CHAPTER

16 Human Impact on Ecosystems

KEY CONCEPTS

16.1 Human Population Growth and Natural Resources
As the human population grows, the demand for Earth's resources increases.

16.2 Air Quality
Fossil fuel emissions affect the biosphere.

16.3 Water Quality
Pollution of Earth's freshwater supply threatens habitat and health.

16.4 Threats to Biodiversity
The impact of a growing human population threatens biodiversity.

16.5 Conservation
Conservation methods can help protect and restore ecosystems.

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What happened to this forest?

This once lush hillside has been destroyed by acid rain. Emissions from a nearby steel plant release chemical compounds that change the natural pH of rain, forming acid rain. Not only does acid rain damage leaves and branches, but because it lowers soil pH, it can damage plant root systems and kill useful microorganisms that release nutrients from dead organic material.

Connecting CONCEPTS

Plant Cells The acidity of rain affects plants at the cellular level. As you can see in this cross-section of a leaf, the plant cells on the left are healthy, but the cells on the right have been greatly damaged by water with a lowered pH. Acid rain destroys cell walls and can damage or even kill plants. (LM; magnification 30×)

16.1 Human Population Growth and Natural Resources

KEY CONCEPT As the human population grows, the demand for Earth's resources increases.

MAIN IDEA

- Earth's human population continues to grow.
- The growing human population exerts pressure on Earth's natural resources.
- Effective management of Earth's resources will help meet the needs of the future.

VOCABULARY

nonrenewable resource, p. 485
renewable resource, p. 485
ecological footprint, p. 487

Review
carrying capacity, population, limiting factor

CALIFORNIA STANDARDS

6.b ***Students know*** **how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.**

6.c *Students know* how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

Connect Humans depend upon Earth's nutrient and energy cycles. We harness Earth's energy to power our televisions, radios, streetlights, automobiles, airplanes—and everything else in our homes and cities. Your cotton T-shirt and this paper page came from plants that depend on Earth's nutrient cycles. The water you drink comes from water sources replenished by the hydrologic cycle. We do not just use Earth's cycles, we are a part of Earth's cycles. Everything we eat, drink, and use comes from Earth. But the overuse of resources and the production of waste can cause disruptions in the energy and nutrient cycles of Earth.

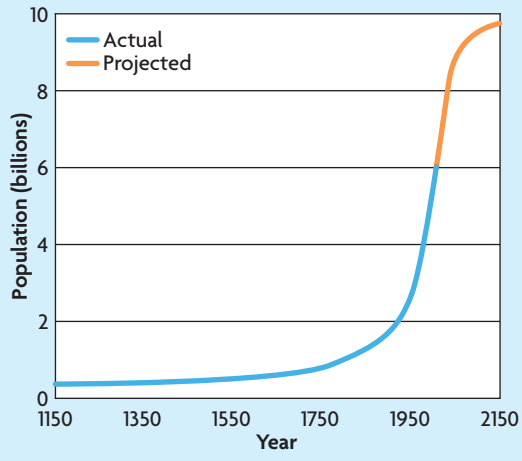
Animated BIOLOGY
Watch human population growth over time at ClassZone.com.

MAIN IDEA

Earth's human population continues to grow.

How many people can Earth support? In other words, what is the carrying capacity for humans on Earth? Recall that carrying capacity refers to the maximum population size that an environment can consistently support.

FIGURE 16.1 WORLD POPULATION



Source: United Nations, World Population Prospects, Population Reference Bureau

Earth's Carrying Capacity

Our predictions of Earth's human carrying capacity have changed over time. In the late 1700s, a young economist named Thomas Malthus wrote a controversial essay in which he claimed that the human population was growing faster than Earth's resources could support. Today, scientists use his observations and predictions when they are describing the concept of an ecosystem's carrying capacity. In Malthus's lifetime, the world population was around 1 billion. The graph in **FIGURE 16.1** shows how population size has changed over time. Today's human population of more than 6 billion has exceeded many earlier predictions. In the future, will Earth support 10 billion people, 20 billion, or even 50 billion people? Although we do not know of a fixed limit to the number of people that Earth can support, some limit must exist—Earth cannot support an infinite number of people.

Technology and Human Population

Recall that the carrying capacity of an environment can change as the environment changes. As humans have modified their environment through agriculture, transportation, medical advances, and sanitation, the carrying capacity of Earth has greatly increased.

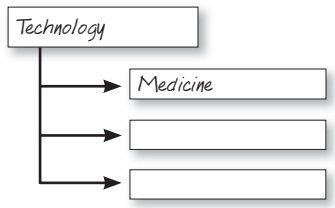
Technologies developed by humans have allowed Earth to support many more people than Malthus could ever have imagined. Gas-powered farm equipment, for example, made possible the production of huge quantities of food—much more than could be produced by human and animal power. Medical advances have also contributed to population growth. For example, infant mortality rates in the United States have dropped steadily over the last 70 years. In 1940, more than 40 infants died for every 1000 births. In 2002, only 7 infants died in 1000 births. Antibiotics and antiseptic cleaners have lowered infant mortality and the spread of diseases.

For a moment, think about how much we depend on technology. How have human lives changed with the help of plumbing to bring fresh water into homes and to take human waste out of homes? What if there were no transportation to move food and materials around the globe? What if there were no medicines? How many people could Earth support without electricity or gas, or if all construction had to be done by hand? Technological advances have allowed for continued human population growth.

Connect **What technologies do you depend on each day?**

TAKING NOTES

Use a diagram to summarize how technology has helped the human population grow.



MAIN IDEA

The growing human population exerts pressure on Earth's natural resources.

Two resources, oil and coal, currently support the majority of our country's energy use. Oil and coal are the result of natural processes. Over millions of years, natural processes transformed dead organisms into the concentrated carbon substances we use today as oil and coal. Oil and coal are **nonrenewable resources** because they are used faster than they form. In 2006, the human population was using oil at a rate of about 77 million barrels per day, and world oil use continues to rise. The growing use of this limited resource will lead to energy crises in the decades ahead unless technologies are developed to use other forms of energy.

Not all resources are nonrenewable. Resources that cannot be used up or can replenish themselves over time are called **renewable resources.** For example, wind energy—captured by wind turbines such as those shown in **FIGURE 16.2**—and solar energy are renewable resources because they cannot be used up by humans. Other resources, such as those that come from plants and animals, can be used up, but because they could last indefinitely through regrowth and reproduction, they are renewable. As long as these resources are replenished faster than they are used, they are considered renewable. But if renewable resources are not used carefully, they can become nonrenewable.

FIGURE 16.2 Giant wind turbines such as these capture renewable energy from Earth's natural processes.

Drinking water is a renewable resource, but pollution and overuse threaten its supply. Pesticides, industrial waste, and other contaminants have been found in water sources that supply tens of millions of people across the United States with fresh water. Groundwater is also being extracted from aquifers faster than it is replaced.

As Earth's human population continues to grow, the management of renewable and nonrenewable resources will play an important role. Today, the United States uses more resources and produces more waste than any other country on Earth. Each year, the United States generates about 230 million tons of garbage. That is about 4.2 pounds per day, per person, or almost 1 ton per year. What would happen if each of Earth's 6 billion humans generated 1 ton of garbage each year?

Analyze **Explain how a renewable resource such as water could become a nonrenewable resource.**

Connecting CONCEPTS

Hydrologic Cycle In **Chapter 13**, you learned how the hydrologic cycle moves water through Earth's atmosphere and back to Earth's surface. This cycling of water from resources such as lakes, rivers, and aquifers sustains the needs of the surrounding ecosystem.

MAIN IDEA

Effective management of Earth's resources will help meet the needs of the future.

Management of Earth's resources affects both current and future generations. The responsible use of Earth's resources can help to maintain these resources for future generations.

The story of Easter Island is a cautionary tale of destruction caused by careless use of resources. When humans first landed on Easter Island between A.D. 400 and 700, it was thickly forested on rich soil, with many bird and mammal species. The human colony grew quickly over the next 1000 years, building the stone monuments for which the island is now famous. The island inhabitants cut down the forests for lumber and for building boats. The trees were cut down faster than they could grow back. Eventually, Easter Island was left with no trees, as shown in **FIGURE 16.3**. Without trees, there was no wood for shelter or boats, the rich soil washed away, and habitat for the island's animal populations was lost. Without boats, there was no offshore fishing. With no food and island resources nearly gone, the Easter Island human population crashed and the Easter Islanders disappeared.

FIGURE 16.3 Today, the barren landscapes of Easter Island are an eerie reminder of the fate of the island's ancient inhabitants.

The Easter Islanders' use of trees was unsustainable. In other words, the islanders used trees to meet their short-term needs. But this resource could not be maintained into the future, and its use had negative long-term effects. In contrast, sustainable use of resources means using resources in such a way that they will be available for future generations.

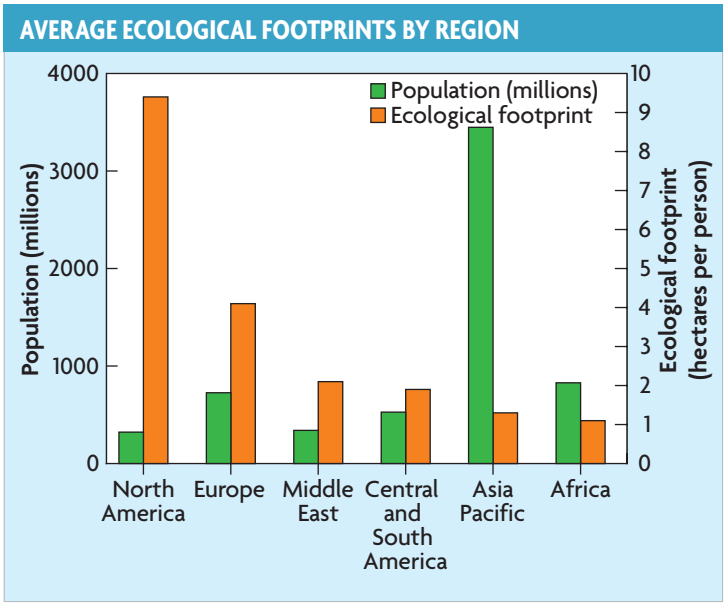
Ecological Footprint

Humans need natural resources to survive, but the way resources are used threatens the welfare of the human population. Earth's carrying capacity depends on how much land is needed to support each person on Earth. The amount of land necessary to produce and maintain enough food and water, shelter, energy, and waste is called an **ecological footprint.** The size of an ecological footprint depends on a number of factors. These include the amount and efficiency of resource use, and the amount and toxicity of waste produced.

As shown in **FIGURE 16.4**, individuals and populations vary in their use of resources and production of waste, and therefore in the size of their ecological footprints. The average U.S. citizen's ecological footprint covers an area larger than 24 football fields (9.7 hectares) and is one of the largest in the world. But the ecological footprint of individuals in developing nations is growing, and nations such as China and India have populations that are more than three times the size of the U.S. population. Individuals in the United States may have a large footprint, but other nations have a lot more "feet."

As the world population continues to grow, we face many challenging decisions. Waste production and management is an issue that will become more important as we move into the future. Should we have rules to regulate resource use and waste production? If so, how much resource use and waste production should individuals and populations be allowed? How much land needs to be maintained for agriculture, how much for living space, and how much for other uses? How much fresh water should be used for crop irrigation and how much reserved for humans to drink? Our welfare, and the welfare of future generations, depends on sustainable management of Earth's resources.

Analyze **Why is our ecological footprint related to an area of land?**



Source: Global Footprint Network

FIGURE 16.4 Different regions of the world have varying levels of impact on their environment. This graph shows the average ecological footprint of individuals around the world.

NSTA scilinks.org SCILINKS

To learn more about Earth's human population, go to scilinks.org.
Keycode: MLB016

16.1 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Give three examples of how technology has influenced human population growth.
2. What is the difference between **renewable** and **nonrenewable resources**?
3. Describe how a population can use resources in a sustainable way.

CRITICAL THINKING

4. **Connect** What factors can limit the growth of the human population? 6.c
5. **Synthesize** How could the Easter Islanders have prevented their population crash? 6.b

Connecting CONCEPTS

6. **Carrying Capacity** The progressive increase in Earth's human carrying capacity came from advances in technology. What density-independent and density-dependent limiting factors may prevent the human population from continued growth?

16.2 Air Quality

KEY CONCEPT Fossil fuel emissions affect the biosphere.

MAIN IDEA

- Pollutants accumulate in the air.
- Air pollution is changing Earth's biosphere.

VOCABULARY

pollution, p. 488
smog, p. 488
particulate, p. 488
acid rain, p. 489
greenhouse effect, p. 490
global warming, p. 492

CALIFORNIA STANDARDS

6.b ***Students know*** **how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.**

Connect Fossil fuels are an important part of modern society. Consider that every time you ride in a car, you are being transported by energy that originally came from the Sun. This energy was absorbed by ancient organisms and stored in their biomass. Today, as humans burn these fuels in the form of gas and oil, we are creating compounds that pollute Earth's biosphere. Without this energy our lives would be very different, but how does air pollution from fossil fuels affect the biosphere?

MAIN IDEA

Pollutants accumulate in the air.

Although it is sometimes easy to forget, humans are an important part of the biosphere. Our actions have direct and indirect effects on Earth's natural cycles. Each year humans add synthetic chemicals and materials to the Earth. Many of them cannot be integrated into normal ecosystem functions. The addition of these materials to the environment is called pollution. **Pollution** describes any undesirable factor, or pollutant, that is added to the air, water, or soil. Pollution can take the form of microscopic air particles, or waste products from factories and sewers, or household chemicals that are poured down the kitchen sink. The harmful effects of pollutants can be immediate or delayed, but these effects may add up over time and can disrupt the function of ecosystems.

FIGURE 16.5 The hazy fog over the city of Los Angeles is largely produced by automobile emissions and industrial processes. Smog is a growing problem in many areas of the United States.

Smog and Ozone

The most common air pollution comes from the waste products produced by burning fossil fuels such as gas and oil. Chemical compounds released through this process can combine to form a haze of matter called smog, shown in **FIGURE 16.5.** **Smog** is a type of air pollution caused by the interaction of sunlight with pollutants produced by fossil fuel emissions. There are several components of smog, including particulate matter and ground-level ozone. **Particulates** are microscopic bits of dust, metal, and unburned fuel, 1–10 microns in size, that are produced by many different industrial processes. Once in the air, some particulates may stay in the atmosphere for weeks before they settle to the ground. Fine particulates can be inhaled and can cause many different types of health problems.

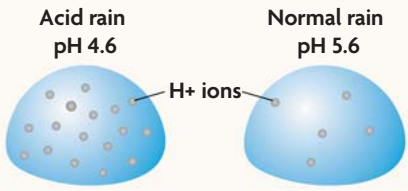
The second component of smog is ground-level ozone. In the presence of sunlight, two types of chemicals react to produce ground-level ozone (O_3). Nitrogen oxides are produced during fossil fuel combustion, and these chemicals give smog a yellowish color. Ozone is formed when nitrogen dioxide (NO_2) reacts with oxygen (O_2) present in the atmosphere. In this reaction, one oxygen from an NO_2 molecule is transferred to an O_2 molecule, forming ozone (O_3). The ozone produced by reactions of nitrogen oxide and oxygen tends to stay close to the ground, where it can be harmful to human health and ecosystem functions. Although ozone is harmful to organisms, it also plays an important, protective role in the Earth's upper atmosphere. High concentrations of ozone in the stratosphere, also known as the ozonosphere or ozone layer, act as a shield protecting Earth's biosphere against harmful ultraviolet rays found in sunlight.

Acid Rain

The chemicals produced by the burning of fossil fuels become part of the ecosystem and can change the products of natural cycles. For example, nitrogen oxides and sulfur oxides from fossil fuel emissions can lead to the formation of acid rain. **Acid rain** is a type of precipitation produced when pollutants in the water cycle cause rain pH to drop below normal levels.

VISUAL VOCAB

Acid rain is a type of precipitation produced when pollutants in the water cycle cause rain pH to drop below normal levels.



During the water cycle, rain falls through Earth's atmosphere and interacts with carbon dioxide molecules. As it falls, water molecules react with carbon dioxide molecules to form a weak carbonic acid, which then breaks apart, leaving lone hydrogen ions. This is normal. All rain that falls is slightly acidic, with a pH around 5.6. When pollutants such as nitrogen oxides and sulfur oxides become a part of the water cycle, acid rain is the result. Reactions between these chemicals and the oxygen and water normally present in the atmosphere create sulfuric and nitric acids that can cause pH levels to fall below 5.6.

Acid rain falls in many areas of the United States and has a major effect on ecosystems. By decreasing pH levels in lakes and streams, acid rain threatens water supplies and species habitat. Acid rain can cause a decline in growth rates, as shown in **FIGURE 16.6.** It can also cause leaves and bark to break down more quickly and make trees more vulnerable to disease and weather.

Synthesize **As the human population continues to increase and use more fossil fuels, why might acid rain become a bigger problem?**

Connecting **CONCEPTS**

pH Recall from **Chapter 2** that the pH is a measure of the concentration of H+ ions in a solution. Concentrations of H+ ions in acid rain are very high, giving the rain a lower pH level.

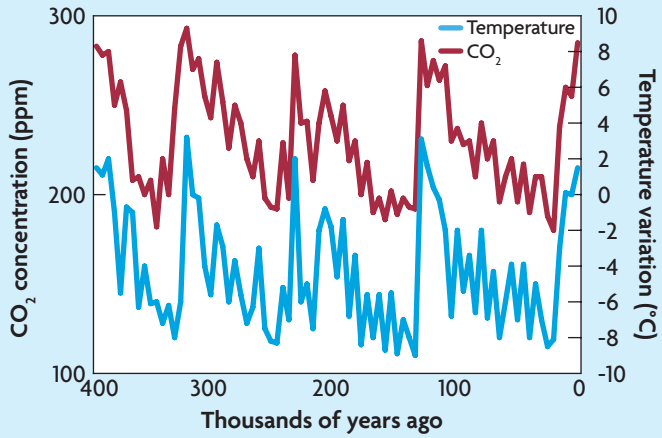
FIGURE 16.6 The wide growth rings of this tree indicate a healthy environment. The smaller growth rings illustrate how acid rain directly impacts plant growth.

MAIN IDEA

Air pollution is changing Earth's biosphere.

Earth's atmosphere naturally includes molecules of carbon dioxide that play an important part in keeping the biosphere at a temperature that can support life. The levels of atmospheric carbon dioxide rise and fall over time as a normal part of the climate cycles of Earth. Collections of data from arctic ice cores allow scientists to look deep into Earth's atmospheric history. They have discovered that cycles of rising and falling carbon dioxide levels follow known patterns of periodic warming and cooling. The relationship between changes in global average temperatures and carbon dioxide levels is shown in **FIGURE 16.7.** We know that high levels of carbon dioxide are typical of Earth's warmer periods, while low levels are associated with cool climates, eventually leading to periods of extreme cold called ice ages.

WORLD TEMPERATURE CHANGE



Source: Petit, J.R., et al., *Nature* 387:359.

FIGURE 16.7 Scientists have found that changes in Earth's temperature correspond with fluctuations in global carbon dioxide levels.

The Greenhouse Effect

Earth gets nearly all of its energy from the wavelengths of both visible and invisible light emitted by the Sun. When the Sun's waves reach Earth, some are absorbed by Earth's atmosphere, but many of these rays pass through the atmosphere and reach Earth's surface. Some of this energy is absorbed by Earth's surface, but it is later reradiated as invisible infrared radiation—heat. After being reradiated from Earth's surface, this energy could travel away from Earth, be lost into space, and leave an extremely cold Earth that could never sustain life. But Earth is not cold and does have life. So what keeps Earth's temperature from dropping to extreme freezing conditions?

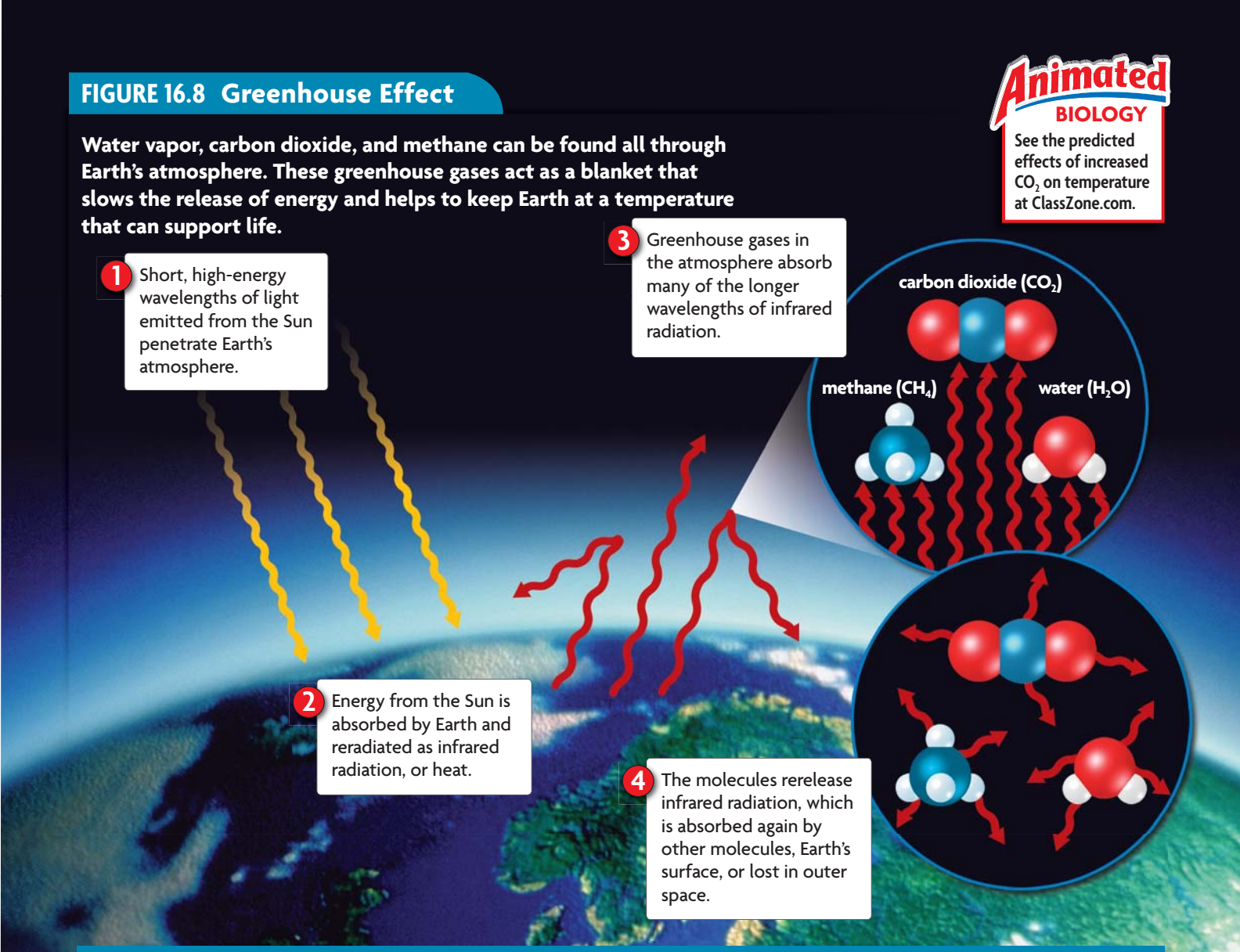
To answer this question, think about the greenhouses that scientists and gardeners use to grow plants. Greenhouses use glass that allows sunlight to pass radiation through and provide energy for plant growth. The glass also prevents infrared radiation from escaping. This infrared radiation keeps the inside of the greenhouse warm. This same phenomenon occurs in a car, causing the inside to heat up when the windows are closed.

In the same way that greenhouse glass creates an environment for plants to grow, the chemical composition of Earth's atmosphere plays an important role in maintaining an environment that is suitable for life. Earth's atmosphere contains gases called greenhouse gases that act as insulators and slow the loss of heat through the atmosphere. Water vapor, carbon dioxide, and methane are three of the most common greenhouse gases found in the atmosphere. Greenhouse gases absorb wavelengths of infrared radiation. This process is called the greenhouse effect and is illustrated in **FIGURE 16.8.** The **greenhouse effect** occurs when carbon dioxide, water, and methane molecules absorb energy reradiated by Earth's surface and slow the release of this energy from Earth's atmosphere.

FIGURE 16.8 Greenhouse Effect

Water vapor, carbon dioxide, and methane can be found all through Earth's atmosphere. These greenhouse gases act as a blanket that slows the release of energy and helps to keep Earth at a temperature that can support life.

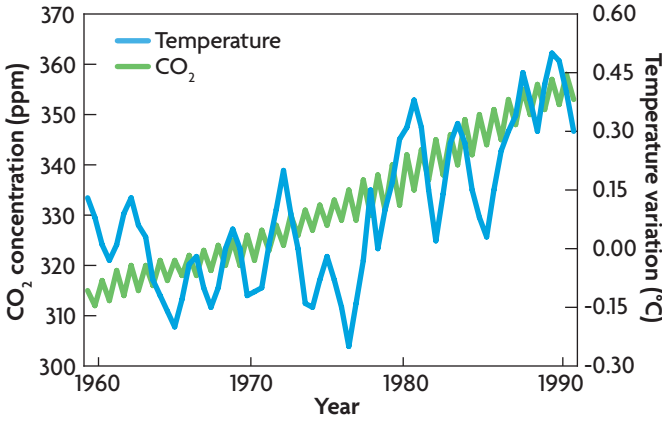
Animated BIOLOGY
See the predicted effects of increased CO_2 on temperature at ClassZone.com.



GLOBAL WARMING

As automobile use and industry have grown, so have the levels of carbon dioxide and other greenhouse gases in the atmosphere. This graph shows average global temperature changes (blue) against atmospheric carbon dioxide levels (green) measured at Mauna Loa Observatory in Hawaii.

Global Temperature And Carbon Dioxide Levels Over Time



Source: University of California, Scripps Institute of Oceanography/ Hadley Centre for Climate Prediction and Research

CRITICAL VIEWING How would an increase in atmospheric greenhouse gases contribute to an increase in average global temperatures?

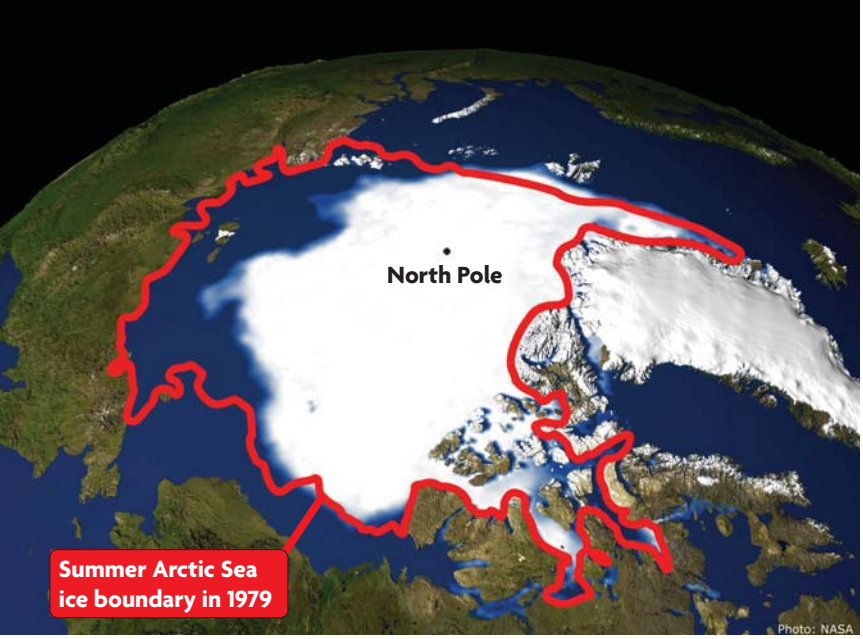


FIGURE 16.9 Over the past 20 years, increasing global temperatures have decreased summer ice pack around the North Pole by about 20 percent.

Global Warming

Over the past 100 years, the average global temperature has risen 0.6°C (1.2°F), with the most dramatic change occurring over the past 40 years. What is causing this rise in temperature? Global temperature fluctuations are a normal part of Earth's climate cycle. But major changes in temperature generally occur over tens of thousands of years, not over 100 years.

The trend of increasing global temperatures is known as **global warming.** From a variety of evidence, scientists can infer that the changes in temperature are the result of increased levels of greenhouse gases such as carbon dioxide, water, and methane. There is no doubt that the growth of industry and use of automobiles has increased the emission of greenhouse gases over the past 100 years. Scientists may disagree on how much this human impact is influencing global warming, but most agree that we must take steps to slow the warming process.

Scientists do not know how these atmospheric changes will affect the global biosphere. What they do know is that evidence shows global warming is already threatening ecosystems around the world. Ecological disasters, such as increased flooding, stronger tropical storms, and the loss of biodiversity, are just a few of the threats that may be caused by global warming. As shown in **FIGURE 16.9**, the polar ice pack is melting at a rapid pace, which may eventually affect global weather patterns. These changes may be part of a slow warming process, or they may be the beginning of a rapid global climate change. The future of global warming is uncertain, but scientists predict that average temperatures on Earth could increase anywhere from 1.4 to 5.8°C (2.2 to 10°F) by the year 2100, a change that could have dramatic effects on Earth's biosphere, and change the planet that we call home.

Connect **How might global warming affect seasonal temperature changes?**

16.2 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Name and describe two ways in which **pollution** affects ecosystems. 6.b
2. How does the **greenhouse effect** keep Earth warm?
3. Explain how a build-up of carbon dioxide in the atmosphere could increase Earth's global temperature.

CRITICAL THINKING

4. **Predict** Describe how **acid rain** falling in a forest could disrupt the trophic structure of the ecosystem. 6.b
5. **Connect** Greenhouse gases are found close to Earth's surface and high above in the atmosphere. Name two important functions of greenhouse gases at Earth's surface.

Connecting CONCEPTS

6. **Food Webs** Ocean producers such as phytoplankton are an important part of food webs, but they need a specific temperature to survive. How might increased water temperatures affect these ocean food webs?

Acid Rain

In this lab, you will determine the effects of acid rain on plant growth. You will use water with different levels of acidity to water plants and monitor how it affects plant growth over a two-week period.

PROBLEM How does acid rain affect plant growth?

MATERIALS

- 4 potted radish seedlings
- sharpened pencil
- marker
- water, pH 6
- water, pH 5
- water, pH 4
- water, pH 3
- 250-mL beaker
- metric ruler

PROCESS SKILLS

- **Designing Experiments**
- **Hypothesizing**
- **Collecting Data**
- **Analyzing Data**

CALIFORNIA STANDARDS

IE.1.b Identify and communicate sources of unavoidable experimental error.

IE.1.c Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

IE.1.d Formulate explanations by using logic and evidence.

DESIGN YOUR EXPERIMENT

1. Write a procedure to explain how you will set up and conduct an experiment to test how acid rain affects plant growth. Identify the independent and dependent variables and constants you will maintain. For example:
   - What amount of water will you use to water the plants?
   - How often will you water the plants?
   - How will you measure the effects of acid rain on plant growth, both quantitatively and qualitatively?
   - How often will you collect data?

2. Form a hypothesis about the effects of acidic water on plant growth.
3. Design a data table to organize your results.
4. Have your teacher approve your experimental design.
5. Obtain your materials. Set up and conduct your experiment.

ANALYZE AND CONCLUDE

1. **Analyze** What were the independent and dependent variables in your experiment? What variables were held constant?
2. **Graph Data** Determine the best way to graph the data you collected. Determine whether a line graph or bar graph is appropriate, and construct that type of graph.
3. **Analyze Data** Write a summary statement that describes the results of your experiment. Include the qualitative data as well as the quantitative data. Is your hypothesis supported by the data you collected? Why or why not?
4. **Experimental Design** Identify possible sources of unavoidable experimental error in your design. List possible reasons for inconsistent results you may have observed.
5. **Apply** How does acid rain appear to affect plant growth?

EXTEND YOUR INVESTIGATION

Measure the pH of rain in your area. Based on the results of your experiment, what could you conclude about how the pH of rain might affect the growth of plants?

16.3 Water Quality

KEY CONCEPT Pollution of Earth's freshwater supply threatens habitat and health.

MAIN IDEA

- Water pollution affects ecosystems.
- Biomagnification causes accumulation of toxins in the food chain.

VOCABULARY

indicator species, p. 494
biomagnification, p. 495

Review
pollution

CALIFORNIA STANDARDS

6.b ***Students know*** **how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.**

6.f *Students know* at each link in a food web some energy is stored in newly made structures but much energy is dissipated into the environment as heat. This dissipation may be represented in an energy pyramid.

Connect When you swallow a pill, your body only uses a part of the medicine in the pill and gets rid of the rest as waste, which is flushed away. Scientists have detected traces of many prescription drugs in freshwater supplies. Several fish species that live in fresh waters have been exposed to the female hormone, estrogen. Some of the male fish have begun showing female characteristics. These "gender-bending" fish are only one effect of water pollution. What other pollutants can be found in our water?

MAIN IDEA

Water pollution affects ecosystems.

Pollution can have a major impact on water ecosystems. Chemical contaminants, raw sewage, trash, and other waste products are only a few pollutants that make their way into rivers, lakes, and aquifers all over the world.

Runoff from farms and cities may contain toxic chemicals and debris that can disrupt the chemical balance of freshwater lakes and streams and put entire freshwater ecosystems at risk. For example, detergents and fertilizers used in fields can affect a lake ecosystem by stimulating plant and algae overgrowth. A buildup of algae, such as the one shown in **FIGURE 16.10**, can drastically lower the levels of dissolved oxygen, leading to the dying off of fish populations. A lack of oxygen can also keep detritivores from breaking down waste materials. Over time, lakes and ponds slowly begin to fill in through a process called eutrophication.

FIGURE 16.10 A buildup of algae in lakes such as this one is the direct result of pollution. Eventually, the process of eutrophication will lead to the disappearance of the lake.

One way in which scientists can determine the health of an ecosystem is through the study of natural indicator species. An **indicator species,** also known as a bioindicator, is a species that provides a sign, or indication, of the quality of the ecosystem's environmental conditions. The gender-bending fish discussed above is an example of an aquatic indicator species. Frogs are sometimes considered an indicator species for water quality. Because the skin of tadpoles and adults is water-permeable, they come into direct contact with pollutants that can cause deformities such as extra arms and legs, as well as body tumors. Terrestrial ecosystems have indicator species as well, but the environmental impacts on these species are shown in different ways. Aquatic indicator species show the direct effects of pollution.

The Forster's tern, a bird species native to coastal regions of the United States, has provided scientists with clues about pollution in the San Francisco Bay. This indicator species occupies a niche at the top of this ecosystem's food web. An important part of the tern's diet is fish it catches in the San Francisco Bay. By studying the tissues of dead tern chicks, scientists are finding large amounts of chemical contaminants such as mercury and PCBs, or polychlorinated biphenyls. These chemicals can harm developing eggs and can cause problems in the nervous system of adult birds. The high levels of these pollutants found in birds could lead to a decrease in the tern population and disrupt the balance of this aquatic ecosystem.

Apply **If the population of an indicator species is increasing, what might you infer about the conditions of the ecosystem?**

MAIN IDEA

Biomagnification causes accumulation of toxins in the food chain.

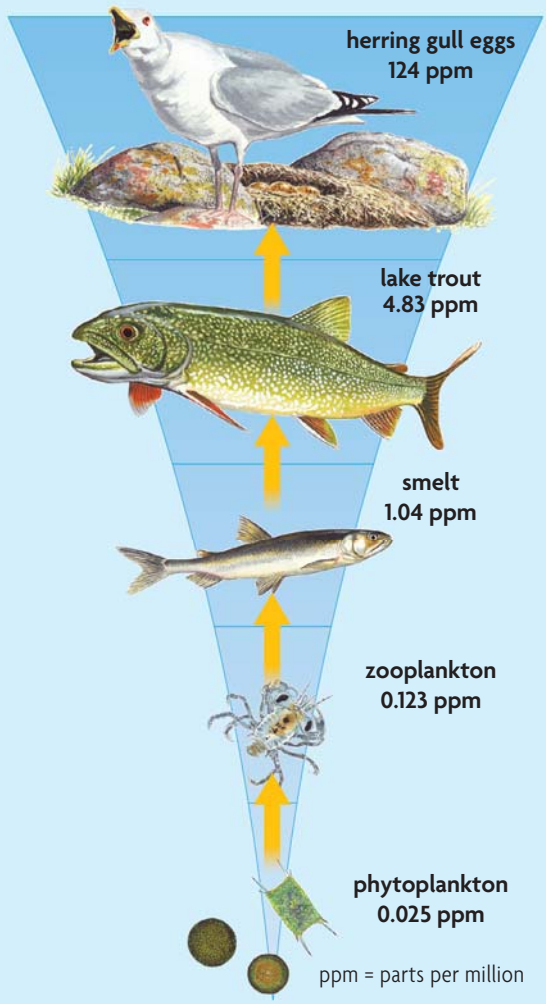
The high death rates in young Forster's terns are due to high levels of toxic compounds found in the parents. How did these chemicals get into the adult birds?

Some pollutants are water-soluble, which means that they dissolve in water and will exit an organism through its wastes. Other pollutants are fat-soluble and stay in the body fat of an organism. Fat-soluble pollutants can also move from one organism to another in a process known as biomagnification. In **biomagnification,** a pollutant moves up the food chain as predators eat prey, accumulating in higher concentrations in the bodies of predators. Scientists measure pollutants in parts per million (ppm). The illustration in **FIGURE 16.11** shows how biomagnification moves small traces of a pollutant to higher concentrations further up the food chain.

After a pesticide is sprayed onto fields, large amounts of the chemical are washed into ponds and lakes, where phytoplankton pick up the chemical from their environment. The phytoplankton contain very small concentrations of the chemical, but when zooplankton feed on phytoplankton, they are also eating the chemical. Because the zooplankton eat many phytoplankton, higher levels of the chemical build up in the zooplankton. Secondary consumers such as small fish eat zooplankton and collect larger concentrations in their own body fat. Larger fish eat the chemical-laden fish, and the amount of the chemical in their fat builds up as they eat more and more. The increase in contamination is dramatic and causes the consumer at the top of the food chain, often a large predator such as an eagle or hawk, to receive the most concentrated dose of the pollutant.

FIGURE 16.11 Biomagnification

The movement of fat-soluble pollutants through a food chain results in higher concentrations in the top consumer.



Connect **Are humans likely affected by biomagnification? If so, what foods might be dangerous?**

Connecting CONCEPTS

Energy Pyramid In **Chapter 13,** you learned how energy is lost as it moves up through trophic levels. In comparison, the process of biomagnification increases toxic material as it moves up the trophic structure.

QUICK LAB MODELING

Modeling Biomagnification

In this lab, you will model biomagnification. Small cups represent smelt, a fish that feeds on zooplankton. Medium-sized cups represent trout, which feed on smelt. The large cup represents an eagle, which feeds on trout.

PROBLEM How are contaminants magnified up the food chain?

MATERIALS

- 4 small paper cups
- 2 medium paper cups
- 1 large paper cup
- marker
- sharpened pencil
- 10 cm masking tape
- 400 mL salt
- 16 beads
- 500-mL beaker

PROCEDURE

1. Label the cups, smelt, trout, and eagle according to size. Punch holes in the bottom of each cup with the pencil. Cover the holes with masking tape.
2. Fill each of the cups halfway with salt. Add 4 beads to each small cup.
3. Hold each of the small cups over the beaker and remove the tape. Allow the salt to flow through the holes into the beaker.
4. Pour the remaining contents of two small cups into one medium cup. Pour the contents of the other two small cups into the second medium cup. Repeat step 3 with the medium-sized cups.
5. Pour the remaining contents of both of the medium cups into the large cup.

ANALYZE AND CONCLUDE

1. **Analyze** What do the beads represent in this model of biomagnification?
2. **Evaluate** Why is the following statement true: "Carnivores at the top of the food chain tend to be most affected by pollutants released into the environment"?

CALIFORNIA STANDARDS

IE.1.g Recognize the usefulness and limitations of models and theories as scientific representations of reality.

Biomagnification has the most serious effect on species near the top of the food chain. For example, the beluga whale is a top predator that lives in cold ocean waters and feeds on a wide variety of fish species. Studies of a beluga whale population in eastern Canada have shown such extreme levels of toxic chemicals that some whale carcasses have been treated as hazardous waste.

As top level consumers, humans can also be affected by biomagnification. Scientists have recently found small amounts of PCBs in the blood of newborn babies. Exposure to fat-soluble toxins such as PCBs during pregnancy and nursing can be dangerous to the developing fetus, and may also affect growth and development in young children.

Compare Why would tertiary consumers have higher concentrations of toxins than primary consumers?

16.3 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. What does an **indicator species** tell us about the health of an ecosystem?
2. How do PCBs affect bird populations through **biomagnification**? 6.b

CRITICAL THINKING

3. **Compare** How are the concepts of carrying capacity and indicator species related?
4. **Synthesize** Would a buffalo or a mountain lion be more affected by biomagnification? Why?

Connecting CONCEPTS

5. **Energy Pyramid** How does the biomagnification "pyramid" compare with the energy pyramid? 6.f

DATA ANALYSIS
ClassZone.com

Types of Quantitative Data

Collecting data is a fundamental part of the scientific process. Before you design and carry out an experiment, it is important to understand the two different types of quantitative data: discrete and continuous.

Discrete data Data that cannot be broken down into smaller units and have meaning, such as the number of frogs in a pond, are called discrete data. Bar graphs are usually used for discrete data.

Continuous data Data that have fractional values—that are not whole numbers—are called continuous data. The length and mass of a frog are continuous data. Continuous data are usually shown on a line graph. The values of points that were not actually measured in an experiment can be inferred from the graph.

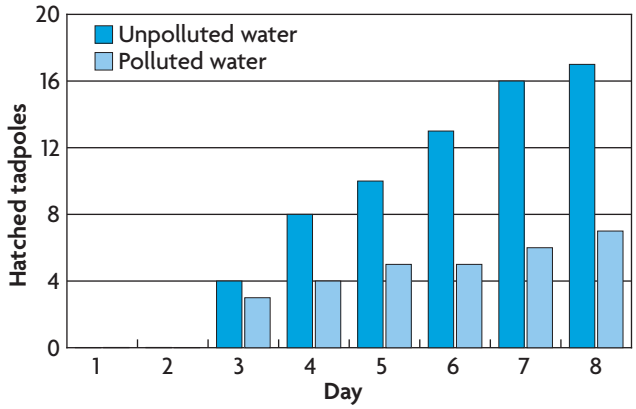
EXAMPLE

Frogs are commonly used as a biological indicator for water quality. A classroom of students wishes to test how water quality affects growth rates in frogs. Frogs hatch from eggs into tadpoles and then slowly mature into adult frogs.

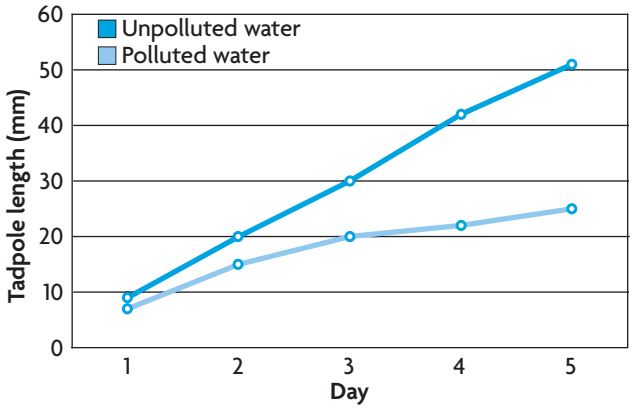
Students compared hatching rates in frog eggs over an eight-day period. Eggs were raised in one of two water samples, a sample from a known polluted pond, and a sample from an unpolluted pond. These data are discrete because a certain number of eggs hatched. There were no half or quarter tadpoles.

After hatching, students measured tadpole growth in both polluted and unpolluted water over the next five days. These data are continuous because they can be broken down further and data points between measurements can be inferred.

GRAPH 1. HATCHED TADPOLES (DISCRETE DATA)



GRAPH 2. AVERAGE TADPOLE LENGTH (CONTINUOUS DATA)



IDENTIFY DISCRETE AND CONTINUOUS DATA

For each example, identify whether the data are discrete or continuous.

1. **Apply** A student collects data each spring and summer for five years about populations of endangered frogs in a wetland by counting the number of individual frogs in quadrats.
2. **Classify** The EPA compiles data about the mass of recycled aluminum (millions of tons) for every year since 1990.
3. **Analyze** Since 1860, the National Oceanic and Atmospheric Association has collected data about the change in Earth's surface temperature and the concentration of carbon dioxide in the atmosphere.

CALIFORNIA STANDARDS

IE.1.d Formulate explanations by using logic and evidence.

16.4 Threats to Biodiversity

KEY CONCEPT The impact of a growing human population threatens biodiversity.

MAIN IDEA

- Preserving biodiversity is important to the future of the biosphere.
- Loss of habitat eliminates species.
- Introduced species can disrupt stable relationships in an ecosystem.

VOCABULARY

habitat fragmentation, p. 499
introduced species, p. 500

Review
biodiversity

CALIFORNIA STANDARDS

6.b *Students know* how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

Connect Imagine yourself taking a walk down your favorite street. But instead of bright colors and interesting sights, you see only one type of everything. There is one type of tree, one type of flower, and one type of car. At school all of your friends look exactly like you, lunch is the same every day, and everyone listens to the same music. We rarely think of the diversity we experience each day. The diversity of Earth makes our planet unique and maintains the stability of ecosystems.

MAIN IDEA

Preserving biodiversity is important to the future of the biosphere.

Ecosystems are constantly changing, and populations are always adjusting to these changes. Many times, human actions alter ecosystems in ways that harm a population and threaten biodiversity. The loss of habitat and the growing pollution problem are affecting animal and plant populations around the world. The value of biodiversity is not just measured in dollars. Biodiversity ensures the future of Earth.

Biodiversity is the diverse world of living things—the wide array and assortment of species that are found in any ecosystem. A decrease in an ecosystem's biodiversity will have a ripple effect through the entire ecosystem, affecting all species. Biodiversity is the foundation of much of our world.

Many medical and technological advancements come from nature. Nearly half of prescribed medicines are derived from plants. On the technological front, scientists in many fields continue to get inspiration from nature. For example, an adhesive from a mussel is being used as the pattern for a new coating for medical implants.

The loss of biodiversity has long-term effects. When a species goes extinct, it is gone forever. In many cases, all that remains of extinct species is a few dead specimens in a museum that can give little information other than where they were discovered. A loss of biodiversity can reduce an ecosystem's stability and make it more difficult for the ecosystem to handle future change.

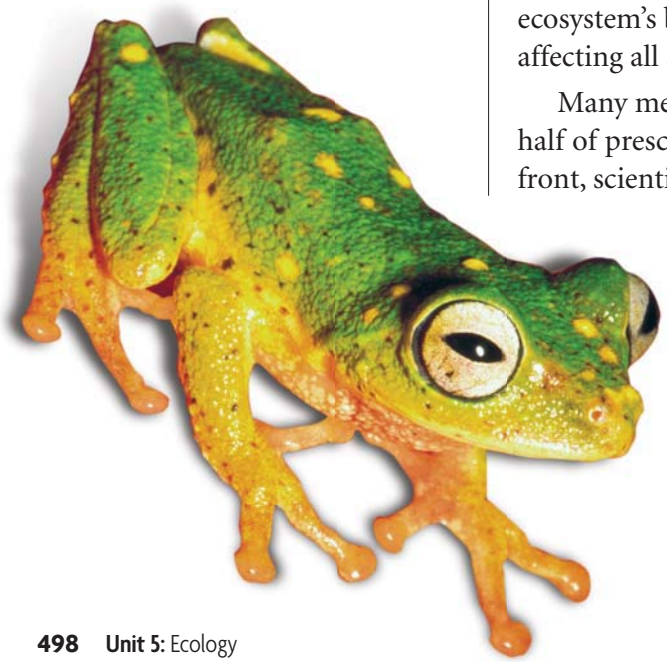


FIGURE 16.12 Rare frog species of the Sri Lankan rain forests, such as this Knuckles leaf nesting frog, are in danger of becoming extinct due to habitat destruction.

For example, as the nation of Sri Lanka has modernized, the natural resources of the island have become increasingly depleted. Ninety-five percent of the island's rain forests have been lost, and with them more than 19 different frog species have gone extinct. In addition, numerous other species, such as the rare frog species shown in **FIGURE 16.12**, are endangered. The loss of even a single species can harm the overall stability of an island ecosystem.

Biodiversity is highest in the rain forest biomes of the world, and it is these areas that are most threatened. Currently, about 1 percent of this biome is lost each year to logging or to clearing for agricultural use. Preserving the rain forests of the world will do a great deal to protect and preserve the biodiversity of our planet.

Connecting CONCEPTS

Carbon Cycle Rain forests around the world play an integral role in Earth's carbon cycle, storing large amounts of carbon in their structures.

Connect **Why is biodiversity highest in tropical rain forests?**

MAIN IDEA

Loss of habitat eliminates species.

One way to protect species is to monitor and manage their numbers, and to ensure they have adequate habitat for survival. Governments and organizations around the world are developing programs to protect species that are threatened by overhunting, overcollecting, and habitat loss.

As the human population moves into what was formerly wilderness, people are moving into the territory of many different species of wildlife. In many parts of the world, the loss of habitat can put species in danger of becoming extinct. Historically, for example, wetland habitats were viewed as breeding grounds for disease and as "wasted land." Between the 1780s and the 1980s, more than 53 percent of wetland habitat in the United States was eliminated. This destruction displaced large numbers of wildlife and disrupted migration patterns for many species of water birds.

Efforts to ensure adequate habitat must take into account the life history of the organism, including mating habits and migration patterns. Ecologists have become particularly worried about habitat fragmentation. **Habitat fragmentation** occurs when a barrier forms that prevents an organism from accessing its entire home range. Often, habitat fragmentation is caused by the building of roadways or the harvesting of forests. Bears, deer, raccoons, and opossums are just a few of the animals that find their home ranges fragmented as urban sprawl increases. To try to fix this growing problem, some states are building underpasses and overpasses so that wildlife can avoid busy roadways. Corridors such as the one shown in **FIGURE 16.13** help to maintain continuous tracts of habitat for those species that move between different areas.

Connect **Why is wetland habitat important for migrating birds?**

FIGURE 16.13 By providing a safe way to cross barriers such as roads and highways, land bridges such as this one in Canada allow animals to move safely from one part of their habitat to the next.

FIGURE 16.14 Mice plagues in Australia and China can cost farmers millions of dollars in lost crops.

MAIN IDEA

Introduced species can disrupt stable relationships in an ecosystem.

Introduced species have a direct impact on the biodiversity and natural flow of energy in an ecosystem. An **introduced species** is any organism that was brought to an ecosystem as the result of human actions. Introduced species can pose a great threat to the stability of an ecosystem if they prey on or crowd out native species. In some instances, introduced species can cause economic damage. Just as native species interact with one another and their habitat, nonnative or introduced species are active and sometimes disruptive in their new ecosystems. Invasive species are successful in environments under many different circumstances. If an environment has a niche that the invasive species can exploit, or if the invasive species is a better competitor in a particular niche, native species may be pushed out. Invasive species are also successful if there is a lack of predators to keep the population stable.

Effect on Native Species

The Florida Everglades is a dynamic ecosystem where unique plants and animals have evolved for tens of thousands of years. The climate is similar to that of a tropical jungle, and the Everglades can support a great diversity of organisms. One species that has been introduced to this region originally came from the tropical jungles of Southeastern Asia. The Burmese python, shown in **FIGURE 16.15**, came to the United States as a pet species. Growing more than 6 meters (20 ft) in length, this massive snake can be difficult to care for. Irresponsible owners have released many of the snakes back into the wild. A large number of Burmese pythons have been captured and removed from Everglades National Park, and officials say that there is a good chance that a breeding population is present. As a constrictor species, the Burmese python feeds on small animals such as rats, birds, raccoons, and even dogs. Threats to endangered bird species in the park worry officials. As the python population begins to grow, endangered species protected in the Everglades could be affected.

FIGURE 16.15 Introduced species such as the Burmese python are growing in numbers in places like the Florida Everglades.

Introduced animals are not the only problem. Plant species such as kudzu, another native of southeastern Asia, are invasive in the United States and are choking out native species of plants across the southeastern United States. The kudzu plant, shown in **FIGURE 16.16,** was introduced in 1876 as an ornamental tropical houseplant enjoyed for its fragrant flowers and large leaves. It was planted as field cover to prevent soil loss from erosion, but it rapidly began to spread out of the fields. Currently, kudzu is a classified as a problematic weed species in much of the eastern United States. Kudzu is a hardy plant, at home in virtually any soil, and it can grow up to 18 meters (60 ft) in a single growing season. This growth rate makes it difficult to control. Very few plant species can survive in an environment once kudzu is introduced. By blanketing trees and shrubs with its large leaves, kudzu deprives other plants of the sunlight they need to survive. The plant is resistant to most types of herbicides and can live for many years.

FIGURE 16.16 After a few months of being left in a single place, this car has become covered with kudzu. Fast-growing kudzu can destroy natural habitats in just a few years.

Economic Damage

Invasive species can have a major impact on humans as well as ecosystems. The common house mouse is an introduced species to the Australian continent. During the late 1700s, mice came from Europe as stowaways on British cargo ships. Today, mice are considered a major pest species in Australia and have caused widespread economic damage. Every four or five years, mice populations increase exponentially. Seasons of heavy rainfall lead to bumper crops of corn and grain, causing a dramatic rise in mouse populations and leading to huge numbers of mice moving from one food source to another. It was estimated that during the 1993–1994 season, the mouse population in Australia cost farmers about $65 million in lost revenue. Mice continue to be a problem throughout the region.

Predict **How might a species of carnivorous fish introduced into a lake have a negative impact on the lake ecosystem?**

16.4 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Give two reasons why biodiversity is important to humans.
2. How does **habitat fragmentation** affect migrating bird populations?
3. What types of damage can **introduced species** cause?

CRITICAL THINKING

4. **Analyze** How could continued habitat fragmentation reduce biodiversity?
5. **Connect** How might the introduction of a mouse predator help with the mouse problem in Australia? What problems might it cause? **6.b**

Connecting CONCEPTS

6. **Population Growth** Using your knowledge of populations, describe what will eventually happen to mouse populations in Australia as they run out of food.

16.5 Conservation

KEY CONCEPT Conservation methods can help protect and restore ecosystems.

MAIN IDEA

- Sustainable development manages resources for present and future generations.
- Conservation practices focus on a few species but benefit entire ecosystems.
- Protecting Earth's resources helps protect our future.

VOCABULARY

sustainable development, p. 502

umbrella species, p. 503

Review

ecosystem, habitat, keystone species

CALIFORNIA STANDARDS

6 Stability in an ecosystem is a balance between competing effects.

Connect When Rachel Carson's book *Silent Spring* was published in 1962, the wheels were set in motion for the creation of the modern environmental movement. The book, which described how the pesticide DDT was affecting wildlife, brought about a public uproar and helped lead to a ban on the use of DDT in the United States. Since then, a variety of measures have been put into place, both to restore Earth's biosphere and to protect it from further degradation.

MAIN IDEA

Sustainable development manages resources for present and future generations.

To ensure that Earth can continue to support, or sustain, a growing human population, it is important to secure the future of the Earth's ecosystems. This way of thinking is known as sustainable development. **Sustainable development** is a practice in which natural resources are used and managed in a way that meets current needs without hurting future generations.

Sustainable development covers a wide range of resource management methods. Concerns about the condition of the environment have led to changes in methods of harvesting natural resources. In the timber industry, for example, old growth forests are being lost at a fast rate due to a method called clear cutting. By cutting down large sections of wooded areas and removing entire forest ecosystems, lumber companies serve a growing need for building supplies. Today, with the raised awareness of forest ecosystem

FIGURE 16.17 Forests of bamboo in China grow quickly and can provide an abundant supply of wood to support the growing demand for building materials.

safety, several companies are choosing to cut selected trees rather than clear-cutting forests. This practice encourages rapid regrowth of trees, and makes sure there is only minimal impact to the forest ecosystem. When choosing where and when to harvest trees, foresters must consider how the soil, water, and wildlife of the area will be affected and change their harvest strategy accordingly.

Global fisheries are also in need of sustainable development practices. Overfishing has depleted fish populations worldwide. Fish stocks are not as hardy as they once were. One reason for this is that the fish that are caught represent the healthy, reproducing age groups of the fish population. By removing the reproducing individuals from the population, the fishing industry is actually hurting itself. Without fish to reproduce now, there will be no fish for the future. In addition, unsustainable fishing techniques damage marine and coastal environments. A number of techniques can be adopted by fisheries to make the industry sustainable:

- **Rotation** Rotating catches between different species gives the "off" species time to recover their numbers following a harvest.
- **Fishing gear review** The gear used to catch fish can damage the sea floor and often unintentionally catches other species. Reviewing and possibly banning certain fishing gear could help avoid damaging the sea floor and prevent ecologically important organisms from being killed.
- **Harvest reduction** Slowing the harvests of deep-water species that grow very slowly allows them more time to recover their populations.
- **Fishing bans** Creating and enforcing fishing bans in certain areas helps to replenish populations within that area, which may lead to greater fish numbers in nearby locations.

Connect **What important services do forests provide? How might their destruction have an effect on humans?**

Connecting CONCEPTS

Natural Selection Recall from **Chapter 11** that in natural selection the environment favors certain traits over others. In a fish's environment, nets used by humans catch fish that are large and slow. Fish that may be smaller and faster have a distinct advantage, thus leading to a genetic shift in the population.

FIGURE 16.18 The West Indian manatee is an umbrella species whose protection helps to re-establish marine habitats.

MAIN IDEA

Conservation practices focus on a few species but benefit entire ecosystems.

Laws written to protect individual species also help to protect their habitats. The Endangered Species Act in the United States, for example, is designed to protect individual species that are near extinction by establishing protection for the organism and its environment. When a single species within an ecosystem is placed on a list of endangered species, many other species within the ecosystem also benefit. The listed species is often called an **umbrella species** because its protection means a wide range of other species will also be protected. Such is the case with the West Indian manatee. These aquatic mammals, shown in **FIGURE 16.18**, live in the waters of the Gulf of Mexico and Atlantic Ocean along the coast of the southeastern United States. Their range extends as far west as Texas and as far north as Virginia.

The manatee was placed on the endangered species list in 1967. Its listing resulted from a variety of factors including loss of habitat, overhunting, and deaths due to collisions with powerboats. Today, the situation for manatees is difficult, and fewer than 3000 manatees remain in the United States. To promote their survival, local, state, and federal agencies are working to develop policies to protect their habitat. When developing recovery plans for an endangered species, scientists must consider many factors. For example, since manatees rely on seagrass as their main food source, areas rich in this resource must also be protected. By protecting waterways from pollution, restoring damaged areas, and limiting boating, the marine ecosystem that is the natural habitat for manatees is also protected. As a result, entire ecosystems can benefit from efforts to save a single species from extinction.

Apply **What factors might scientists consider when developing a recovery plan for the endangered grizzly bear of western North America?**

MAIN IDEA

Protecting Earth's resources helps protect our future.

All living things, including humans, share Earth and its resources, and the value of the services our planet provides is priceless. The cycling of nutrients and the regulation of water provide essential resources that are almost impossible for humans to manufacture. If we were to put a human economic value on it, the total value of the services Earth's natural ecosystems provide has been estimated to be over $30 trillion a year.

Global warming, pollution, and the loss of biodiversity are only a few of the direct threats our planet is facing. To prevent further loss of the valuable resources of Earth, public actions are helping to preserve and protect the future of our planet.

FIGURE 16.19 Yosemite Falls in California is the tallest waterfall in the United States, and is just one of the wonders that the founders of the National Park System hoped to preserve.

Protecting Natural Resources

The Environmental Protection Agency was created as part of the National Environmental Policy Act in 1970. Its creation paved the way for the development of policies and regulations to protect the environment across the United States. Laws such as the Clean Air Act, Clean Water Act, and Endangered Species Act have had a major impact on the environment. The Clean Air Act, signed into law in 1970, has helped to increase air quality across the nation. It regulates emissions from industrial factories and automobiles. In 1970, only 36 percent of the lakes and waterways in the United States were considered safe for swimming. Since the Clean Water Act was signed in 1972, regulations against pollution and an increased public awareness have helped to double the number of waterways that are safe today. Since 1973, when the Endangered Species Act was signed, breeding pairs of the bald eagle, once in danger of extinction, grew from 791 pairs to almost 6500 pairs in 2000.

Setting aside areas as public land is another way that governments can protect ecosystems. The Yosemite Grant of 1864 was the United States' first step to protect nature from development. This grant established what would

eventually become Yosemite National Park, part of which is shown in **FIGURE 16.19**. The success of this grant eventually led to the formation of the National Park Service. The management of multiple-use areas and wilderness areas balances recreation for visitors with protection of the natural ecosystem. Today, grassroots environmental organizations are working with local governments and private citizens to purchase and restore areas of land across the country to increase the amount of suitable habitat for wildlife.

A Sustainable Earth

As we have seen, humans represent an integral part of Earth's ecosystems and are subject to the same limitations as other species living on the planet. However, unlike other organisms, we have a much larger impact on our environment because of our population size and the fact that we are found over the entire globe. At the same time, we have the ability and technology to change the extent of our impact on Earth's biosphere and ultimately control our destiny.

- We have the ability to control how fast our population grows, through controlling birth rates.
- We can develop technology to produce more food and produce less waste.
- Most importantly, we have the ability to change our practices and take action to protect and maintain ecosystems. In some cases, we can reduce or even eliminate the pressures we place on the planet's biogeochemical processes.

FIGURE 16.20 Each year on Arbor Day, people around the world plant trees and play an important role in rebuilding ecosystems for future generations.

No places on Earth are untouched by humans. While we may not have directly visited each square inch of the planet, human-caused pollutants, invasive species, or ecosystem alterations have reached the world over. Yet our economies, and our very lives, depend on a healthy, thriving, sustainable Earth.

Connect **How could you reduce the amount of waste produced by your school?**

16.5 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Give two examples of **sustainable development.**
2. Describe how the protection of an **umbrella species** can be beneficial to an ecosystem.
3. How do governmental actions help to preserve natural habitats and protect resources?

CRITICAL THINKING

4. **Connect** What can humans do to minimize the impact of urban sprawl on wildlife?
5. **Evaluate** Could the West Indian manatee be considered a keystone species? Justify your answer.

Connecting CONCEPTS

6. **Nutrient Cycling** Natural ecosystems provide important cleansing and recycling functions to humans. What specific products do Earth's natural cycles provide for humans?

Use these inquiry-based labs and online activities to deepen your understanding of human impact on ecosystems.

INVESTIGATION

Water Quality Testing

CALIFORNIA STANDARDS

IE.1.a Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

IE.1.d Formulate explanations by using logic and evidence.

IE.1.j Recognize the issues of statistical variability and the need for controlled tests.

The United States Environmental Protection Agency (EPA) regulates the drinking water that comes from public water systems. In this lab, you will test two water samples to determine if they meet EPA standards.

SKILLS Measuring, Comparing

PROBLEM Which sample meets EPA standards?

MATERIALS

- 2 plastic cups
- marker
- 2 100-mL graduated cylinders
- 100 mL water sample A
- 100 mL water sample B
- 2 chlorine test strips
- 2 copper test strips
- 2 iron test strips
- 2 nitrate test strips
- 2 nitrite test strips

PROCEDURE

1. Label one cup water sample A and the second cup water sample B. Fill each cup half full with the corresponding water sample.
2. Read the instructions for each type of testing strip and then collect data on both water samples. Record your data in a chart like the one below.

TABLE 1. TEST RESULTS AND EPA STANDARDS FOR DRINKING WATER

Possible Contaminant	EPA Maximum Level (mg/L)	Sample A	Sample B
Chlorine	4		
Copper	1.3		
Iron*	0.3		
Nitrate	100		
Nitrite	1		

*EPA Recommended Standard

ANALYZE AND CONCLUDE

1. **Analyze** Compare the results of your tests with the EPA standards listed in Table 1. Does either of the water samples not meet the recommended standards? What conclusions can you reach about the water samples based on your results? (**Note:** Check to make sure you are comparing the same units between your tests and the EPA standards.)
2. **Apply** Suppose you collect and analyze a water sample that receives runoff from a large area of farmland. Predict how the quality of the water may be affected. Assume that you test for the same contaminants listed in the table above.

EXTEND YOUR INVESTIGATION

Research how exposure to high levels of the toxins listed above can affect human health.

INVESTIGATION

Contamination of Groundwater

Leakage of toxic chemicals from underground storage tanks (USTs) is the leading threat to the security of the U.S. drinking water supply. This contamination can have devastating effects on nearby ecosystems. In this activity, you will work to map an area and locate a UST contaminated area.

SKILL Modeling

PROBLEM How much land can be contaminated by a leaking UST?

MATERIALS

- shoebox containing hidden water balloon
- 1 m string
- 10 cm masking tape
- toothpick
- craft stick
- graph paper
- ruler

PROCEDURE

1. Obtain a container with a water balloon (UST) buried in surrounding kitty litter.
2. Using string and masking tape, section the container into quadrats about 2.5 cm × 2.5 cm. Copy the quadrats onto graph paper and label with a grid system.
3. Systematically, gently insert the craftstick in each grid to locate all quadrats the UST sits inside.
4. Sketch on your map the location of the UST.
5. Insert a toothpick to break the UST to determine the number of quadrats contaminated.

ANALYZE AND CONCLUDE

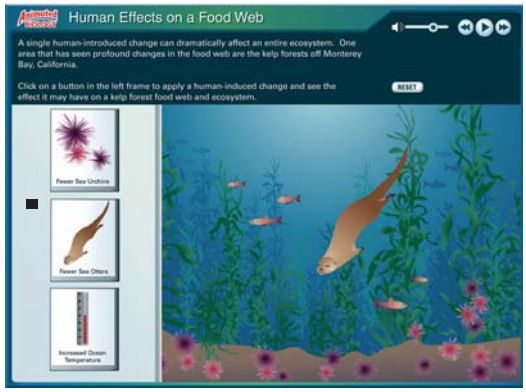
1. What effect might a leaking UST have on an ecosystem?
2. What other problems might result when a UST must be removed from the ground?

Online BIOLOGY CLASSZONE.COM

ANIMATED BIOLOGY

Human Effects on a Food Web

Humans can have a profound effect on the organisms in an ecosystem. Apply a human-induced change to a food web and see how the change ripples through the system.



WEBQUEST

Invasive species are a leading cause of extinctions of native species around the world. In this WebQuest, you will explore an invasive species in your area. Determine if the species has a harmful effect within your local environment and what can be done to control its damage.

DATA ANALYSIS ONLINE

Humans introduced trout into wilderness lakes of the Sierra Nevada in California for sport fishing. Since the fish were introduced, the number of mountain yellow-legged frogs has declined significantly. Graph frog density in lakes with no trout and in lakes from which trout were removed over time to see if the fish do affect frog population size.

CHAPTER 16

Interactive Review @ CLASSZONE.COM

CLASSZONE.COM

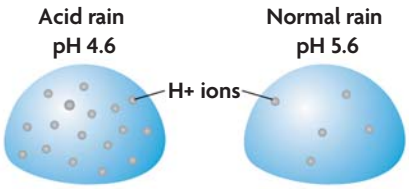
KEY CONCEPTS | Vocabulary Games | Concept Maps | Animated Biology | Online Quiz

16.1 Human Population Growth and Natural Resources

As the human population grows, the demand for Earth's resources increases. The human population has grown tremendously due to advancements in technology. But a large population puts pressure on nonrenewable resources such as fossil fuels as well as on renewable resources such as water. Balancing the needs of our population with the resources of our environments will help to reduce our ecological footprint to sustainable levels.

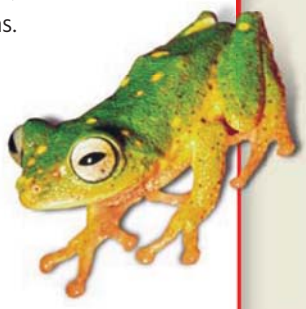
16.2 Air Quality

Fossil fuel emissions affect the biosphere. Pollution is the addition of undesirable factors to the air, water, and soil. Fossil fuel emissions from industrial processes are causing an increase in smog and acid rain, which both threaten Earth's ecosystems. Carbon dioxide, methane, and other greenhouse gases slow the release of energy from Earth's atmosphere. But increased fossil fuel emissions appear to be contributing to rapid climate change in a process called global warming.



16.3 Water Quality

Pollution of Earth's freshwater supply threatens habitat and health. Indicator species help us understand the effects of pollution on an ecosystem. The process of biomagnification is a threat to both humans and ecosystems, as toxins accumulate at the top of food chains.



16.4 Threats to Biodiversity

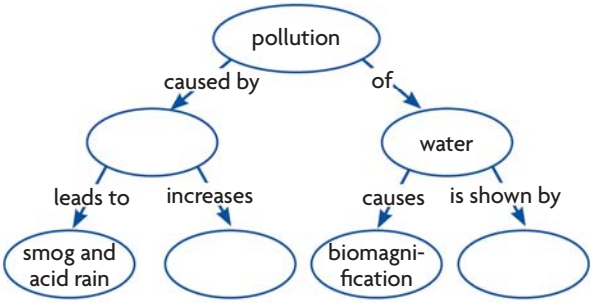
The impact of a growing human population threatens biodiversity. The biodiversity of a region helps keep ecosystems stable. Habitat fragmentation and destruction are threatening biodiversity. Nonnative species can have a negative effect on ecosystems by pushing out native species and using up resources.

16.5 Conservation

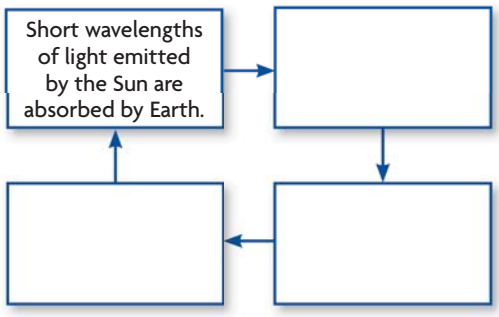
Conservation methods can help protect and restore ecosystems. To protect Earth's natural resources for future generations, we need to plan for sustainable development. In addition, the protection of umbrella species and the positive support of government and industry can help to ensure Earth is protected for future generations.

Synthesize Your Notes

Concept Map Use a concept map like the one below to display the effects of pollution.



Process Diagram Use the process diagram like the one below to explain the greenhouse effect.



Chapter Assessment

Chapter Vocabulary

16.1 nonrenewable resource, p. 485
renewable resource, p. 485
ecological footprint, p. 487

16.2 pollution, p. 488
smog, p. 488
particulate, p. 488
acid rain, p. 489
greenhouse effect, p. 490
global warming, p. 492

16.3 indicator species, p. 494
biomagnification, p. 495

16.4 habitat fragmentation, p. 499
introduced species, p. 500

16.5 sustainable development, p. 502
umbrella species, p. 503

Reviewing Vocabulary

Compare and Contrast

Describe one similarity and one difference between the two terms in each of the following pairs.

1. renewable resource, nonrenewable resource
2. smog, acid rain
3. greenhouse effect, global warming
4. indicator species, umbrella species

Word Origins

5. The word *sustain* comes from the Latin words *sub-*, which means "below," and *tenere*, which means "to hold." Explain how these meanings relate to the term *sustainable development*.

6. The term *biomagnification* is comprised of the prefix *bio-*, which means "life," and the word *magnify*, which comes from a Latin word meaning "great" or "large." Explain how the meanings of the word parts make up the meaning of the term.

7. The word *umbrella* comes from the Latin word *umbra*, which means "shadow." How does the everyday meaning of the word *umbrella* relate to the ecological meaning of the term *umbrella species*?

Draw Cartoons

For each vocabulary term below, draw a cartoon that will best summarize the definition.

8. ecological footprint
9. global warming
10. introduced species

Reviewing MAIN IDEAS

11. Earth's human carrying capacity has exceeded many earlier predictions. How has technology affected human population growth? **6.c**

12. The United States uses more resources and produces more waste than any other country. How is this resource use reflected in the ecological footprint of the United States? **6.b**

13. What are the major causes of smog and acid rain? What are the effects of each type of pollution? **6.b**

14. Since the 1970s, human activity has released approximately 150 billion tons of carbon dioxide into the atmosphere. How could the increase in atmospheric carbon dioxide impact the greenhouse effect? **6.b**

15. Which organism is most likely to have accumulated toxins through biomagnification: plankton, a small plankton-eating fish, or a large fish that eats smaller fish? Explain. **6.f**

16. How could the extinction of a single species, such as a predatory bird, affect an entire ecosystem? **6.f**

17. In what ways can an introduced species impact an ecosystem it has colonized? **6.b**

18. The North American grizzly bear is considered an umbrella species. Explain how the protection of the grizzly bear may affect the larger ecosystem to which the bear belongs.

19. Analyze Assuming all other factors are the same, the more meat in a person's diet, the larger that person's ecological footprint. Why might this be the case?

20. Connect Nationwide, automobiles are the major source of carbon monoxide, carbon dioxide, nitrogen oxides, particulate matter, and cancer-causing toxins. What can you do to decrease your fossil fuel use?

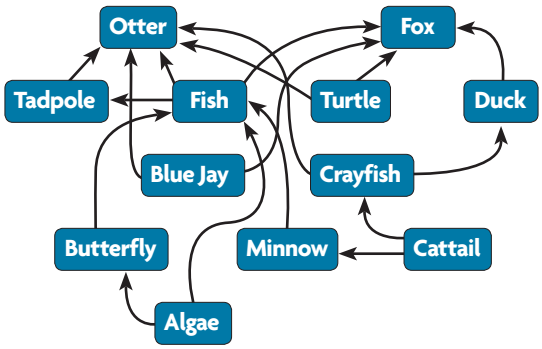
21. Evaluate An ecological footprint is a measure of the impact of the resources we use on the environment. Explain how buying a carton of milk relates to your ecological footprint.

22. Infer Frogs are commonly used as an indicator species in aquatic habitats. Could a large predator such as a bear or an eagle be used as an indicator species? Explain. 6.b

23. Synthesize Explain how a predator insect species, introduced to help control insect pests, could become a threat to an ecosystem. 6.f

Interpreting Visuals

Use the simple food web outlined below to answer the next three questions.



24. Apply Which of these organisms is likely to be most affected by biomagnification of toxins? Explain your answer. 6.f

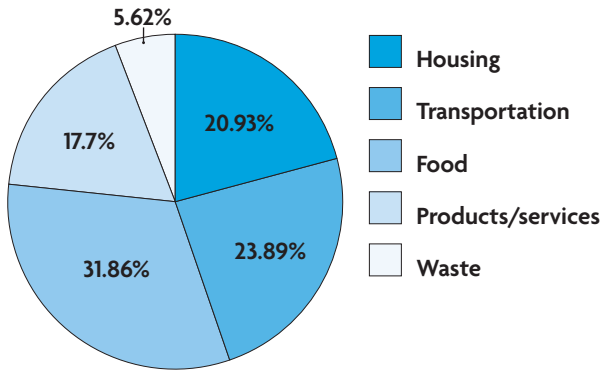
25. Predict This food web includes both aquatic and terrestrial organisms. Imagine that a new road separates the aquatic environment from the nearby terrestrial environment. Do you think the turtle or the duck would be more affected by this habitat fragmentation? Explain. 6.f

26. Predict Imagine that an introduced species results in the local extermination of crayfish. How might this change affect the larger ecosystem? 6.b

Analyzing Data

This circle graph shows the components of the ecological footprint for a resident of a North American city. Use the graph to answer the next two questions.

ECOLOGICAL FOOTPRINT OF A NORTH AMERICAN CITY



27. Apply Does the circle graph show discrete or continuous data? Explain.

28. Analyze In order of biggest to smallest impact, list the components of human activity that make up the average ecological footprint, according to this graph.

Connecting CONCEPTS

29. Write a Scenario Imagine that successful efforts in sustainable development have made global resource use and waste production fully sustainable by the year 2099. Write a few paragraphs that describes what a sustainable world might look like in 2099. Include information about resource use, waste production, pollution, biodiversity, and conservation.

30. Connect Look again at the damaged forest ecosystem on page 483. The emissions produced in this region have led to the rapid decline in the biodiversity of this area. How might this decline affect the resources of local animal populations? 6.b

CALIFORNIA STANDARDS-BASED ASSESSMENT

Test Practice
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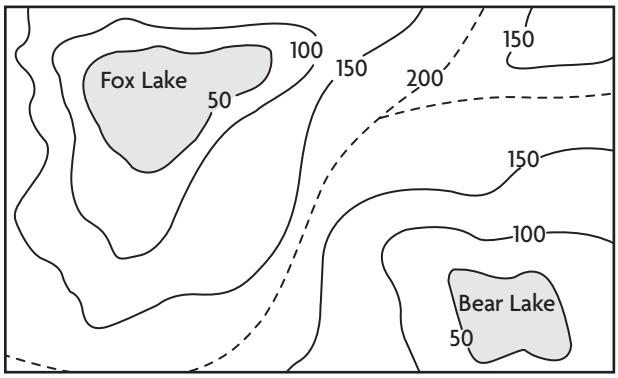
1.



This topographic map shows the Fox Lake and Bear Lake watersheds, or regions that drain into these lakes. The watershed boundary, shown with a dashed line, determines which lake water will flow into. According to the map, this boundary follows IE.1.h

A the highest elevation points between the lakes.

B the lowest elevation points between the lakes.

C a river that likely flows between the lakes.

D exactly halfway between the two lakes.

2. Which of the following *most* directly played a role in the human population growth of the 20th century? 6.c

A improved transportation, which increased immigration

B satellite technology, which increased global communication

C improved public health, which decreased death rates

D readily available contraception, which decreased birth rates

3. The nonnative zebra mussel was first found in a lake near Detroit in 1988. By 1989, it had colonized all Great Lakes waterways. Which scenario is *most* likely true regarding the introduction of this species? 6.b

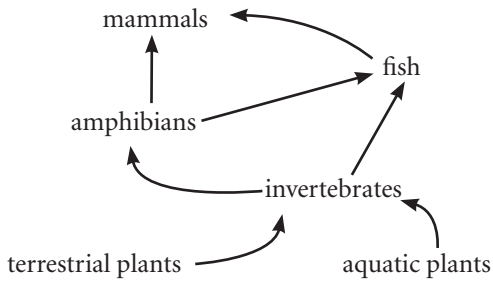
A Native fish naturally eat zebra mussels.

B The higher biodiversity leads to healthier lakes.

C They compete with native mussels for food and other resources.

D Native mussel populations are growing rapidly.

4.



Through the process of biomagnification, certain pollutants build up at each link of a food web. In a polluted river, at what link in the food web above would pollutant concentrations be the highest? 6.f

A aquatic plants

B fish

C invertebrates

D mammals

5. Which situation would *most* efficiently decrease the size of a field mouse population? 6.b

A decreased death rates and emigration.

B decreased birth rates and immigration.

C increased death rates and immigration.

D increased death rates and emigration.

THINK THROUGH THE QUESTION

As you look at the answer choices, think carefully about how each factor—birth rates, death rates, immigration, and emigration—affect population size.

6. CO_2 is important in our atmosphere because it is required for photosynthesis and it traps some heat, keeping Earth warm. However, human-produced CO_2 is a problem because it 6.b

A leads to higher global temperatures

B disrupts the natural cycling of other greenhouse gasses.

C adds too much CO_2 to the oceans.

D causes uncontrolled photosynthesis.

UNIT 5: ECOLOGY

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Strange Biology

As global temperatures rise and arctic ice melts, polar bears are losing important hunting grounds.

Global Warming—Changing the Planet

Polar bears are beginning to drown. In the summer, the area of arctic sea ice on which these carnivores hunt seals has declined 10 to 15 percent as worldwide temperatures rise. As this ice is lost, polar bears must swim as far as 100 kilometers (about 60 mi) to find their prey. Some of these polar bears do not make it. If global warming is changing the shape of one of Earth's coldest regions, how will it affect the rest of our planet?

Ecosystems at Risk

In the 21st century, the average global temperature is expected to rise about 0.22°C (0.4°F) per decade. This may seem like a small change, but this change is magnified in the seasonal temperature changes of a region. In some parts of the world, such as the Arctic, the temperature is changing much faster. Average annual temperatures in Alaska have risen 3.3°C (5.9°F) since 1949. Sea ice area has been shrinking over the past 100 years, and the ice has become 40 percent thinner in the past several decades, leaving coastal land vulnerable to erosion.

Good and Bad News?

In the rest of the world, the impact of global warming on Earth's species may not be as bad. Many animal species, such as birds and butterflies, can move to cooler areas as the climate warms. But the microorganisms that cause infectious diseases, such as malaria and yellow fever, are also spreading toward the poles. Plant species are moving as well, but many are not able to move as quickly as the climate is expected to change.

Researchers are also finding that changing temperatures can affect animals in surprising ways. The sex of some reptiles, for example, is partially determined by the temperature of the developing egg. A consistent warming trend could cause some reptiles to become extinct by creating entire generations that are all the same sex. Migratory birds and marine mammals also face challenges. For example, birds that wait until their normal migration time to fly north in the spring may arrive too late, missing the best weeks for laying eggs and catching the insects they need to raise their young. In addition, marine mammals face challenges in their own food webs. Several researchers are predicting that the productivity of phytoplankton, the algae on which ocean food webs are based, may decline in some areas. A change of this sort could cause a domino effect in marine food webs. If phytoplankton levels decline, fish will have less food and will be less numerous. If fish are less numerous, marine mammals and birds will have less to eat too.

TECHNOLOGY

Deep Sea Sediment Coring

Analyzing ocean floor sediments can provide scientists with data about how plants and animals were affected during past climate changes. The process of collecting deep sea sediments is expensive and time-consuming, but the results of this research give scientists a look at what life in the oceans was like millions of years ago.

To study these ancient organisms, scientists need sediment samples that are hundreds of meters long. To obtain these, they must use drills similar to the drills used by the oil and gas industry. Taking these samples requires many hours and can be dangerous if the seas are rough or full of ice. Once scientists have obtained the cores, they first split the core in half lengthwise. One half is sampled for fossils of ancient organisms. This is the "working half." The other half, the "archive half," is saved and stored away so that future scientists who may develop other questions can have access to this difficult-to-obtain material.

By carefully dissecting the working half of the sample, scientists discover microscopic fossils of marine animals. Scientists know that these ancient animals were very sensitive to slight changes in temperature and chemistry. These microfossils can tell scientists how Earth's climate has changed over millions of years.

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These "working half" cores will be carefully dissected and analyzed to better understand Earth's changing climate.

Computer modeling programs such as this one work to predict the effects of global warming by simulating different temperature increases.

The news may not be all bad. Global warming is caused by increased levels of carbon dioxide in the atmosphere. Many plants, including crops such as cotton, soybeans, wheat, and rice, can benefit from the increase in CO_2. They can absorb the CO_2 and yield more at harvest time as a result. On the other hand, in warmer weather crops may also be more at risk from insect pests and from severe storms or droughts.

Unanswered Questions

Scientists have little doubt that Earth's climate is changing. Unfortunately, it is impossible to predict exactly how any particular ecosystem will be affected by global warming. However, biologists and climatologists are collecting data about processes including solar radiation, precipitation, evaporation, the transfer of heat energy by winds and by ocean currents, and the ways in which plants affect climate. Then, by using computer models that interpret this information, they can begin to answer questions about how global warming will affect Earth.

- Does global warming cause the number of tropical storms and hurricanes to increase?
- Could global warming alter certain ocean currents, changing Earth's temperatures further?
- How quickly might the polar ice caps melt?
- How have global climate changes affected Earth's ecosystems in the past?

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CAREERS

Oceanographer in Action

RUTH CURRY

TITLE Oceanographer, Woods Hole Oceanographic Institute

EDUCATION B.S., Geology, Brown University

For Ruth Curry, spending time on the ocean waves has nothing to do with surfing or vacationing. She spends her time studying the ocean currents that affect our lives each day. Ruth Curry is an oceanographer at the Woods Hole Oceanographic Institute, an organization of scientists who research and study how the ocean affects the global environment.

Curry's research focuses on the North Atlantic circulation and the currents that carry warm waters from tropical regions northward. As these warm waters reach higher latitudes, they release heat that warms the air above them and warms the climate of western Europe. As warm water cools, its density increases and it sinks to the bottom of the ocean. There it begins a southward journey back to the tropics. This conveyor belt of water plays an important role in maintaining Earth's climate. Normally, the salinity, or saltiness, of ocean water stays about the same. But changes in global temperatures are melting large sheets of ice in Greenland, which is introducing large amounts of fresh water into the ocean. This fresh water is diluting the ocean water, making it less salty. A decrease in salinity makes ocean waters less dense and prevents them from sinking to the bottom of the ocean. Eventually, the melting of ice sheets in Greenland could cause the North Atlantic currents to slow and eventually stop, leading to dramatic changes in the Northern Hemisphere's climate.

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