural phenomena that make you wonder.

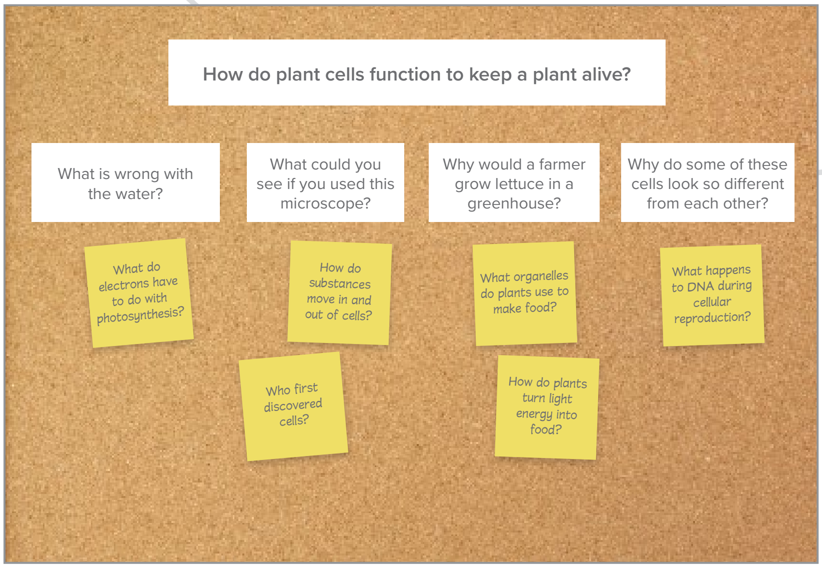


Unit Opener



Module Opener

Phenomenon Video

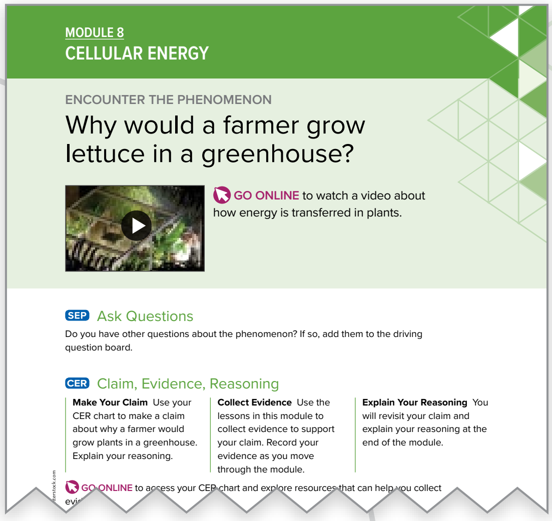


2 Ask Questions

At the beginning of each unit and module, make a list of the questions you have about the phenomenon. Talk about and share your questions with your classmates.

3 Claim, Evidence, Reasoning

As you investigate each phenomenon, you will write your claim, gather evidence by performing labs and completing reading assignments and Applying Practices, and explain your reasoning to answer the unit and module phenomena.


MODULE 8
CELLULAR ENERGY

ENCOUNTER THE PHENOMENON
Why would a farmer grow lettuce in a greenhouse?

GO ONLINE to watch a video about how energy is transferred in plants.

SEP Ask Questions
Do you have other questions about the phenomenon? If so, add them to the driving question board.

CER Claim, Evidence, Reasoning
Make Your Claim Use your CER chart to make a claim about why a farmer would grow plants in a greenhouse. Explain your reasoning.
Collect Evidence Use the lessons in this module to collect evidence to support your claim. Record your evidence as you move through the module.
Explain Your Reasoning You will revisit your claim and explain your reasoning at the end of the module.

GO ONLINE to access your CER chart and explore resources that can help you collect evi

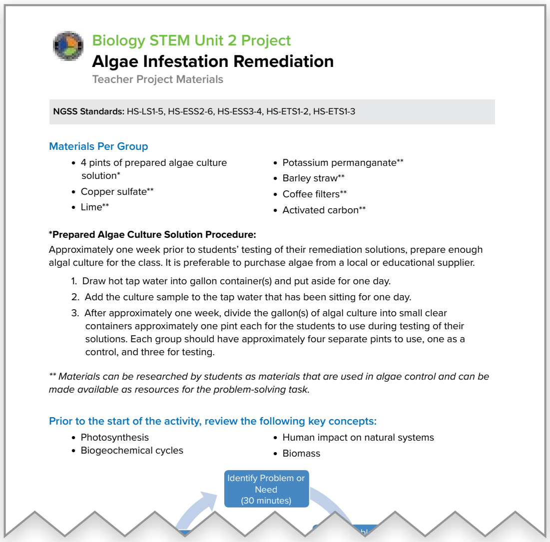
SUMMARY TABLE					
Activity Model	Observation Evidence	Explanation Reasoning	Connection to Phenom	Questions Answered	New Questions
Applying Practices: Modeling Photosynthesis	The reactants of photosynthesis are CO_2, H_2O, and sunlight; the products are sugar and O_2.	Photosynthesis allows autotrophs to convert energy from the Sun to chemical energy that is stored in sugar.	Unit: Photosynthesis is one of the cellular processes needed to keep plants alive. Module: A greenhouse optimizes the conditions for plants to photosynthesize.	How do plants turn light energy into food?	How fast does photosynthesis occur?

4 Summarize Your Work

When you collect evidence, you can record your data in a summary table and use the data to collaborate with others to answer the questions you had.

5 Apply Your Evidence and Reasoning

At the end of the unit, modules, and lessons, you can use all of the data you collected to help complete your STEM Unit Project.


Biology STEM Unit 2 Project
Algae Infestation Remediation
Teacher Project Materials

NGSS Standards: HS-LS1-5, HS-ESS2-6, HS-ESS3-4, HS-ETS1-2, HS-ETS1-3

Materials Per Group
- 4 pints of prepared algae culture solution*
- Copper sulfate**
- Lime**
- Potassium permanganate**
- Barley straw**
- Coffee filters**
- Activated carbon**

***Prepared Algae Culture Solution Procedure:**
Approximately one week prior to students' testing of their remediation solutions, prepare enough algal culture for the class. It is preferable to purchase algae from a local or educational supplier.
1. Draw hot tap water into gallon container(s) and put aside for one day.
2. Add the culture sample to the tap water that has been sitting for one day.
3. After approximately one week, divide the gallon(s) of algal culture into small clear containers approximately one pint each for the students to use during testing of their solutions. Each group should have approximately four separate pints to use, one as a control, and three for testing.

*** Materials can be researched by students as materials that are used in algae control and can be made available as resources for the problem-solving task.*

Prior to the start of the activity, review the following key concepts:
- Photosynthesis
- Biogeochemical cycles
- Human impact on natural systems
- Biomass

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Each advisor provided valuable feedback and suggestions regarding effective science instruction.
We thank them for their help.

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Smithsonian

Smithsonian

Following the mission of its founder James Smithson for “an establishment for the increase and diffusion of knowledge,” the Smithsonian Institution today is the world’s largest museum, education, and research complex. To further their vision of shaping the future, a wealth of Smithsonian online resources are integrated within this program.

SpongeLab Interactives

SpongeLab Interactives is a learning technology company that inspires learning and engagement by creating gamified environments that encourage students to interact with digital learning experiences.

Students participate in inquiry activities and problem-solving to explore a variety of topics using games, interactives, and video while teachers take advantage of formative, summative, or performance-based assessment information that is gathered through the learning management system.

PhET Interactive Simulations

The PhET Interactive Simulations project at the University of Colorado Boulder provides teachers and students with interactive science and math simulations. Based on extensive education research, PhET sims engage students through an intuitive, game-like environment where students learn through exploration and discovery.

ABOUT THE AUTHORS

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Alton was a biology educator in Texas public schools for more than 30 years. He has a BS and an MS in biology from Texas A & M University—Commerce. Mr. Biggs was the founding president of the Texas Association of Biology Teachers in 1983 and president of the National Association of Biology Teachers (NABT) in 1992. He received the NABT Outstanding Biology Teacher Award for Texas in 1982 and 1995.

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Whitney retired from a 33 year teaching career. She has a BA and an MA in biological sciences from Mount Holyoke College and an MAT from Duke University. In 1999, she was a Massachusetts NABT Outstanding Biology Teacher Award recipient. In 2005, she was awarded the Siemens Foundation AP Award for Math and Science Teachers for Massachusetts. She currently works as a Bio Teach Mentor and Program Coordinator at MassBio.

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William retired as a science education professor at the University of Maryland (College Park), and before 1986, was a professor at the University of Calgary (Alberta, Canada). He served as president of the National Association for Research in Science Teaching and later as an elected board member to the National Science Teachers Association. He has an MS in biological sciences and a PhD in science education. Dr. Holliday's multifaceted teaching experience totals more than 40 years.

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Linda has more than 25 years of experience teaching science at the middle school, high school, and college levels, including ten years at Bear Creek High School in Lakewood, Colorado. For eight years, she was a research associate in the Department of Science and Technology at the University of Colorado at Denver. Ms. Lundgren has a BA in journalism and zoology from the University of Massachusetts and an MS in zoology from The Ohio State University. In 1991, she was named Colorado Science Teacher of the Year.

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UNIT 1

ECOLOGY

ENCOUNTER THE PHENOMENON

What might happen to the plants that are covered by kudzu?

J.K. York/Shutterstock

INTRODUCTION TO BIOLOGY

This module introduces the nature of science, what Biology is, and provides tools for the study of Biology.

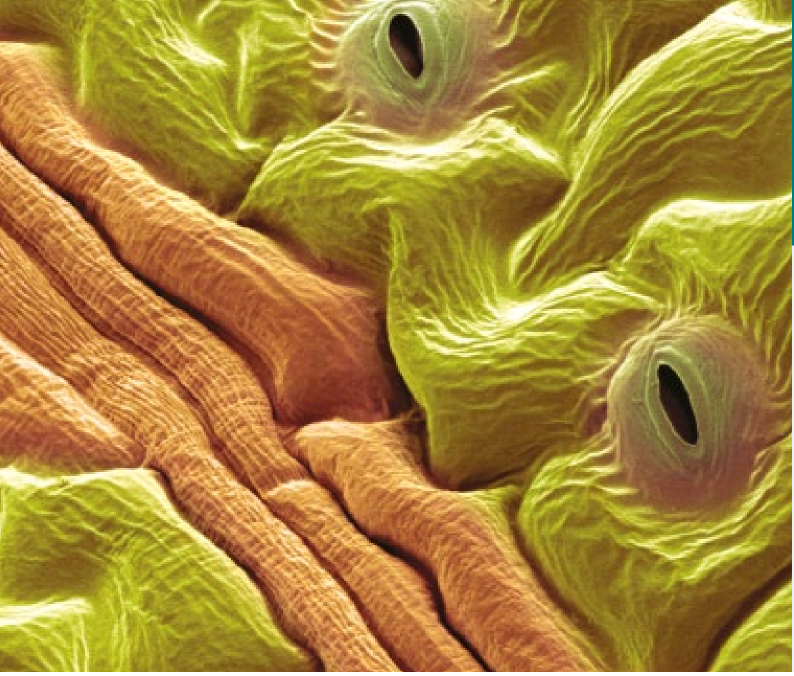
MODULE 1: THE STUDY OF LIFE

MODULE 2: PRINCIPLES OF ECOLOGY

MODULE 3: COMMUNITIES, BIOMES, AND ECOSYSTEMS

MODULE 4: POPULATION ECOLOGY

MODULE 5: BIODIVERSITY AND CONSERVATION



UNIT 2

THE CELL

ENCOUNTER THE PHENOMENON

How do plant cells function to keep a plant alive?

UNIT 3

GENETICS

ENCOUNTER THE PHENOMENON

Why are there numerous breeds of domestic dogs?

MODULE 10: INTRODUCTION TO GENETICS AND PATTERNS OF INHERITANCE

MODULE 11: MOLECULAR GENETICS

MODULE 12: BIOTECHNOLOGY

Frank Gaglione/The Image Bank/Getty Images

UNIT 4

HISTORY OF BIOLOGICAL DIVERSITY

ENCOUNTER THE PHENOMENON

Why are new fossil findings so important and interesting?

UNIT 5

THE DIVERSITY OF LIFE

ENCOUNTER THE PHENOMENON

Mudskippers are amphibious fish that have adapted to live in the water and on land. How is this possible?

twospeeds/Shutterstock

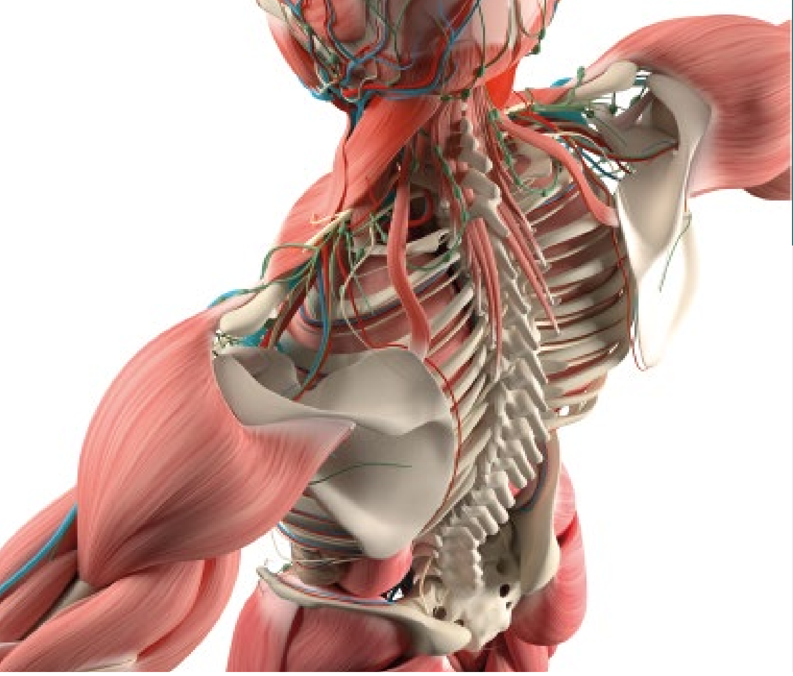
MODULE 17: BACTERIA AND VIRUSES

MODULE 18: PROTISTS AND FUNGI

MODULE 19: INTRODUCTION TO PLANTS

MODULE 20: INTRODUCTION TO ANIMALS

MODULE 21: ANIMAL BEHAVIOR AND DIVERSITY



Anatomy Insider/Shutterstock

UNIT 6

THE HUMAN BODY

ENCOUNTER THE PHENOMENON

How do organ systems work together to keep you alive?

J.K. York/Shutterstock

UNIT 1

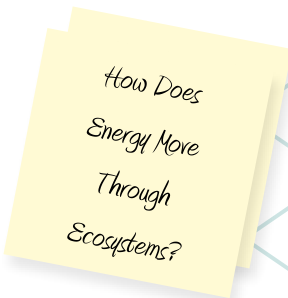
ECOLOGY

ENCOUNTER THE PHENOMENON

What might happen to the plants that are covered by kudzu?

SEP Ask Questions

What questions do you have about the phenomenon? Write your questions on sticky notes and add them to the driving question board for this unit.



Look for Evidence

As you go through this unit, use the information and your experiences to help you answer the phenomenon question as well as your own questions. For each activity, record your observations in a Summary Table, add an explanation, and identify how it connects to the unit and module phenomenon questions.

Solve a Problem

STEM UNIT PROJECT

Biodiversity on a Rooftop Investigate how a rooftop garden can support biodiversity within an ecosystem.

GO ONLINE In addition to reading the information in your Student Edition, you can find the STEM Unit Project and other useful resources online.

André Gilden/Alamy Stock Photo

MODULE 2

PRINCIPLES OF ECOLOGY

ENCOUNTER THE PHENOMENON

Why would a bird build a nest in a tree with thorns?

GO ONLINE to watch a video about community interactions in an ecosystem.

SEP Ask Questions

Do you have other questions about the phenomenon? If so, add them to the driving question board.

CER Claim, Evidence, Reasoning

Make Your Claim Use your CER chart to make a claim about why a bird would build a nest in a tree with thorns. Explain your reasoning.

Collect Evidence Use the lessons in this module to collect evidence to support your claim. Record your evidence as you move through the module.

Explain Your Reasoning You will revisit your claim and explain your reasoning at the end of the module.

GO ONLINE to access your CER chart and explore resources that can help you collect evidence.

LESSON 1: Explore & Explain: Levels of Organization

LESSON 2: Explore & Explain: Energy Flow in an Ecosystem: Food Webs

Smithsonian

Additional Resources

LESSON 1

ORGANISMS AND THEIR RELATIONSHIPS

FOCUS QUESTION

What relationships among organisms might exist with a bird nest built in a thorny tree?

Ecology

The best way for scientists to gain valuable insight about the interactions between organisms and their environments and between different species of organisms is by observation. By completing such observations, scientists have determined that each organism, regardless of where it lives, depends on nonliving factors found in its environment and on other organisms living in the same environment for survival. In other words, all living things need both non-living and living things to survive.

For example, green plants provide a source of food for many organisms as well as a place to live. The animals that eat the plants provide a source of food for other animals. The interactions and interdependence of organisms with each other and their environments are not unique. The same type of dependency occurs whether the environment is a barren desert, a tropical rain forest, or a grassy meadow. **Ecology** is the scientific discipline in which the relationships among living organisms and the interactions the organisms have with their environments are studied.

The study of organisms and their environments is not new. The word *ecology* was first introduced in 1866 by Ernst Haeckel, a German biologist. However, the field of ecology did not really become prominent until the twentieth century. Since that time, it has continued to increase in importance and scope. You can see just some of the many significant milestones in ecology in **Figure 1,** on the next page.

Get It?

Describe some of the interactions that occur between living and nonliving things in your community.

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

BioLab: Explore Habitat Size and Species Diversity
Plan and carry out an investigation to determine what effect increasing the size of a habitat has on species diversity.

Virtual Investigation: Model Ecosystems
Use a model to determine how energy flows through an ecosystem.

Figure 1

Milestones in Ecology

Ecologists have worked to preserve and protect natural resources.

1 **1905** Theodore Roosevelt urges the U.S. Congress to set aside over 70 million hectares of land to protect the natural resources found on them.

2 **1962** Rachel Carson publishes a best-selling book, *Silent Spring*, warning of the environmental danger of pollution and pesticides.

3 **1967** The government of Rwanda and international conservation groups begin efforts to protect mountain gorillas, due in a large part to the work of Dian Fossey.

4 **1987** The United States and other countries sign the Montreal Protocol, an agreement to phase out the use of chemical compounds that destroy atmospheric ozone.

5 **1990** The Indigenous Environmental Network (IEN), directed by Tom Goldtooth, is formed by Native Americans to protect their tribal lands and communities from environmental damage.

6 **2004** Wangari Maathai wins a Nobel Prize. She began the Green Belt Movement in Africa, which hires women to plant trees to slow the process of deforestation and desertification.

7 **2015** The island fox found in the California Channel Islands, which was nearly extinct, makes a comeback due to successful conservation efforts.

Scientists who study ecology are called ecologists. Ecologists observe, experiment, and model using a variety of tools and methods.

Ecologists like the one shown in **Figure 2** perform tests to determine relationships among groups of organisms and environmental factors. Results from these tests might give clues as to why organisms are able to survive in a particular body of water, why organisms become ill or die from drinking the water, or what organisms could live in or near the water.

Figure 2 Ecologists work in the field and in laboratories. This ecologist is enduring harsh conditions to study seals.

Ecologists also observe organisms to understand the interactions among them. Because all organisms in an ecosystem are connected (either directly or indirectly), understanding relationships can be challenging. Like all scientists, ecologists rely on scientific models to help them perform tests.

Scientific models are a way of creating a visual representation to answer a question or test a hypothesis. When you hear the word "model," you may think of a physical model, such as a model of the human heart. Scientists also use mathematical models, such as equations, and computer models.

A model allows a scientist to simulate a process or system. Studying organisms in the field can be difficult because there often are too many variables to study at one time. Models allow ecologists to control the number of variables present and to slowly introduce new variables in order to fully understand the effect of each variable.

For example, the scientist in **Figure 2** may wish to determine how a particular group of seals might be affected by the number of fish in their environment. It would be extremely difficult, if not impossible, to control all of the variables in an area of the environment. Attempting to control variables in an experiment would also likely cause further damage to the environment. The scientist can use a computer model to run simulations to test different ways of solving a problem, such as a fewer fish being available for the seals to eat. Data generated by the model can be presented to persuade conservationists and policy makers about what steps should be taken to help the seals.

Get It?

Explain how physical and computer models can help design a solution for an ecological problem.

WORD ORIGINS

ecology

comes from the Greek words *oikos*, meaning *house*, and *ology*, meaning *to study*.

Alasdair Turner/Aurora Photos/Alamy

The Biosphere

Because ecologists study organisms and their environments, their studies take place in the biosphere. The **biosphere** (BI uh sfihr) is the portion of Earth that supports life. The photo of Earth taken from space shown in **Figure 3** shows why the meaning of the term *biosphere* should be easy to remember. The term *bio* means "life," and a sphere is a geometric shape that looks like a ball. When you look at Earth from this vantage point, you can see how it is considered to be "a ball of life."

Although "ball of life" is the literal meaning of the word *biosphere*, this is somewhat misleading. The biosphere includes only the portion of Earth that includes life. The biosphere forms a thin layer around Earth. It extends several kilometers above Earth's surface into the atmosphere and extends several kilometers below the ocean's surface to the deep-ocean vents. It includes landmasses, bodies of freshwater and saltwater, and all locations below Earth's surface that support life.

Figure 4 shows a glimpse into the vast amount of diversity contained within Earth's biosphere. From rainforests to deserts to deep-ocean vents, diverse organisms populate diverse locations.

Figure 3 This color-enhanced satellite photo of Earth taken from space shows a large portion of the biosphere.

The biosphere's diverse locations contain organisms that are able to survive in the unique conditions found in their particular environment. Ecologists study these organisms, their adaptations, and the factors in their environment. These factors are divided into two large groups—the living factors and the nonliving factors.

Get It?

Define the term *biosphere*.

Figure 4 Rainforests, deserts, and deep-ocean vents are all home to unique organisms. The plants, animals, and microorganisms that live in each of these parts of the biosphere are adapted to the living and nonliving factors there.

(t) NASA GSFC image by Robert Simmon and Reto Stöckli; (cl) ©H Lansdown/Alamy; (cr) NOAA PMEL Vents Program; (b) Ken Canning/E+/Getty Images

Biotic factors

The living factors in an organism's environment are called the **biotic** (by AH tihk) **factors.** Consider the biotic factors in the stream community shown in **Figure 5.** These biotic factors include all of the organisms that live in the water, such as fish, algae, frogs, and microscopic organisms. In addition, organisms that live on the land adjacent to the water are biotic factors for the deer. Additionally, migratory animals, such as birds that pass through the area, are biotic factors.

The interactions among organisms are necessary for the health of all species in the same geographic location. For example, the deer need other members of its species to reproduce. Deer also depend on other organisms for food and, in turn, are a food source for other organisms.

Abiotic factors

The nonliving factors in an organism's environment are called **abiotic** (ay bi AH tihk) **factors.** The abiotic factors for different organisms vary across the biosphere, but organisms that live in the same geographic area might share the same abiotic factors. These factors might include temperature, air or water currents, sunlight, soil type, rainfall, or available nutrients.

Organisms depend on abiotic factors for survival. For example, the abiotic factors important to a particular plant might be the amount of rainfall, the amount of sunlight, the type of soil, the range of temperature, and the nutrients available in the soil. The abiotic factors for the deer in **Figure 5** include the air temperature, the minerals present in the rocks, and the hours of sunlight per day.

Organisms are adapted to surviving in the abiotic factors that are present in their natural environments. If an organism moves to another location with a different set of abiotic factors, the organism might die if it cannot adjust quickly to its new surroundings. For example, if a lush green plant that normally grows in a swampy area is transplanted to a dry desert, the plant likely will die because it cannot adjust to abiotic factors present in the desert.

Get It?

Compare and contrast abiotic and biotic factors shown in the photo at the beginning of this module.

Figure 5 The deer standing on this rock is a biotic factor in this stream community. Other organisms in the water, such as frogs and algae, also are biotic factors.

Explain *how organisms are dependent on other organisms.*

STEM CAREER Connection

Conservation Scientist

Do you care about preserving and protecting national and state parks and other natural areas? Conservation scientists are responsible for managing the overall land quality of forests, parks, rangelands, and other natural resources. They oversee foresting and conservation activities on public park lands, and they also may work with private land owners or organizations.

Limiting factors

Any abiotic factor or biotic factor that restricts the numbers, reproduction, or distribution of organisms is called a **limiting factor.** Abiotic limiting factors include sunlight, climate, temperature, water, nutrients, fire, soil chemistry, and space. Biotic limiting factors include living things, such as other plant and animal species. Factors that restrict the growth of one population might enable another to thrive. In a desert oasis, water is a limiting factor for all the organisms. Temperature might also be a limiting factor. Desert species must be able to withstand extreme temperatures.

Range of tolerance

For any environmental factor, an upper limit and lower limit define the conditions in which an organism can survive. For example, steelhead trout live in cool, coastal rivers and streams from California to Alaska. The ideal range of water temperature for steelhead trout is between 13˚C and 21˚C, as illustrated in **Figure 6**. However, steelhead trout can survive water temperatures from 9˚C to 25˚C. At these temperatures, steelhead trout experience physiological stress, such as inability to grow or reproduce. They will die if the water temperature goes beyond the upper or lower limits.

The ability of any organism to survive when subjected to abiotic factors or biotic factors is called **tolerance.** Consider **Figure 6** again. Steelhead trout tolerate a specific range of temperatures. That is, the range of tolerance of water temperature for steelhead is 9˚C to 25˚C. Notice that the greatest number of steelhead live in the optimum range in which the temperature is best for survival. Between the optimum range and the tolerance limits lies the zone of physiological stress. At these temperatures, there are fewer fish. Beyond the upper tolerance limit of 25˚C and the lower tolerance limit of 9˚C, there are no steelhead trout. Therefore, water temperature is a limiting factor for steelhead when water temperature is outside the range of tolerance.

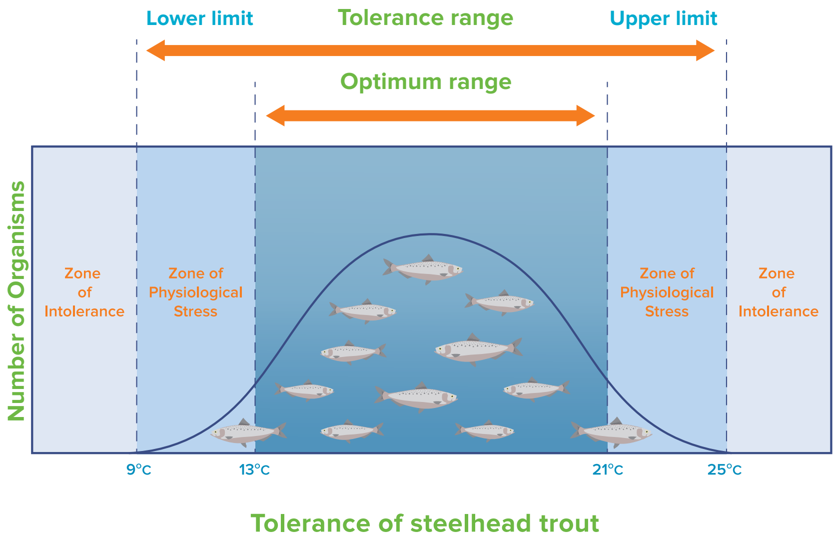


Figure 6 Steelhead trout are limited by the temperature of the water in which they live.
Infer *which other abiotic factors might limit the survival of steelhead trout.*

Levels of Organization

The biosphere is too large and complex for most ecological studies. To study relationships within the biosphere, ecologists look at different levels of organization or smaller pieces of the biosphere. The levels increase in complexity as the numbers and interactions between organisms increase. The levels of organization are: organism, population, biological community, ecosystem, biome, and biosphere. Refer to **Figure 7** as you read about each level.

Organisms, populations, and biological communities

The lowest level of organization is the individual organism itself. In **Figure 7** on the next page, the organism is represented by a single fish. Individual organisms of a single species that share the same geographic location at the same time make up a **population.** The school of fish represents a population of organisms. Individual organisms often compete for the same resources, and if resources are plentiful, the population can grow. Usually there are factors that prevent populations from becoming extremely large. For example, when the population has grown beyond what the available resources can support, the population size declines until it reaches the number of individuals that the available resources can support.

The next level of organization is the **biological community,** a group of interacting populations that occupy the same geographic area at the same time. Organisms might or might not compete for the same resources in a biological community. The collection of plant and animal populations, including the school of fish, represent a biological community.

Ecosystems, biomes, and the biosphere

The next level of organization after a biological community is an ecosystem. An **ecosystem** is a biological community and all of the abiotic factors that affect it. As you can see in **Figure 7**, an ecosystem might contain an even larger collection of organisms than a biological community. In addition, it contains the abiotic factors present, such as water temperature and light availability. Although **Figure 7** represents an ecosystem as a large area, an ecosystem also can be small, such as an aquarium or tiny puddle. The boundaries of an ecosystem are somewhat flexible and can change, and ecosystems even might overlap. The next level of organization is the biome.

A **biome** is a large group of ecosystems that share the same climate and have similar types of communities. The biome shown in **Figure 7** is a marine biome. All of the biomes on Earth combine to form the highest level of organization—the biosphere.

Get It?

Infer what other types of biomes might be found in the biosphere if the one shown in **Figure 7** is called a marine biome.

CCC CROSSCUTTING CONCEPTS

Scale, Proportion, and Quantity When building a model, it is important to consider different measures of size, time, and energy. Design a model that illustrates the levels of organization in the biosphere. Trade models with a classmate and offer feedback about how changes in scale, proportion, or quantity affect the performance of the model.

STUDY TIP

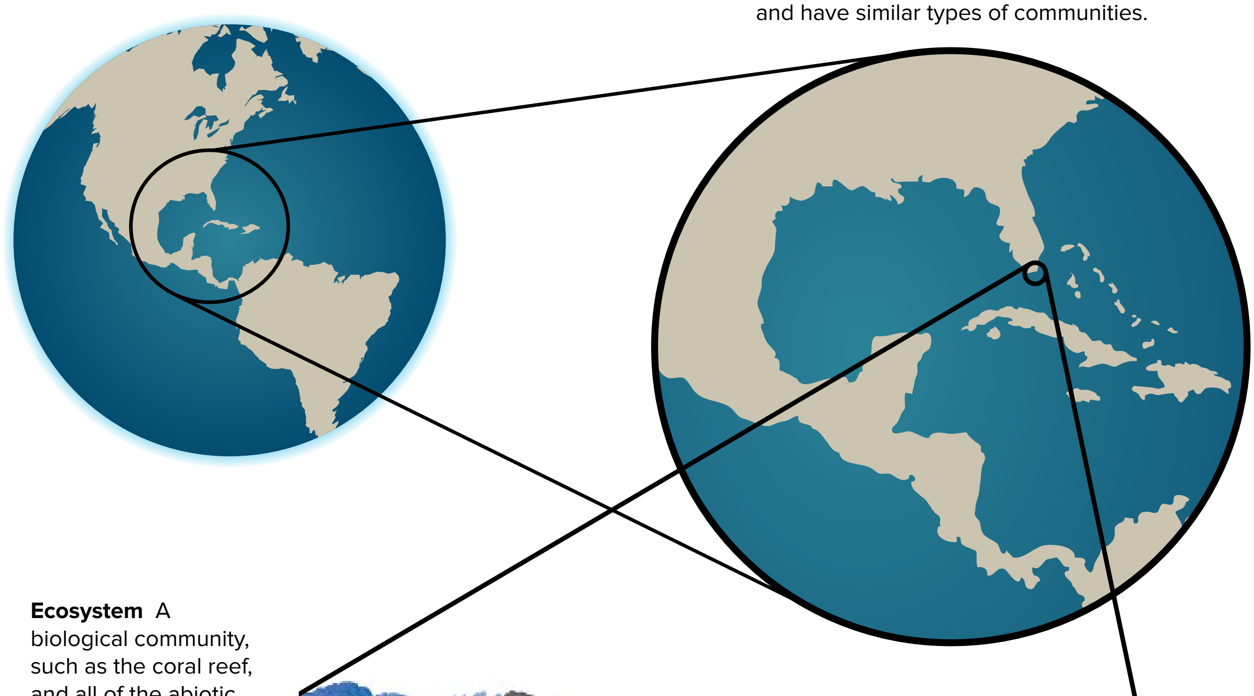
Question Session Study the levels of organization illustrated in **Figure 7** with a partner. Question each other about the topic to deepen your knowledge.

Figure 7 Visualizing Levels of Organization

In order to study relationships within the biosphere, it is divided into smaller levels of organization. The simplest level of organization is the organism, with increasing complexity shown in the population, biological community, ecosystem, and biome until reaching the most complex level of biosphere.

Biosphere The highest level of organization is the biosphere, which is the layer of Earth—from high in the atmosphere to deep in the ocean—that supports life.

Biome A biome is a group of ecosystems, such as the coral reefs off the coast of the Florida Keys, that share the same climate and have similar types of communities.

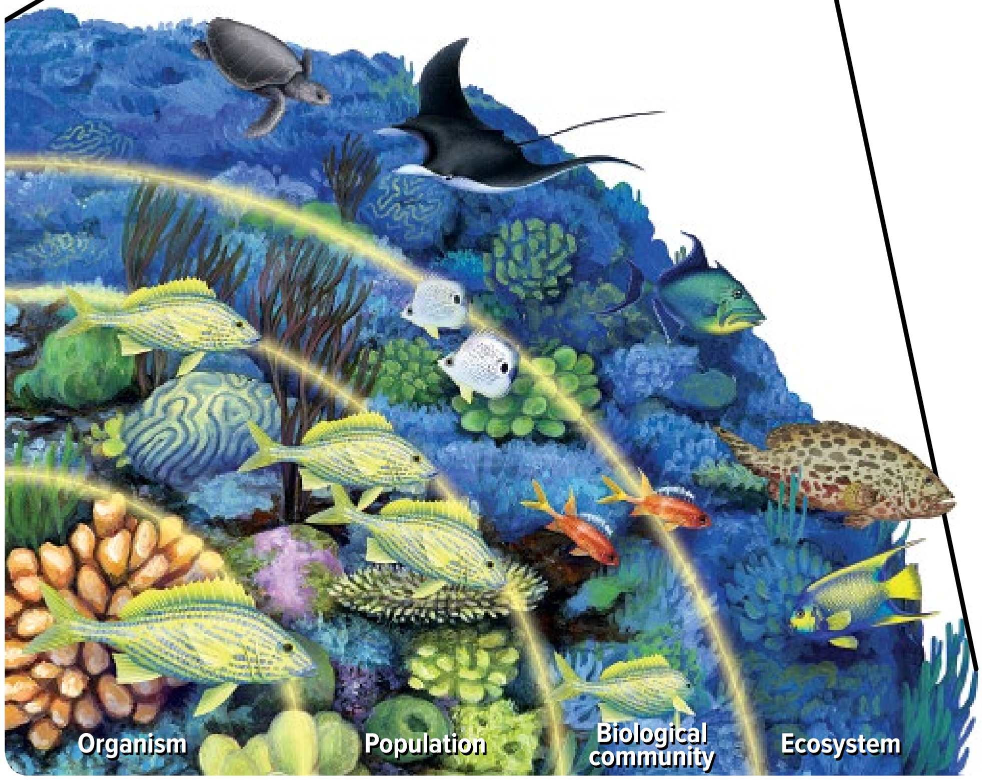


Ecosystem A biological community, such as the coral reef, and all of the abiotic factors, such as the sea water, that affect it make up an ecosystem.

Biological community All of the populations of species—fishes, coral, and marine plants—that live in the same place at the same time make up a biological community.

Population A group of organisms of the same species that interbreed and live in the same place at the same time, such as the school of striped fish, is a population.

Organism An individual living thing, such as one striped fish, is an organism.



Ecosystem Interactions

The interactions between organisms are important in an ecosystem. A community of organisms increases the chances for survival of any one species by using the available resources in different ways. If you look closely at a tree in the forest, like the one shown in **Figure 8**, you will find a community of different birds using the resources of the tree in different ways. For example, one bird species might eat insects on the leaves while another species of bird might use pieces of bark as nesting materials. The chance of survival for the birds increases because they are using different resources.

The trees shown in **Figure 8** also are habitats. A **habitat** is an area where an organism lives. A habitat might be a single tree for an organism that spends its life on one tree. If the organism moves from tree to tree, its habitat would be a grove of trees.

Organisms not only have a habitat—they have a niche as well. A **niche** (NIHCH) is the role or position that an organism has in its environment. An organism's niche is how it meets its needs for food, shelter, and reproduction. The niche might be described in terms of requirements for living space, temperature, moisture, or in terms of appropriate mating or reproduction conditions.

Get It?

Compare and contrast a habitat and a niche.

Figure 8 These trees are the habitat for the community of organisms that live in them.

Figure 9 During droughts, animals compete for water; when water is plentiful, competition decreases.

Community Interactions

Organisms that live together in a biological community constantly interact. These interactions, along with the abiotic factors, shape an ecosystem. Interactions include competition for basic needs such as food, shelter, and mates, as well as relationships in which organisms depend on each other for survival.

Competition

Competition occurs when more than one organism uses a resource at the same time. Resources are necessary for life and might include food, water, space, and light. For example, during a drought, as shown in **Figure 9**, water might be scarce for many organisms. The strong organisms directly compete with the weak organisms for survival. Usually the strong survive and the weak die. Some organisms might move to another location where water is available. At times when water is plentiful, all organisms share the resources and competition is not as fierce.

Predation

Many species get their food by eating other organisms. The act of one organism pursuing and consuming another organism for food is **predation** (prih DAY shun). The organism that pursues another organism is the predator, and the organism that is pursued is the prey. If you have watched a cat catch a bird or mouse, you have witnessed a predator catch its prey.

Some insects also prey on other insects. Ladybugs and praying mantises are two examples of insects that are predators. Insect predators, such as these two, also are called beneficial insects because they can be used to kill harmful insects. For example, organic gardeners use beneficial insects for insect control. Instead of using insecticides, organic gardeners rely on beneficial insects to control unwanted insect populations.

Animals are not the only organisms that are predators. The Venus flytrap, a plant native to some regions of North and South Carolina, has modified leaves that form small traps for insects and other small animals. The plant emits a sweet, sticky substance that attracts insects. When the insect lands on the leaf, the leaf trap snaps shut. Then, the plant secretes a substance that digests the insect over several days.

Get It?

Describe one example each of competition and predation.

Figure 10 Algae live in this sloth's fur as part of a symbiotic relationship.

Explain *why this is an example of a mutualistic relationship.*

Symbiotic relationships

Some species survive because of relationships they have developed with other species. The close relationship that exists when two or more species live together is **symbiosis** (sihm bee OH sus). There are three different kinds of symbiosis: mutualism, commensalism, and parasitism.

Mutualism The relationship between two or more organisms that live closely together and benefit from each other is **mutualism** (MYEW chuh wuh lih zum). **Figure 10** displays an example of a mutualistic relationship between a mammal and an algae. A specific kind of algae grows and takes shelter in the sloth's fur. The sloth's fur also absorbs water easily, providing the algae with the moisture it needs to survive. In return, the sloth receives additional camouflage from the green-colored algae, and it may also absorb some nutrients produced by the algae through its skin.

Another example of a mutualistic relationship is found in lichens. Lichens are formed by a mutualistic relationship between fungi and algae. The algae provide food for the fungi, and the fungi provide a habitat for the algae. The close association of these two organisms provides two basic needs for the organisms—food and shelter.

Commensalism Have you ever seen lichens growing on a tree? The lichens benefit from their relationship to the tree by gaining more exposure to sunlight. The tree is not harmed by the lichen, but it does not receive any benefit from the lichen either. This type of relationship is commensalism. **Commensalism** (kuh MEN suh lih zum) is a relationship in which one organism benefits and the other organism is neither helped nor harmed.

The relationship between the clownfish and the sea anemone in which it lives is likely commensal. The clownfish finds food and protection by living in the sea anemone. While the sea anemone is not harmed, it does not receive any apparent benefit from the relationship with the clownfish.

Parasitism A symbiotic relationship in which one organism benefits at the expense of another organism is **parasitism** (PER us suh tih zum). Parasites can be external, such as ticks and fleas, or internal, such as bacteria, tapeworms, and roundworms. In most cases of parasitism, the parasite does not kill the host, instead only harming or weakening it. This is because the death of the host would also mean the death of the parasite unless it could quickly find another host. This is not the case of the tomato hornworm that is infected with cocoons of a parasitic wasp in **Figure 11**, because the pupating wasps will most likely kill their host.

Another type of parasitism is brood parasitism. Brown-headed cowbirds demonstrate brood parasitism because they rely on other bird species to build their nests and incubate their eggs. A brown-headed cowbird lays its eggs in another bird's nest and abandons the eggs. The host bird incubates and feeds the young cowbirds. Often the baby cowbirds push the host's eggs or young from the nest, resulting in the survival of only the cowbirds. In some areas, the brown-headed cowbirds have significantly lowered the population of songbirds through this type of parasitism.

Figure 11 This tomato hornworm is host to a number of pupating parasitic wasps. This case of parasitism is unusual because the wasps will likely kill their host.

Check Your Progress

Summary

- Ecology is the branch of biology that focuses on interrelationships between organisms and their environments.
- Abiotic and biotic limiting factors restrict the growth of a population within a community.
- Organisms have a range of tolerance for each limiting factor that they encounter.
- Levels of organization in ecological studies include organism, population, biological community, ecosystem, biome, and biosphere.
- Symbiotic relationships such as commensalism, parasitism, and mutualism exist when two or more species live together.

Demonstrate Understanding

1. **Predict** how unfavorable abiotic and biotic factors affect a species.
2. **Identify** how temperature is a limiting factor for polar bears.
3. **Describe** how ranges of tolerance affect the distribution of a species.
4. **Differentiate** between the habitat and niche of an organism that is found in your community.

Explain Your Thinking

5. **Interpret Figure 6** and predict the general growth trend for steelhead trout in a stream that is 22°C.
6. **MATH Connection** **Graph** the following data to determine the range of tolerance for catfish. The first number in each pair of data is temperature in degrees Celsius; the second number is the number of catfish found in the stream: (0, 0); (5, 0); (10, 2); (15, 15); (20, 13); (25, 3); (30, 0); (35, 0). Choose an appropriate scale and units for your graph.

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LESSON 2

FLOW OF ENERGY IN AN ECOSYSTEM

FOCUS QUESTION

How does energy flow through an ecosystem?

Energy in an Ecosystem

One way to study the interactions of organisms within an ecosystem is to follow the energy that flows through it. Organisms differ in how they obtain energy and are classified as autotrophs or heterotrophs based on how they obtain it.

Autotrophs

All of the green plants and other organisms that produce their own food in an ecosystem are primary producers called autotrophs. An **autotroph** (AW tuh trohf) is an organism that collects energy from sunlight or inorganic substances to produce food.

Organisms that contain chlorophyll absorb light energy during photosynthesis and use it to convert the inorganic substances carbon dioxide and water to organic molecules. In places where sunlight is unavailable, some bacteria use hydrogen sulfide and carbon dioxide to make organic molecules to use as food. Autotrophs, including plants and algae, are the foundation of all ecosystems because they make energy available for all other organisms in an ecosystem.

Heterotrophs

A **heterotroph** (HE tuh roh trohf) is an organism that gets its energy requirements by consuming other organisms. Therefore, heterotrophs also are called *consumers*. A heterotroph that eats only plants, such as a cow, rabbit, or grasshopper, is an **herbivore** (HUR buh vor). Heterotrophs that prey on other heterotrophs, such as wolves, lions, and lynxes, shown in **Figure 12**, are called **carnivores** (KAR nuh vorz).

John Luke/Stockbyte/Getty Images

Figure 12 This wolf is a heterotroph that is about to consume another heterotroph, a moose.

Identify *an additional classification for each of these animals.*

3D THINKING | DCI Disciplinary Core Ideas | CCC Crosscutting Concepts | SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Applying Practices: Ecological Pyramids

HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

Figure 13 This fungus is obtaining food energy from the dead log. Fungi are decomposers that recycle materials found in dead organisms.

Explain *why decomposers are important in an ecosystem.*

Organisms that eat both plants and animals are called **omnivores** (AHM nih vorz). Bears, humans, and mockingbirds are examples of omnivores.

The **detritivores** (duh TRYD uh vorz) eat fragments of dead matter in an ecosystem, returning nutrients to the soil, air, and water. Detritivores include worms and many aquatic insects that live on stream bottoms. Decomposers, similar to detritivores, break down dead organisms by releasing digestive enzymes. Fungi, such as those in **Figure 13**, and bacteria are decomposers.

All heterotrophs perform some decomposition when consuming another organism. The primary role of decomposers is to break down organic compounds and make nutrients available to producers. Without the presence and activities of detritivores and decomposers, organic material and the nutrients would not be available to other organisms to reuse.

Models of Energy Flow

Ecologists use food chains and food webs to model the energy flow through an ecosystem. Food chains and food webs are simplified representations of the flow of energy. Each step in a food chain or food web is called a **trophic** (TROH fihk) **level.** Autotrophs make up the first trophic level in all ecosystems. Heterotrophs make up the remaining levels. With the exception of the first trophic level, organisms at each trophic level get their energy from the trophic level before it.

Food chains

A **food chain** is a model that shows how energy flows through an ecosystem. **Figure 14** shows a typical grassland food chain. Arrows represent the energy flow, which typically moves from autotrophs to heterotrophs. The flower uses energy from the Sun to make its own food. The grasshopper obtains energy from eating the flower. The mouse obtains energy from eating the grasshopper. Finally, the snake gains energy from eating the mouse. At each step in the food chain, some energy is used for cellular processes and to build new cells and tissues. Some energy is released into the environment.

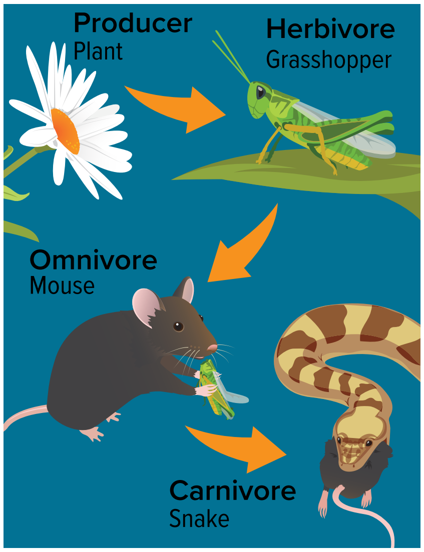

Figure 14 A food chain is a simplified model representing the transfer of energy from organism to organism.

CCC CROSSCUTTING CONCEPTS

Energy and Matter Create a physical model of a food chain that describes the flow of energy and matter through the system.

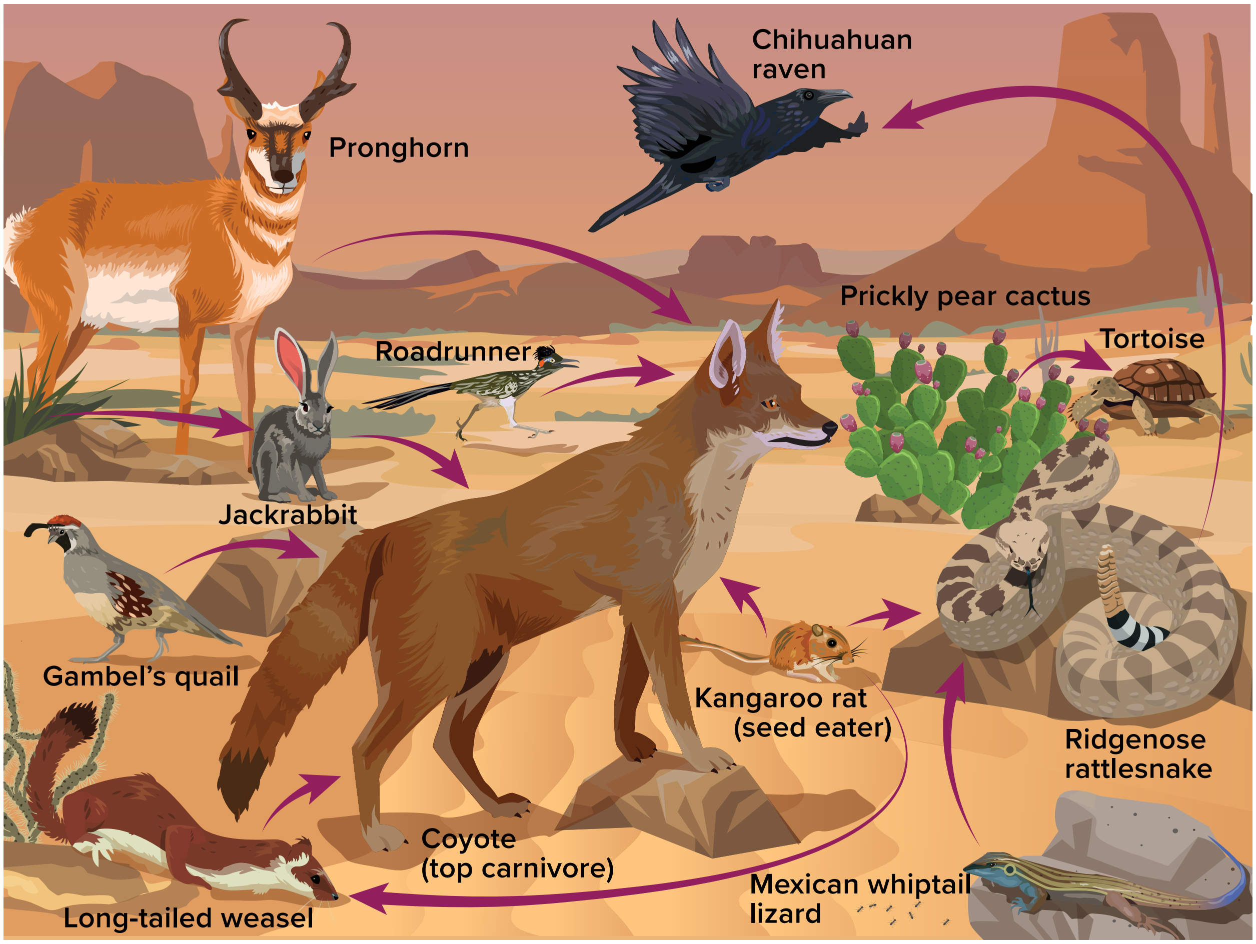

Figure 15 A food web is a model of the many ways in which energy flows through organisms.

Food webs

Feeding relationships usually are more complex than a single food chain because most organisms feed on more than one species. Birds, for instance, eat a variety of seeds, fruits, and insects. The model most often used to represent the feeding relationships in an ecosystem is a food web. A **food web** is a model representing the many interconnected food chains and pathways in which energy flows through a group of organisms. **Figure 15** shows a food web illustrating the feeding relationships in a desert community.

Ecological pyramids

Another model that ecologists use to show how energy flows through ecosystems is the ecological pyramid. An ecological pyramid is a diagram that can show the relative amounts of energy, biomass, or numbers of organisms at each trophic level in an ecosystem.

Notice in **Figure 16,** on the next page, that in a pyramid of energy, only 10 percent of all energy is transferred to the level above it. This occurs because most of the energy contained in the organisms at each level is consumed by cellular processes or released to the environment as heat. Usually, the amount of **biomass**—the total mass of living matter at each trophic level—decreases at each trophic level.

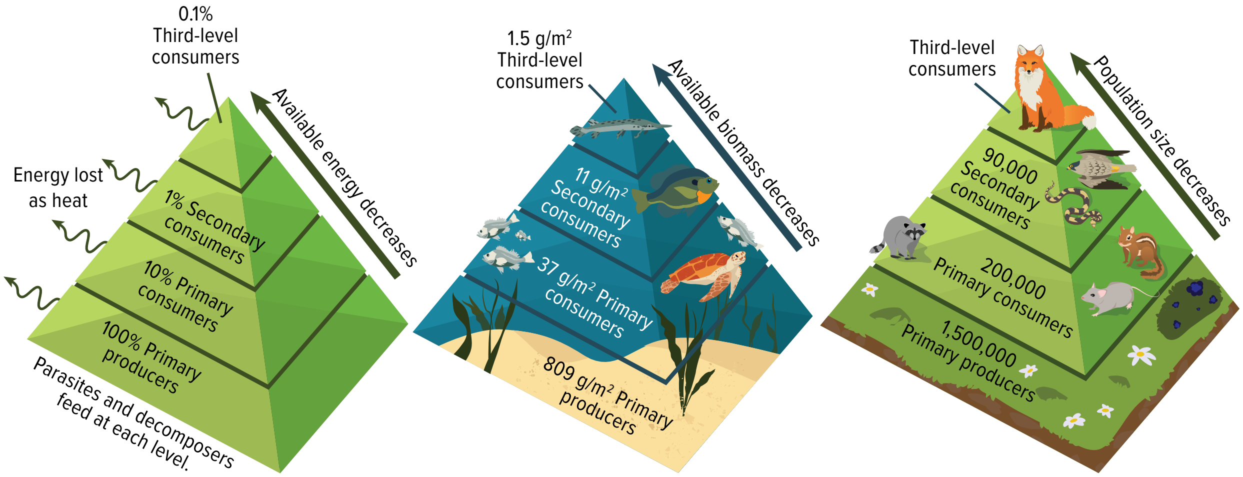

Figure 16 Ecological pyramids are models used to represent trophic levels in ecosystems.
Identify *the process by which autotrophs at the bottom of the pyramid convert energy from the Sun.*

As shown in the pyramid of numbers, the relative number of organisms at each trophic level also decreases because there is less energy available to support organisms. The ecosystem determines the shape of an ecological pyramid.

Check Your Progress

Summary

- Autotrophs capture energy from the Sun or use energy from certain chemical substances to make food.
- Heterotrophs include herbivores, carnivores, omnivores, and detritivores.
- A trophic level is a step in a food chain or food web.
- Food chains, food webs, and ecological pyramids are models used to show how energy moves through ecosystems.

Demonstrate Understanding

1. **Distinguish** producers, consumers, and decomposers from one another.
2. **Explain** how photosynthesis and cellular respiration provide energy in each step of a food chain.
3. **Classify** a pet dog as an autotroph or heterotroph and as an herbivore, carnivore, or omnivore. Explain.

Explain Your Thinking

4. **Create and use** a simple food web to identify producers, consumers, and decomposers in your community.
5. **MATH Connection** **Draw** an energy pyramid for a food chain made up of grass, a caterpillar, tiger beetle, lizard, snake, and a roadrunner. Assume that 100 percent of the energy is available for the grass. At each stage, calculate and show how much energy is lost and how much is available to the next trophic level.
6. **WRITING Connection** Write a paragraph that explains the pathway of energy transfer through the pyramid of energy shown in **Figure 16**.

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LESSON 3

CYCLING OF MATTER

FOCUS QUESTION

How does matter flow through an ecosystem?

Cycles in the Biosphere

The law of conservation of mass states that matter is not created or destroyed. All new life on the Earth is built from existing atoms. Therefore, natural processes cycle matter through the biosphere. **Matter**—anything that takes up space and has mass—provides the nutrients needed for organisms to function. A **nutrient** is a chemical substance that an organism must obtain from its environment to sustain life. All organisms contain water and nutrients such as carbon, nitrogen, and phosphorus.

The exchange of matter through the biosphere is called a **biogeochemical cycle.** These cycles involve living organisms (*bio*), geological processes (*geo*), and chemical processes (*chemical*). Chemical elements that make up the molecules of organisms pass through food webs and biogeochemical cycles, combining and recombining in different ways.

CHEMISTRY Connection Refer back to the energy and biomass pyramids in **Figure 16**. At each link upward in a food web, only a fraction of the matter and energy consumed is transferred to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, fewer organisms are found at higher levels of the food web.

Algae and plants are the lowest level of the food chain. As the matter and energy move through an ecosystem like that in **Figure 17**, some matter reacts to release energy for life functions, some is stored, and much is discarded. Regardless of how the matter and energy change, they are conserved.

Javier Larrea/Pixtal/age fotostock

Figure 17 Chemical elements are cycled through the biosphere through organisms. As producers, grasses begin the cycle by capturing energy from the Sun.

Explain *how chemical elements continue to be cycled through the biosphere in this photo.*

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Applying Practices: The Cycling of Matter and Flow of Energy in Aerobic and Anaerobic Conditions

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

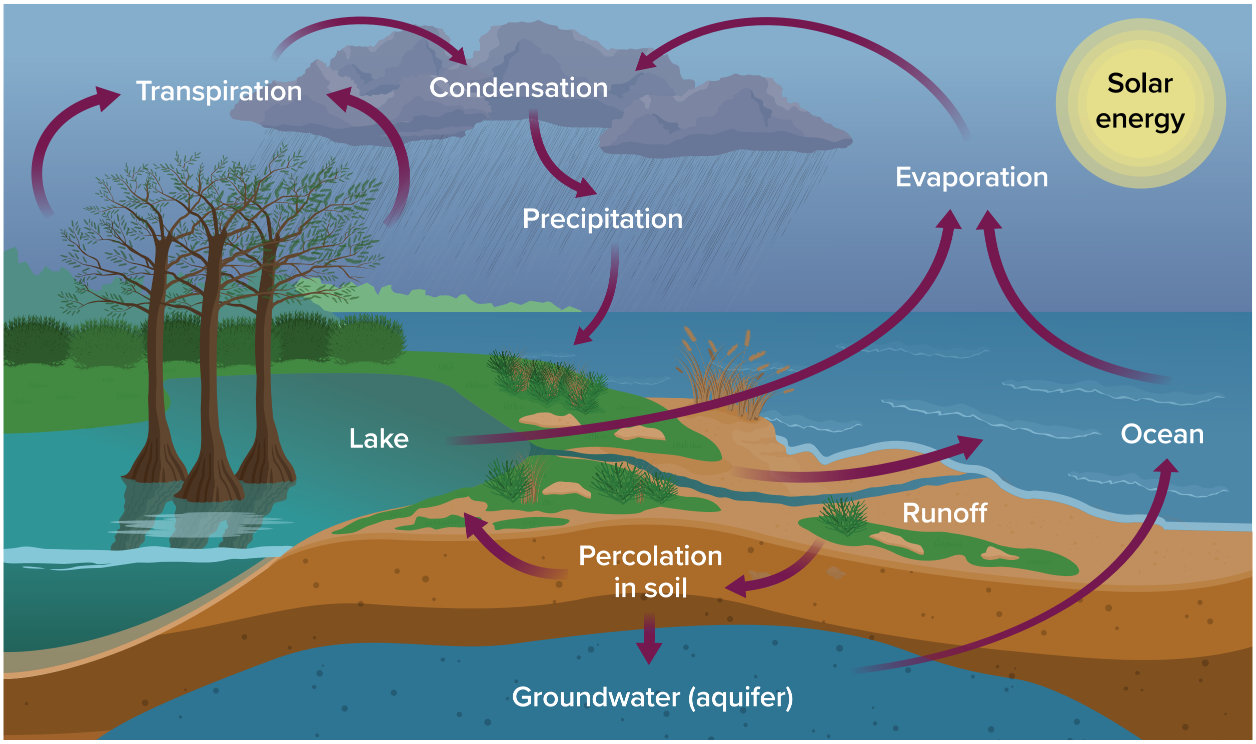

Figure 18 The water cycle is the process by which water is continuously cycled through the biosphere.

The water cycle

Water moves through the biosphere through the water cycle, shown in **Figure 18.**

EARTH SCIENCE Connection Energy from the Sun causes water to constantly evaporate from the Earth's surface. Water enters the atmosphere in a form called water vapor. Approximately 90 percent of water vapor evaporates from oceans, lakes, and rivers; about 10 percent evaporates from the surfaces of plants through a process called transpiration. Clouds form when water vapor rises, cools, and condenses into droplets around dust particles in the atmosphere. Water falls from clouds to the Earth's surface as precipitation in forms such as rain or snow. Some surface water percolates, or moves through, the soil, and enters groundwater. Other water flows over the Earth's surface as runoff, and enters streams, rivers, lakes, and oceans. The cycle then continues.

Get It?

Identify three processes in the water cycle.

CCC CROSSCUTTING CONCEPTS

Systems and Systems Models Describe the boundaries and specifications for a model of an ecosystem at your school. How do the parameters of your model help make it useful? Write the specifications into a proposal for the model.

STEM CAREER Connection

Water Resource Engineer

Civil engineers who create systems that ensure that people have a continuous supply of clean, uncontaminated water are called water resource engineers.

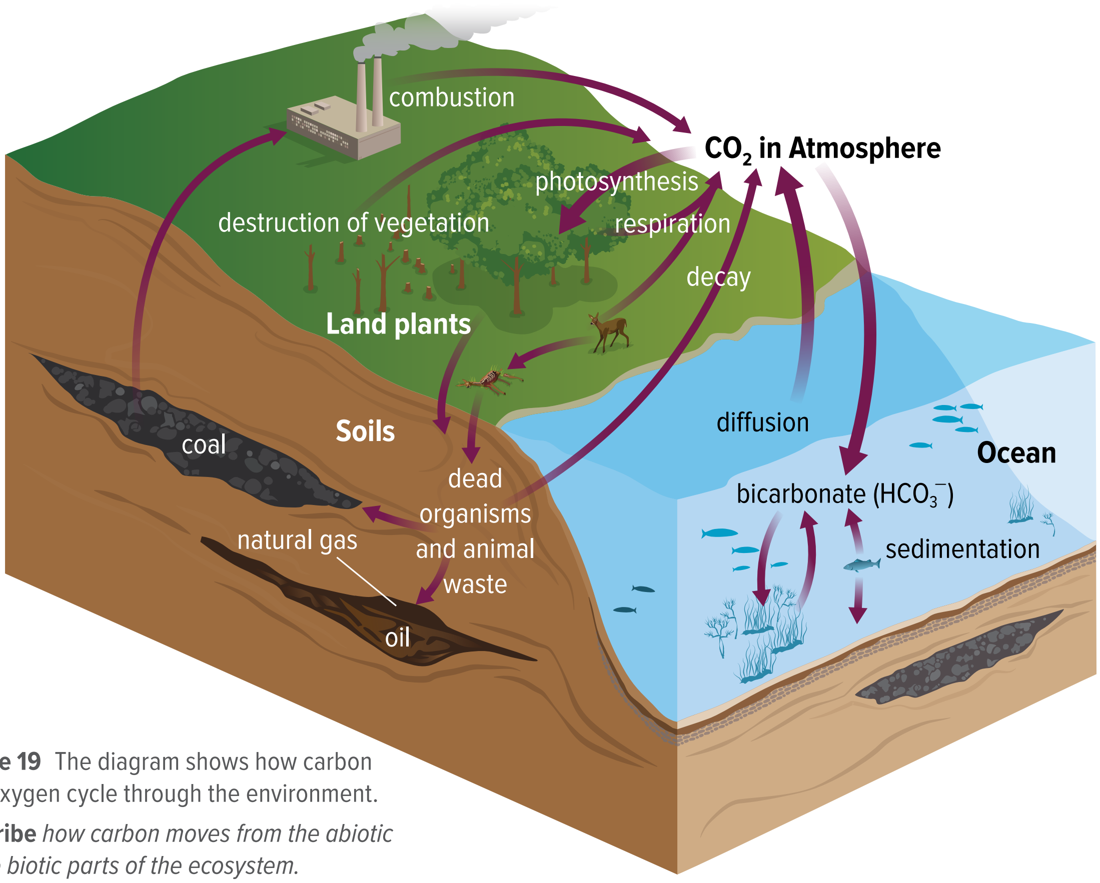

Figure 19 The diagram shows how carbon and oxygen cycle through the environment.

Describe *how carbon moves from the abiotic to the biotic parts of the ecosystem.*

The carbon and oxygen cycles

Carbon and oxygen often combine to form molecules essential for life, including carbon dioxide and simple sugars. The cycles of these two elements are shown in **Figure 19**.

Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, and biological processes. During photosynthesis, plants and algae convert carbon dioxide and water into carbohydrates and release oxygen back into the air. Living organisms consume oxygen and release carbon dioxide during cellular respiration. Carbon dioxide also enters the atmosphere as dead organisms decay, and carbon enters the soil through the decomposition of plant and animal matter and animal waste.

Carbon enters a long-term cycle when organic matter is buried underground and converted to fossil fuels such as coal, oil, or gas. Carbon dioxide returns to the atmosphere those fossil fuels combust (burn).

Carbon and oxygen enter long-term cycles when they combine with calcium to create calcium carbonate. When the shells of some sea creatures fall to the ocean floor, they form vast deposits of calcium carbonate in limestone rock, such as those found in the white cliffs pictured in **Figure 20**. Carbon and oxygen remain in these deposits until weathering and erosion release them from the rocks.

Figure 20 The white cliffs in Dover, England, are composed almost entirely of calcium carbonate, or chalk. The carbon and oxygen found in these cliffs are in the long-term part of the cycle for carbon and oxygen.

The nitrogen cycle

Most of the Earth's nitrogen is found in the atmosphere. Before it can be used by plants and animals, this nitrogen must undergo **nitrogen fixation**. In fixation, nitrogen gas, N_2, is converted to ammonium, NH_4^+. Specialized bacteria and other microorganisms perform nitrogen fixation. The nitrogen cycle is shown in **Figure 21**. After fixation, the next step in the cycle is nitrification. Nitrification is the chemical process that turns ammonium, NH_4^+, into nitrogen-oxygen compounds, NO_2^- and NO_3^-. Plants use these compounds to make proteins. Nitrogen-oxygen compounds may also be created by the energy from lightning.

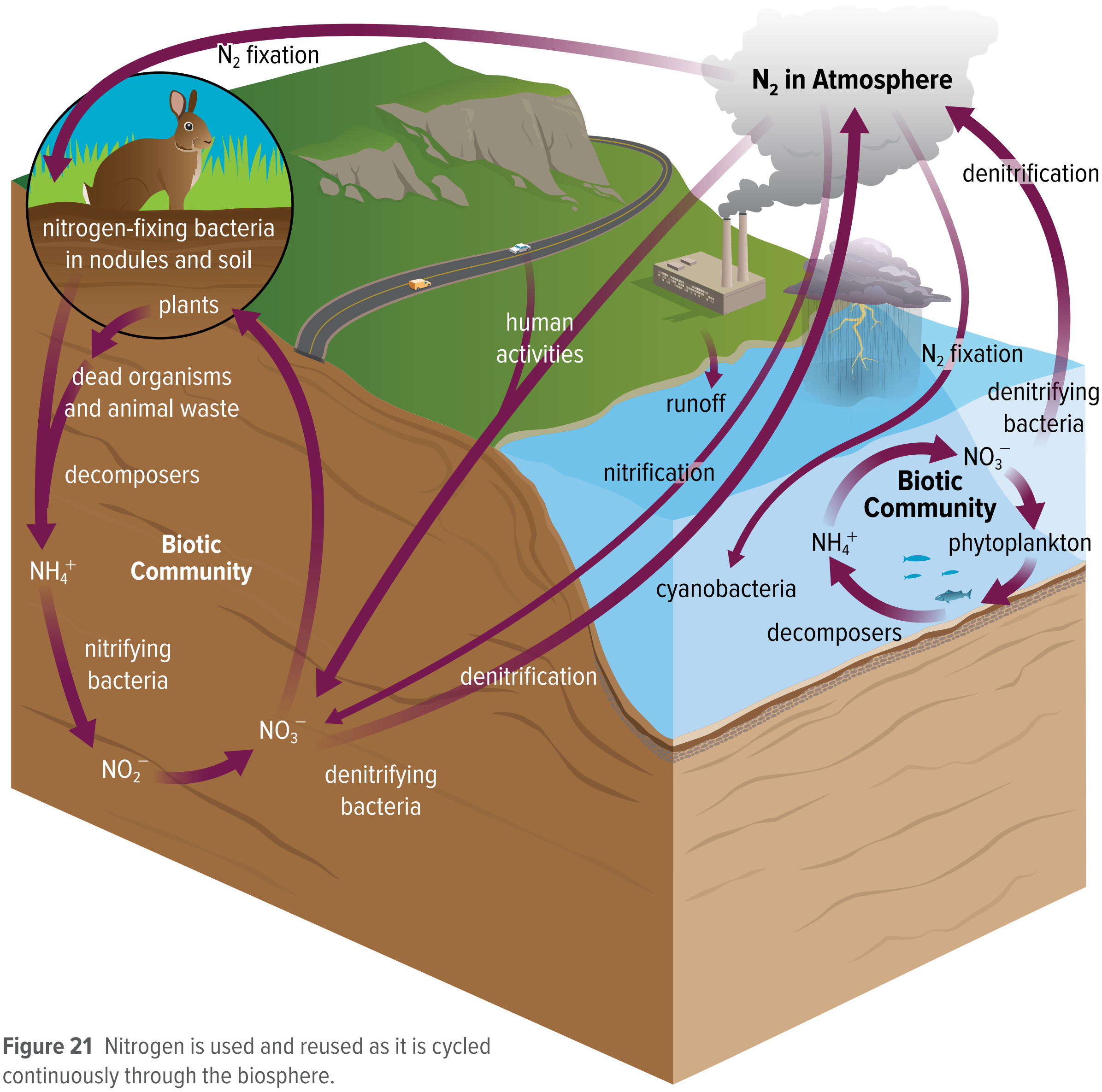

Figure 21 Nitrogen is used and reused as it is cycled continuously through the biosphere.

Nitrogen moves through the food web as organisms consume plants and each other. It returns to the soil through animal wastes and by the decomposition of dead matter into ammonia. Organisms in the soil convert ammonia into nitrogen compounds that can be used by plants. In a process called **denitrification,** some soil bacteria convert NO_2^- and NO_3^- back into nitrogen gas (N_2), which returns to the atmosphere. Human activities also play a role in the nitrogen cycle. The high nitrogen content in runoff from fertilizer can create algae overgrowth, call algae blooms. Nitrogen-oxygen compounds released into the atmosphere from factories combine with water to form acid rain.

The phosphorous cycle

Phosphorus is an element that is essential for the growth and development of organisms. **Figure 22** shows both the short-term and long-term phases of the phosphorus cycle. In the short-term cycle, phosphorus in phosphates in solution are cycled from the soil to producers and then from the producers to consumers. When organisms die or produce waste products, decomposers return the phosphorus to the soil where it can be used again.

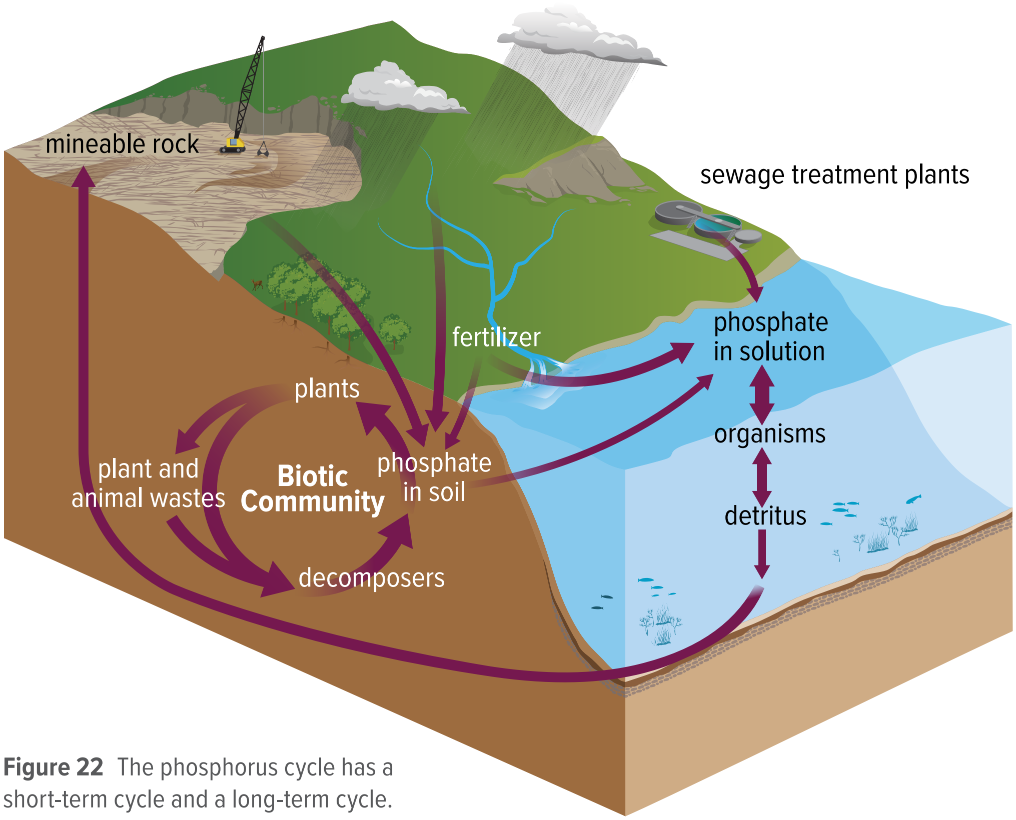

Figure 22 The phosphorus cycle has a short-term cycle and a long-term cycle.

Figure 23 Increased amounts of nitrogen and phosphorus that enter the environment from mining, sewage, or fertilizers can cause algae overgrowth like that seen in this pond.

Phosphorus moves from the short-term cycle to the long-term cycle through precipitation and sedimentation to form rocks. Phosphorus that settles into sediment in aqueous environments is transferred to the land by geological changes and uplift. Phosphorus that undergoes sedimentation does not become available to land organisms again until weathering or erosion of rocks that contain phosphorus slowly adds phosphorus to the soil.

Human activities, such as phosphate mining, sewage treatment, and fertilizer production, increase the amount of phosphate cycling through the environment. Too much phosphate can result in algae overgrowth, called algae blooms, like that shown in **Figure 23**, and upset the balance of an ecosystem. Algae blooms can occur in freshwater or marine ecosystems.

Check Your Progress

Summary

- Biogeochemical cycles exchange of important nutrients between the abiotic and biotic parts of an ecosystem.
- The carbon and oxygen cycles are closely intertwined.
- Nitrogen gas is limited in its ability to enter biotic portions of the environment.
- Phosphorus and carbon have short-term and long-term cycles.

Demonstrate Understanding

1. **Name** four important biogeochemical processes that cycle matter.
2. **Analyze** the role of photosynthesis and cellular respiration in the carbon cycle.
3. **Identify** the living and nonliving parts of the nitrogen cycle.
4. **Compare and contrast** the role of plants in the carbon and nitrogen cycles.
5. **Describe** how phosphorus moves through the biotic and abiotic parts of an ecosystem.

Explain Your Thinking

6. **Describe** the flow of energy and matter through a food web that begins with algae at the lowest level.

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STEM AT WORK

How Can Computer Models Predict an Ecosystem's Future?

Studying the impact of changes in a complex ecosystem can be difficult, especially if you want to predict the effect a change might have before it occurs. Like other scientists, ecologists build and interpret computer models to study changes in complex systems.

The hydrology of the San Pedro Basin is critical to the humans and wildlife that live in the area. Ecologists have developed a computer model to help predict how climate change will impact the availability of water in the region.

Scientists Use Models

Scientists develop computer models by using mathematical equations called algorithms, which use patterns to predict future events. Ecological modelers use data collected from real ecosystems to build computer models that can accurately describe past events.

When scientists test the model to find out if it describes known or past events accurately, they are validating the model. Validation ensures that the researchers can trust the predictions and descriptions generated when unknown or hypothetical scenarios are run through the model.

In climate change research, many scientists are building and using computer models to try to describe how the climate has changed, predict how it will change, and forecast how different interventions would help to curb the rate of change. Information from larger scale models can be used to build smaller scale models of specific regions and ecosystems.

For example, some researchers assessed the impact of climate change on water resources of the San Pedro Basin, shown in the figure above, an arid region in southeastern Arizona and northern Sonora, Mexico. By using clearly defined parameters regarding the ecosystem they wanted to study and combining data from multiple climate change models, they built a three-dimensional transient groundwater-surface water flow model. Then, they used the model to simulate the hydrology of the region from 2000 to 2100. The results of the study were published in a peer reviewed journal and will be used to inform future decisions impacting the region's water supply.

COMMUNICATE SCIENTIFIC AND TECHNICAL INFORMATION

Read a scientific study that used a computer model to describe or predict an environmental event or outcome related to climate change. Summarize the study into a brief article to share with your class.

MODULE 2
STUDY GUIDE

GO ONLINE to study with your Science Notebook.

Lesson 1 ORGANISMS AND THEIR RELATIONSHIPS

- Ecology is the branch of biology in which interrelationships between organisms and their environments are studied.
- Abiotic and biotic factors shape an ecosystem and determine the communities that will be successful in it.
- Abiotic and biotic limiting factors restrict the growth of a population within a community.
- Organisms have a range of tolerance for each limiting factor that they encounter.
- Levels of organization in ecological studies include organism, population, biological community, ecosystem, biome, and biosphere.
- Symbiosis is the close relationship that exists when two or more species live together. There are three types of symbiotic relationships.

- ecology
- biosphere
- biotic factor
- abiotic factor
- limiting factor
- tolerance
- population
- biological community
- ecosystem
- biome
- habitat
- niche
- predation
- symbiosis
- mutualism
- commensalism
- parasitism

Lesson 2 FLOW OF ENERGY IN AN ECOSYSTEM

- Autotrophs capture energy from the Sun or use energy from certain chemical substances to make food.
- Heterotrophs include herbivores, carnivores, omnivores, and detritivores.
- A trophic level is a step in a food chain or food web.
- Food chains, food webs, and ecological pyramids are models used to show how energy moves through ecosystems.

- autotroph
- heterotroph
- herbivore
- carnivore
- omnivore
- detritivore
- trophic level
- food chain
- food web
- biomass

Lesson 3 CYCLING OF MATTER

- Biogeochemical cycles include the exchange of important nutrients between the abiotic and biotic parts of an ecosystem.
- The carbon and oxygen cycles are closely intertwined.
- Nitrogen gas is limited in its ability to enter biotic portions of the environment.
- Phosphorus and carbon have short-term and long-term cycles.

- matter
- nutrient
- biogeochemical cycle
- nitrogen fixation
- denitrification

THREE-DIMENSIONAL THINKING

Module Wrap-Up

REVISIT THE PHENOMENON

Why would a bird build a nest in a tree with thorns?

CER Claim, Evidence, Reasoning

Explain Your Reasoning Revisit the claim you made when you encountered the phenomenon. Summarize the evidence you gathered from your investigations and research and finalize your Summary Table. Does your evidence support your claim? If not, revise your claim. Explain why your evidence supports your claim.

STEM UNIT PROJECT

Now that you've completed the module, revisit your STEM unit project. You will summarize your evidence and apply it to the project.

GO FURTHER

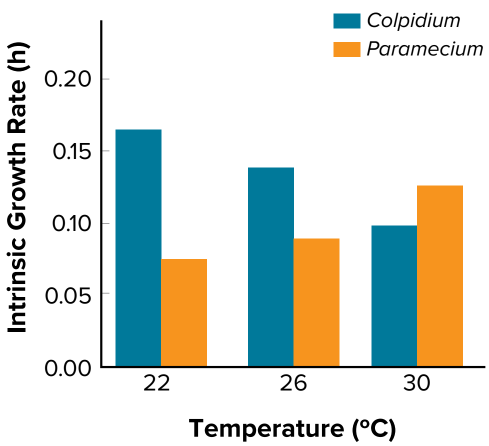
SEP Data Analysis Lab

Does temperature affect growth rates of protozoans?

Researchers studied the effect of temperature on the growth rates of protozoans. They hypothesized that increasing temperature would increase the growth rate of the protozoans.

Data and Observations The graph shows the effect of temperature on the growth rate of *Colpidium* and *Paramecium*.

Effect of Temperature on Growth Rate



*Data obtained from: Jiang, L. and Kulczycki, A. 2004. Competition, predation, and species responses to environmental change. *Oikos* 106: 217–224.

CER Analyze and Interpret Data

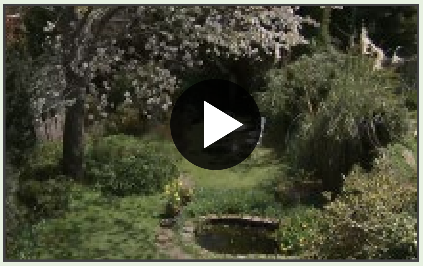
1. **Identify** the dependent and independent variables.
2. **Claim, Evidence, Reasoning** Does the data support the hypothesis? What does the data show about the relationships between the dependent and independent variables? How does the data support your claim?
3. **Evaluate** What might be the next step in the researchers' investigation? Explain.

Celso Diniz/Alamy Stock Photo

MODULE 3
COMMUNITIES, BIOMES, AND ECOSYSTEMS

ENCOUNTER THE PHENOMENON

Why would you grow a garden in a city?



GO ONLINE to watch a video about community interactions in an ecosystem.

SEP Ask Questions

Do you have other questions about the phenomenon? If so, add them to the driving question board.

CER Claim, Evidence, Reasoning

Make Your Claim Use your CER chart to make a claim about why you would grow a garden in the city. Explain your reasoning.

Collect Evidence Use the lessons in this module to collect evidence to support your claim. Record your evidence as you move through the module.

Explain Your Reasoning You will revisit your claim and explain your reasoning at the end of the module.

GO ONLINE to access your CER chart and explore resources that can help you collect evidence.

LESSON 1: Explore & Explain: Ecological Succession

LESSON 2: Explore & Explain: Biomes

Smithsonian

Additional Resources

(t)Video Supplied by BBC Worldwide Learning; (bl)Samson1976/iStock/Getty Images; (br)Harold R. Stinnette Photo Stock/Alamy

LESSON 1

COMMUNITY ECOLOGY

FOCUS QUESTION

What is an ecological community?

Communities

When you describe your community, you probably include your family, the students in your school, and the people who live nearby. A biological **community** is a group of interacting populations that occupy the same area at the same time. Therefore, your community also includes other people, plants, animals, bacteria, and fungi. Not every community includes the same variety of organisms. An urban community is different from a rural community, and a desert community is different from a polar community.

You have learned that organisms living in the same ecosystem depend on one another for survival. You also learned about abiotic factors and how they affect individual organisms. Recall that limiting factors can influence an organism's ability to survive or to reproduce.

How might abiotic factors affect communities? For example, consider soil, which is an abiotic factor. If soil becomes too acidic, some species might die or become extinct. This might affect food sources for other organisms, resulting in a change in the community.

Organisms can adapt to the conditions in which they live. For example, a wolf's heavy fur coat enables it to survive in harsh winter climates, and a cactus's ability to retain water enables it to tolerate the dry conditions of a desert. Depending on which factors are present, and to what extent, organisms can survive in some ecosystems but not in others. For example, the camel and trees shown in **Figure 1** have adaptations that enable them to thrive in desert conditions, but would not be useful in colder climates.

Figure 1 Plants and animals in a desert community have adaptations to help them survive periods of drought.

Radius Images/Getty Images

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Applying Practices: Local Ecosystem Dynamics

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Ecological Succession

A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. However, ecosystems are constantly changing. They might be modified in small ways, such as a tree falling in the forest, or in large ways, such as a forest fire. Such changes might alter the communities that exist in the ecosystem. Forest fires can be good and even necessary for the forest community. Forest fires return nutrients to the soil. Some plants, such as fireweed, have seeds that will not sprout until they are heated by fire. Some ecosystems depend on fires to get rid of debris. If fires are prevented, debris builds up to the point where the next fire might burn the shrubs and trees completely. A forest fire might change the habitat so drastically that some species can no longer survive, but other species might thrive in the new, charred conditions.

The change that occurs in an ecosystem when one community replaces another as a result of changing abiotic and biotic factors is known as **ecological succession.** There are two types of succession—primary succession, shown in **Figure 2,** and secondary succession, shown on the next page in **Figure 3**. Both result in a changed ecosystem.

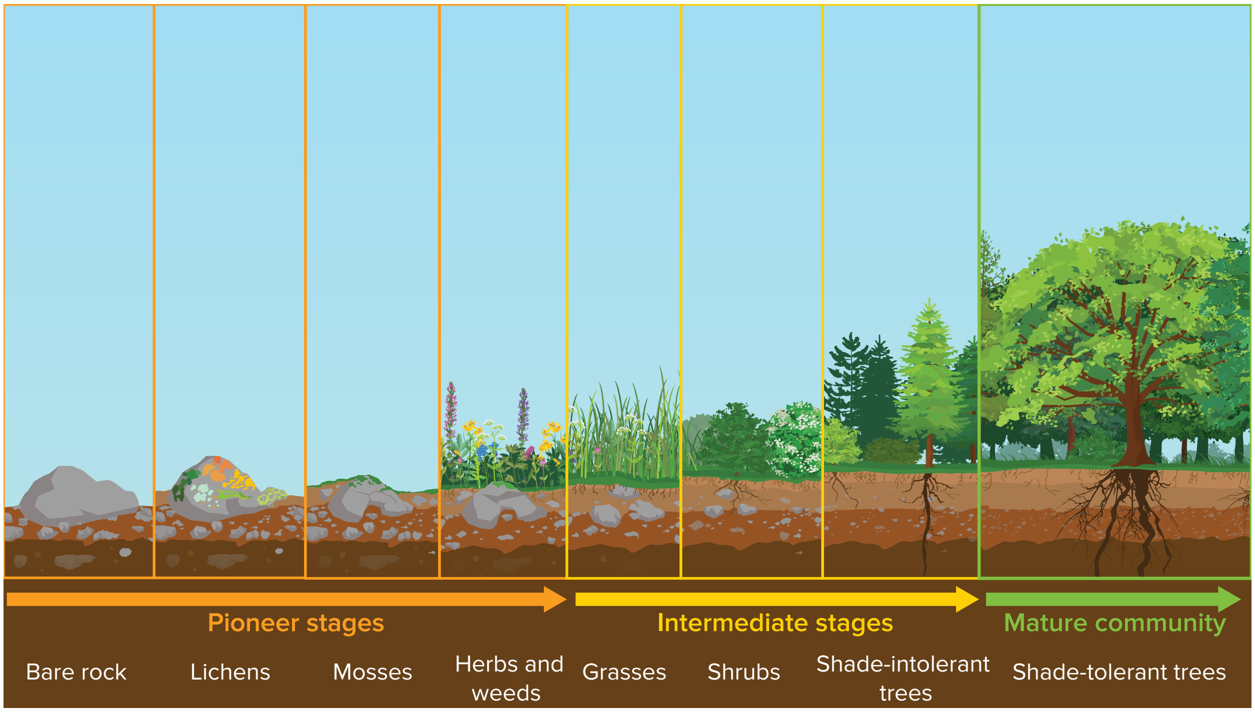


Figure 2 The formation of soil is the first step in primary succession. Once soil formation starts, there is progressive succession toward a climax community.

VOCABULARY:
SCIENCE USAGE v. COMMON USAGE

primary

Science usage: first in rank, importance, value, or order *A doctor's primary concern should be the patient.*

Common usage: the early years of formal education *Elementary grades, up to high school, are considered to comprise a student's primary education*

CCC **CROSSCUTTING CONCEPTS**

Stability and Change Over the weekend spend some time outside in the local area around your school, home, or nearby park. Observe the biotic and abiotic factors present in the area. Do you think succession is taking place in the area? What evidence suggests that things are changing? What evidence suggests that things haven't changed for a long time? Use your phone or other video camera to record the evidence.

Primary succession

On a solidified lava flow or exposed rocks on a cliff, no soil is present. If you took a sample from such a site and looked at it under a microscope, the only biological organisms you would observe would be bacteria and perhaps fungal spores or pollen grains that drifted there on air currents. The establishment of a community in an area of exposed rock that does not have any topsoil is **primary succession,** which is illustrated in **Figure 2** on the last page. Primary succession usually occurs very slowly at first.

Almost all plants require soil for growth. But how is soil formed? Usually lichens, a mutualistic combination of a fungus and algae, begin to grow on the rock. Because lichens are among the first organisms to appear, they are called pioneer species. Pioneer species help to create soil by producing acids that help to break down rocks. As pioneer organisms die, their decaying organic materials, along with bits of sediment from the rocks, make up the first stage of soil development. At this point, small plants, including ferns, and other organisms such as fungi and insects, become established. As these organisms die, additional soil is created. Seeds, transported by animals, water, or wind, begin to grow in the newly formed soil. Eventually, enough soil is present so that shrubs and trees can grow.

A mature community can eventually develop from bare rock, as shown in the last page in **Figure 2.** The stable, mature community that results when there is little change in the composition of species is a **climax community.** Scientists today realize that disturbances, such as climate change, are ongoing; therefore, a true climax community is unlikely to occur.

Secondary succession

Disturbances such as a fire, flood, or windstorm can disrupt a community. Human activities also affect the species that might be present. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original state (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. After a disturbance, new species of plants and animals might occupy the habitat.

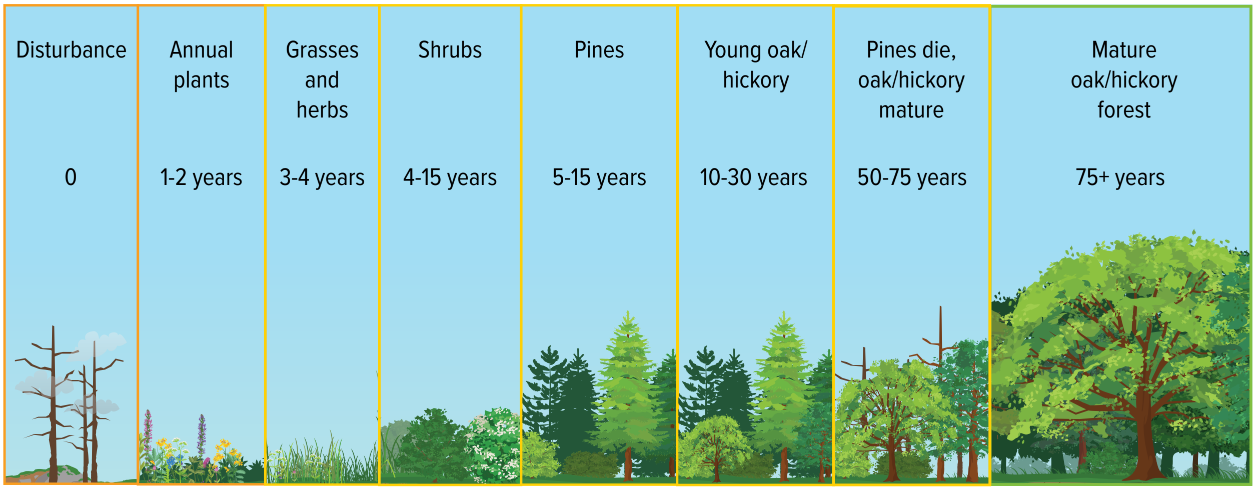


Figure 3 After a fire, a forest might appear devastated. However, a series of changes ultimately leads back to a mature community.

Secondary succession is the orderly and predictable change that takes place after a community of organisms has been removed but the soil has remained intact. Pioneer species – mainly plants – that establish in the disturbed area are the first species to start secondary succession. Over time, there is a natural tendency for the species that belong to the mature community to return.

During secondary succession, as in primary succession, the community of organisms changes over a period of time. **Figure 3** on the previous page shows how species composition changes after a forest fire. Secondary succession usually occurs faster than primary succession because soil already exists and some species will still be present (although there might be fewer of them). Also, undisturbed areas nearby can be sources of seeds and animals.

Succession's end point

Ecological succession is a complex process that involves many factors. The end point of succession after a disturbance cannot be predicted. Natural communities are continuously changing at different rates, and the process of succession is very slow.

Get It?

Describe how the community where you live may have changed over time because of succession.

Check Your Progress

Summary

- A biological community is a group of interacting populations that occupy the same area at the same time.
- Ecological succession occurs when one community replaces another as a result of changing abiotic and biotic factors.
- Primary succession occurs on areas of exposed rock or bare sand (no soil).
- Communities progress until there is little change in the composition of species.
- Secondary succession occurs as a result of a disturbance in a mature community.

Demonstrate Understanding

1. **Predict** how unfavorable abiotic and biotic factors affect a species.
2. **Classify** the stage of succession of a field that is becoming overgrown with shrubs after a few years of disuse.
3. **Contrast** primary and secondary succession.

Explain Your Thinking

4. **Describe** how the stages of succession can change a rocky field into a mature forest.
5. **WRITING Connection** **List** at least five organisms that are present in your biological community. Then write a paragraph that provides evidence of how an abiotic factor supports each organism.
6. **Predict** what might happen to your backyard if it was left unattended for several years. Use information from this lesson to explain your prediction.

LEARNSMART® Go online to follow your personalized learning path to review, practice, and reinforce your understanding.

LESSON 2
TERRESTRIAL BIOMES

FOCUS QUESTION

What characteristics do scientists consider when they are describing different regions of the world?

Effects of Latitude and Climate

Regardless of where you live, you are affected by weather and climate. **Weather** is the condition of the atmosphere at a specific place and time. What causes the variation in the weather patterns on Earth? One of the keys to understanding weather and its effect on biological communities is to be aware of latitude and climatic conditions.

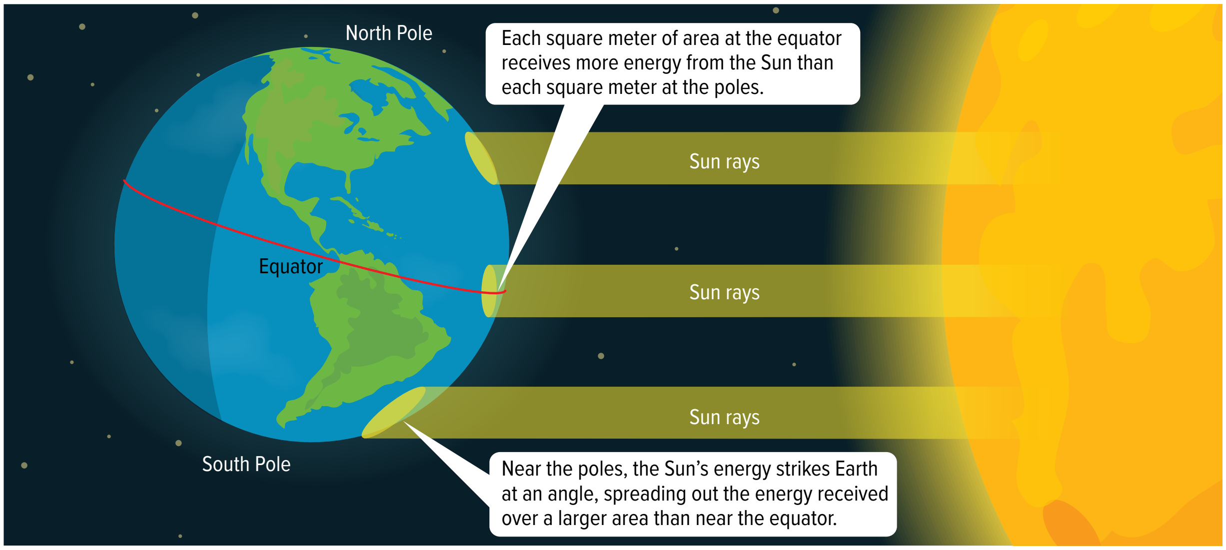


Figure 4 Because of Earth's curved surface, the Sun's rays strike the equator more directly than areas toward the north or south poles.

3D THINKING | DCI Disciplinary Core Ideas | CCC Crosscutting Concepts | SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

BioLab: How does your biome grow?
Plan and carry out an investigation to determine the impact abiotic factors have on biomes.

Virtual Investigation: Ecosystems, Organisms, and Trophic Levels
Use a model to determine energy flow within food webs of biomes and ecosystems.

Latitude

EARTH SCIENCE Connection The distance of any point on the surface of Earth north or south from the equator is **latitude.** Latitudes range from 0° at the equator to 90° at the poles. Light from the Sun strikes Earth more directly at the equator than at the poles, as illustrated in **Figure 4** on the previous page. As a result, Earth's surface is heated differently in different areas. Ecologists refer to these areas as "zones." Polar zones extend to about 66° from each pole, while tropical zones extend about 23° north and south of the equator. Temperate zones are found between the polar and tropical zones.

Climate

The average weather conditions in an area, including temperature and precipitation, describe the area's **climate.** An area's latitude has a large effect on its climate. If latitude were the only abiotic factor involved in climate, biomes would be spread in equal bands encircling Earth. However, other factors such as elevation, continental landmasses, proximity to mountains, and ocean currents also affect climate.

Recall that a biome is a large group of ecosystems that share the same climate and have similar types of communities. It is a group of plant and animal communities that have adapted to a region's climate and other abiotic factors.

The graph in **Figure 5** shows how temperature and precipitation influence the communities that develop in an area, and help to define the various biomes. Note that there is considerable variation in temperature and precipitation in most of the biomes.

There can be more than one ecosystem in a biome. A biome's ecosystems occur over a large area and have similar plant communities. Even a small difference in temperature or precipitation can affect the composition of a biome.

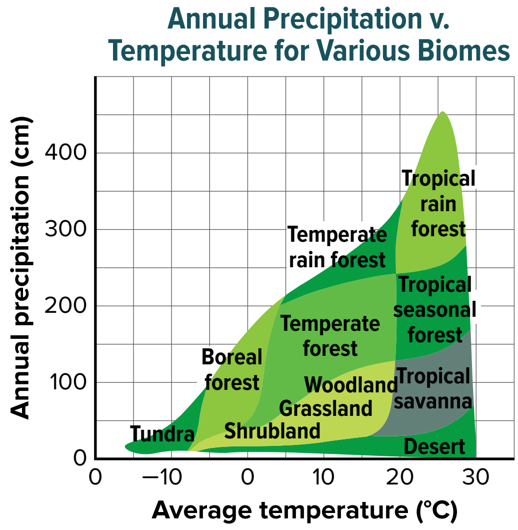


Figure 5 Temperature and precipitation are two major factors that influence the kind of vegetation that can exist in an area.

Analyze *Which biome would you expect in an area that receives 200 cm of precipitation annually if the average annual temperature is 10°C?*

Refer to **Figure 6** on the next page to learn how Earth's ocean currents and prevailing winds affect climate. Also illustrated in **Figure 6** are two ways humans might be affecting climate—through the hole in the ozone layer and through global warming. Global warming is in part a result of the greenhouse effect.

Get It?

Explain the difference between weather and climate.

Major Land Biomes

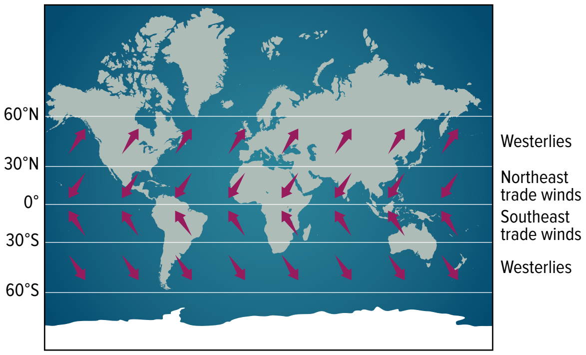
Biomes are classified primarily according to the characteristics of their plants. Biomes also are characterized by abiotic climate characteristics such as temperature, precipitation, the amount of sunlight, and the amount and type of wind.

The plants and abiotic characteristics in a biome influence the types of animals that live there. This section describes each of the major land biomes.

Figure 6 Visualizing Global Effects on Climate

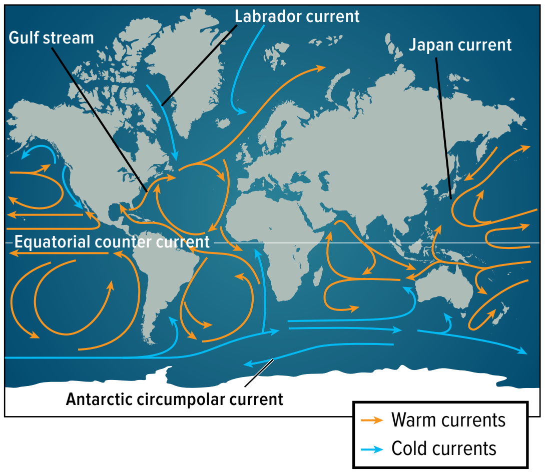
Some parts of Earth receive more heat from the Sun. Earth's winds and ocean currents contribute to climate and balance the heat on Earth. Many scientists think human impacts on the atmosphere upset this balance.

Winds on Earth



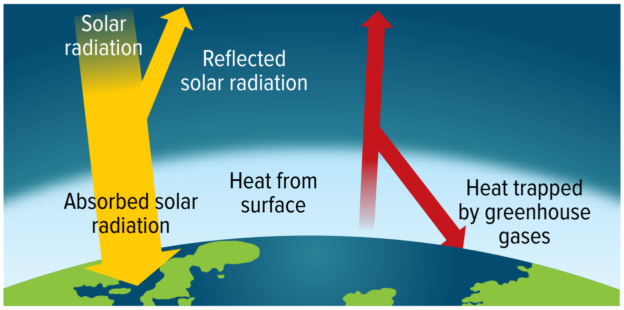
Winds are created from temperature imbalances. Distinct global wind systems transport cold air to warm areas and warm air to cold areas.

Earth's Ocean Currents



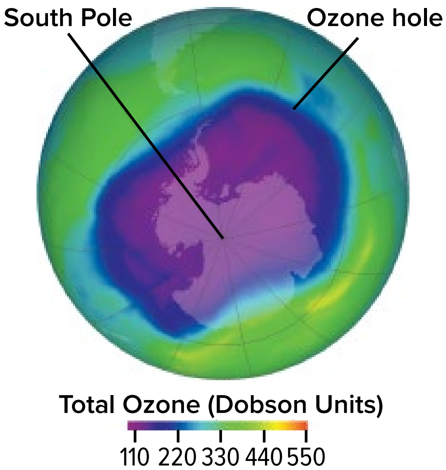
Ocean currents carry warm water toward the poles. As the water cools, it sinks toward the ocean floor and moves toward tropical regions.

Greenhouse Effect

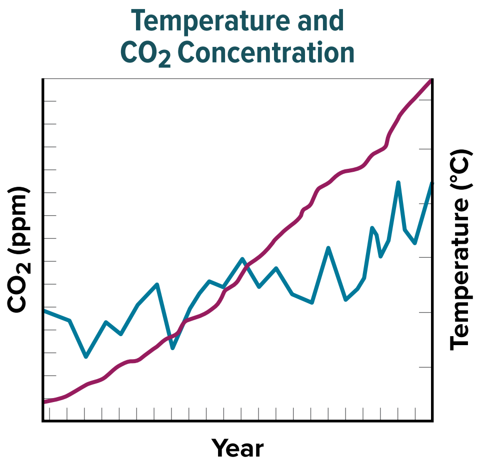


Earth's surface is warmed by the greenhouse effect. Certain gases in Earth's atmosphere, including naturally occurring water vapor, reduce the amount of energy Earth radiates into space. Other important greenhouse gases are carbon dioxide and methane.

Human Impact on the Atmosphere



The ozone layer is a protective layer in the atmosphere that absorbs most of the harmful UV radiation from the Sun. Atmospheric studies have indicated that chlorofluorocarbons (CFCs) contribute to a seasonal reduction in ozone concentration over Antarctica, forming the Antarctic ozone hole.



The measured increase of carbon dioxide (CO_2) in the atmosphere (red line) is mainly due to the burning of fossil fuels. As carbon dioxide levels have increased, the average global temperature (blue line) has increased.

Aura satellite/NASA

Tundra

Extending in a band below the polar ice caps across northern Europe, North America, and Siberia in Asia is the tundra. The **tundra** is a treeless biome with a layer of permanently frozen soil below the surface called permafrost. Although the ground thaws to a depth of a few centimeters in the summer, its constant cycles of freezing and thawing do not allow tree roots to grow. Plants that are able to survive in the tundra have very shallow roots. Animals like the caribou in **Figure 7** have adapted to tundra conditions.

Figure 7 Tundra

Average precipitation: 15–25 cm per year

Temperature range: –70°C to 12°C

Plant species: short grasses, shrubs

Animal species: caribou, polar bears, birds, insects, wolves, arctic hares, musk ox

Geographic location: south of the polar ice caps in the Northern Hemisphere

Abiotic factors: soggy summers; permafrost; cold and dark much of the year

Boreal forest

South of the tundra is the **boreal forest,** a band of dense evergreen forest extending across North America, Europe, and Asia. Also called the northern coniferous forest, or taiga, this biome's summers are longer and warmer than tundra summers, and its ground lacks a permafrost layer. Animals like the wolverine in **Figure 8** have adapted to the cold.

Figure 8 Boreal forest

Average precipitation: 30–84 cm per year

Temperature range: –54°C to 21°C

Plant species: spruce and fir trees, deciduous trees, small shrubs

Animal species: birds, moose, beavers, deer, wolverines, lynx

Geographic location: northern part of North America, Europe, and Asia

Abiotic factors: summers are short and moist; winters are long, cold, and dry

(tl)ajlikala/Moment/Getty Images; (tr)Jason Witherspoon/Design Pics; (bl) Pete Niesen/Alamy Stock Photo; (br)Magnus Elander/Johner Images/Alamy

Temperate forest

Temperate forests cover much of southeastern Canada, the eastern United States, most of Europe, and parts of Asia and Australia. The **temperate forest** is composed mostly of broad-leaved, deciduous (dih SIH juh wus) trees—trees that shed their leaves in autumn. The falling leaves return nutrients to the soil. All four seasons occur in temperate forests. In spring, warm temperatures and precipitation restart the growth cycles of plants and trees. Warmer temperatures also enable amphibians like the red salamander shown in **Figure 9** to survive.

Figure 9 Temperate forest

Average precipitation: 75–150 cm per year

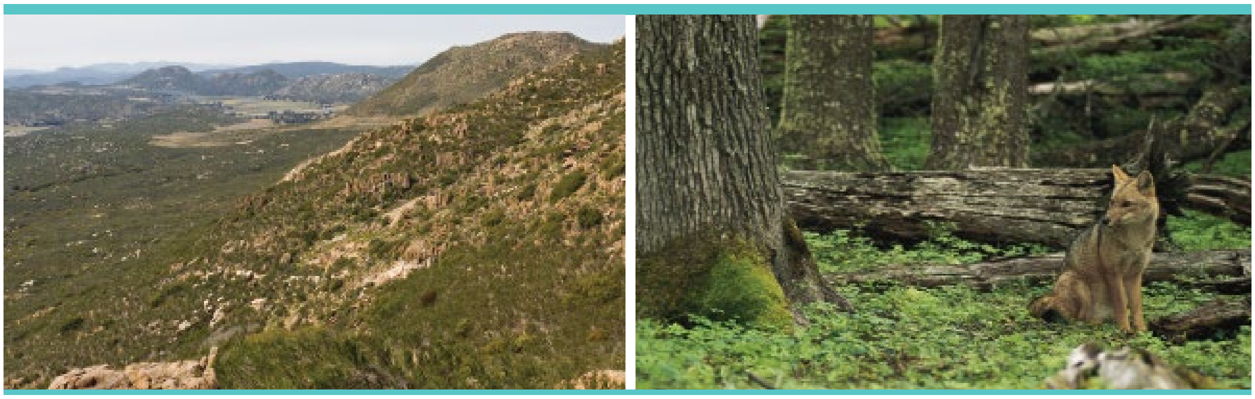
Temperature range: –30°C to 30°C

Plant species: oak, beech, and maple trees, shrubs

Animal species: amphibians and reptiles, squirrels, rabbits, skunks, birds, deer, foxes, black bears, frogs, snakes

Geographic location: Australia, and south of the boreal forest in North America, Europe and eastern Asia

Abiotic factors: well-defined seasons; summers are hot, and winters are cold



Temperate woodland and shrubland

Open **woodlands** and mixed shrub communities are found in areas with less annual rainfall than in temperate forests. The woodland biome occurs in areas surrounding the Mediterranean Sea, on the western coasts of North and South America, in South Africa, and Australia. Areas that are dominated by shrubs, such as in California, are called the chaparral. Woodland animals like the fox in **Figure 10** must have adaptations that allow them to survive in both hot, dry summers and cool, wet winters.

Figure 10 Temperate woodland and shrubland

Average precipitation: 38–100 cm per year

Temperature range: 10°C to 40°C

Plant species: evergreen shrubs, cork oak

Animal species: foxes, jackrabbits, bobcats, coyotes, reptiles, butterflies

Geographic location: surrounds the Mediterranean Sea, western coasts of North and South America, South Africa, and Australia

Abiotic factors: hot, dry summers and cool, wet winters

Temperate grassland

A biome that is characterized by fertile soils that are able to support a thick cover of grasses is called **grassland.** Drought, grazing, fires, and animals like the bison in **Figure 11** keep grasslands from becoming forests. Due to their underground stems and buds, perennial grasses and herbs are not eliminated by the fires that destroy most shrubs and trees. Temperate grasslands are found in the middle latitudes of North America, South America, Asia, Africa, and Australia. Grasslands are called prairies in North America, pampas and llanos in South America, steppes in Asia, savannas and veldts in Africa, and rangelands in Australia.

Figure 11 Temperate grassland

Average precipitation: 50–89 cm per year

Temperature range: –40°C to 38°C

Plant species: grasses, herbs, flowers

Animal species: gazelles, bison, horses, lions, deer, mice, coyotes, foxes, wolves, birds, snakes, grasshoppers, spiders

Geographic location: North America, South America, Asia, Africa, and Australia

Abiotic factors: summers are hot, and winters are cold; moderate rainfall; fires possible

Desert

Deserts exist on every continent except Europe. A **desert** is any area in which the annual rate of evaporation exceeds the rate of precipitation. You might imagine a desert as a desolate place full of sand dunes, but many deserts do not match that description. Deserts can be home to a wide variety of plants and animals, including reptiles like the western diamondback rattlesnake shown in **Figure 12**.

Figure 12 Desert

Average precipitation: 2–26 cm per year

Temperature range: high: 20°C to 49°C, low: –18°C to 10°C

Plant species: cacti and other succulents such as Aloe vera and Joshua trees

Animal species: lizards, bobcats, birds, tortoises, rats, antelope, desert toads

Geographic location: every continent except Europe

Abiotic factors: varying temperatures; low rainfall

Tropical savanna

A **tropical savanna** is characterized by grasses and scattered trees in climates that receive less precipitation than some other tropical areas. Tropical savanna biomes occur in Africa, South America, and Australia. Herds of grazing animals like the zebras and wildebeest shown in **Figure 13** are common to tropical savannas.

Figure 13 Tropical savanna

Average precipitation: 50–130 cm per year

Temperature range: 20°C to 30°C

Plant species: grasses and scattered trees

Animal species: lions, hyenas, wildebeest, cheetahs, elephants, giraffes, zebras, koalas, emus, insects

Geographic location: Africa, South America, and Australia

Abiotic factors: summers are hot and rainy; winters are cool and dry

Tropical seasonal forest

Tropical seasonal forests, also called tropical dry forests, grow in areas of Africa, Asia, Australia, and South and Central America. In one way, the tropical seasonal forest resembles the temperate deciduous forest because during the dry season, almost all of the trees drop their leaves to conserve water. Animals like the African forest elephant in **Figure 14** also have adaptations that help them conserve water.

Figure 14 Tropical seasonal forest

Average precipitation: >200 cm per year

Temperature range: 20°C to 25°C

Plant species: deciduous and evergreen trees, orchids, mosses

Animal species: elephants, tigers, monkeys, koalas, rabbits, frogs, spiders

Geographic location: Africa, Asia, Australia, and South and Central America

Abiotic factors: rainfall is seasonal

Get It?

Compare and contrast tropical savannas and tropical seasonal forests.

Tropical rain forest

Warm temperatures and large amounts of rainfall throughout the year characterize the **tropical rain forest** biome shown in **Figure 15**. Tropical rain forests are found in much of Central and South America, southern Asia, west central Africa, and northeastern Australia. The tropical rain forest is the most diverse of all land biomes. Tall, broad-leaved trees make up the canopy of the tropical rain forest. Shorter trees, shrubs, and plants make up another layer, the understory.

Figure 15 Tropical rain forest

Average precipitation: 200–1000 cm per year

Temperature range: 24°C to 27°C

Plant species: broadleaf evergreens, bamboo, ferns, orchids

Animal species: chimpanzees, Bengal tigers, orangutans, bats, toucans, sloths, cobra snakes

Geographic location: Central and South America, southern Asia, west central Africa, and northeastern Australia

Abiotic factors: humid all year; hot and wet

Other Terrestrial Areas

You might have noticed that the list of terrestrial biomes does not include some important areas. Many ecologists omit mountains from the list. Mountains do not fit the definition of a biome because their climate characteristics and plant and animal life vary depending on elevation. Polar regions also are not considered true biomes because they are ice masses, not true land areas with soil.

Mountains

If you go up a mountain, you might notice that abiotic conditions, such as temperature and precipitation, change with increasing elevation. These variations allow many communities to exist on a mountain. As **Figure 16** illustrates, biotic communities also change with increasing altitude, and the tops of tall mountains may support communities that resemble those of the tundra.

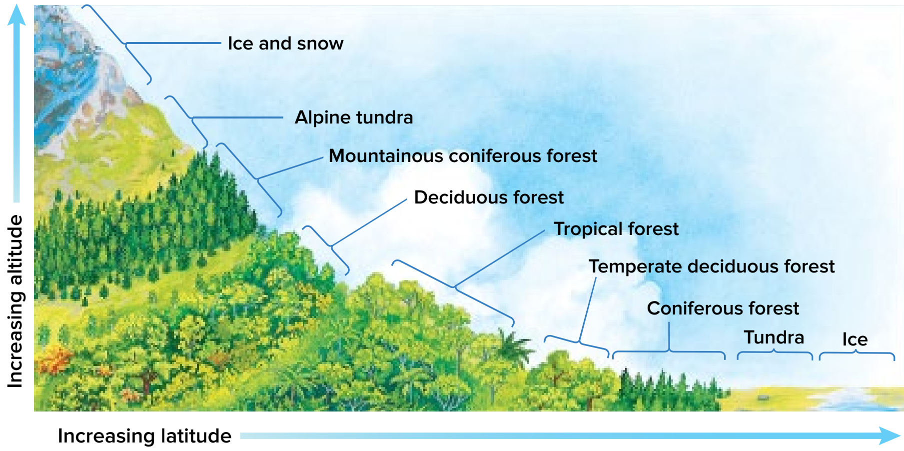


Figure 16 As you climb a mountain or increase in latitude, the temperature drops and the climate changes.

Describe *the relationship between altitude and latitude.*

CCC CROSSCUTTING CONCEPTS

Cause and Effect Use the Internet and other sources to research the impact of human activity on climate. In a brief report summarize the evidence that human activities are contributing to global warming and use this evidence to predict what might happen during your lifetime to the biome in which you live. As you prepare your report, think about whether you would be willing to make changes in your lifestyle to help prevent further climate change.

STEM CAREER Connection

Environmental Engineer Earth's ecosystems are constantly changing! Some of these changes are natural and some are caused by human activity. What are the impacts of these changes? How do we prevent or cope with these impacts? Environmental engineers work with other engineers and urban planners to develop plans for preventing environmental changes or for adapting to changes that cannot be prevented.

Polar regions

Polar regions border the tundra at high latitudes, and are cold all year. The coldest temperature ever recorded, –89°C, was in Antarctica, the continent that lies in the southern polar region. Whales and seals patrol the coast, preying on fish, shrimp-like invertebrates called krill, or penguins like the ones shown in **Figure 17.**

Animals like polar bears and arctic foxes inhabit the arctic polar region, and human societies have also inhabited this region throughout history. The Arctic includes the Arctic Ocean and several large islands, including Greenland, but does not have a continental land mass like that of Antarctica.

Figure 17 A surprising number of species inhabit the polar regions, including these penguins in Antarctica.

Check Your Progress

Summary

- Two major abiotic factors, latitude and climate, determine terrestrial biomes.
- Latitude affects terrestrial biomes because of the different angles at which sunlight strikes Earth.
- Latitude, elevation, ocean currents, and other abiotic factors determine climate.
- There are nine major terrestrial biomes.
- There are two additional terrestrial regions, mountains and polar regions, that do not fit into these categories.
- Terrestrial biomes are defined primarily by the characteristics of their plants.

Demonstrate Understanding

1. **Describe** the nine major terrestrial biomes.
2. **Describe** the changes in a temperate forest ecosystem that result from changing seasons.
3. **Summarize** variations in climate among three major zones as you travel south from the equator toward the South Pole.
4. **Indicate** the differences between temperate grasslands and tropical savannas.
5. **Compare and contrast** the climate and biotic factors of tropical seasonal forests and temperate forests.

Explain Your Thinking

6. **Hypothesize** why the tropical rain forests have the greatest diversity of living things.
7. **WRITING Connection** Tropical forests are being felled at a rate of 17 million hectares per year, which represents almost two percent of the forests' area. Use this information to write a pamphlet describing how much rain forest area exists and when it might be gone.

LEARNSMART® Go online to follow your personalized learning path to review, practice, and reinforce your understanding.

AQUATIC ECOSYSTEMS

FOCUS QUESTION

What are some examples and characteristics of aquatic communities?

The Water on Earth

When you think about water on Earth, you might recall a vacation at the ocean or a geography lesson in which you located Earth's oceans and seas. You probably have heard about other large bodies of water, such as the Amazon River and the Great Salt Lake. A photograph of Earth from space shows Earth as mainly blue in color because the planet is largely covered with water. Ecologists recognize the importance of water because of the biological communities that water supports. In this lesson, you will read about freshwater, transitional, and marine aquatic ecosystems. You also will read about the abiotic factors that affect these ecosystems.

Freshwater Ecosystems

The major freshwater ecosystems include ponds, lakes, streams, rivers, and wetlands. Plants and animals in these ecosystems are adapted to the low salt content in freshwater and are unable to survive in areas of high salt concentration. Only about 2.5 percent of the water on Earth is freshwater, as illustrated by the circle graph on the left in **Figure 18** on the next page.

The graph on the right in **Figure 18** shows that, of the 2.5 percent of Earth's water that is fresh, 68.9 percent is contained in glaciers, 30.8 percent is groundwater, and only 0.3 percent is found in lakes, ponds, rivers, streams, and wetlands. Interestingly, almost all of the freshwater species live in this 0.3 percent.

Get It?
Infer how climate change will likely change the graph in **Figure 18**.

3D THINKING | DCI Disciplinary Core Ideas | CCC Crosscutting Concepts | SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

BioLab: A pond in a jar
Plan and carry out an investigation to determine the stability and change of a miniature ecosystem.

Virtual Investigation: Communities and Ecosystems
Use a model to create a stable and balanced marine ecosystem.

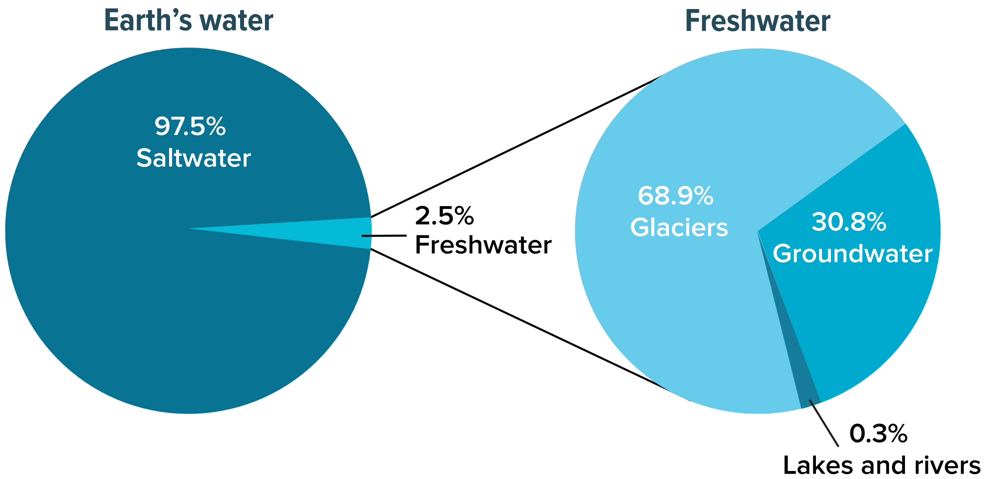


Figure 18 The vast majority of Earth's water is salt water. Most of the freshwater supply is locked in glaciers.

Rivers and streams

The water in rivers and streams flows in one direction, beginning at a source called a head-water and traveling to the mouth, where the flowing water empties into a larger body of water, as illustrated in **Figure 19.** Rivers and streams also might start from underground springs or from snowmelt. The slope of the landscape determines the direction and speed of the water flow. When the slope is steep, water flows quickly, causing a lot of sediment to be picked up and carried by the water.

Sediment is material that is deposited by water, wind, or glaciers. As the slope levels, the speed of the water flow decreases and sediments are deposited in the form of silt, mud, and sand.

The characteristics of rivers and streams change during the journey from the source to the mouth. Interactions between wind and the water stir up the water's surface, which adds a significant amount of oxygen to the water. Interactions between land and water result in erosion, in nutrient availability, and in changing the path of the river or stream.

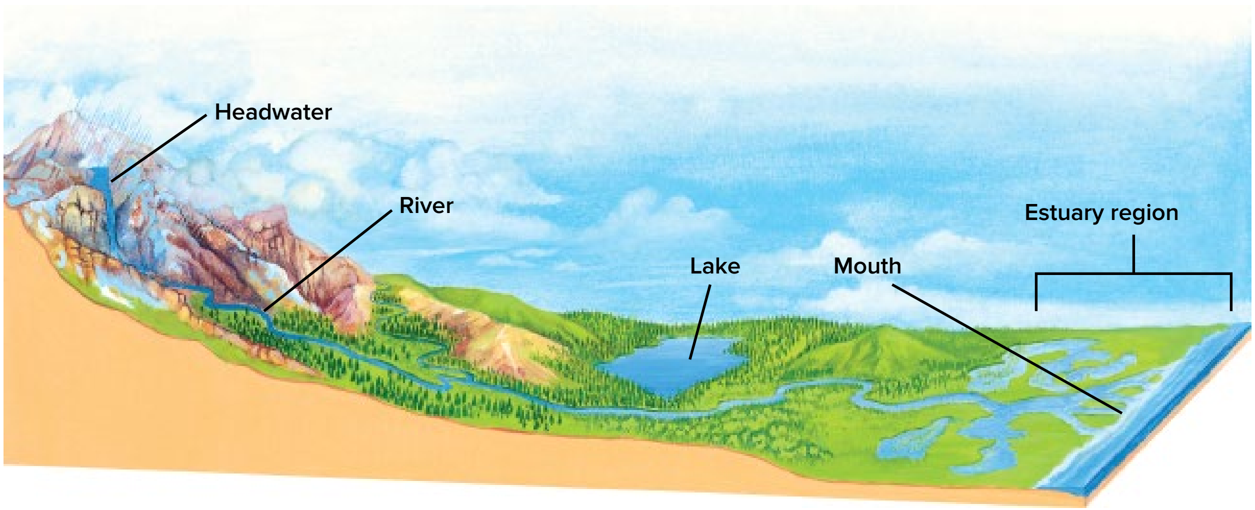


Figure 19 Mountain streams have clear, cold water that is highly oxygenated and supports the larvae of many insects and the coldwater fish that feed on them. Rivers become increasingly wider, deeper, and slower. At the mouth, many rivers divide into many channels where wetlands or estuaries form.

The currents and turbulence of fast-moving rivers and streams prevent much accumulation of organic materials and sediment. For this reason, there are usually fewer species living in rapid waters like those in **Figure 20.** An important characteristic of life in rivers and streams is the ability to withstand the constant water current. Plants that root themselves into the streambed are common in areas where water is slowed by rocks or sandbars. Young fish hide in these plants and feed on the drifting microscopic organisms and aquatic insects. In slow-moving water, insect larvae are the primary food source for many fish, including American eel, brown bullhead catfish, and trout. Other organisms, such as crabs, worms, newts, tadpoles, and frogs are often present in slow-moving or calm water.

Figure 20 The turbulent churning action of fast-moving rivers and streams does not allow for many species to inhabit these waters.

Lakes and ponds

An inland body of standing water is called a lake or a pond. It can be as small as a few square meters or as large as thousands of square meters. Some ponds might be filled with water for only a few weeks or months each year, whereas some lakes have existed for thousands of years. **Figure 21** illustrates how in temperate regions the temperature of lakes and ponds varies depending on the season.

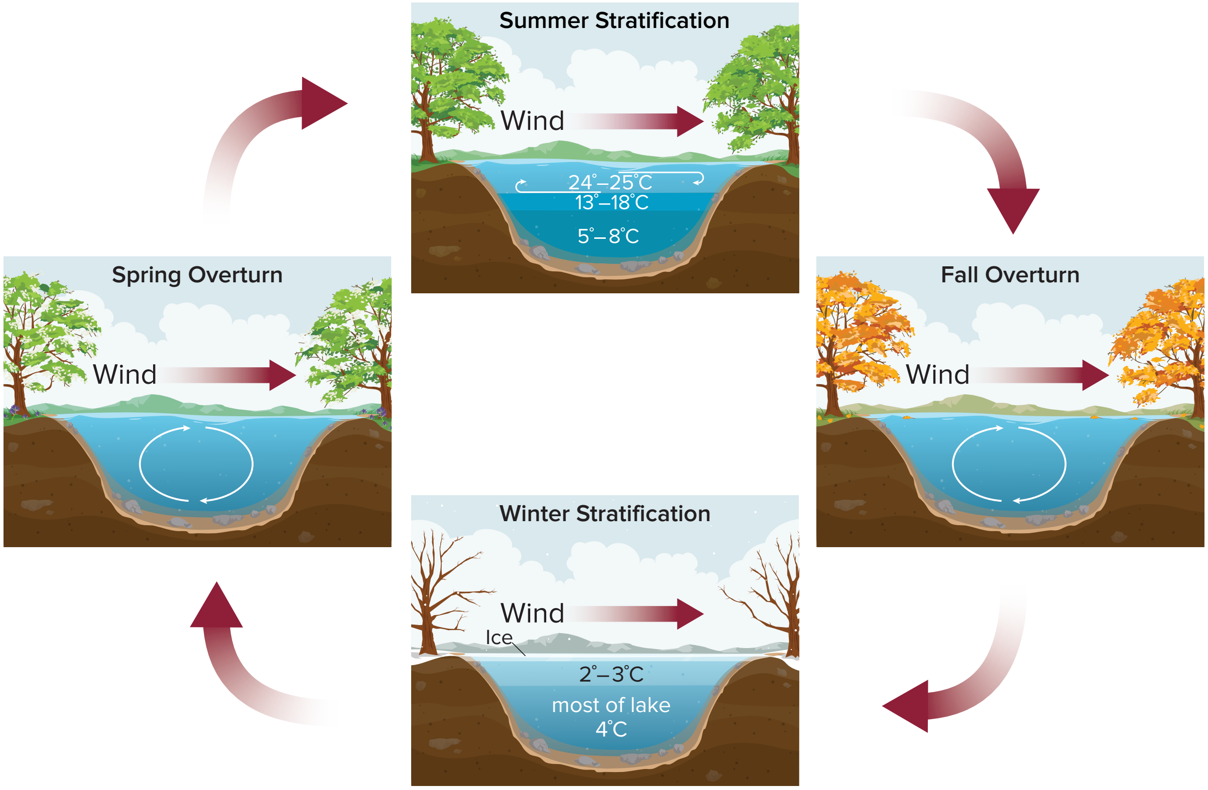


Figure 21 The temperature of lakes and ponds varies depending on the season. During spring and autumn, deep water receives oxygen from the surface water and surface water receives inorganic nutrients from the deep water.

Compare *the type of life that might live in a shallow lake in the tropics to one in the mid-latitudes.*

During the winter, most of the water in a lake or pond is the same temperature. In the summer, the warmer water on top is less dense than the colder water at the bottom. During the spring and fall, as the water at or near the surface warms or cools, turnover occurs. The top and bottom layers of water mix, often due to winds, and this results in a uniform water temperature. This mixing circulates oxygen and brings nutrients from the bottom to the surface.

Nutrient-poor lakes, called oligotrophic (uh lih goh TROH fihk) lakes, are often found high in the mountains. Few plant and animal species are present as a result of small amounts of organic matter and nutrients. Nutrient-rich lakes, called eutrophic (yoo TROH fihk) lakes, usually are found at lower altitudes. Many plant and animal species are present as a result of organic matter and plentiful nutrients, some of which come from agricultural and urban activities.

Figure 22 identifies the zones and biodiversity of lakes and ponds. Lakes and ponds are divided into three zones based on the amount of sunlight that penetrates the water. The area closest to the shore is the **littoral** (LIH tuh rul) **zone.** The water in this zone is shallow, which allows sunlight to reach the bottom. Many producers, such as aquatic plants and algae, live in these shallow waters. The abundance of light and producers make the littoral zone an area of high photosynthesis. Many consumers, including frogs, turtles, worms, crustaceans, insect larvae, and fish also inhabit this zone.

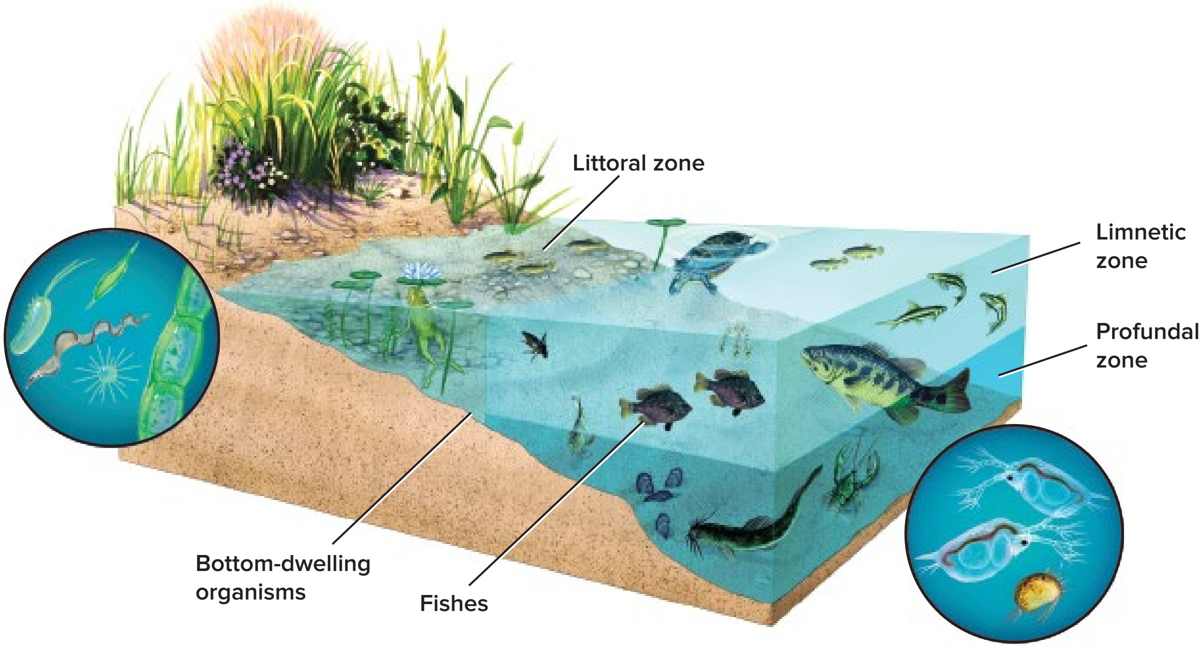


Figure 22 Most of a lake's biodiversity is found in the littoral and limnetic zones. However, many species of bottom dwellers depend on nutrients and materials that drift down from above.

WORD ORIGINS

eutrophic/oligotrophic

eu- prefix; from Greek, meaning *well*

oligo- prefix; from Greek, meaning *few*

-trophic; from Greek, meaning *nourish*

The **limnetic** (lihm NEH tihk) **zone** is the open water area that is well lit and is dominated by plankton. **Plankton** are freefloating autotrophs and heterotrophs that live in freshwater or marine ecosystems. Many species of freshwater fish live in the limnetic zone because food, such as plankton, is readily available. Minimal light is able to penetrate through the limnetic zone into the deepest areas of a large lake, which is called the **profundal** (pruh FUN dul) **zone.** The profundal zone is therefore much colder and lower in oxygen than the other two zones. A limited number of species live in this harsh environment.

Marine Ecosystems

EARTH SCIENCE Connection Earth is sometimes called "the water planet." As such, marine ecosystems have a significant impact on the planet. For example, through photosynthesis, marine algae consume carbon dioxide from the atmosphere and produce over 50 percent of the atmosphere's oxygen. Additionally, the evaporation of water from oceans eventually provides the majority of precipitation—rain and snow. Like ponds and lakes, oceans are separated into distinct zones.

Intertidal zone

The **intertidal** (ihn tur TY dul) **zone** is a narrow band where the ocean meets land. Organisms that live in this zone must be adapted to the constant changes that occur as daily tides and waves alternately submerge and expose the shore. The intertidal zone is further divided into vertical zones, as illustrated in **Figure 23.**

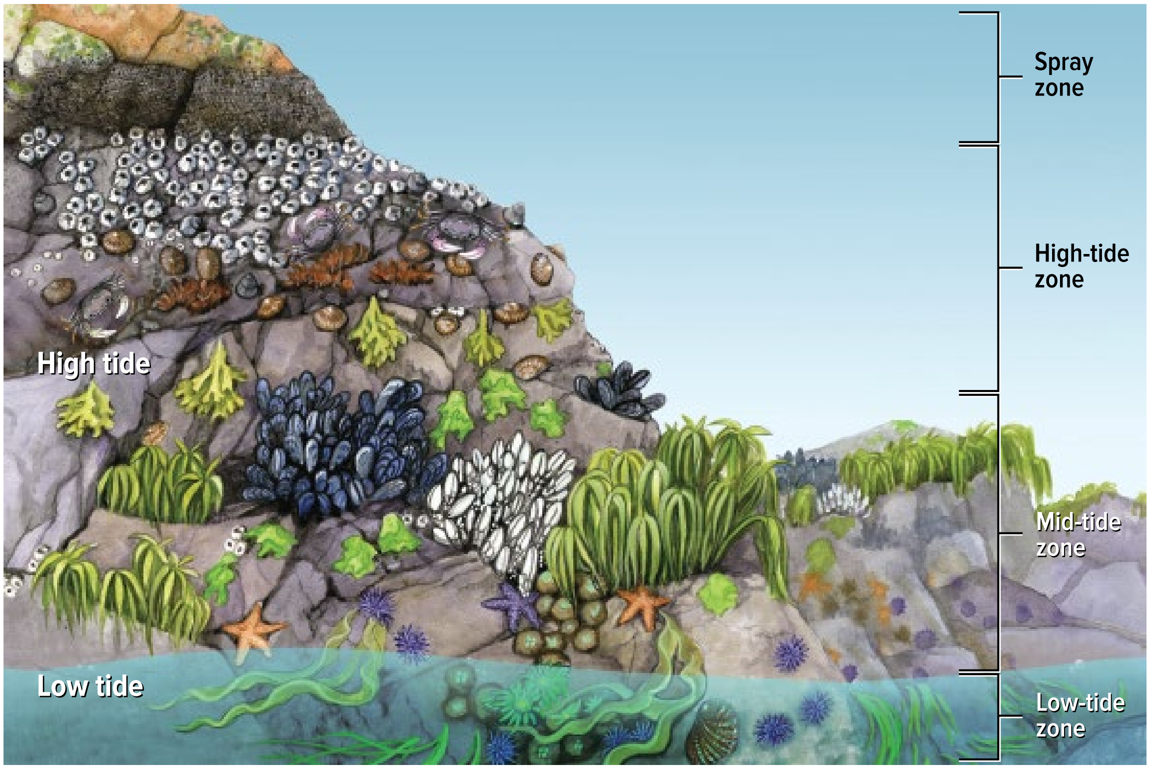


Figure 23 The intertidal zone is further divided into zones where different communities exist.
Compare and contrast *the zones illustrated in* ***Figures 22*** *and* ***23****.*

The area of the spray zone is dry most of the time. It is only during high tides that this part of the shoreline is sprayed with salt water, and few plants and animals are able to live in this environment. The high-tide zone is under water only during high tides. However, this area receives more water than the spray zone, so more plants and animals are able to live there.

The mid-tide zone undergoes severe disruption twice a day as the tides cover and uncover the shoreline with water. Organisms in this area must be adapted to long periods of air and water. The low-tide zone is covered with water unless the tide is unusually low, and is the most populated area of the intertidal zone.

Get It?

Describe environmental variation in intertidal zones.

Open ocean ecosystems

As illustrated in **Figure 24** on the next page, the zones in the open ocean include the pelagic (puh LAY jihk) zone and benthic zone. All the water in the open ocean that is not in the intertidal zone or very near the bottom is considered to be the **pelagic zone.**

The area to a depth of about 200 m of the pelagic zone is the **photic zone,** also called the euphotic zone. The photic zone is shallow enough that sunlight is able to penetrate. As depth increases, light decreases. Autotrophic organisms in the photic zone include surface seaweeds and plankton. Animals in the photic zone include many species of fish, sea turtles, jellyfish, whales, and dolphins. Many of these animals feed on plankton, but others feed on larger species.

Below the photic zone lies the **aphotic zone,** an area where sunlight is unable to penetrate. This region of the pelagic zone remains in constant darkness and generally is cold, but there is thermal layering with a mixing of warm and cold ocean currents. Organisms that depend on light energy to survive cannot live in the aphotic zone.

The deepest region of the pelagic zone is often referred to as the **abyssal zone.** The abyssal zone generally includes areas at depths greater than 4,000 m. Water in such areas is very cold. Most organisms in this zone rely on food materials that drift down from the zones above. However, on the seafloor along the boundaries of Earth's plates, hydrothermal vents spew large amounts of hot water, hydrogen sulfide, and other minerals. In these locations scientists have found bacterial communities that can use the sulfide molecules for energy. These organisms are at the bottom of a food chain that includes invertebrates, such as clams and crabs, and vertebrates, such as fishes.

WORD ORIGIN

photic
comes from the Greek word *photos*, meaning *light*.

ACADEMIC VOCABULARY

constant
occurring all of the time or continually
There is a constant flow of cars on the highway.

The **benthic zone** is the area along the ocean floor that consists of sand, silt, and dead organisms. In shallow benthic zones, sunlight can penetrate to the bottom of the ocean floor. As depth increases, light and temperature decrease. Species diversity tends to decrease with depth, except in areas with hydrothermal vents, where shrimp, crabs, and many species of tubeworms are found. Many species of fishes, octopuses, and squids live in the benthic zone.

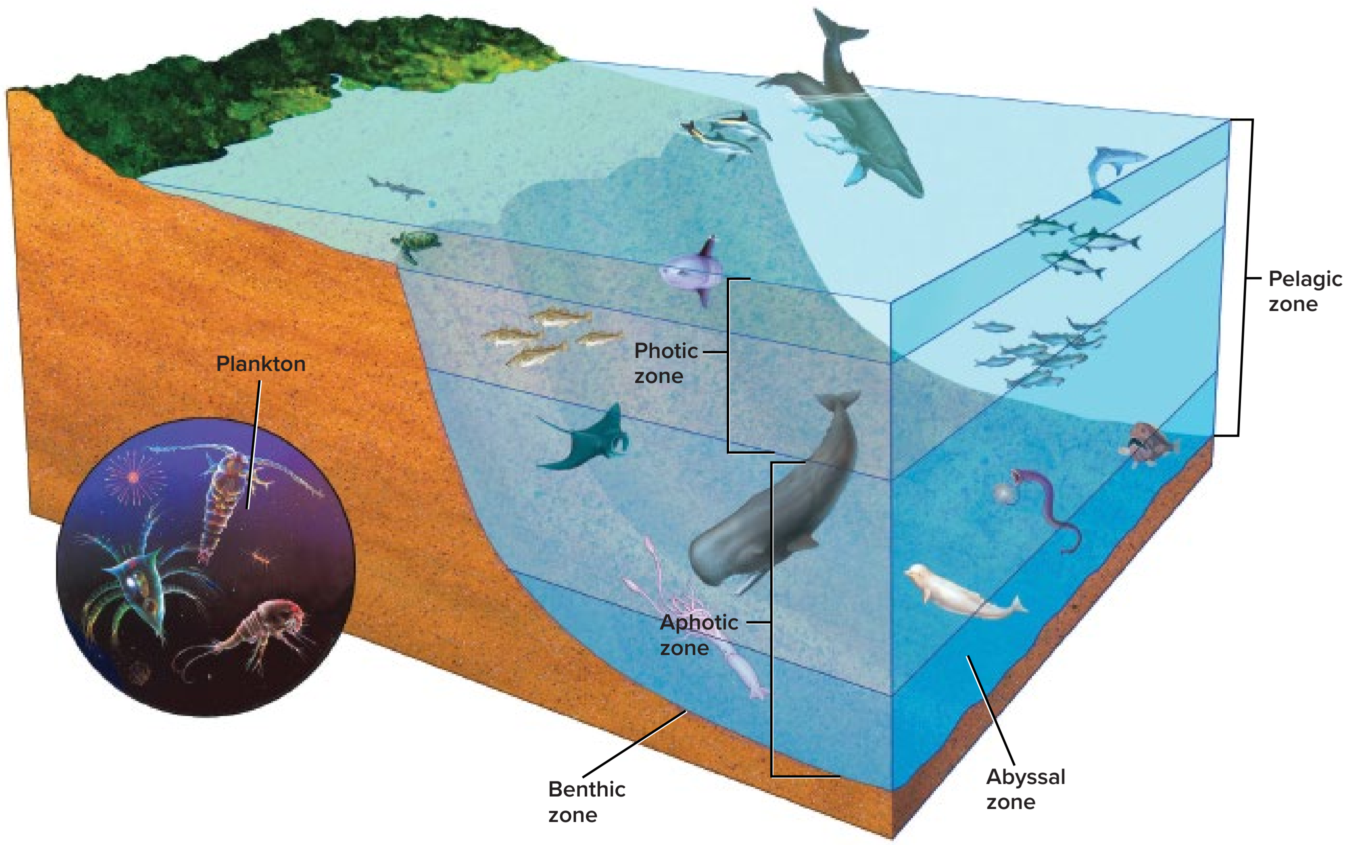


Figure 24 Producers are found mainly in the photic zone. Consumers live in the pelagic (photic and aphotic) and benthic zones.

Coastal ocean and coral reefs

One of the world's largest coral reefs is off the southern coast of Florida. Coral reefs are among the most diverse ecosystems. They are widely distributed in warm shallow marine waters. Coral reefs form natural barriers along continents that protect shorelines from erosion. The dominant organisms in coral reefs are corals. When you think of coral, you might picture a hard, stony structure, but this is only the framework secreted by tiny animal polyps. Corals are soft-bodied invertebrates that live in the stonelike structures.

Most coral polyps have a symbiotic relationship with algae called zooxanthellae (zoo uh zan THEL uh). These algae provide corals with food, and in turn, the coral provides protection and access to light for the algae. Corals also feed by extending tentacles to obtain plankton from the water. Other coral reef animals include species of microorganisms, sea slugs, octopuses, sea urchins, sea stars, and fishes.

Figure 25 Coral reefs off the southern tip of Florida are among the world's largest and most diverse reefs.

Figure 25 shows only a small portion of the diversity of Florida's coral reefs.

Like all ecosystems, coral reefs are sensitive to changes in the environment. Changes that are the result of naturally occurring events, such as increased sediment from a tsunami, can cause the death of a reef.

Human activities, such as land development and harvesting for calcium carbonate, can also damage or kill a coral reef. The increase in atmospheric carbon dioxide (CO_2) indirectly affects coral reefs. As seawater absorbs more CO_2 the pH of the water decreases, making the water more acidic. This can reduce the availability of the calcium carbonate minerals which coral polyps use to build their hard protective structure. Today, ecologists monitor reefs and reef environments to help protect these delicate ecosystems.

Transitional Aquatic Ecosystems

In many areas, aquatic ecosystems do not look like a stream, a lake, a pond, or even an ocean. In fact, many aquatic environments are a combination of two or more different environments.

Ecologists refer to these areas as transitional aquatic ecosystems, areas where land and water or salt water and freshwater intermingle. Wetlands and estuaries are common examples of transitional aquatic ecosystems.

Wetlands

Areas of land such as marshes, swamps, and bogs that are saturated with water and that support aquatic plants are called **wetlands.** Plant species that grow in the moist, humid conditions of wetlands include duckweed, pond lilies, cattails, sedges, mangroves, cypress, and willows. Bogs, like the one in **Figure 26,** are wet and spongy areas of decomposing vegetation that also support many species of organisms.

Wetlands have high levels of species diversity. Many amphibians, reptiles, birds (such as ducks and herons), and mammals (such as raccoons and mink) live in wetlands.

Figure 26 Bogs are a type of wetland characterized by moist, decaying plant material.

Estuaries

An **estuary** (ES chuh wer ee) is an ecosystem that is formed where freshwater from a river or stream merges with salt water from the ocean. An estuary is a very important transitional ecosystem.

Estuaries are among the most diverse ecosystems, rivaled only by tropical rain forests and coral reefs. Estuaries are places of transition, from freshwater to saltwater and from land to sea, that are inhabited by a wide variety of species. Algae, seaweeds, and marsh grasses are the dominant producers. However, many animals, including a variety of worms, oysters, and crabs, depend on detritus for food. Detritus (dih TRY tus) is comprised of tiny pieces of organic material.

Figure 27 Salt-tolerant plants above the low-tide line dominate estuaries formed in temperate areas.

Infer *how an estuary would differ in a tropical area.*

Mangrove trees also can be found in tropical estuaries, such as the Everglades National Park in Florida, where they sometimes form swamps. Many species of marine fishes and invertebrates use estuaries as nurseries for their young. Ducks and other waterfowl depend on estuary ecosystems for nesting, feeding, and migration rest areas. **Figure 27** shows the salt-tolerant plants that live in an estuary.

Salt marshes are a habitat type found within estuaries. Salt-tolerant grasses dominate above the low-tide line, and seagrasses grow in submerged areas of salt marshes. Salt marshes support different species of animals, such as shrimp and shellfish.

Check Your Progress

Summary

- Freshwater ecosystems include ponds, lakes, streams, rivers, and wetlands.
- Marine ecosystems are divided into zones that are classified according to abiotic factors.
- Estuaries and coral reefs are among the most diverse of all ecosystems.
- Wetlands and estuaries are transitional aquatic ecosystems.

Demonstrate Understanding

1. **List** the abiotic factors that are used to classify aquatic ecosystems.
2. **Describe** how water quality changes from the source of a river to the mouth.
3. **Explain** how the salinity (salt concentration) of an estuary affects the kinds of organisms that live there.

Explain Your Thinking

4. **Infer** how autotrophs in the abyssal zone of the ocean are different from those of the photic zone.
5. **Explain** how light, depth, and temperature affect the number and type of organisms that live in each ocean zone.
6. **Describe**, based on the information in this lesson and your acquired knowledge, some ways that human activities are affecting aquatic ecosystems. Propose strategies that individuals can use and governments can implement that would prevent or reduce these human impacts.

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SCIENCE & SOCIETY

Out on a Limb

The vast Amazon rainforest covers about 7.8 million km^2 of land in South America, spanning the borders of Brazil, Peru, Bolivia, Venezuela, and Columbia. Trees that grow in the Amazon remove enormous amounts of carbon dioxide from the atmosphere during photosynthesis. Rainforests store this carbon, helping to slow climate change. Of all the carbon on Earth stored by terrestrial plants, 17 percent is found in the Amazon rainforest. Half of that carbon is concentrated in just 150 species of the Amazon's estimated 16,000 species of trees. That's a mere one percent of the tree species in the rainforest. What happens to Earth's climate when these key tree species are destroyed?

Cattle ranching is one of the causes of deforestation.

Threats to the Rainforest

For decades human activities have caused large-scale deforestation in the Amazon. These activities include logging, pollution, forest fires, building roads, and clearing land for farms and cattle ranches. Droughts also contribute to deforestation.

Some scientists estimate that as much as 57 percent of the Amazon's tree species might be classified as threatened by 2050. Of the five tree species that store the most carbon in the Amazon, two are listed as vulnerable by the International Union for Conservation of Nature, including the Brazil nut tree.

Consequences of Deforestation

If these predictions are correct, large portions of the Amazon rainforest may soon cease to exist. When trees die, they have a double effect on levels of atmospheric carbon dioxide: they release carbon dioxide into the atmosphere as they decay and they no longer remove carbon dioxide from the atmosphere during photosynthesis.

CONSTRUCT AN ARGUMENT FROM EVIDENCE

Brainstorm ideas about how people can stop deforestation in the Amazon rainforest. Write several paragraphs summarizing your ideas, using evidence from the feature to explain why stopping deforestation is necessary.

MODULE 3
STUDY GUIDE

GO ONLINE to study with your Science Notebook.

Lesson 1 COMMUNITY ECOLOGY

- A biological community is a group of interacting populations that occupy the same area at the same time.
- Ecological succession occurs when one community replaces another as a result of changing abiotic and biotic factors.
- Primary succession occurs on areas of exposed rock or bare sand (no soil).
- Communities progress until there is little change in the composition of species.
- Secondary succession occurs as a result of a disturbance in a mature community.

- community
- ecological succession
- primary succession
- climax community
- secondary succession

Lesson 2 TERRESTRIAL BIOMES

- Two major abiotic factors, latitude and climate, determine terrestrial biomes.
- Latitude affects terrestrial biomes because of the different angles at which sunlight strikes Earth.
- Latitude, elevation, ocean currents, and other abiotic factors determine climate.
- There are nine major terrestrial biomes.
- There are two additional terrestrial regions, mountains and polar regions, that do not fit into these major categories.
- Terrestrial biomes are defined primarily by the characteristics of their plants.

- weather
- latitude
- climate
- tundra
- boreal forest
- temperate forest
- woodland
- grassland
- desert
- tropical savanna
- tropical seasonal forest
- tropical rain forest

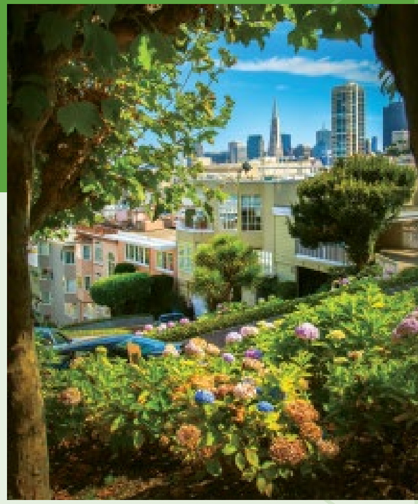
Lesson 3 AQUATIC ECOSYSTEMS

- Freshwater ecosystems include ponds, lakes, streams, rivers, and wetlands.
- Marine ecosystems are divided into zones that are classified according to abiotic factors.
- Estuaries and coral reefs are among the most diverse of all ecosystems.
- Wetlands and estuaries are transitional aquatic ecosystems.

- sediment
- littoral zone
- limnetic zone
- plankton
- profundal zone
- intertidal zone
- pelagic zone
- photic zone
- aphotic zone
- abyssal zone
- benthic zone
- wetlands
- estuary

THREE-DIMENSIONAL THINKING

Module Wrap-Up



REVISIT THE PHENOMENON

Why would you grow a garden in a city?

CER Claim, Evidence, Reasoning

Explain your Reasoning Revisit the claim you made when you encountered the phenomenon. Summarize the evidence you gathered from your investigations and research and finalize your Summary Table. Does your evidence support your claim? If not, revise your claim. Explain why your evidence supports your claim.

STEM UNIT PROJECT

Now that you've completed the module, revisit your STEM unit project. You will summarize your evidence and apply it to the project.

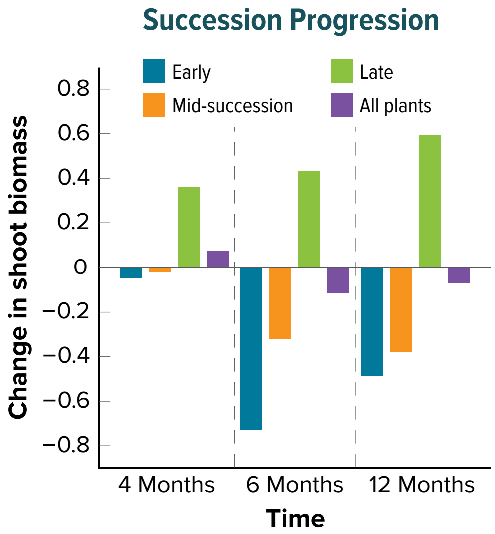
GO FURTHER

SEP Data Analysis Lab

How do soil invertebrates affect secondary succession in a grassland environment?

An experiment was performed by adding soil invertebrates to controlled grassland communities. The growth of various plants was measured at four months, six months, and twelve months. Growth was measured by recording shoot biomass—the mass of the grass stems.

Data and Observations The bars on the graph indicate the change in the biomass of the plants over time.



*Data obtained from: De Deyn, G.B. et al. 2003. Soil invertebrate fauna enhances grassland succession and diversity. *Nature* 422: 711–713.

CER Analyze and Interpret Data

1. **Infer** what a negative value of change in shoot biomass indicates.
2. **Claim, Evidence, Reasoning** Generalize which communities were most positively affected and which were most negatively affected by the addition of soil invertebrates.

MODULE 4
POPULATION ECOLOGY

blickwinkel/Alamy

POPULATION ECOLOGY

ENCOUNTER THE PHENOMENON

Why are bee populations declining?

GO ONLINE to watch a video about the impact of global resource consumption on populations.

SEP Ask Questions

Do you have other questions about the phenomenon? If so, add them to the driving question board.

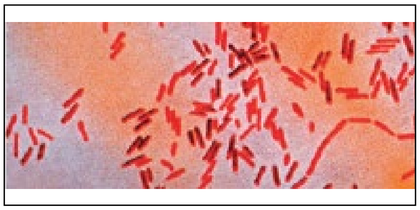
CER Claim, Evidence, Reasoning

Make Your Claim Use your CER chart to make a claim about the impacts of global resource consumption on populations. Explain your reasoning.

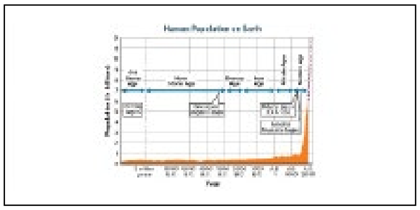
Collect Evidence Use the lessons in this module to collect evidence to support your claim. Record your evidence as you move through the module.

Explain Your Reasoning You will revisit your claim and explain your reasoning at the end of the module.

GO ONLINE to access your CER chart and explore resources that can help you collect evidence.



LESSON 1: Explore & Explain: Population Characteristics



LESSON 2: Explore & Explain: Human Population Growth

Smithsonian

Additional Resources

(t)Video Supplied by BBC Worldwide Learning; (b)Courtesy of the CDC

LESSON 1

POPULATION DYNAMICS

FOCUS QUESTION

What are characteristics of populations and how are they determined?

Population Characteristics

All species occur in groups called populations. There are certain characteristics that all populations have, such as population density, spatial distribution, and growth rate. These characteristics are used to classify all populations of organisms, including bacteria, animals, and plants.

Population density

One characteristic of a population is its **population density,** which is the number of organisms per unit area. For example, the population density of cattle egrets, shown with the Cape buffalo in **Figure 1**, is greater near the buffalo than farther away. Near the Cape buffalo, there might be three birds per square meter. Fifty meters from the Cape buffalo, the density of birds might be zero.

Maggy Meyer/Shutterstock.com

Figure 1 The population density of the cattle egrets is greater near the Cape buffalo.
Suggest *the type of dispersion you would expect these birds to have.*

3D THINKING   DCI Disciplinary Core Ideas   CCC Crosscutting Concepts   SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

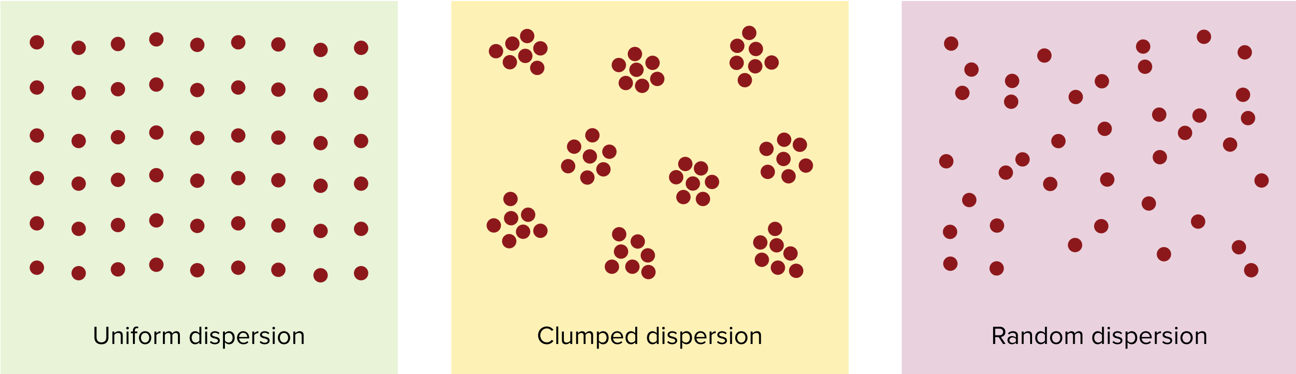
Applying Practices: Local Ecosystem Dynamics
HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

Figure 2 Visualizing Population Characteristics

Black Bear	American Bison	White-tailed Deer

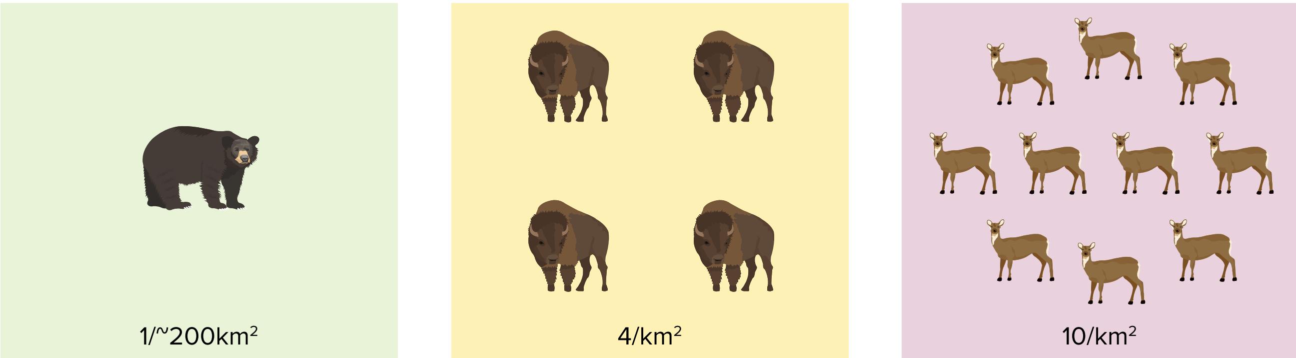
Spatial distribution

The pattern of spacing of a population within an area; one of the primary factors in the pattern of dispersion for all organisms is the availability of resources such as food.



Population density

The number of organisms per unit area; can be calculated by dividing the number of organisms in the population by the area the population occupies.



Population range

Some species have a very limited population range, or distribution. Other species have a vast distribution. A species might not be able to expand its population range because it cannot survive the abiotic conditions found in the expanded region.

Spatial distribution

Another characteristic of a population is called **dispersion**—the pattern of spacing of a population within an area. **Figure 2** on the previous page shows the three main types of dispersion—uniform, clumped, and random. Black bears are typically dispersed in a uniform arrangement. American bison are dispersed in clumped groups or herds. White-tailed deer are dispersed randomly with unpredictable spacing. The availability of resources such as food and water is one of the main determinants of spatial distribution of a population within its ecosystem.

Population ranges

No population, not even the human population, occupies all habitats in the biosphere. Some species, such as the Hawaiian honeycreeper shown in **Figure 3**, have a very limited population range, or distribution. This songbird is found only on some of the islands of Hawaii. Other species, such as the peregrine falcon shown in **Figure 3**, have a vast distribution. Peregrine falcons are found on all continents except Antarctica. Note the ranges of the animals in **Figure 2.**


Hawaiian honeycreeper


Peregrine falcon

Figure 3 The Hawaiian honeycreeper lives only on some of the Hawaiian islands. The peregrine falcon is found worldwide.

CCC CROSSCUTTING CONCEPTS

Scale, Proportion, and Quantity The coyote lives in almost every habitat in California, with the exception of major city centers. The Department of Fish and Wildlife estimates a population of between 250,000 and 750,000 animals. Why do you think that the estimate is such a wide range of values? Find the area of the state and then determine the range of the estimated population density. What evidence would be needed to determine a more accurate estimate of the coyote population density? Debate with your classmates whether coyotes are a pest or simply just another wild animal looking for suitable habitat.

You may have learned that organisms adapt to the biotic and abiotic factors in their environment. A species might not be able to expand its population range because it cannot survive the abiotic conditions found in the expanded region. A change in temperature range, humidity level, annual rainfall, or sunlight might make a new geographic area uninhabitable for the species. In addition, biotic factors, such as predators, competitors, and parasites, present threats that might make the new location difficult for survival.

Get It?

Describe two reasons why a species might not be able to expand its range.

Population-Limiting Factors

Limiting factors are biotic or abiotic factors that keep a population from continuing to increase indefinitely. Decreasing a limiting factor, such as the available food supply, often changes the number of individuals that are able to survive in a given area. In other words, if the food supply increases a larger population might result, and if the food supply decreases a smaller population would likely result.

Density-independent factors

Any factor in the environment that does not depend on the number of members in a population per unit area is a **density-independent factor.** These factors usually are abiotic and include natural phenomena such as weather events. Weather events that limit populations include drought or flooding, extreme heat or cold, tornadoes, hurricanes, or fires (as shown in **Figure 4**).

Crown fire damage | Managed ground fire damage

Figure 4 A crown fire is a density-independent factor that can limit population growth. However, small ground fires can promote growth in a forest community.

Explain *why these two situations involving fire have different results on the tree populations.*

STEM CAREER Connection

Population Biologist

Why is it important to know the characteristics, such as size, growth, and distribution, of populations? How would you study a population to determine these characteristics? Would you like a job that requires you to be in the field studying organisms in their natural habitat? If these questions interest you, you might be a future population biologist. Population biologists use their findings to predict the future of populations and determine what can be done to lessen negative impacts.

ACADEMIC VOCABULARY

dominant

more powerful, successful, or in control than something else

The hand with which you write and do most other tasks is called your dominant hand.

Figure 4 on the last page shows an example of the effects that fire can have on a population. The ponderosa pines have been damaged by a crown fire, a fire that advances to the tops of the trees. In this example, the fire limits the population of ponderosa trees by killing many of the trees. However, smaller but more frequent ground fires have the opposite effect on the population. By thinning lower growing plants that use up nutrients, a healthier population of mature ponderosa pines is produced.

Populations can be limited by the results of human interference. For example, over the last 100 years, building dams and other human activities on the Colorado River have significantly reduced the river's water flow and changed its temperature. In addition, the introduction of nonnative fish species altered the river's biotic factors. Because of the changes in the river, the number of small fish called humpback chub was reduced. During the 1960s, the number of humpback chub dropped so low that they were in danger of disappearing from the Colorado River altogether. Air, land, and water pollution are the result of human activities that also can limit populations. Pollution reduces the available resources by making some of the resources toxic.

Density-dependent factors

Any factor in the environment that depends on the number of members in a population per unit area is a **density-dependent factor.** Density-dependent factors are often biotic factors such as predation, disease, competition, and parasites.

Predation A study of density-dependent factors was done on the wolf and moose populations in northern Michigan on Isle Royale, located in Lake Superior. The results of this study are shown in **Figure 5**.

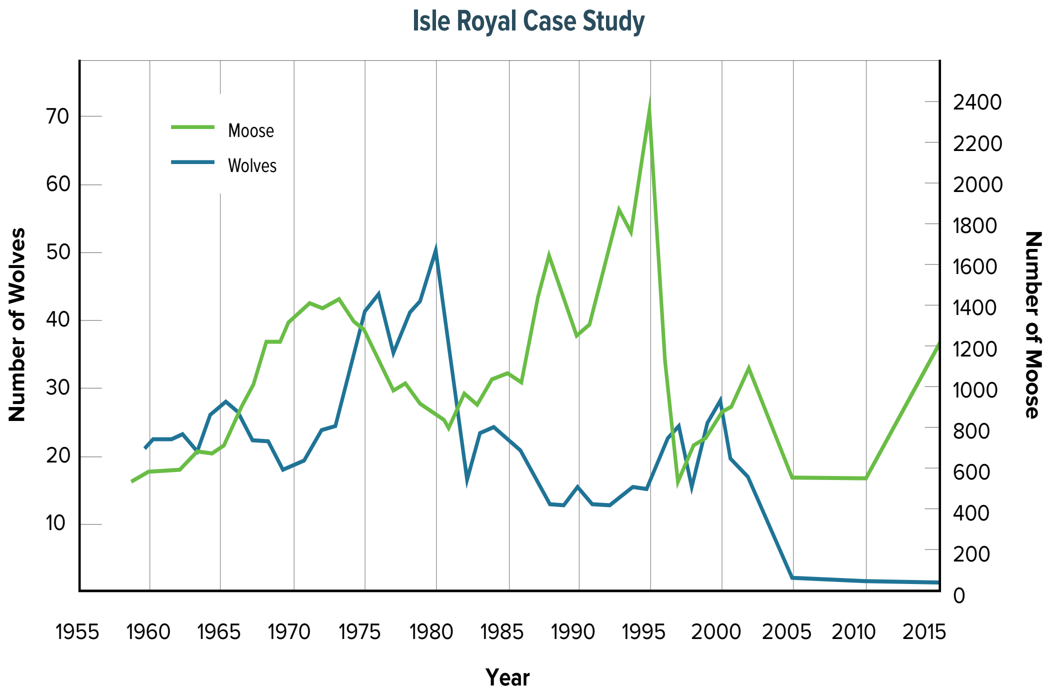


Figure 5 The long-term study of the wolf and moose populations on Isle Royale shows the relationship between the number of predators and prey over time.

Infer *what might have caused the increase in the number of moose between 1990 and 1995.*

Prior to the winter of 1947–48 there were apparently no wolves on Isle Royale. During that winter, a single pair of wolves crossed the ice on Lake Superior, reaching the island. During the next ten years the population of wolves reached about twenty individuals. Notice that the graph in **Figure 5** on the previous page shows that the rise and fall of the numbers of each group was dependent on the other group. For example, follow the wolves' line on the graph. As the number of wolves decreased, the number of moose increased.

Disease Another density-dependent factor is disease. Outbreaks of disease tend to occur when population size has increased and population density is high. When population density is high, disease is transmitted easily from one individual to another because contact between individuals is more frequent. Therefore, the disease spreads easily and quickly through a population. This is just as true for human populations as it is for populations of protists, plants, and other species of animals.

Competition Competition between organisms also increases when density increases. When the population increases to a size where resources such as food or space become limited, individuals in the population must compete for the available resources. Competition can occur within a species or between two different species that use the same resources. For example, the foxes fighting over the squirrel in **Figure 6** also compete with other species, such as coyotes, for the same food source.

Figure 6 A decrease in the food supply can trigger competition between members of the same species.

Roberta Olenick/All Canada Photos/Getty Images

Competition for insufficient resources might result in a decrease in population density in an area due to starvation or to individuals leaving the area in search of additional resources. As the population size decreases, competition becomes less severe.

Parasites Like disease, parasitic organisms can place limits on a population. The presence of parasites is a density-dependent factor that can negatively affect population growth at higher densities.

Population growth rate

An important characteristic of any population is its growth rate. The **population growth rate** (PGR) explains how fast a given population grows. One of the characteristics of the population ecologists must know, or at least estimate, is natality. The natality of a population is the birthrate, or the number of individuals born in a given time period. Ecologists also must know the mortality—the number of deaths that occur in the population during a given time period.

The number of individuals emigrating or immigrating also is important. **Emigration** (em uh GRAY shun) is the term ecologists use to describe the number of individuals moving away from a population.

Immigration (ih muh GRAY shun) is the term ecologists use to describe the number of individuals moving into a population. In most instances, emigration is about equal to immigration. Therefore, natality and mortality usually are the most important factors in determining the population growth rate.

Some populations tend to remain approximately the same size from year to year. Other populations vary in size depending on conditions within their habitats. To better understand why populations grow in different ways, you should understand two mathematical models for population growth—the exponential growth model and the logistic growth model.

Exponential growth model

Look at **Figure 7** to see how a population of mice would grow if there were no limits placed on it by the environment.

Assume that two adult mice breed and produce a litter of two young. Also assume the two offspring are able to reproduce in one month. If all of the offspring survive to breed, the population grows slowly at first. This slow growth period is defined as the lag phase. The rate of population growth soon begins to increase rapidly because the total number of organisms that are able to reproduce has increased. After only two years, the experimental mouse population would reach more than three million mice.

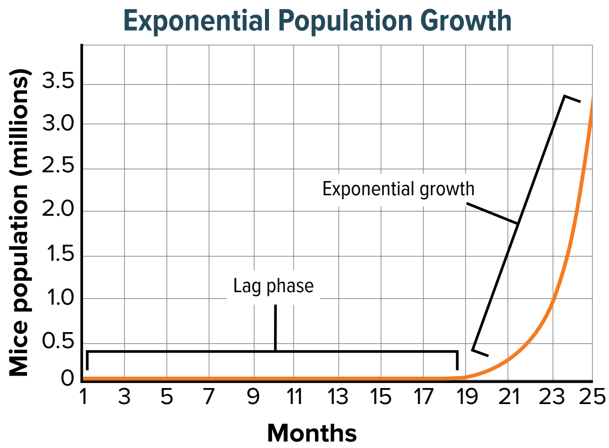


Figure 7 If mice were allowed to reproduce unhindered, the population would grow slowly at first but would accelerate quickly.

Infer *why mice or other populations do not continue to grow exponentially.*

MATH Connection Notice in **Figure 7** that once the mice begin to reproduce rapidly, the graph becomes J-shaped. A J-shaped growth curve illustrates exponential growth. Exponential growth, also called geometric growth, occurs when the growth rate is proportional to the size of the population. All populations grow exponentially until some limiting factor slows the population's growth. It is important to recognize that even in the lag phase, the use of available resources is exponential. Because of this, the resources soon become limited and population growth slows.

Logistic growth model

Most populations grow like the model shown in **Figure 8** rather than the model shown in **Figure 7**. Notice that the graphs look exactly the same through some of the time period: the number of individuals begins very low, then increases very rapidly. During this period, competition for resources among individuals in the population is low.

The second graph, however, curves into the S-shape typical of logistic growth. Population growth stops increasing when an environment's carrying capacity has been reached.

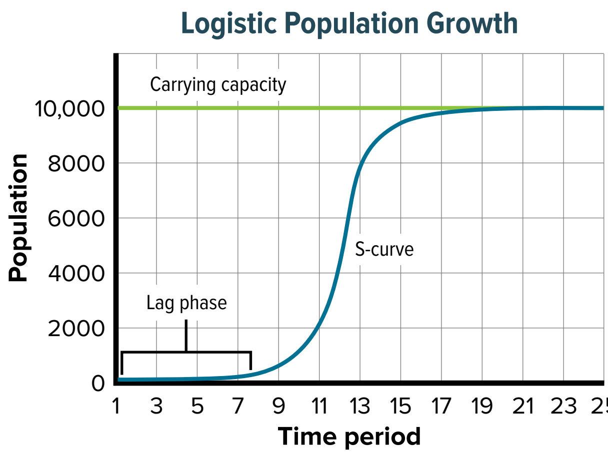


Figure 8 When a population exhibits growth that results in an S-shaped graph, it exhibits logistic growth. The population levels off at a limit called the carrying capacity.

Carrying capacity Ecosystems have limits to the numbers of organisms and populations they can support. The maximum number of individuals in a species that an environment can support for the long term is the **carrying capacity.** You will notice in **Figure 8** on the last page that logistic growth levels off at the line on the graph identified as the carrying capacity.

Carrying capacity is limited by such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. When populations develop in an environment with plentiful resources, there are more births than deaths. The population soon reaches or passes the carrying capacity. As a population nears the carrying capacity, resources become limited.

If a population exceeds the carrying capacity, deaths outnumber births because adequate resources are not available to support all of the individuals. The population then falls below the carrying capacity as individuals die. The concept of carrying capacity is used to explain why many populations tend to stabilize.

Reproductive patterns

The graph in **Figure 8** shows the number of individuals increasing until the carrying capacity is reached. The graph is a useful population model, and can be used to predict how a population's number might change over time.

However, there are several additional factors that must be considered for real populations. Species of organisms vary in the number of births per reproduction cycle, in the age that reproduction begins, and in the life span of the organism. Both plants and animals are placed into groups based on their reproductive factors. However, not all organisms fit under a specific reproductive strategy.

Members of one of the groups are called the *r*-strategists. The rate strategy, or *r*-strategy, is an adaptation for living in an environment where fluctuation in biotic or abiotic factors occur. Fluctuating factors might be availability of food, changing temperatures, or migrating animals. An *r*-strategist is generally a small organism such as a fruit fly, a mouse, or the locusts shown in **Figure 9**. *r*-strategists usually have short life spans and produce many offspring.

The reproductive strategy of an *r*-strategist is to produce as many offspring as possible in a short time period in order to take advantage of some environmental factor. Organisms classified as *r*-strategists typically expend little or no energy in raising their young to adulthood. Populations of *r*-strategists are usually controlled by density-independent factors, and they usually do not maintain a population near the carrying capacity.

Figure 9 Locusts, which are an example of *r*-strategists, produce many offspring in their short lifetimes.

Infer *what specific factors might fluctuate in a locust's environment.*

Just as some environments fluctuate, others are fairly predictable. The elephants in **Figure 10** experience a carrying capacity that changes little from year to year. The carrying-capacity strategy, or *k*-strategy, is an adaptation for living in environments that are fairly stable.

A *k*-strategist generally is a larger organism that has a long life span, produces few offspring, and whose population reaches equilibrium at the carrying capacity.

Figure 10 Elephants are *k*-strategists that produce few offspring, but they invest a lot of care in the raising of their offspring.

The reproductive strategy of a *k*-strategist is to produce only a few offspring that have a better chance of living to reproductive age because of the energy, resources, and time invested in the care for the young. The number of individuals in a population of *k*-strategists usually are controlled by density-dependent factors and not by density-independent factors. For example, a ten-degree change in temperature might be enough to drastically reduce the number of locusts in a population, but it would not likely influence the number of elephants in a population.

Check Your Progress

Summary

- There are population characteristics that are common to all populations of organisms, including plants, animals, and bacteria.
- Populations tend to be distributed randomly, uniformly, or in clumps.
- Population-limiting factors are either density-independent or density-dependent.
- Populations tend to stabilize near the carrying capacity of their environment.

Demonstrate Understanding

1. **Compare and contrast** spatial distribution, population density, and population growth rate.
2. **Summarize** the concepts of carrying capacity and limiting factors, and their effects on reproductive patterns.
3. **Sketch** diagrams showing population dispersion patterns.
4. **Analyze** the impact a nonnative species might have on a native species in terms of population dynamics.

Explain Your Thinking

5. **Design** an experiment that you could perform to determine which population growth model applies to fruit fly populations.
6. **WRITING Connection** Write a newspaper article describing how a weather event, such as drought, has affected a population of animals in your community.

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HUMAN POPULATION

FOCUS QUESTION

What factors affect human population growth?

Human Population Growth

The study of human population size, density, distribution, movement, and birth and death rates is **demography** (de MAH gra fee). The graph in **Figure 11** shows demographers' estimated human population on Earth for several thousand years.

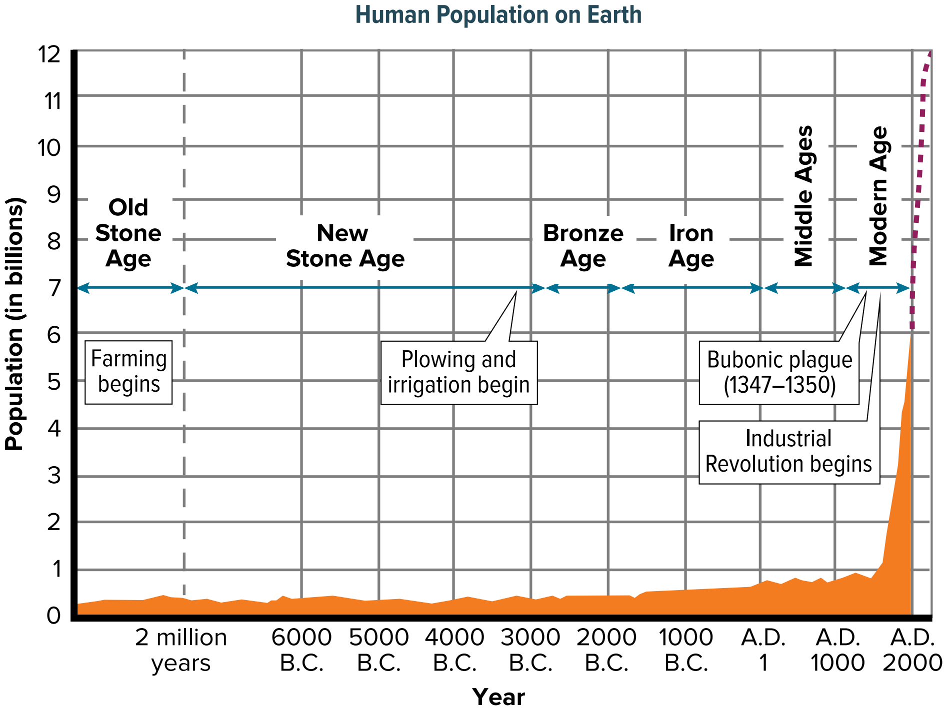


Figure 11 The human population on Earth was relatively constant until recent times, when the population began to grow at an exponential rate.

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

BioLab: How can you show a population trend?
Plan and carry out an investigation to determine the cause and effect of population trends.

Quick Investigation: Evaluate Factors
Analyze and interpret data to determine the factors that affect population growth.

Notice **Figure 11** on the last page shows a relatively stable number of individuals over thousands of years—until recently. Notice also the recovery of the human population after the outbreak of the bubonic plague in the 1300s when an estimated one-third of the population of Europe died. Perhaps the most significant feature in this graph is the increase in the population in recent times. In 1804, the population of Earth was an estimated one billion people. Earth reached a milestone in 2011, when our population was recorded at seven billion people. With the current growth rate at just over 83 million people per year we are expected to reach a population of 9.8 billion by 2050.

Technological advances

For thousands of years, environmental conditions kept the size of the human population at a relatively constant number below the environment's carrying capacity. More recently, however, humans have altered the environment in ways that appear to have changed its carrying capacity. Agriculture and domestication of animals have increased the human food supply. Technological advances and medicine have improved the chances of human survival by reducing the number of deaths from parasites and disease. In addition, improvements in shelter have made humans less vulnerable to climatic impacts.

Get It?

Explain the factors that have contributed to an increase in the survival rate of the human population. Have these factors contributed to the homeostasis of the population within its enviroment? Explain.

Human population growth rate

Although the human population is still growing, the rate of its growth has slowed. **Figure 12** shows the percent increase in human population from the late 1940s through 2016. The graph also includes the projected population increase through 2050.

Notice the sharp dip in human population growth in the 1960s. This was due primarily to a famine in China in which about 60 million people died. The graph also shows that human population growth reached its peak at over 2.2 percent in 1963. By 2016, the percent increase in human population growth had dropped to less than 1.2 percent.

Population models predict the overall population growth rate to be below 0.6 percent by 2050. The decline in human population growth is due primarily to diseases such as AIDS and voluntary population control.

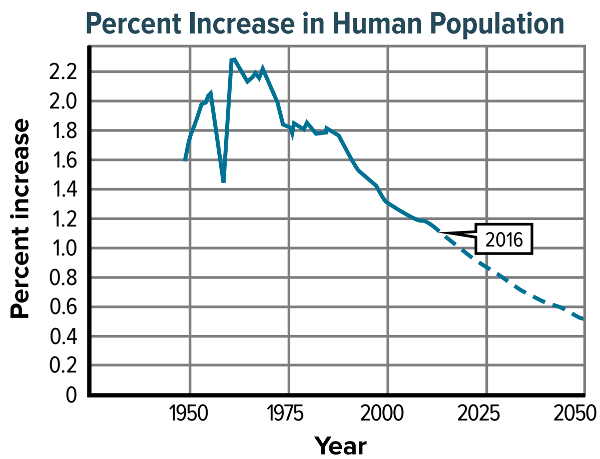


Figure 12 This graph shows the percent increase in the global human population using data from the late 1940s through 2016 and the projected percent increase to 2050.

Determine *the approximate population increase in the year 2025.*

Trends in Human Population Growth

The graph in **Figure 12** on the last page is somewhat deceptive. Population trends can be altered by events such as disease and war. **Figure 13** (next page) shows a few historical events that have changed population trends. **Figure 12** could also easily be misinterpreted because human population growth is not the same in all countries. However, population growth trends are often similar in countries that have similar economies.

For example, one trend that has developed during the previous century is a change in the population growth rate in industrially developed countries such as the United States. An industrially developed country is advanced in industrial and technological capabilities and has a population with a high standard of living. Criteria for determining developed countries include average national income, individual average health and education, and national export and import of goods.

In its early history, the United States had a high birthrate and a high death rate. It was not uncommon for people to have large families and for individuals to die by their early forties. Many children also died before reaching adulthood. Presently, the birthrate in the United States has decreased dramatically and the life expectancy is greater than seventy years. This change in a population from high birth and death rates to low birth and death rates is called a **demographic transition.**

MATH Connection How do population growth rates (PGR) compare in industrially developed countries and developing countries? As an example, we will compare the 2008 populations for the United States and Honduras, a small country in Central America. The calculation for PGR is

$$\frac{\text{birthrate} - \text{death rate} + \text{migration rate}}{10} = \text{PGR (\%)}$$

In our example, we'll have to divide the final answer by 10 to get a percentage because the rates are calculated per 1000. The United States has birthrate 14.1 (per 1000), death rate 8.3 (per 1000), and migration rate 2.9 (per 1000). This gives a PGR of 0.87 percent for the United States. Honduras has birthrate 26.9 (per 1000), death rate 5.4 (per 1000), and migration rate -1.3 (per 1000). This gives a PGR of 2.02 percent for Honduras.

Get It?

Compare the population growth rates in the United States and the United Kingdom, which has a birthrate of 12 (per 1000), death rate 8.8 (per 1000), and migration rate 2.5 (per 1000).

WORD ORIGINS

demography

demo– from the Greek word *demos*; meaning *people*

–ography from the French word *graphie*; meaning *writing*

Figure 13

History of Human Population Trends

Many factors have affected human population growth throughout history.

1 **1347-1351** The bubonic plague kills one-third of Europe's population and 75 million people throughout the world.

2 **1798** The first essay on human population is written by Thomas Malthus, who predicted exponential population growth leading to famine, poverty, and war.

3 **1800** The Industrial Revolution leads to a dramatic population explosion.

4 **1918** The Spanish flu kills between 50 and 100 million people.

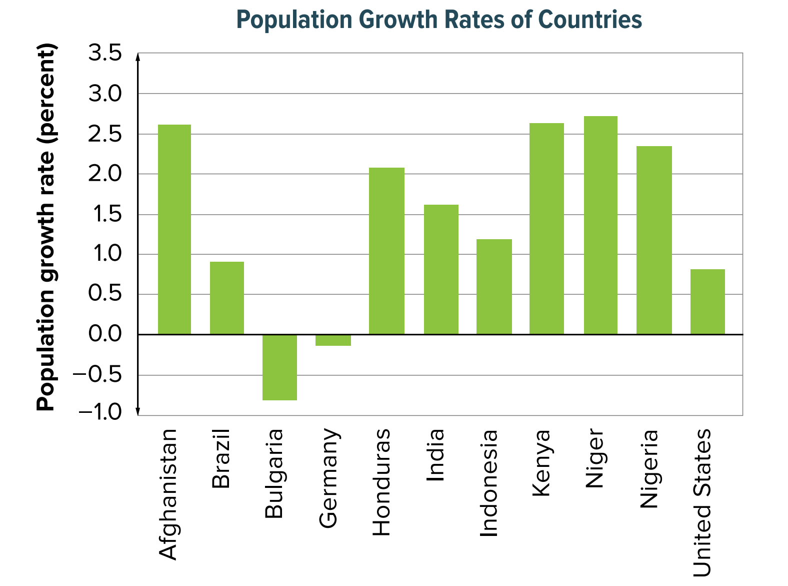
5 **1939-1945** Approximately 58 million people are killed during World War II.

6 **1954** Improved medical care, medicines, and sanitation leads to an increase in human population.

7 **2014** An estimated 1.2 million people die from AIDS-related causes.

Table 1 Population Growth Rates of Countries

Country	Population Growth Rate (percent)	Location
Afghanistan	2.63	
Brazil	0.98	
Bulgaria	–0.81	
Germany	–0.04	
Honduras	2.02	
India	1.58	
Indonesia	1.18	
Kenya	2.76	
Niger	2.88	
Nigeria	2.38	
United States	0.88	



Population growth models predict that the total number of people added to the world population in developing countries will be greater than the total number of people added in the industrially developed countries. For example, between now and 2050, the developing country Niger—shown in **Table 1**—will be one of the fastest growing countries. Assuming that the growth rate remains the same, its population is expected to expand from 13 to 53 million people. The industrially developed country Bulgaria is expected to have a population decline from seven to five million people in the same time period.

Zero population growth

Another trend that populations can experience is zero population growth. **Zero population growth** (ZPG) occurs when births plus immigration equals deaths plus emigration for a generation. This will mean that the population has stopped growing, because births and deaths occur at the same rate. Once the world population reaches ZPG, the age structure eventually should be more balanced with numbers at pre-reproductive, reproductive, and post-reproductive ages being approximately equal.

Zero population growth is a goal of many countries and societies. Many population planners and environmentalists believe that ZPG will contribute to the sustainability of Earth's ecosystems.

CCC CROSSCUTTING CONCEPTS

Scale, Proportion, and Quantity Carefully study the data presented in **Table 1.** Research to find the current population of each of these countries. Assuming that the growth rate remains the same, determine what the population of these countries will be in 10 years. Select a country that you think has a problematic trend and prepare a report for its government summarizing the population trend for the next decade. Use your evidence to identify potential problems and suggest solutions for these problems.

STUDY TIP

Interactive Reading As you read, write three questions about human population dynamics. The questions should begin with why, how, where, or when. Ask a partner the questions about the content in the module.

Age structure

Another important characteristic of any population is its age structure. A population's **age structure** is the number of males and females in each of three age groups: pre-reproductive stage, reproductive stage, and post-reproductive stage. Humans are considered to be pre-reproductive before age 20 even though they are capable of reproduction at an earlier age. The reproductive years are considered to be between 20 and 44, and the post-reproductive years are after age 44.

Analyze the age structure diagrams for three different representative countries in **Figure 14**. The age structure diagrams are typical of many countries in the world. Notice the shape of the overall diagram for a country that is rapidly growing, one that is growing slowly, and one that has reached negative growth. The age structure for the world's human population looks more like that of a rapidly growing country.

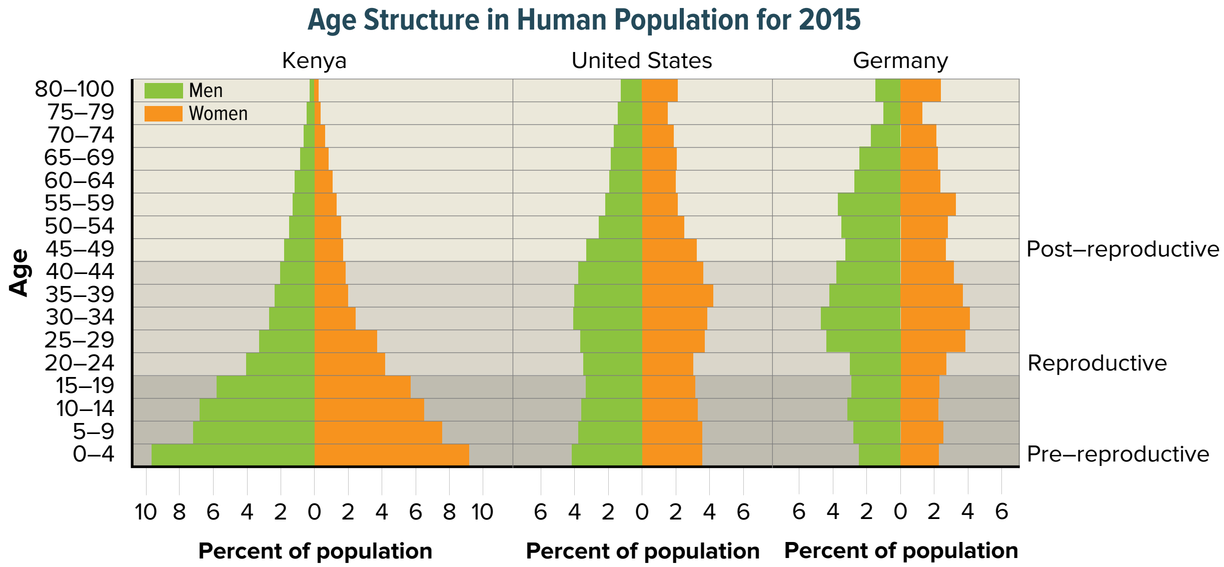


Figure 14 The relative numbers of individuals in pre-reproductive, reproductive, and post-reproductive years are shown for three representative countries.

Get It?

Compare and contrast the age structures of the countries shown in **Figure 14**.

Earth's carrying capacity for humans

Calculating population growth rates is not just a mathematical exercise. Scientists are concerned about the human population reaching or exceeding the carrying capacity. As you learned in Lesson 1, all populations are limited by the carrying capacity of their ecosystems, and the human population is no exception. Many scientists suggest that human population growth needs to be reduced. In many countries, voluntary population control is occurring through family planning. Unfortunately, if the human population continues to grow—as most populations do— and areas become overcrowded, disease and starvation will occur. However, technology has allowed humans to increase the carrying capacity of Earth, at least temporarily. It might be possible for technology and planning to keep the human population at or below Earth's carrying capacity.

Another important factor in keeping the human population at or below the carrying capacity is the amount of resources from the biosphere that are used by each person. Currently, individuals in industrially developed countries use far more resources than those individuals in developingv countries, as shown in **Figure 15**. This graph shows the estimated amount of land required to support a person through his or her life, including land used for production of food, forest products and housing, and the additional forest land required to absorb the carbon dioxide produced by the burning of fossil fuels. Countries such as India are becoming more industrialized, and they have a high growth rate. These countries are adding more people and are increasing their use of resources. At some point, the land needed to sustain each person on Earth might exceed the amount of land that is available. At that time the human population will likely have exceeded Earth's carrying capacity.

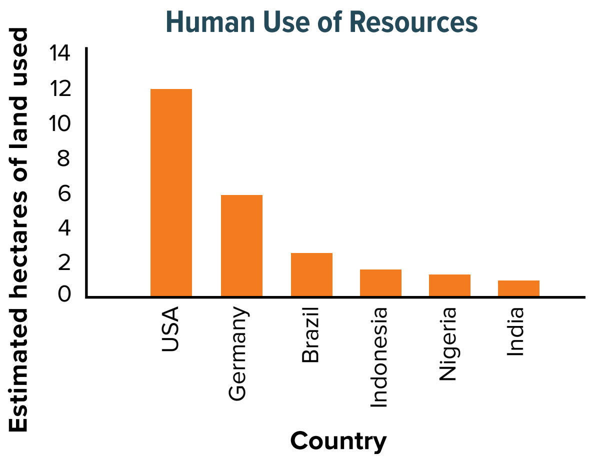


Figure 15 The amount of resources used per person varies around the world.

Check Your Progress

Summary

- Human population growth rates vary in industrially developing countries and industrialized countries.
- Zero population growth occurs when the birthrate and immigration rate of a population equals the death rate and the emigration rate.
- The age structure of the human population is a contributing factor to population growth in some countries.
- Earth has an undefined carrying capacity for the human population.

Demonstrate Understanding

1. **Describe** the change in human population growth over time.
2. **Describe** the differences between the age structure graphs of nongrowing, slowly growing, and rapidly growing countries.
3. **Assess** the consequences of exponential population growth of any population.
4. **Summarize** why the human population began to grow exponentially in the Modern Age.

Explain Your Thinking

5. **Analyze** how a newly emerging disease might affect the population size in an industrially developing and in an already developed country.
6. **MATH Connection** Construct an age-structure diagram using the following percentages: 0–19 years: 44.7; 20–44 years: 52.9; 45 years and over: 2.4. Which type of growth is this country experiencing?

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STEM AT WORK

As Easy (or Not) as 1, 2, 3

Biologists and other scientists often count populations of organisms as part of their work in the field. There are several different methods scientists can use to determine or estimate a population count.

In mark-recapture sampling, scientists often insert a passive integrated transponder into an animal to record information on its growth, movements, and survival.

Complete Counts, Sampling, and Indirect Counts

With a *complete count,* scientists count every member of a population. They can use an airplane to fly over a population and take photographs of its members, or they can walk across an area and count every population member they see. With *sampling*, scientists count a small number of population members and use that number to estimate the total population. With an *indirect count*, scientists count signs left by a population—such as scat, nests, and dens—instead of counting the actual members of the population.

Quadrat sampling is used with plant species, which do not move, or with animal species that move very slowly. Scientists count all members of a population in a specific area (called a quadrat) and then extrapolate to estimate the total population. In *transect sampling*, scientists "draw" lines across an area instead of marking off a quadrat. They walk the lines and count the plants or animals they see along the lines. They use those numbers to estimate the total population.

Mark-recapture

Mark-recapture is a sampling method used with animals. Scientists capture members of a population, tag them, and release them.

Later, scientists recapture population members. They count the number of untagged and already-tagged animals. They then use these numbers to determine a ratio (tagged to untagged animals) and extrapolate that to an estimation of the total population.

PLAN AND CONDUCT AN INVESTIGATION

Work with a partner to conduct a quadrat sampling population count on an area of one square meter. Record your data in a table. Discuss how to use your data to estimate the total population.

MODULE 4

STUDY GUIDE

GO ONLINE to study with your Science Notebook.

Lesson 1 POPULATION DYNAMICS

- There are population characteristics that are common to all populations of organisms, including plants, animals, and bacteria.
- Populations tend to be distributed randomly, uniformly, or in clumps.
- Population limiting factors are either density-independent or density-dependent.
- Populations tend to stabilize near the carrying capacity of their environment.

- population density
- dispersion
- density-independent factor
- density-dependent factor
- population growth rate (PGR)
- emigration
- immigration
- carrying capacity

Lesson 2 HUMAN POPULATION

- Human population growth rates vary in industrially developing countries and industrialized countries.
- Zero population growth occurs when the birthrate and immigration rate of a population equals the death rate and the emigration rate.
- The age structure of the human population is a contributing factor to population growth in some countries.
- Earth has an undefined carrying capacity for the human population.

- demography
- demographic transition
- zero population growth (ZPG)
- age structure

THREE-DIMENSIONAL THINKING

Module Wrap-Up

REVISIT THE PHENOMENON

Why are bee populations declining?

CER Claim, Evidence, Reasoning

Explain Your Reasoning Revisit the claim you made when you encountered the phenomenon. Summarize the evidence you gathered from your investigations and research and finalize your Summary Table. Does your evidence support your claim? If not, revise your claim. Explain why your evidence supports your claim.

STEM UNIT PROJECT

Now that you've completed the module, revisit your STEM unit project. You will summarize your evidence and apply it to the project.

GO FURTHER

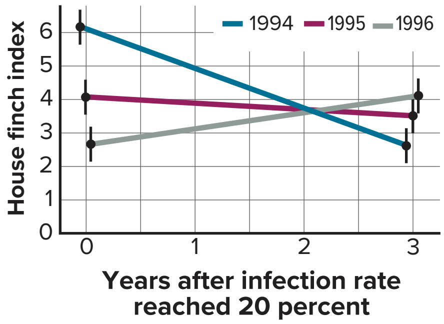
SEP Data Analysis Lab

Do parasites affect the size of a host population?

In 1994, the first signs of a serious eye disease caused by the bacterium *Mycoplasma gallisepticum* were observed in house finches that were eating in backyard bird feeders. Volunteers collected data at the beginning of three different years on the number of finches infected with the parasite and the total number of finches present.

Data and Observations The graph shows the abundance of house finches in areas where the infection rate was at least 20 percent of the house finch population. It also shows the changes in the population over the three years following the initial count.

House Finches and *Mycoplasma gallisepticum* Infection



*Data obtained from: Gregory, R., et al. 2000. Parasites take control. *Nature* 406: 33–34.

CER Analyze and Interpret Data

1. **Compare** the data from the three years.
2. **Claim, Evidence, Reasoning** Explain why the house finch abundance stabilized in 1995 and 1996.
3. **Infer** whether the parasite is effective in limiting the size of house finch populations. Explain.

blickwinkel/Alamy


Pat Canova/Alamy

MODULE 5

BIODIVERSITY AND CONSERVATION

ENCOUNTER THE PHENOMENON

What happens to this ecosystem if the river is destroyed?

GO ONLINE to watch a video about community interactions in an ecosystem.

SEP Ask Questions

Do you have other questions about the phenomenon? If so, add them to the driving question board.

CER Claim, Evidence, Reasoning

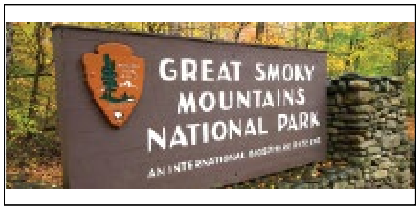
Make Your Claim Use your CER chart to make a claim about what happens to the ecosystem if the river is destroyed. Explain your reasoning.

Collect Evidence Use the lessons in this module to collect evidence to support your claim. Record your evidence as you move through the module.

Explain Your Reasoning You will revisit your claim and explain your reasoning at the end of the module.

GO ONLINE to access your CER chart and explore resources that can help you collect evidence.

LESSON 2: Explore & Explain: Extinction Rates



LESSON 3: Explore & Explain: Protecting Biodiversity

Smithsonian

Additional Resources

(t)Video Supplied by BBC Worldwide Learning; (bl)Brian Mckay Photography/Moment/Getty Images; (br)©Marvin Dembinsky Photo Associates/Alamy

LESSON 1

BIODIVERSITY

FOCUS QUESTION

Why is biodiversity important?

What is Biodiversity?

The loss of an entire species in a food web is not an imaginary situation. Entire species permanently disappear from the biosphere when the last member of the species dies in a process called **extinction.** As species become extinct, the variety of species in the biosphere decreases, which decreases the health of the biosphere. **Biodiversity** is the variety of life in an area that is determined by the number of different species in that area. It is increased by the formation of new species and decreased by the loss of species (extinction). Biodiversity increases the stability of an ecosystem and contributes to the health of the biosphere. There are three types of biodiversity to consider: genetic diversity, species diversity, and ecosystem diversity.

Genetic diversity

The variety of genes or inheritable characteristics that are present in a population comprises its **genetic diversity.** **Figure 1** shows characteristics that are shared by Asian ladybird beetles, such as general body structure.

Figure 1 These Asian ladybird beetles, *Harmonia axyridis*, demonstrate some visible genetic diversity because of their different colors.

Suggest *some other characteristics that might vary among the beetles.*

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Applying Practices: Biodiversity in Leaf Litter

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

The variety of colors in the beetles demonstrates a form of genetic diversity. The beetles have other characteristics that differ, but they are not as apparent as their color. These characteristics might include resistance to a particular disease, the ability to recover from a disease, or the ability to obtain nutrients from a new food source should the old food source disappear. The beetles with these characteristics are more likely to survive and reproduce than beetles without these characteristics. Genetic diversity within interbreeding populations increases the chances that some individuals will survive during changing environmental conditions or during an outbreak of disease.

Figure 2 Many species gather at this watering hole, making it a habitat rich in species diversity.

Species diversity

The number of different species and the relative abundance of each species in a biological community is called **species diversity.** As you look at **Figure 2**, notice how many different species of organisms are in this one area. This habitat represents an area with a high level of species diversity because there are many species present in one location.

Species diversity, however, is not evenly distributed over the biosphere. As you move geographically from the polar regions to the equator, species diversity increases. For example, **Figure 3** on the next page shows the number of bird species from Alaska to Central America. Use the color key to see how diversity changes as you move toward the equator.

Get It?

Compare and contrast genetic and species diversity.

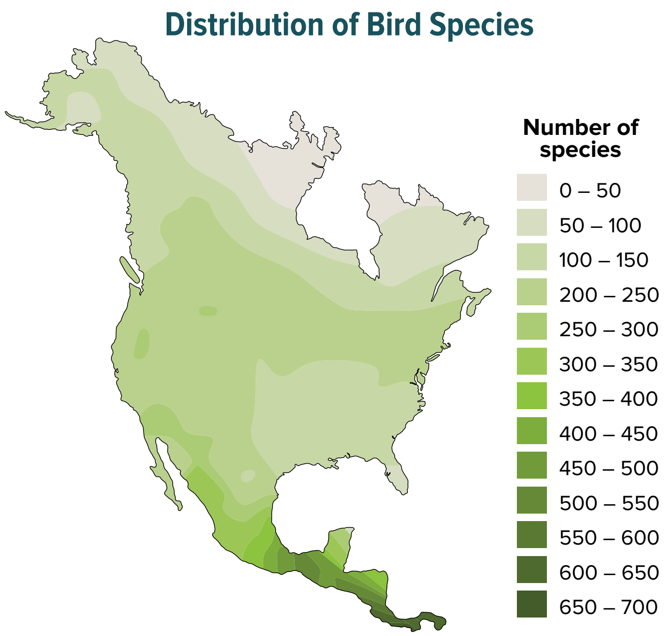


Figure 3 This map shows the distribution of bird species in North and Central America. As you move toward the tropics, biodiversity increases.

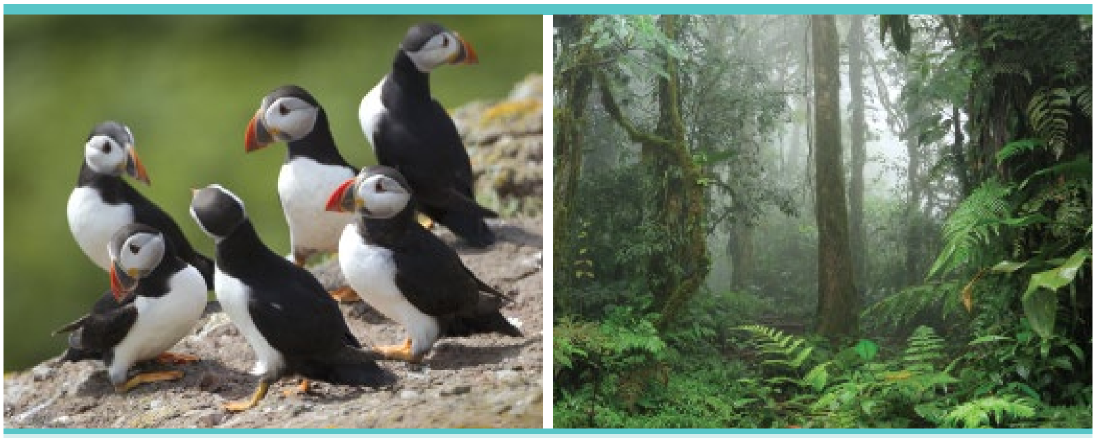
Estimate *the number of bird species where you live.*

Ecosystem diversity

The variety of ecosystems present in the biosphere is called **ecosystem diversity.** An ecosystem is made up of interacting populations and the abiotic factors that support them. The interactions of organisms affect the development of stable ecosystems. Different locations around the world have different abiotic factors that support different types of life. For example, an ecosystem in Alaska has a set of abiotic factors that supports puffins, which are shown in **Figure 4**. An ecosystem in South America has a different set of abiotic factors that supports the tropical plant life shown in **Figure 4**. Like these ecosystems, most of the ecosystems on Earth support a diverse collection of organisms.

Get It?

Explain why the health of a species is closely tied to the health of the habitat.



Puffins in the Arctic | Rainforest in South America

Figure 4 Ecosystems with diverse abiotic factors support a variety of organisms.

The Importance of Biodiversity

Sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Humans depend on the living world for resources and other benefits provided by diversity. There are economic, aesthetic, and scientific reasons for preserving biodiversity.

Direct economic value

Maintaining biodiversity has a direct economic value to humans. Humans depend on plants and animals to provide food, clothing, energy, medicine, and shelter. Preserving species that are used directly is important, but it also is important to preserve the genetic diversity in species that are not used directly. Those species serve as possible sources of desirable genes that might be needed in the future.

The reason there might be a future need for desirable genes is that most of the world's food crops come from just a few species. These plants have relatively little genetic diversity and share the same problems that all species share when genetic diversity is limited, such as lacking resistance to disease. In many cases, close relatives of crop species still grow wild in their native habitat. These wild species serve as reservoirs of desirable genetic traits that might be needed to improve domestic crop species.

The distant relative of corn, teosinte, shown in **Figure 5**, is resistant to the viral diseases that damage commercial corn crops. Using this wild species, plant pathologists developed disease-resistant corn varieties. If this wild species had not been available, this genetic diversity would have been lost, and the ability to develop disease-resistant corn varieties would also have been lost.

In addition, biologists are able to transfer genes that control inherited characteristics from one species to the other. This process is sometimes referred to as genetic engineering. Crops have been produced that are resistant to some insects, that have increased nutritional value, and that are more resistant to spoilage. Most wild species of plants and animals have not been evaluated for useful genetic traits. The opportunity to benefit from these genes is lost forever if wild species of plants and animals become extinct. This increases the importance of species that currently have no perceived economic value because their economic value might increase in the future.

Teosinte plant

Commercial corn plant

Figure 5 The teosinte plant contains genes that are resistant to viral diseases that affect corn plants. These genes have been used to produce virus-resistant commercial corn varieties.

HEALTH Connection Many of the medicines that are used today are derived from plants or other organisms. You probably know that penicillin, a powerful antibiotic discovered in 1928 by Alexander Fleming, is derived from bread mold. Ancient Greeks, Native Americans, and others extracted salicin, a painkiller, from the willow tree. Today, a version of this drug is synthesized in laboratories and is known as aspirin. **Figure 6** shows a Madagascar periwinkle flower, which was found to yield an extract that is useful in treating some forms of leukemia. This extract has been used to develop drugs that have increased the survival rate for some leukemia patients from 20 percent to more than 95 percent.

Figure 6 Medicines developed from an extract from Madagascar periwinkle, *Catharanthus roseus*, are used to treat forms of leukemia.

Summarize *Why is it important to maintain biodiversity for medical reasons?*

Scientists continue to find new extracts from plants and other organisms that help in the treatment of human diseases. However, many species of organisms are yet to be identified, especially in remote regions of Earth, so their ability to provide extracts or useful genes is unknown.

Indirect economic value

A healthy biosphere provides many services to humans and other organisms that live on Earth. For example, green plants provide oxygen to the atmosphere and remove carbon dioxide. Natural processes provide drinking water that is safe for human use. Substances are cycled through living organisms and nonliving processes, providing nutrients for all living organisms. As you will soon learn, healthy ecosystems provide protection against floods and drought, generate and preserve fertile soils, detoxify and decompose wastes, and regulate local climates.

STEM CAREER Connection

Agronomist

How can we continue to feed Earth's growing human population? Do you want to help develop solutions to one of humanity's biggest challenges? Agronomists apply what they know about soil and plant science to improve crop production and increase the food supply.

CCC CROSSCUTTING CONCEPTS

Cause and Effect Choose a species that you're familiar with and think about how changing environmental conditions might challenge its survival. Develop a model to illustrate how genetic diversity within interbreeding populations of the species would increase the chances that some individuals survive changing environmental conditions. What evidence supports your model?

It is difficult to attach an economic value to the services that a healthy biosphere provides. However, some scientists and economists have attempted to do just that. In the 1990s, New York City was faced with the decision of how to improve the quality of its drinking water. A large percentage of New York City's drinking water was supplied by watersheds, as shown in **Figure 7**. Watersheds are land areas where the water on them or the water underneath them drains to the same place. The Catskill and Delaware watersheds did not meet clean water standards and no longer could supply quality drinking water to the city.

The city was faced with two choices: build a new water filtration system for more than $6 billion or preserve and clean up the watersheds for approximately 1.5 billion dollars. The economic decision was clear in this case. A healthy ecosystem was less expensive to maintain than using technology to perform the same services.

Figure 7 New York City's drinking water is supplied by the Catskill and Delaware watersheds.

Infer *What types of human activities could affect a watershed and decrease its water quality?*

This example shows that nature can provide services, such as water that is safe for human consumption, at less expense than using technology to provide the same service. Some scientists think the natural way should be the first choice for providing these services. Research indicates that when healthy ecosystems are preserved, the services the ecosystems provide will continue to be less expensive than performing the same services with technology.

Aesthetic and scientific values

Biodiversity and healthy ecosystems have aesthetic and scientific values. Sustaining biodiversity helps humanity by preserving landscapes of recreational or inspirational value, such as the ecosystem shown in **Figure 8**.

Figure 8 This photo of Lake Tahoe's Emerald Bay shows the aesthetic value of preserving the environment.

The body of water shown in **Figure 8** is Lake Tahoe's Emerald Bay in California. This area is an environment with many aesthetic qualities. Lake Tahoe was once pristine, but urbanization, increased runoff, and other forms of pollution have harmed the environment's health. Invasive species such as clams, pond weed, and even domestic goldfish have also upset the lake's ecosystem. Many groups are working together to remedy these problems, and to try to keep Lake Tahoe healthy and beautiful.

There is also value in scientific study of the environment. Every human on the planet is part of Earth's biosphere, so study of the environment has the potential to benefit everyone. Attempting to solve a problem often brings diverse groups of people together. Each group can have their own ideas about how to approach the situation. Bringing together these different perspectives not only increases the likelihood of finding a solution, it can also lead to a greater understanding of other cultures or groups. Bringing together people to study the environment can also lead to the formation and development of new technologies.

Sometimes the scientific benefits of biodiverse ecosystems can be difficult for people to see or understand. However, many scientists are finding ways to show the value in protecting and studying the environment.

Check Your Progress

Summary

- Biodiversity is important to the health of the biosphere
- There are three types of biodiversity: genetic, species, and ecosystem
- Biodiversity has aesthetic and scientific values, and direct and indirect economic value.
- It is important to maintain biodiversity to preserve the reservoir of genes that might be needed in the future.
- Healthy ecosystems can provide some services at a lesser expense than the use of technology.

Demonstrate Understanding

1. **Explain** why sustaining biodiversity is essential to supporting and enhancing life on Earth.
2. **Explain** how extinction affects biodiversity.
3. **Generalize** why maintaining biodiversity has a direct economic value to humans.
4. **Differentiate** between the direct and indirect economic value of biodiversity.
5. **Evaluate and discuss** the importance of maintaining biodiversity for future medical needs.

Explain Your Thinking

6. **Design** a course of action for the development of a building project in your community, such as a housing development, city park, or highway, that provides for the maintenance of biodiversity in the plan.
7. WRITING Connection **Write** an argument that describes the importance of maintaining genetic diversity in domesticated animals, such as dogs, cats, pigs, cattle, and chickens. Include the advantages and disadvantages in your report.

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LESSON 2
THREATS TO BIODIVERSITY

FOCUS QUESTION

How can the decline of a single species affect an entire ecosystem?

Extinction Rates

Species become extinct because they can no longer survive and reproduce in an environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species to evolve is lost. Many species that lived on Earth millions of years ago have become extinct. Paleontologists study fossils of those species. Not all species that have become extinct have been gone long enough to leave fossils. Several species of amphibians, insects, and even mammals have become extinct over the past several decades. The gradual process of species becoming extinct is known as **background extinction.** Stable ecosystems can be changed by the activity of other organisms, climate changes, or natural disasters. This natural process of extinction is not what concerns scientists. Instead, many worry about a recent increase in the rate of extinction. Some scientists predict that between one-third and two-thirds of all plant and animal species will become extinct during the second half of this century. Most of these extinctions will occur near the equator, and affect organisms like the frog in **Figure 9**.

Some scientists estimate that the current rate of extinction is about 1000 times the normal background extinction rate. They think that we are witnessing a period of mass extinction. **Mass extinction** is an event in which a large percentage of all living species become extinct in a relatively short period of time. The last mass extinction occurred about 65 million years ago, as illustrated in **Table 1** on the next page.

Dirk Ercken/Shutterstock.com

Figure 9 Animals that live in the tropical rain forests, like the blue poison frog, are more likely to go extinct than animals in other areas.

3D THINKING — DCI Disciplinary Core Ideas — CCC Crosscutting Concepts — SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Applying Practices: Evaluating Impacts of Environmental Change on Populations

HS-LS4-5. Evaluate evidence that supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Table 1 **Five Most Recent Mass Extinctions**

	Ordovician Period	Devonian Period	Permian Period	Triassic Period	Cretaceous Period
Time	about 444 million years ago	about 360 million years ago	about 251 million years ago	about 200 million years ago	about 65 million years ago
Example	 Graptolites	 Dinichthys	 Trilobite	 Cynognathus	 Ammonite

HISTORY Connection The accelerated loss of species began several centuries ago. **Table 2** shows the estimated number of extinctions that have occurred by group since 1600. Many of the species' extinctions in the past have occurred on islands. For example, 60 percent of the mammals that have become extinct in the past 500 years lived on islands, and 81 percent of bird extinctions occurred on islands.

Table 2 **Estimated Number of Extinctions Since 1600**

Group	Mainland	Island	Ocean	Total	Approximate Number of Known Species	Percent of Group Extinct
Mammals	30	51	4	85	4000	2.1
Birds	21	92	0	113	9000	1.3
Reptiles	1	20	0	21	6300	0.3
Amphibians*	2	0	0	2	4200	0.05
Fish	22	1	0	23	19,100	0.1
Invertebrates	49	48	1	98	1,000,000+	0.01
Flowering Plants	245	139	0	384	250,000	0.2

*An alarming decrease of amphibian populations has occurred since the mid-1970s, and many species might be on the verge of extinction.

Species on islands are particularly vulnerable to extinction because of several factors. Many of these species evolved without the presence of natural predators. As a result, when a predator, such as a dog, cat, rat, or human, is introduced to the population, the native animals do not have the ability or skills to escape. When a nonnative species is introduced to a new population, it can be a carrier of a disease to which the native population has no resistance. The native population often dies off as a result. In addition, islands typically have relatively small population sizes and individual animals rarely travel between islands, both of which increases the vulnerability of island species to extinction.

(l to r) De Agostini Picture Library/Getty Images; Sabena Jane Blackbird/Alamy; farbled/Shutterstock.com; The Natural History Museum/Alamy; Blackbeck/iStock/Getty Images

Factors That Threaten Biodiversity

Anthropogenic changes to the environment are changes induced by human activity. They include habitat loss, pollution, the introduction of invasive species, overexploitation, and climate change. These changes can disrupt an ecosystem and threaten the survival of some species. Today's high rate of extinction differs from past mass extinctions. After a mass extinction in the past, new species evolved and biodiversity recovered after several million years. This time, the recovery might be different. Humans are changing conditions on Earth faster than new traits can evolve in some species to cope with the new conditions. Evolving species might not have the natural resources they need. **Natural resources** are all materials and organisms found in the biosphere, including minerals, fossil fuels, nuclear fuels, plants, animals, soil, clean water, clean air, and solar energy.

Overexploitation

One of the factors that is increasing the current rate of extinction is the **overexploitation,** or excessive use, of species that have economic value.

For example, wood from mahogany trees is prized for its beauty and its durability. These trees are native to tropical areas of the globe. Because they grow so slowly, it takes about 100 years for a mahogany tree to fully mature. Overexploitation of mahogany tree populations and illegal logging have led some varieties of this tree to border on extinction.

Plants are not the only living organisms that have been subjected to overexploitation. the great herds of bison that once roamed the central plains of North America were hunted to the brink of extinction because their meat and hides could be sold commercially and because they were hunted for sport. At one time, it is estimated that there were 50 million bison. By 1889, there were less than 1000 bison left.

Passenger pigeons are another example of a species that were overexploited. At one time, there were huge flocks of these birds that would darken the skies of North America during their migration. Unfortunately, they were overhunted and forced from their habitats. By the early 1900s, they had become extinct.

Get It?

Explain the term overexploitation as it relates to species extinction.

CCC CROSSCUTTING CONCEPTS

Stability and Change Some scientists think we are living in a time of mass extinction. As you read about the anthropogenic changes that threaten biodiversity, think about how the rate of these changes may be changing conditions on Earth faster than some species can evolve. Create a poster that will get others to think about factors that threaten biodiversity. Include evidence that illustrates your points.

WORD ORIGINS

native

from the Latin word *nativus*, meaning to be born

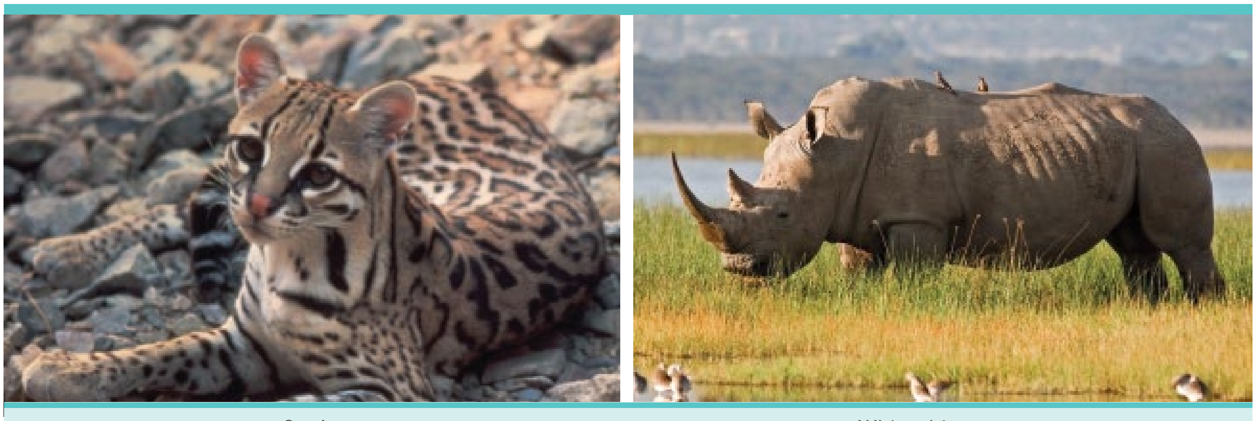

Figure 10 The ocelot and all species of rhinos, including the white rhinoceros, are in danger of becoming extinct, due in part to overexploitation.

The ocelot, shown in **Figure 10**, is found from Texas to Argentina and is in danger of becoming extinct. The increasing loss of their habitat and the commercial value of their fur are reasons for their declining numbers. The white rhinoceros, also shown in **Figure 10**, is one of five species of rhinos, all of which are in danger of becoming extinct. They are hunted and killed for their horns, which are then sold for so-called medicinal purposes. Historically, overexploitation was the primary cause of species extinction. However, the number one cause of species extinction today is the destruction of habitat.

Habitat loss

If a habitat is destroyed or disrupted, the native species might have to relocate or they will die. For example, humans are clearing areas of tropical rain forests and are replacing the native plants with agricultural crops or grazing land.

Destruction of habitat The clearing of tropical rain forests, like what is shown in **Figure 11**, has a direct impact on global biodiversity. As mentioned earlier, the tropical latitudes contain much of the world's biodiversity in their native populations. In fact, estimates show that more than half of all species on Earth live in the tropical rain forests. The removal of so much of the natural forest will cause many species on Earth to become extinct as a result of habitat loss.

Figure 11 Cleared land often is used for agricultural crops or as grazing land for livestock. Planting large expanses of crops reduces the biodiversity of the area.

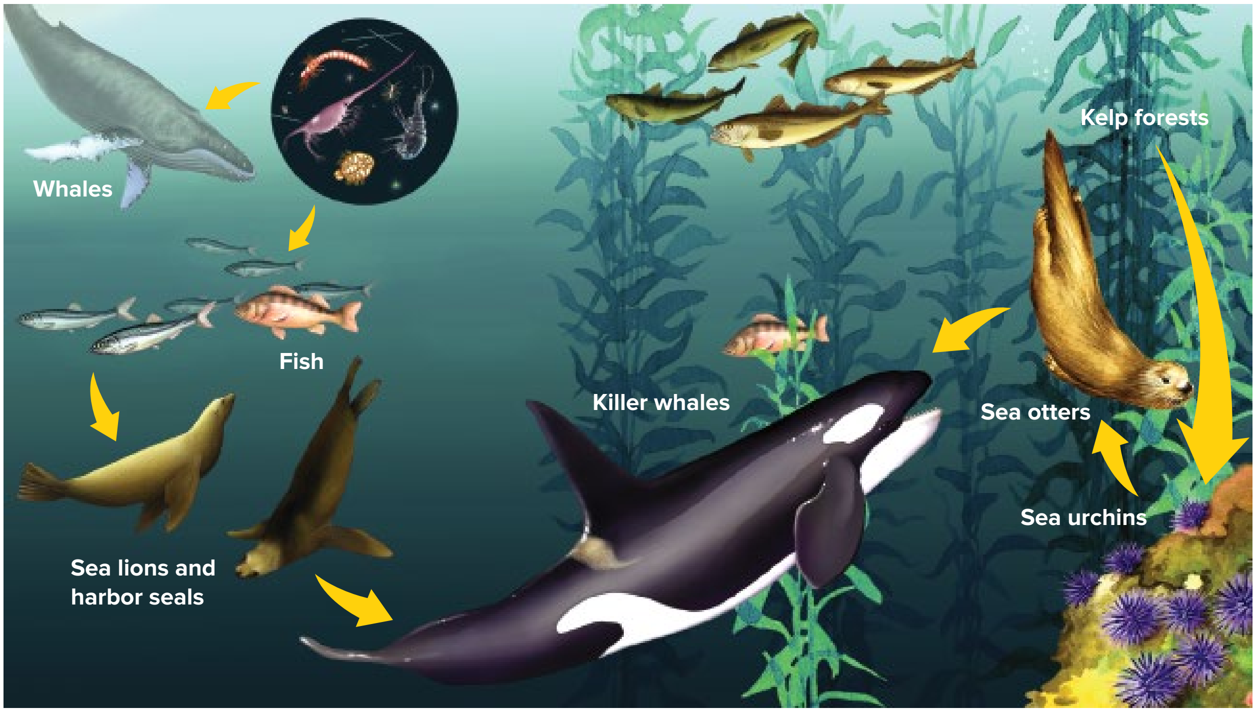

Figure 12 A declining population of one species can affect an entire ecosystem. When the number of harbor seals and sea lions declined, killer whales ate more sea otters. The decline in sea otter population led to an increase in sea urchins, which eat kelp. This led to the ultimate decline in kelp forests.

Disruption of habitat Some habitats might not be destroyed, but they can be disrupted. For example, off the coast of Alaska, a chain of events occurred in the 1970s that demonstrates how the declining numbers of one member of a food web can affect the other members. As you can see from the chain of events shown in **Figure 12**, the decline of one species can affect an entire ecosystem. When one species plays such a large role in an ecosystem, that species is called a keystone species. A decline in various fish populations, possibly due to overfishing, has led to a decline in sea lion and harbor seal populations. Some scientists hypothesize that climate change also played a role in the decline. This started a chain reaction that affected many species.

Fragmentation of habitat

The separation of an ecosystem into small pieces of land is called **habitat fragmentation.** Populations often stay within the confines of the small parcel because they are unable or unwilling to cross the human-made barriers. The smaller the parcel of land, the fewer species it can support. Fragmentation also reduces genetic diversity because it reduces the opportunities for individuals in one area to reproduce with individuals from another area. Smaller, separated, and less genetically diverse populations are less able to resist disease or respond to changing environmental conditions.

Carving the large ecosystem into small parcels increases the number of edges, creating edge effects, as illustrated in **Figure 13**, on the next page. **Edge effects** are different environmental conditions that occur along the boundaries of an ecosystem. For example, edges of a forest near a road have different abiotic factors, such as temperature, wind, and humidity, than does the interior of a forest.

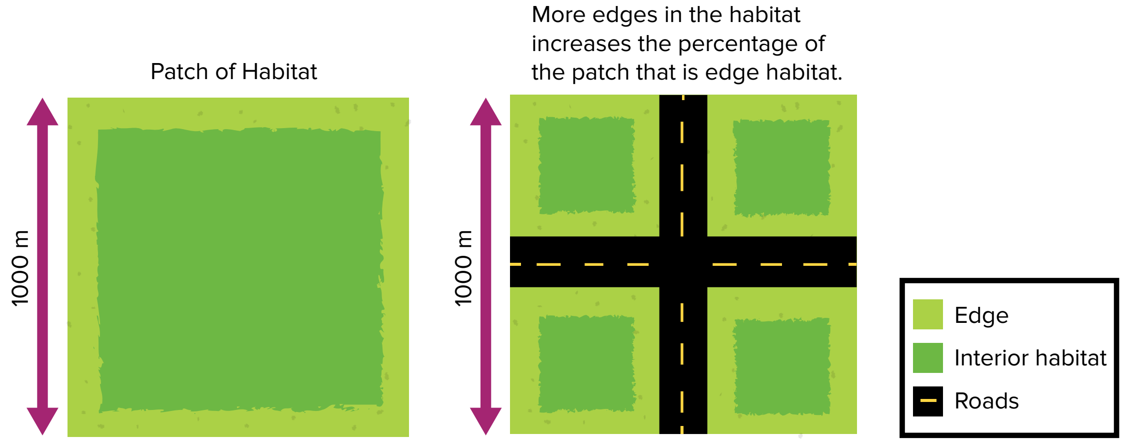

Figure 13 The smaller the habitat size, the greater percentage of the habitat that is subject to edge effects.

Typically, the temperature and wind will be higher and the humidity lower on the edges in a tropical forest. Species that thrive deep in the dense forest might perish on the edges of the ecosystem. Predators and parasites also thrive on the boundaries of ecosystems, which makes the species in these areas more vulnerable to attack.

Climate Change

Species have evolved to live within certain temperature ranges. When these temperatures increase, the species members that cannot adapt die. This threatens the survival of the species as well as other species that depend on it for survival. Climate change is expected to overtake habitat destruction as the greatest threat to biodiversity in the first half of this century. In fact, scientists predict that climate change will threaten approximately 25 percent of all land species by 2050.

Get It?

Explain how an increase in global temperatures threatens biodiversity.

Pollution

Pollution and atmospheric changes threaten biodiversity and global stability. Pollution changes the composition of air, soil, and water. There are many types of pollution. Substances—including many humanmade chemicals that are not found in nature—are released into the environment.

Pesticides, such as DDT (dichloro-diphenyl-trichlor oethane), and industrial chemicals, such as PCBs (polychlo rinated biphenyls), are examples of substances that are found in food webs. These substances are ingested by organisms when they drink water or eat other organisms that contain the toxic substances. Some substances are metabolized by an organism and excreted with other waste products.

However, other substances, such as DDT and PCBs, accumulate in the tissues of organisms. Carnivores at the higher trophic levels seem to be most affected by the accumulation of toxic substances because of a process called biological magnification. **Biological magnification** is the increasing concentration of toxic substances in organisms as trophic levels increase in a food chain or food web.

An example of biological magnification is shown in **Figure 14**. The concentration of a toxic substance is relatively low when it enters the food web; it is only at 0.001 parts per million (ppm) in producers. The concentration of a toxic substance in individual organisms increases as it spreads to higher trophic levels, ultimately resulting in a concentration of 25 ppm in the organisms that live in the highest trophic level of the food web.

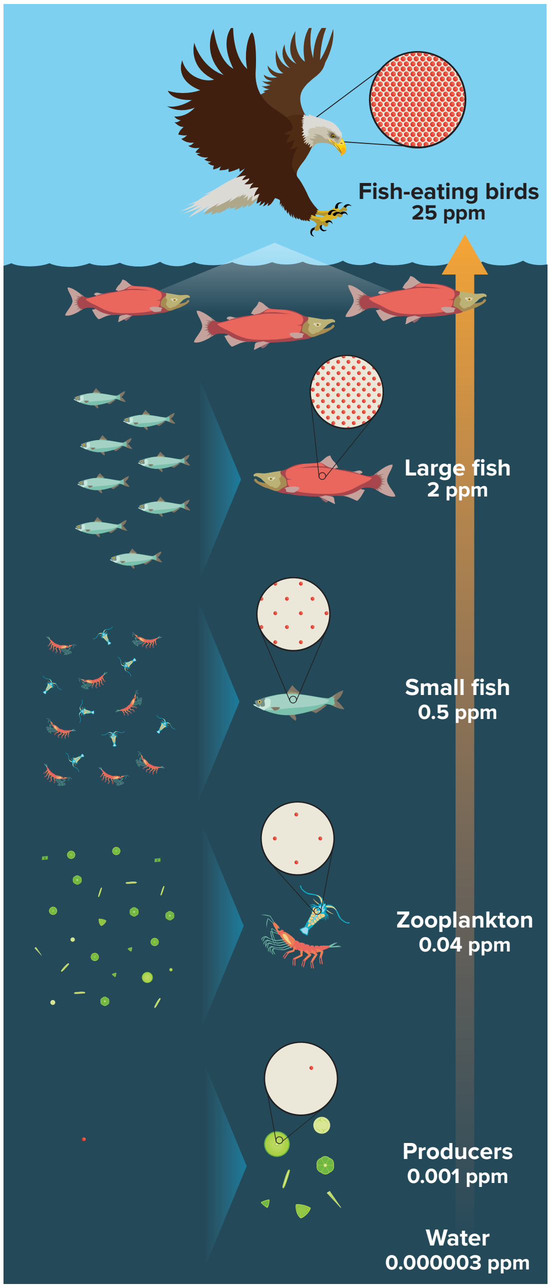

Figure 14 The concentration of toxic substances increases as the trophic level in a food chain increases.

Current research implies that these substances might disrupt normal processes in some organisms. For example, DDT might have played a role in the near extinction of the American bald eagle and the peregrine falcon. DDT is a pesticide that was used from the 1940s to the 1970s to control crop-eating and disease-carrying insects. DDT proved to be a highly effective pesticide, but evidence suggested that it caused the eggshells of fish-eating birds to be fragile and thin, which led to the death of the developing birds. Once these toxic effects were discovered, the use of DDT was banned in some parts of the world.

Acid precipitation Another pollutant that affects biodiversity is acid precipitation. When fossil fuels are burned, sulfur dioxide is released into the atmosphere. In addition, the burning of fossil fuels in automobile engines releases nitrogen oxides into the atmosphere. These compounds react with water and other substances in the air to form sulfuric acid and nitric acid. These acids eventually fall to the surface of Earth in rain, sleet, snow, or fog. Acid precipitation removes calcium, potassium, and other nutrients from the soil, depriving plants of these nutrients. It damages plant tissues and slows their growth. Sometimes, the acid concentration is so high in lakes, rivers, and streams that fish and other organisms die.

Eutrophication Another form of water pollution, called eutrophication, destroys underwater habitats for fish and other species. **Eutrophication** (yoo troh fih KAY shun) occurs when fertilizers, animal waste, sewage, or other substances rich in nitrogen and phosphorus flow into waterways, causing extensive algae growth.

The algae use up the oxygen supply during their rapid growth and after their deaths during the decaying process. Other organisms in the water suffocate. In some cases, algae also give off toxins that poison the water supply for other organisms. Eutrophication is a natural process, but human activities often accelerate the rate at which it occurs.

Invasive species

Introduced species are either intentionally or unintentionally transported to a new habitat. Not all introduced species become invasive. Species that can significantly modify or disrupt that habitat are known as **invasive species.** These species are not a threat to biodiversity in their native habitats. Predators, parasites, and competition between species keep the native ecosystem in balance. However, when these species are introduced into a new area, these controlling factors are not in place. Invasive species often reproduce in large numbers because of a lack of predators.

Figure 15 Invasive species, such as the fire ant, can negatively affect biodiversity.

The imported fire ant shown in **Figure 15** is a species that was accidentally introduced to the United States through the port of Mobile, Alabama, in the 1920s by ships from South America. The fire ants spread throughout the southern and southwestern United States. Fire ants attack and feed on some wildlife, such as newborn deer and hatching or newly hatched ground-nesting birds. Invasive species are a worldwide environmental problem. An estimated 40 percent of the extinctions that have occurred since 1750 are a result of invasive species, and billions of dollars are spent every year in an effort to clean up or control the damage caused by invasive species.

Check Your Progress

Summary

- Some scientists estimate that the current rate of species extinction is abnormally high.
- Species on islands are particularly vulnerable to extinction.
- Historically, overexploitation by humans has led to the extinction of some species.
- Human activities can result in a decrease in biodiversity.

Demonstrate Understanding

1. **Describe** what happens when species cannot adapt to ecosystem changes that are too fast.
2. **Explain** three ways that anthropogenic changes threaten biodiversity.
3. **Choose** one of the factors that threatens biodiversity and suggest one way in which biodiversity can be preserved in a real-life scenario.
4. **Summarize** how the overharvesting of a single species, such as the fish eaten by sea lions, can affect an entire ecosystem.

Explain Your Thinking

5. **Design** a planned community that preserves biodiversity and accommodates the human population. Work in small groups to accomplish this task.
6. **Survey** your community to identify at least five threats to biodiversity and suggest ways in which biodiversity can be preserved.

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LESSON 3

CONSERVING BIODIVERSITY

FOCUS QUESTION

What methods are used to conserve biodiversity?

Natural Resources

The biosphere currently supplies the basic needs for more than six billion humans in the form of natural resources. The human population continues to grow, and the growth is not evenly distributed throughout the world. An increase in human population growth increases the need for natural resources to supply the basic needs of the population, and can have adverse impacts on biodiversity.

The consumption rate of natural resources is also not evenly distributed. **Figure 16** on the next page shows the global consumption of natural resources per person. The natural resource consumption rate is much higher for people living in developed countries than for people living in developing countries. People who live in developing countries tend to rely mostly on agriculture instead of industry for income, and tend to make less income than people who live in developed countries.

As developing countries increase the number and types of industry within their borders, their standard of living, the available amount of goods and money, also increases. To sustain the use of these goods, the rate of natural resource consumption must therefore also increase. Because of the rising human population growth and an increased rate of consumption of natural resources, a long-term plan for the use and conservation of natural resources is important.

Get It?

Compare the per capita use of resources of people in North America to Africa by using Figure 16 on the next page.

3D THINKING | DCI Disciplinary Core Ideas | CCC Crosscutting Concepts | SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Applying Practices: Microbeads, Mega-Problem

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Global Consumption of Natural Resources per Capita (expressed in US dollars)

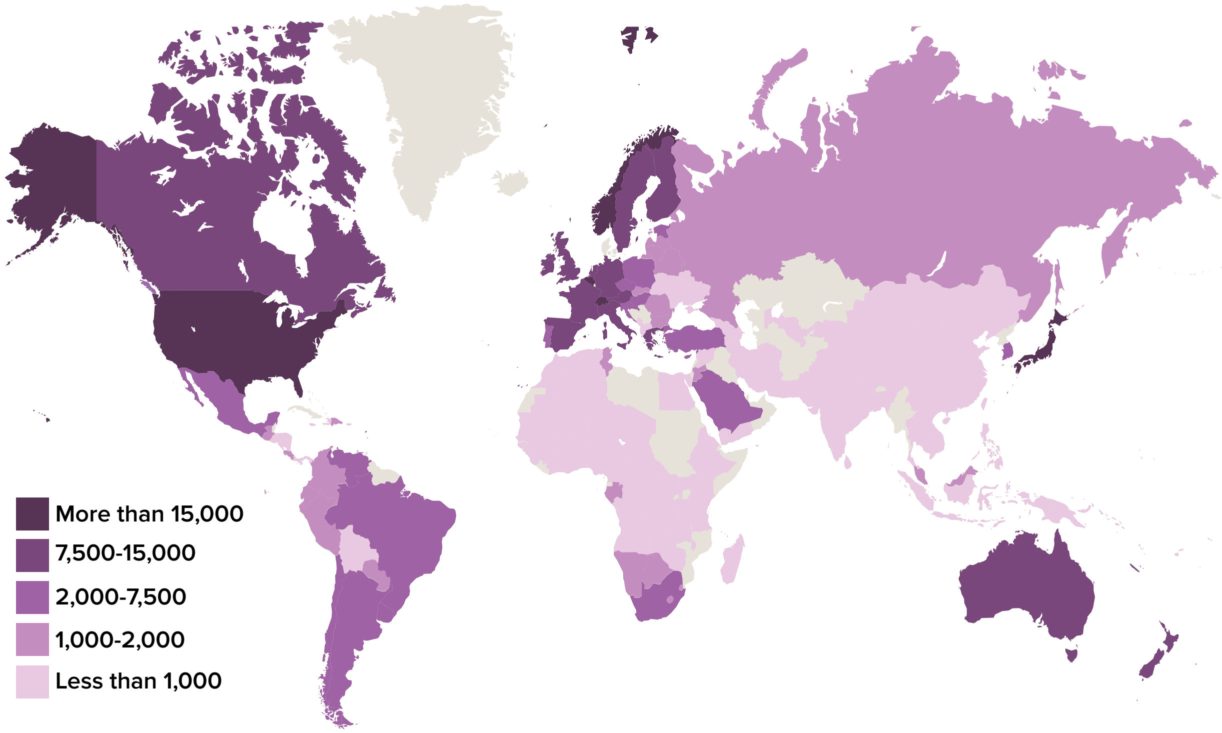

Figure 16 This map shows the consumption of natural resources per person.
Explain *why the use of natural resources is high for developed countries but is low for developing countries.*

Renewable resources

Plans for long-term use of natural resources must take into consideration the difference between the two groups of natural resources—renewable and nonrenewable resources. Those resources that are replaced by natural processes faster than they are consumed are called **renewable resources.** Solar energy is considered a renewable resource because the supply appears to be endless. Agricultural plants, animals, clean water, and clean air are considered renewable because they are normally replaced faster than they are consumed. However, the supply of these resources is not unlimited. If the human demand exceeds the supply of any natural resource, the resource might become depleted.

Nonrenewable resources

Resources that are found on Earth in limited amounts or that are replaced by natural processes over extremely long periods of time are called **nonrenewable resources.** Fossil fuels such as coal, natural gas, and oil, and mineral deposits, such as radioactive uranium, are considered nonrenewable resources. Species are considered renewable resources until the last individual of a species dies. When extinction occurs, a species is nonrenewable because it is lost forever.

Renewable versus nonrenewable resources

Figure 17 This cleared forest is considered a nonrenewable resource. There is not enough of it intact to provide a habitat for the organisms that live there.

The classification of a resource as renewable or nonrenewable depends on the context in which the resource is being discussed. A single tree or a small group of trees in a large forest ecosystem is renewable because replacement trees can be planted or can regrow from seeds present in the soil. Enough of the forest is still intact to serve as a habitat for the organisms that live there. However, when the entire forest is cleared, as shown in **Figure 17**, the forest is not considered a renewable resource. The organisms living in the forest have lost their habitat, and they most likely will not survive. In this example, it is possible that more than one natural resource is nonrenewable: the forest and any species that might become extinct.

Sustainable use

One approach to using natural resources, called sustainable use, is demonstrated in **Figure 18**. Just as the name implies, **sustainable use** means using resources at a rate at which they can be replaced or recycled while preserving the long-term environmental health of the biosphere. Conservation of resources includes reducing the amount of resources that are consumed, recycling resources that can be recycled, and preserving ecosystems, as well as using them in a responsible manner. Sustainable use can be accomplished on an individual level, by companies and industries, or by entire countries.

Figure 18 Replacing resources preserves the health of the biosphere.
Explain *why this process is considered a sustainable use of a resource.*

Protecting Biodiversity

In Lesson 2, you learned how human activities have affected many ecosystems. Many efforts are underway worldwide to slow the loss of biodiversity and to work toward sustainable use of natural resources. When evaluating these efforts and other solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Protected areas in the United States

Conservation biologists recognize the importance of establishing protected areas where biodiversity can flourish. Such places should remain relatively undisturbed by human activies that could destroy plant and animal life. The United States established its first national park, Yellowstone National Park, in 1872 to protect the area's geological features. Many additional national parks and nature reserves have been established since 1872.

International protected areas

The United States is not the only country to establish national parks and nature reserves. Currently, about ten to fifteen percent of the world's land is set aside as some type of reserve. Historically, these protected areas have been small islands of habitat surrounded by areas that contain human activity. Because the reserves are small, they are impacted heavily by human activity. Costa Rica has established megareserves. These reserves contain one or more zones that are protected from human activity by buffer zones, areas in which sustainable use of natural resources is permitted. This approach creates large managed areas for preserving biodiversity while providing natural resources to local populations.

Get It?

Explain how protected areas preserve biodiversity.

Biodiversity hotspots

Conservation biologists have identified locations around the world that are characterized by exceptional levels of **endemic** species—species that are only found in that specific geographic area—and critical levels of habitat loss. They have termed these areas hotspots. To be called a hotspot, a region must meet two criteria. First, there must be at least 1500 species of vascular plants that are endemic, and the region must have lost at least 70 percent of its original habitat. The 36 internationally recognized hotspots are shown in **Figure 19** on the next page.

Approximately half of all plant and animal species are found in hotspots. These hotspots originally covered 17 percent of Earth's surface; however, only about a tenth of that habitat remains.

Biologists who are in favor of recovery efforts in these biological hotspots argue that focusing on a limited area would save the greatest number of species. Other biologists argue that concentrating funding on saving species in these hotspots does not address the serious problems that are occurring elsewhere. For example, saving a wetland area might save fewer species, but the wetland provides greater services by filtering water, regulating floods, and providing a nursery for fish. These biologists think that funding should be spent in areas around the world rather than focused on the biodiversity hotspots. Scientists often use computer simulations to test different ways of solving a problem or to see which one is most efficient or economical.

VOCABULARY: SCIENCE USAGE V. COMMON USAGE

corridor

Science usage: a passageway between two habitat fragments *The deer uses the corridor to safely travel between the two habitat fragments.*

Common usage: a passageway, as in a hotel, into which rooms open *The ice machine is in the hotel corridor by the elevators.*

CCC CROSSCUTTING CONCEPTS

Scale, Proportion, and Quantity In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy. Biologists have debated whether conservation efforts should be focused on biodiversity hotspots. Write a brief argument for or against focusing efforts on hotspots. Consider measures of size, time, and energy. Cite evidence that supports your argument.

Figure 19 Visualize Biodiversity Hotspots

Biodiversity hotspots, highlighted in red on the map, are ecosystems where endemic species are threatened. If these species become extinct, biodiversity will decrease.

1 California Floristic Province
2 Madrean Pine-Oak Woodlands
3 Mesomerica
4 Tumbes-Chocó-Magdalena
5 Tropical Andes
6 Chilean Winter Rainfall-Valdivian Forests
7 Atlantic Forest
8 Cerrado
9 Caribbean Islands
10 Guinean Forests of West Africa
11 Succulent Karoo
12 Cape Floristic Region
13 Maputaland-Pondoland-Albany
14 Madagascar and the Indian Ocean Islands
15 Coastal Forests of Eastern Africa
16 Eastern Aforomontane
17 Mediterranean Basin
18 Caucasus
19 Irano-Anatolian
20 Horn of Africa
21 Western Ghats and Sri Lanka
22 Himalayas
23 Mountains of Central Asia
24 Mountains of Southwest China
25 Indo-Burma
26 Sundaland
27 Southwest Australia
28 Wallacea
29 Philippines
30 Japan
31 Polynesia-Micronesia
32 East Melanesian Islands
33 New Caledonia
34 New Zealand
35 Forests of East Australia
36 North American Coastal Plain

(l to r, t to b) reptiles4all/Shutterstock.com; zaferkizilkaya/Shutterstock.com; Fuse/Getty Images; Humberto Pimentel Fotografia/Moment Open/Getty Images; Darlyne A. Murawski/National Geographic/Getty Images; john austin/Shutterstock.com

Figure 20 Corridors between habitat fragments allow safe passage for animals.
Describe *What are the advantages and disadvantages of corridors?*

Corridors between habitat fragments

Conservation ecologists are maintaining and improving biodiversity by providing corridors, or passageways, between habitat fragments. Corridors, such as those shown in **Figure 20**, are used to connect smaller parcels of land. These corridors allow organisms from one area to move safely to the other area. This creates a larger piece of land that can sustain a wider variety of species and a wider variety of genetic variation. However, corridors do not completely solve the problem of habitat destruction. Diseases easily pass from one area to the next as infected animals move from one location to another. This approach also increases edge effect. One large habitat would have fewer edges, but often a large habitat is hard to preserve.

Legislative actions

During the 1970s, a great deal of attention was focused on destruction of the environment and maintaining biodiversity. Laws were enacted in countries around the world, and many treaties between countries were signed in an effort to preserve the environment. In the United States, the Endangered Species Act was enacted in 1973. It was designed to legally protect the species that were becoming extinct or in danger of becoming extinct. An international treaty, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), was signed in 1973. It outlawed the trade of endangered species and animal parts, such as ivory elephant tusks and rhinoceros horns. Since the 1970s, many more laws and treaties have been enacted and signed with the purpose of preserving biodiversity for future generations.

Restoring Ecosystems

Sometimes, biodiversity is destroyed in an area such that it no longer provides the abiotic and biotic factors needed for a healthy ecosystem. For example, the soil from cleared tropical rain forests becomes unproductive for farming after a few years. After mining activities are completed, land might be abandoned in a condition that does not support biodiversity. Accidental oil spills and toxic chemical spills might pollute an area to such a degree that the native species cannot live there.

Given time, biological communities can recover from natural and human-made disasters, as illustrated in **Figure 21**. The size of the area affected and the type of disturbance are determining factors for recovery time. The length of time for recovery is not related directly to whether the disaster is natural or human-made. In general, the larger the affected area, the longer it takes to recover.

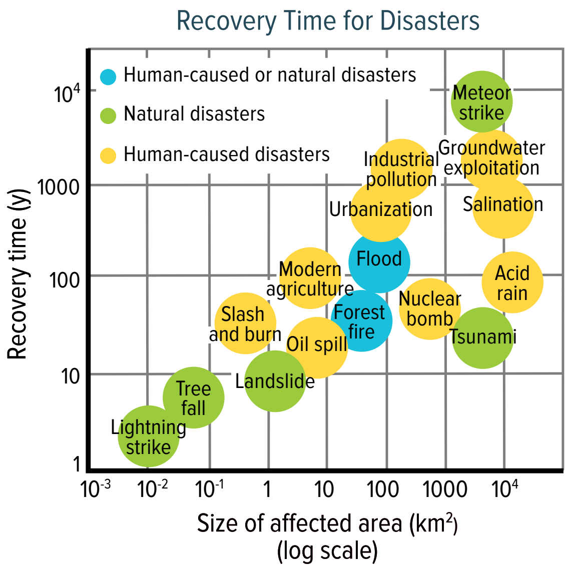

Figure 21 The recovery time for disasters is dependent upon the size of the area affected and on the type of disturbance.

Determine *the approximate recovery time for a landslide.*

Bioremediation

The use of living organisms, such as prokaryotes, fungi, or plants, to detoxify a polluted area is called **bioremediation.** In 1975, a leak from a fuel-storage facility in South Carolina released about 80,000 gallons of kerosene-based jet fuel. The fuel soaked into the sandy soil and contaminated the underground water table. Microorganisms that naturally are found in the soil were able to break down these carbon-based fuels into carbon dioxide.

Scientists found that by adding additional nutrients to the soil, the rate at which the microorganisms decontaminated the area increased. In a few years, the contamination in the area was greatly reduced. These microorganisms can be used in other ecosystems to remove toxins from soils that are contaminated by accidental oil or fuel spills.

Some species of plants are being used to remove toxic substances, such as zinc, lead, nickel, and organic chemicals, from damaged soils, as shown in **Figure 22**. These plants are planted in contaminated soils, where they store the toxic metals in their tissues. The plants then are harvested, and the toxic metals are removed from the ecosystem.

Even animal structures hold some promise in the field of bioremediation. Some studies suggest that applying fish bones to the soil might help to transform lead, which is harmful to humans, into another harmless substance.

Although bioremediation is relatively new, there appears to be great promise in using organisms to detoxify some ecosystems that have been damaged.

Figure 22 Chemical waste from an industrial complex is being treated using reed beds. Bacteria and fungi in the reed beds transform a wide range of pollutants into harmless substances.

Biological control of invasive species

Invasive species can have a profound effect on an ecosystem's biodiversity. In some cases, ecologists attempt to control the invasive species by introducing another organism to the ecosystem. This organism may be a natural predator of the invasive species, or it may be likely to outcompete the invasive species for resources.

Figure 23 Carp can control *Hydrilla* populations.

For example, an invasive plant called *Hydrilla* has had a significant impact on Florida's waterways. *Hydrilla* grows very quickly, and forms dense mats that cover the surface of the water. These mats decrease the growth of bottom-dwelling native plants by preventing light from penetrating the water. In the early 1970s, researchers introduced the Asian grass carp shown in **Figure 23** to control *Hydrilla*. These fish eat large amounts of plants as part of their diets, and have been effective in controlling the amount of *Hydrilla*. If too many carp are present in a body of water, however, they will destroy natural vegetation, and can change water quality. Therefore, ecologists are careful to monitor the number of carp in each body of water.

Check Your Progress

Summary

- One approach to using natural resources is sustainable use.
- There are many approaches used to conserve biodiversity in the world.
- Biodiversity hotspots contain a large number of endemic species that are threatened with extinction.
- Two techniques used to restore an ecosystem are bioremediation and biological augmentation.
- Since the 1970s, many forms of legislation have been passed to protect the environment.

Demonstrate Understanding

1. **Describe** three approaches used to slow down the rate of extinction or to preserve biodiversity.
2. **Define** the two classes of natural resources.
3. **Choose** a human-caused disaster from **Figure 21**. Discuss the methods that could be used to restore biodiversity.

Explain Your Thinking

4. **Create** a script of dialogue that could occur between a conservationist and a person who lives in a biodiversity hotspot. The local person wants to use the natural resources to provide a living for his or her family. The dialogue should include a compromise in which both sides are satisfied with the use of resources. Consider the social, cultural, and environmental impacts of the compromise.
5. **MATH Connection** If Earth has 150,100,000 km^2 of land area, how much land area is included in the biodiversity hotspots?

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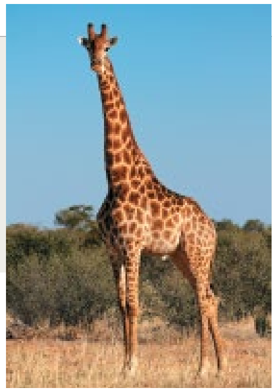
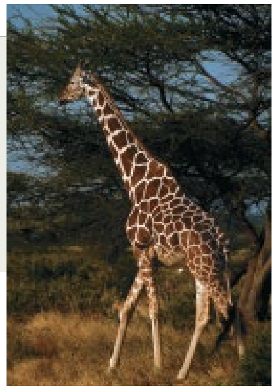
More Species—Fewer Individuals

Giraffes are found in grasslands throughout Africa. These animals—the tallest in the world—eat leaves, seeds, and fruits. They need to consume hundreds of pounds of food per week to survive.

Scientists have determined that there are four genetically distinct giraffe groups, including the Masai giraffe (left) and the reticulated giraffe (right).

Reclassification

Scientists have long thought all giraffes belonged to one species that could be divided into nine subspecies. However, new evidence has led scientists to reconsider this classification. Analysis of DNA from 190 wild giraffes indicates that there are four genetically distinct giraffe groups.

With the discovery of these genetically isolated groups, some scientists think giraffes should be categorized into four species: the northern giraffe, the southern giraffe, the reticulated giraffe, and the Masai giraffe. However, because these four groups are not reproductively isolated—interbreeding between these groups is considered rare but possible—some scientists still think all giraffes belong to only one species.

The genetic findings have brought new attention to conservation efforts. The total number of wild giraffes has dropped from about 150,000 to less than 90,000 in the past 30 years, but giraffes have not been considered a species of great concern because their numbers are still large compared to other species. With the discovery of four genetically distinct groups, concern has increased because the population numbers of some of the groups are low.

For example, there are less than 5,000 northern giraffes left in Africa, making them one of the most endangered large mammals in the world.

Giraffe populations are dropping due to loss of habitat, civil unrest, livestock overgrazing, and hunting. Conservationists are working to protect remaining populations. For example, conservationists are working with the San Diego Zoo Institute for Conservation Research to sequence the giraffe genome.

COMMUNICATE SCIENTIFIC IDEAS

Create a poster that shows why conservationists are concerned about the population numbers of northern and reticulated giraffes. How would losing one of these types of giraffes affect biodiversity in Africa?

MODULE 5

STUDY GUIDE

GO ONLINE to study with your Science Notebook.

Lesson 1 BIODIVERSITY

- Biodiversity is important to the health of the biosphere.
- There are three types of biodiversity: genetic, species, and ecosystem.
- Biodiversity has aesthetic and scientific values, and direct and indirect economic value.
- It is important to maintain biodiversity to preserve the reservoir of genes that might be needed in the future.
- Healthy ecosystems can provide some services at a lesser expense than the use of technology.

- extinction
- biodiversity
- genetic diversity
- species diversity
- ecosystem diversity

Lesson 2 THREATS TO BIODIVERSITY

- Some scientists estimate that the current rate of species extinction is abnormally high.
- Species on islands are particularly vulnerable to extinction.
- Historically, overexploitation of some species by humans has led to their extinction.
- Human activities can result in a decrease in biodiversity.

- background extinction
- mass extinction
- natural resource
- overexploitation
- habitat fragmentation
- edge effect
- biological magnification
- eutrophication
- invasive species

Lesson 3 CONSERVING BIODIVERSITY

- One approach to using natural resources is sustainable use.
- There are many approaches used to conserve biodiversity in the world.
- Biodiversity hotspots contain a large number of endemic species that are threatened with extinction.
- Since the 1970s, many forms of legislation have been passed to protect the environment.
- Two techniques used to restore an ecosystem are bioremediation and biological control of invasive species.

- renewable resource
- nonrenewable resource
- sustainable use
- endemic
- bioremediation

THREE-DIMENSIONAL THINKING

Module Wrap-Up

REVISIT THE PHENOMENON

What happens to this ecosystem if the river is destroyed?

CER Claim, Evidence, Reasoning

Explain Your Reasoning Revisit the claim you made when you encountered the phenomenon. Summarize the evidence you gathered from your investigations and research and finalize your Summary Table. Does your evidence support your claim? If not, revise your claim. Explain why your evidence supports your claim.

STEM UNIT PROJECT

Now that you've completed the module, revisit your STEM unit project. You will apply your evidence from this module and complete your project.

GO FURTHER

SEP Data Analysis Lab

How is the biodiversity of perching birds distributed in the Americas?

The distribution of birds, like that of other species, is not even. Perching birds appear to be more concentrated in some areas of the Americas than others.

Data and Observations Use the map to answer the following questions about the biodiversity of perching birds.

CER Analyze and Interpret Data

1. **Determine** the location of the highest concentration of perching birds.
2. **Generalize** the trend in the number of perching birds as you move from Canada to South America.
3. **Claim, Evidence, Reasoning** Why does the number of perching birds change as you move toward the southern tip of South America?

Distribution of Perching Birds

*Data obtained from: Pimm, S.L. and Brown J.H. 2004. Domains of diversity. *Science* 304: 831–833.

Pat Canova/Alamy