

CHAPTER 16 Human Impact on Ecosystems

BIG IDEA

Human population growth threatens environmental quality and biodiversity, so conservation methods are necessary to protect Earth's natural resources.

16.1 Human Population Growth and Natural Resources **TEKS** 11B, 12D, 12F

16.2 Air Quality **TEKS** 11B, 12F

16.3 Water Quality **TEKS** 11B, 12C, 12D, 12F

Data Analysis DISCRETE AND CONTINUOUS DATA **TEKS** 2G

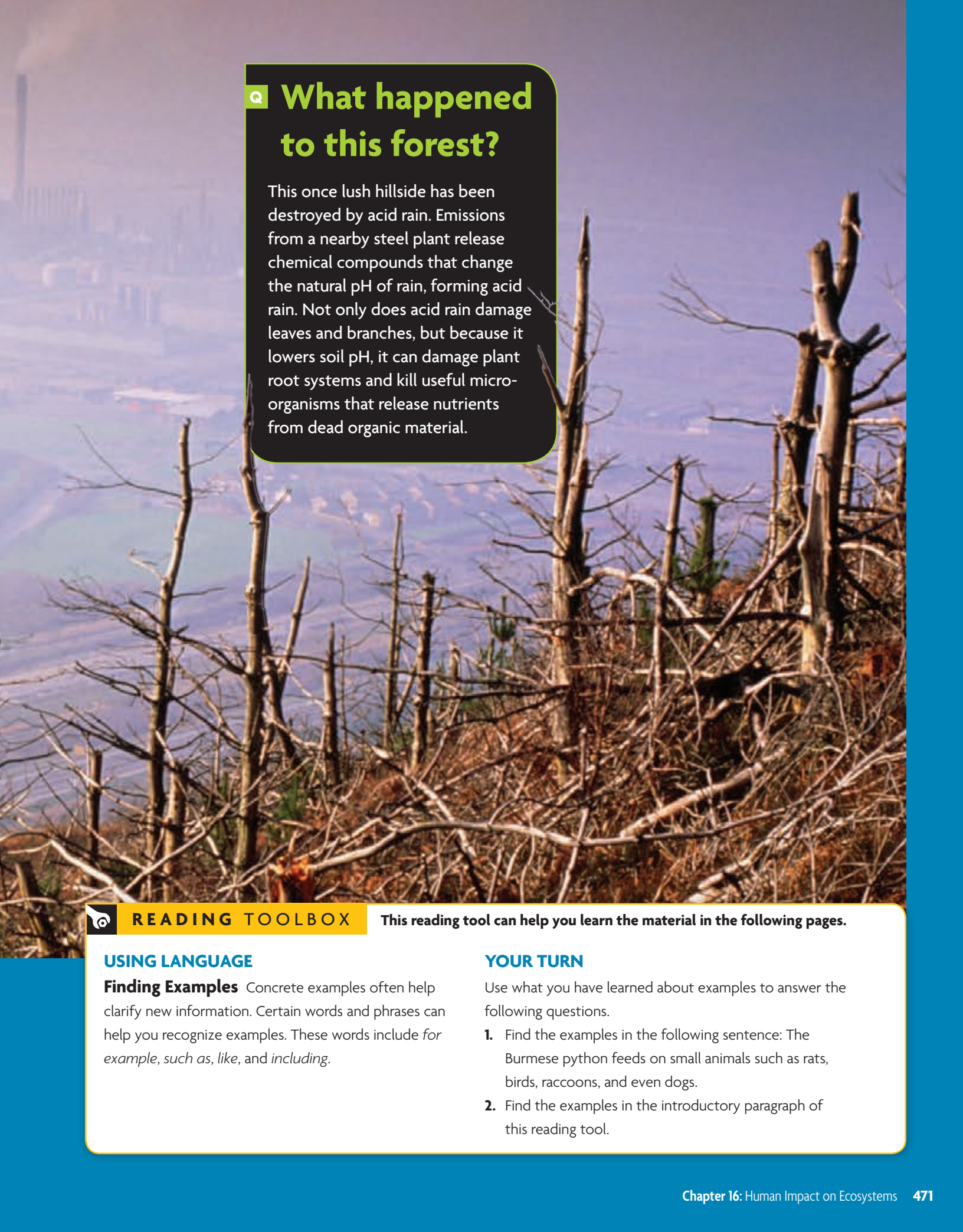
16.4 Threats to Biodiversity **TEKS** 11B, 12B, 12D, 12F

16.5 Conservation **TEKS** 11B, 12D, 12F

ONLINE BIOLOGY HMDSscience.com

ONLINE Labs

- Acid Rain
- **QuickLab** Modeling Biomagnification
- **Open Inquiry Lab** Water Quality
- Water Quality Testing
- Contamination of Groundwater
- Caffeine and Seed Germination
- Investigating How Pollution Affects Plant Life
- Biodiversity and Ecosystems
- Modeling the Effects of Habitat Fragmentation
- **Video Lab** Effects of Acid Rain on Seeds



Q 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.



READING TOOLBOX

This reading tool can help you learn the material in the following pages.

USING LANGUAGE

Finding Examples Concrete examples often help clarify new information. Certain words and phrases can help you recognize examples. These words include *for example*, *such as*, *like*, and *including*.

YOUR TURN

Use what you have learned about examples to answer the following questions.

1. Find the examples in the following sentence: The Burmese python feeds on small animals such as rats, birds, raccoons, and even dogs.
2. Find the examples in the introductory paragraph of this reading tool.



16.1

Human Population Growth and Natural Resources

TEKS 11B, 12D, 12F

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

VOCABULARY

nonrenewable resource
renewable resource
ecological footprint

MAIN IDEAS

- ▶ 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.

TEKS 11B investigate and analyze how organisms, populations, and communities respond to external factors; **12D** recognize that long-term survival of species is dependent on changing resource bases that are limited; **12F** describe how environmental change can impact ecosystem stability

Connect to Your World

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.

▶ MAIN IDEA **TEKS 12D, 12F**

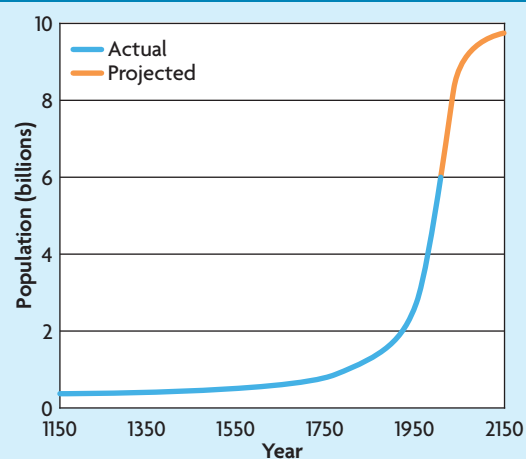
Earth's human population continues to grow.

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.

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 1.1** shows how population size has changed over time. Today's human population of more than 7 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.

FIGURE 1.1 WORLD POPULATION



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

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 more people than Malthus could ever have imagined. Motorized farm equipment, made possible the production of much more food 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 per 1000 births. Antibiotics and antiseptics 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?

MAIN IDEA **TEKS** 12D, 12F

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 the rate at which 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. A natural resource that can be replaced at the same rate at which it is used is called a **renewable resource**. For example, wind energy—captured by wind turbines such as those shown in **FIGURE 1.2**—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.

READING TOOLBOX

TAKING NOTES

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

```
graph TD;
  T[Technology] --> M[Medicine];
  T --> B1[ ];
  T --> B2[ ];
```

FIGURE 1.2 Giant wind turbines such as these capture renewable energy from Earth's natural processes.



CONNECT TO

HYDROLOGIC CYCLE

In the chapter **Principles of Ecology**, 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.

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 become increasingly important. 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 7 billion humans generated 1 ton of garbage each year?

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

MAIN IDEA **TEKS** 11B, 12D, 12F

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 400 CE and 700 CE, it was thickly forested on rich soil, with many bird species. The human colony grew quickly over the next 1000 years, building the stone monuments for which the island is now famous. The 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 1.3**. 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. Without food and island resources nearly gone, the Easter Island human population crashed and the Easter Islanders disappeared.

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.

FIGURE 1.3 Today, the barren landscapes of Easter Island are an eerie reminder of the fate of the island's ancient inhabitants.



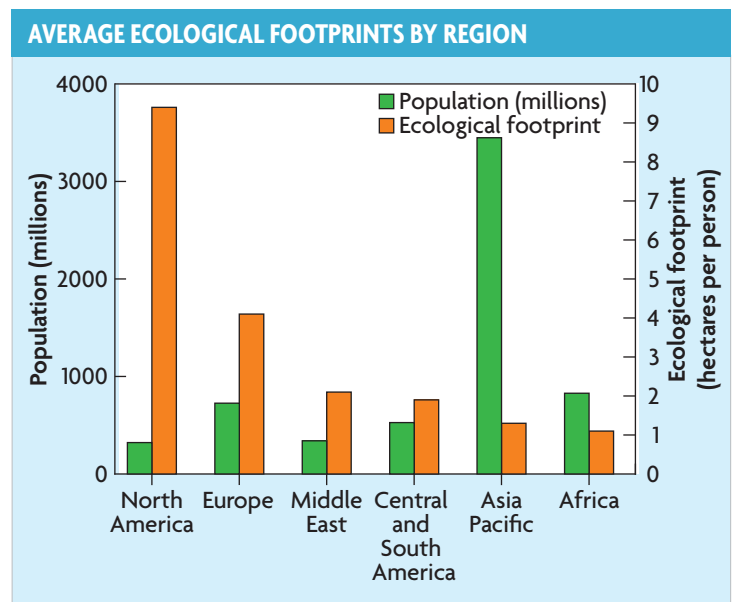
Ecological Footprint

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 1.4**, 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 1.4 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.

16.1 Formative Assessment

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? **TEKS 11B**
5. **Synthesize** How could the Easter Islanders have prevented their population crash? **TEKS 12D**



SELF-CHECK Online
HMDSscience.com

GO ONLINE

CONNECT TO

CARRYING CAPACITY

6. 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? **TEKS 11B**



16.2

Air Quality

TEKS 11B, 12F

KEY CONCEPT Fossil fuel emissions affect the biosphere.

MAIN IDEAS

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

VOCABULARY

- pollution
- smog
- particulate
- acid rain
- greenhouse effect
- global warming

TEKS 11B investigate and analyze how organisms, populations, and communities respond to external factors and **12F** describe how environmental change can impact ecosystem stability

☀️ Connect to Your World

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** **TEKS 11B, 12F**

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.

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 2.1**. **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 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 types of health problems.

FIGURE 2.1 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.



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.

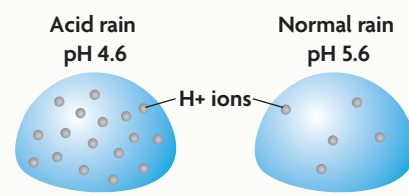
During the water cycle, rain falls through Earth's atmosphere and interacts with carbon dioxide molecules. As it falls, water molecules react with carbon dioxide molecules to form a weak carbonic acid, which then breaks apart, leaving lone hydrogen ions. This is normal. All rain that falls is slightly 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 2.2**. 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?

VISUAL VOCAB

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



CONNECT TO

pH

Recall from the chapter **Chemistry of Life** that pH is a measure of the concentration of H^+ ions in a solution. The concentrations of H^+ ions in acid rain are very high, giving the rain a lower pH level.

FIGURE 2.2 The wide growth rings of this tree indicate a healthy environment. The smaller growth rings illustrate how acid rain directly impacts plant growth.



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 2.3**. 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.

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—energy in the form of 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 light and radiation from sunlight to pass 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 warm 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 2.4**. 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.

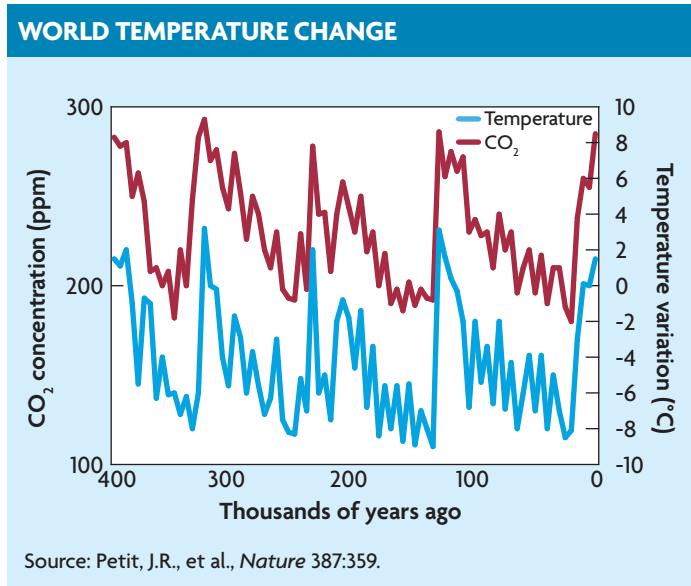


FIGURE 2.3 Scientists have found that changes in Earth's temperature correspond with fluctuations in global carbon dioxide levels.

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

FIGURE 2.4 Greenhouse Effect

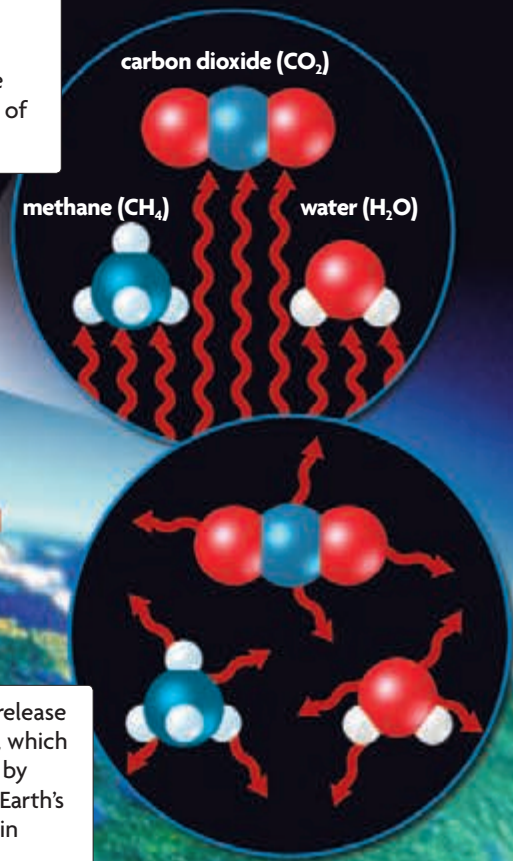
Water vapor, carbon dioxide, and methane can be found all through Earth's atmosphere. These greenhouse gases act as a blanket that slows the release of energy and helps to keep Earth at a temperature that can support life.

1 Short, high-energy wavelengths of light emitted from the sun penetrate Earth's atmosphere.

2 Energy from the sun is absorbed by Earth and reradiated as infrared radiation, or heat.

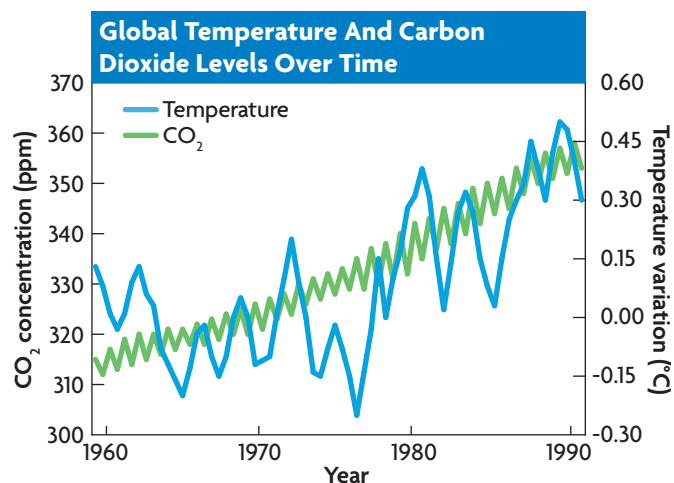
3 Greenhouse gases in the atmosphere absorb many of the longer wavelengths of infrared radiation.

4 The molecules rerelease infrared radiation, which is absorbed again by other molecules, Earth's surface, or is lost in outer space.



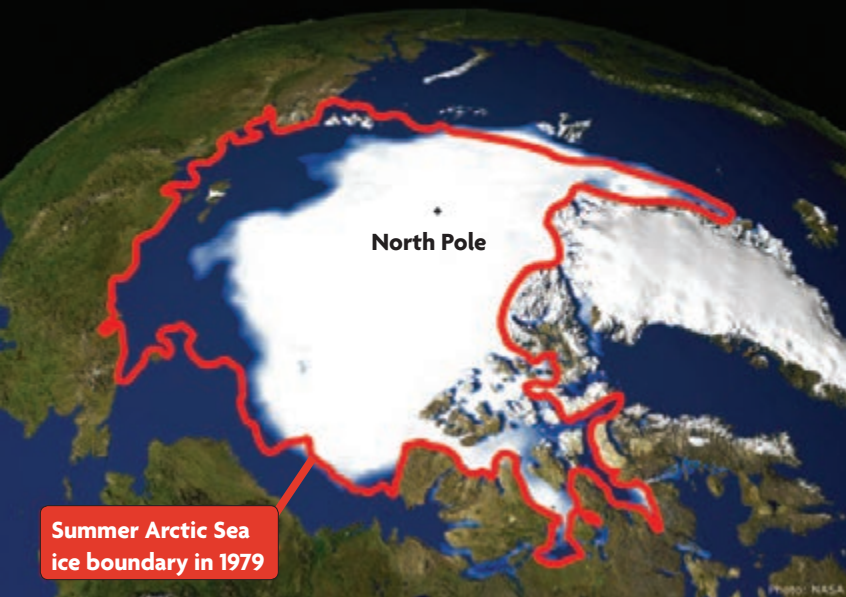
GLOBAL WARMING

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.



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? **TEKS** 12F



Summer Arctic Sea ice boundary in 1979

FIGURE 2.5 Over the past 20 years, increasing global temperatures have decreased summer ice pack around the North Pole by about 20 percent.

Virtual INVESTIGATION
 HMDSscience.com
 GO ONLINE
 Carbon Dioxide and Global Warming

Climate Change

Over the past 100 years, the average global temperature has risen 0.74°C (1.3°F), with the most dramatic change occurring over the past 50 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 the warming trend, but most agree that we must take steps to slow the process.

Scientists do not know how these atmospheric changes will affect the global biosphere. What they do know is that evidence shows climate change 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 climate change. As shown in **FIGURE 2.5**, 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 climate change is uncertain, but scientists predict that average temperatures on Earth could increase anywhere from 1.1 to 6.4°C (2 to 11.5°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 climate change affect seasonal temperature changes?

TEKS 12F

SELF-CHECK Online
 HMDSscience.com
 GO ONLINE

16.2 Formative Assessment

REVIEWING MAIN IDEAS

- Name and describe two ways in which **pollution** affects ecosystems.
TEKS 11B, 12F
- How does the **greenhouse effect** keep Earth warm?
- Explain how a build-up of carbon dioxide in the atmosphere could increase Earth's global temperature.

CRITICAL THINKING

- Predict** Describe how **acid rain** falling in a forest could disrupt the trophic structure of the ecosystem.
TEKS 11B, 12F
- Connect** Name two important functions of greenhouse gases at Earth's surface.

CONNECT TO

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?
TEKS 12C

GO Online!

WORLD WIDE WEBS



Virtual INVESTIGATION

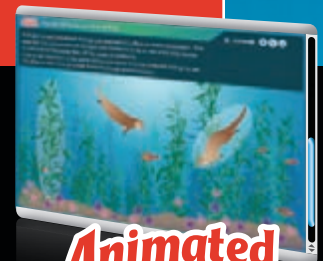
Carbon Dioxide and Global Warming Analyze carbon dioxide levels on Earth over time.



THAT'S Amazing!

VIDEO INQUIRY

Killer Kitties
What happens when house cats go wild? Find out how they can disrupt the balance of an ecosystem, and learn about how we can fix the problem.



Animated BIOLOGY

Human Effects on a Food Web Apply a human-induced change to a food web and see how the change ripples through the system.





16.3

Water Quality

TEKS

11B, 12C, 12D, 12F

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

VOCABULARY

indicator species
biomagnification

MAIN IDEAS

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

TEKS 11B investigate and analyze how organisms, populations, and communities respond to external factors; **12C** analyze the flow of matter and energy through trophic levels using various models, including food chains, food webs, and ecological pyramids; **12D** recognize that long-term survival of species is dependent on changing resource bases that are limited; **12F** describe how environmental change can impact ecosystem stability.

☀️ Connect to Your World

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** **TEKS 11B, 12D, 12F**

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 3.1**, 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.

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.

Biology **VIDEO CLIP**

 HMDSscience.com
GO ONLINE
 Human Impact, Water Pollution

FIGURE 3.1 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.



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? **TEKS 11B**

MAIN IDEA **TEKS 11B, 12C, 12F**

Biomagnification causes accumulation of toxins in the food chain.

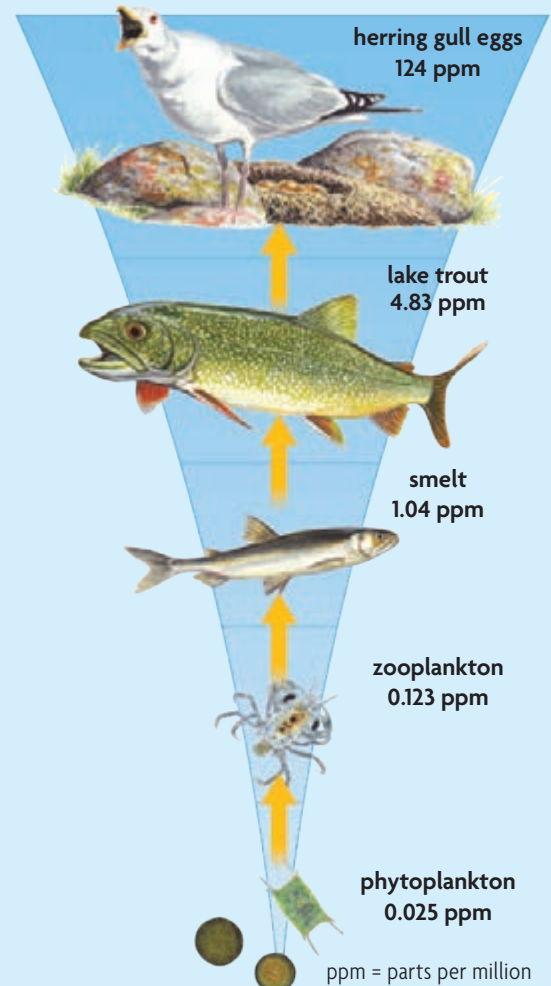
The high death rates in young Forster's terns are due to high levels of toxic compounds found in the parents. How did these chemicals get into the adult birds?

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 3.2** 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 tertiary 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 3.2 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? **TEKS 11B**

CONNECT TO

ENERGY PYRAMID

In the chapter **Principles of Ecology**, 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.



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?

PROCEDURE

1. Label the cups as 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.

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



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"?

Animated
Biology
HMDSscience.com

GO ONLINE

Human Effects on a Food Web

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? **TEKS** 11B, 12F

©age fotostock/SuperStock

16.3 Formative Assessment

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**?
TEKS 11B

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? **TEKS** 12C



SELF-CHECK Online
HMDSscience.com

GO ONLINE

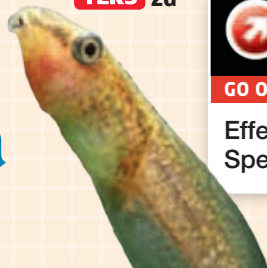
CONNECT TO

ENERGY PYRAMID

5. How does the biomagnification "pyramid" compare with the energy pyramid? **TEKS** 12C

Discrete and Continuous Data

TEKS 2G



Smart Grapher
 HMDSscience.com
 GO ONLINE
 Effects of an Introduced Species

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 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—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.

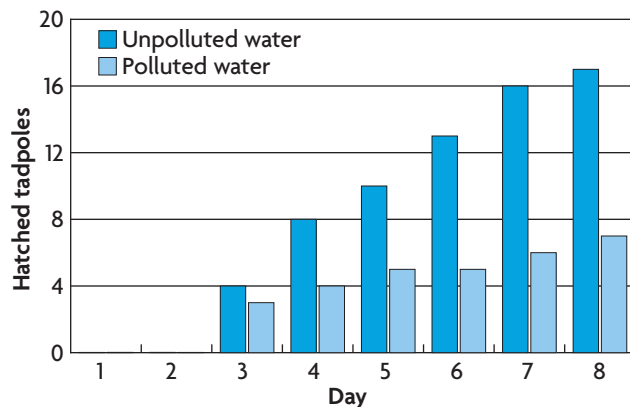
Model

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.

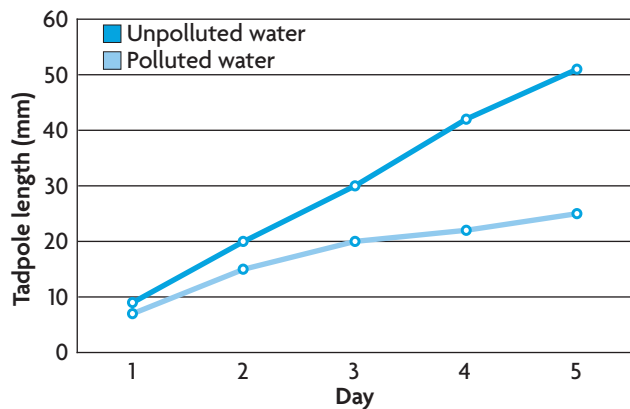
Students compared hatching rates in frog eggs over an eight-day period. Eggs were raised in one of two water samples, a sample from a known polluted pond, and a sample from an unpolluted pond. These data are discrete because a certain number of eggs hatched. There were no half or quarter tadpoles.

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)



Practice Identify Discrete and Continuous Data

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

- 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.
- Classify** The EPA compiles data about the mass of recycled aluminum (millions of tons) for every year since 1990.
- Analyze** Since 1860, the National Oceanic and Atmospheric Administration has collected data about the change in Earth's surface temperature and the concentration of carbon dioxide in the atmosphere.



16.4

Threats to Biodiversity

TEKS

11B, 12B, 12D, 12F

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

VOCABULARY

habitat fragmentation
introduced species

MAIN IDEAS

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

TEKS 11B investigate and analyze how organisms, populations, and communities respond to external factors; **12B** compare variations and adaptations of organisms in different ecosystems; **12D** recognize that long-term survival of species is dependent on changing resource bases that are limited; **12F** describe how environmental change can impact ecosystem stability.

☀️ Connect to Your World

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** **TEKS 11B, 12D, 12F**

Preserving biodiversity is important to the future of the biosphere.

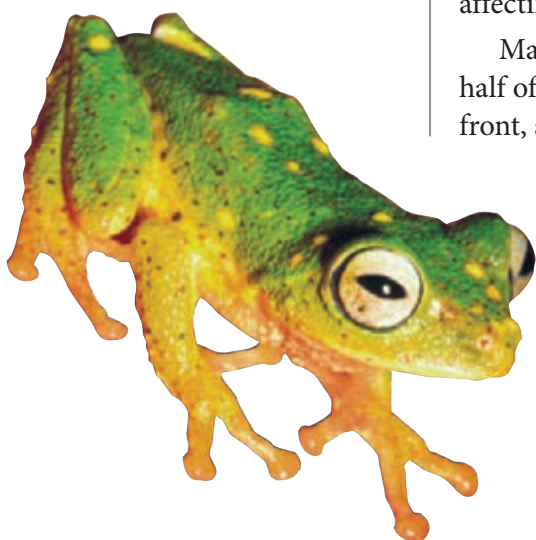
Ecosystems are constantly changing, and populations are always adjusting to these changes. Many times, human actions alter ecosystems in ways that harm a population and threaten biodiversity. The loss of habitat and the growing pollution problem are affecting animal and plant populations around the world. 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 4.1 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 4.1**, are endangered. The loss of even a single species can harm the overall stability of an ecosystem.

Biodiversity is highest in the rain forest biomes of the world, and these are the 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.

Connect Why is biodiversity highest in tropical rain forests?

MAIN IDEA **TEKS** 11B, 12D, 12F

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 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 4.2** help to maintain continuous tracts of habitat for those species that move between different areas.

Connect Why is wetland habitat important for migrating birds?
TEKS 11B

CONNECT TO

CARBON CYCLE

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



FIGURE 4.2 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 4.3 Mice plagues in Australia and China can cost farmers millions of dollars in lost crops.

▶ MAIN IDEA **TEKS** 11B, 12B, 12D, 12F

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 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 4.4**, 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 4.4 Introduced species such as the Burmese python are growing in numbers in places like the Florida Everglades.



WebQuest
HMDSscience.com
GO ONLINE
Invasive Species

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 4.5**, 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 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 4.5 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? **TEKS 12F**

THAT'S Amazing!
Video Inquiry
 HMDSscience.com
GO ONLINE
 Killer Kitties

SELF-CHECK Online
 HMDSscience.com
GO ONLINE

CONNECT TO
POPULATION GROWTH
 6. Using your knowledge of populations, describe what will eventually happen to mouse populations in Australia as they run out of food. **TEKS 12D, 12F**

©Cameron Marlow

16.4 Formative Assessment

REVIEWING MAIN IDEAS

1. Give two reasons why biodiversity is important to humans.
2. How does **habitat fragmentation** affect migrating bird populations?
TEKS 11B, 12F
3. What types of damage can **introduced species** cause?
TEKS 12B, 12F

CRITICAL THINKING

4. **Analyze** How could continued habitat fragmentation reduce biodiversity? **TEKS 11B, 12F**
5. **Connect** How might the introduction of a mouse predator help with the mouse problem in Australia? What problems might it cause?
TEKS 11B, 12F



16.5

Conservation

TEKS 11B, 12D, 12F

KEY CONCEPT Conservation methods can help protect and restore ecosystems.

VOCABULARY

sustainable development
umbrella species

MAIN IDEAS

- ▶ 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.

TEKS 11B investigate and analyze how organisms, populations, and communities respond to external factors; **12D** recognize that long-term survival of species is dependent on changing resource bases that are limited; **12F** describe how environmental change can impact ecosystem stability

☀️ Connect to Your World

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** **TEKS 11B, 12D, 12F**

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



©China Tourism Press/Getty Images

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 to protect them.

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? **TEKS 11B, 12D**

MAIN IDEA **TEKS 11B, 12D, 12F**

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 5.2**, 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.

CONNECT TO

NATURAL SELECTION

Recall from the chapter **The Evolution of Populations** 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 5.2 The West Indian manatee is an umbrella species whose protection helps to re-establish marine habitats.



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, because 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? **TEKS** 11B, 12D, 12F

▶ MAIN IDEA **TEKS** 11B, 12D, 12F

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.

Climate change, 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.

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.

FIGURE 5.3 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.



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 5.3**. 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

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 by controlling birth rates.
- We can develop technology to produce more food and produce less waste.
- 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.

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?



FIGURE 5.4 Each year on Arbor Day, people around the world plant trees and play an important role in rebuilding ecosystems for future generations.

16.5 Formative Assessment

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. **TEKS 11B, 12D**
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? **TEKS 12D, 12F**
5. **Evaluate** Could the West Indian manatee be considered a keystone species? Justify your answer.



SELF-CHECK Online
HMDSscience.com

GO ONLINE



CONNECT TO

NUTRIENT CYCLING

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

16 Summary

BIG IDEA

Human population growth threatens environmental quality and biodiversity, so conservation methods are necessary to preserve Earth's natural resources.

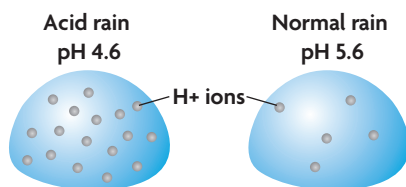
KEY CONCEPTS

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, increasing 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

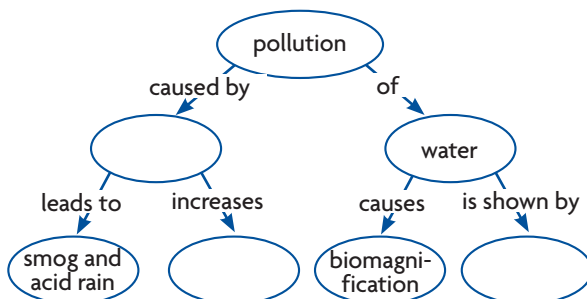


and industry can help to ensure Earth is protected for future generations.

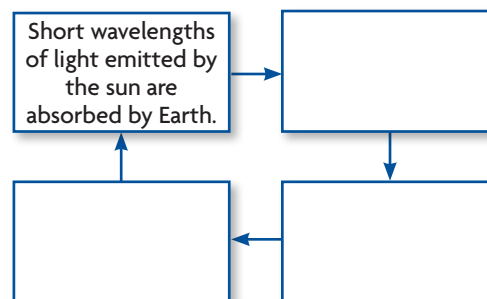
READING TOOLBOX

SYNTHESIZE YOUR NOTES

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



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





CHAPTER VOCABULARY

16.1 nonrenewable resource
renewable resource
ecological footprint

16.2 pollution
smog
particulate
acid rain
greenhouse effect
global warming

16.3 indicator species
biomagnification
16.4 habitat fragmentation
introduced species
16.5 sustainable development
umbrella species

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

READING TOOLBOX 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

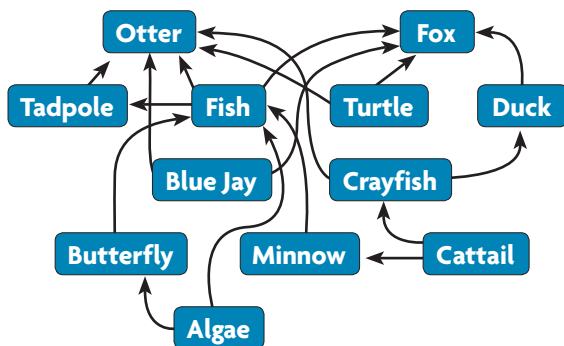
11. Earth’s human carrying capacity has exceeded many earlier predictions. How has technology affected human population growth?
12. The United States uses more resources and produces more waste than any other country. How is this resource use reflected in the ecological footprint of the United States? **TEKS 12F**
13. What are the major causes of smog and acid rain? What are the effects of each type of pollution? **TEKS 11B, 12F**
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? **TEKS 12F**
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. **TEKS 12C**
16. How could the extinction of a single species, such as a predatory bird, affect an entire ecosystem? **TEKS 12F**
17. In what ways can an introduced species impact an ecosystem it has colonized? **TEKS 11B, 12F**
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. **TEKS 11B, 12D**

Critical Thinking

- 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? **TEKS 12F**
- 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. **TEKS 12F**
- 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.
- 23. Synthesize** Explain how a predator insect species, introduced to help control insect pests, could become a threat to an ecosystem. **TEKS 11B, 12F**

Interpreting Visuals

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

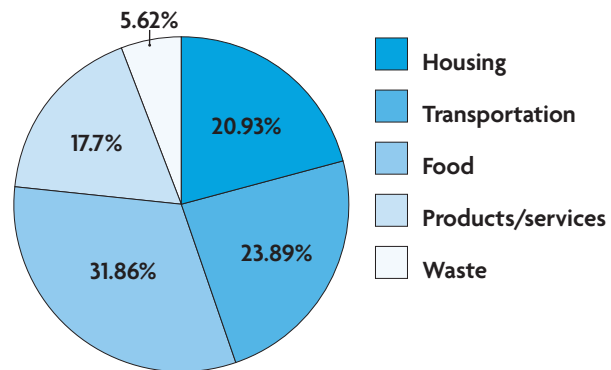


- 24. Apply** Which of these organisms is likely to be most affected by biomagnification of toxins? Explain your answer. **TEKS 12C**
- 25. Predict** This food web includes both aquatic and terrestrial organisms. Imagine that a new road separates the aquatic environment from the nearby terrestrial environment. Do you think the turtle or the duck would be more affected by this habitat fragmentation? Explain. **TEKS 12C**
- 26. Predict** Imagine that an introduced species results in the local extermination of crayfish. How might this change affect the larger ecosystem? **TEKS 11B, 12F**

Analyzing Data Identify Discrete and Continuous 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.

Making Connections

- 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 describe 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 the chapter opener. 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? **TEKS 11B, 12D, 12F**



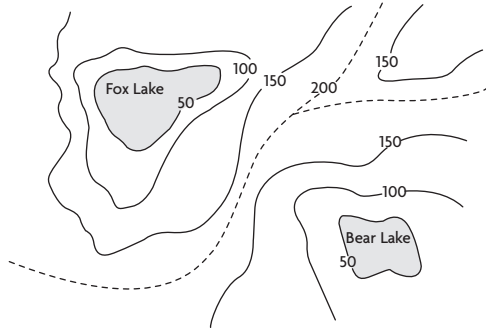
Biology End-of-Course Exam Practice

Record your answers on a separate piece of paper.

MULTIPLE CHOICE

TEKS 11B

1

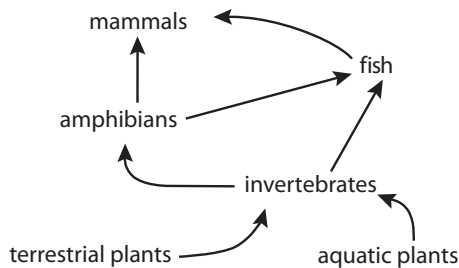


The topographic map above shows the watersheds, or regions that drain into Fox Lake and Bear Lake. The watershed boundary, shown with a dashed line, determines which lake water will flow into. According to the map above, this boundary follows —

- 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 a path exactly halfway between the two lakes

TEKS 11B, 12C

2



A farmer sprays his crops with pesticide. The runoff enters a nearby lake. Based on the food web above, in which of the following organisms would the pesticide concentration be the highest?

- A cattail
- B largemouth bass
- C water striders
- D river otters

TEKS 11B

- 3 Which situation would *most efficiently* decrease the size of a field mouse population?
- 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.

TEKS 9B, 12E

- 4 CO₂ is important in our atmosphere because it is required for photosynthesis and it traps some heat, keeping Earth warm. However, scientists speculate that excessive CO₂ production is a problem because it —
- A leads to higher global temperatures
 - B disrupts the natural cycling of other greenhouse gases
 - C adds too much CO₂ to the oceans
 - D leads to uncontrolled photosynthesis

TEKS 11B, 12A, 12F

- 5 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?
- 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.

Go online for the latest biology news and updates on all BioZine articles.

Expanding the Textbook

News Feeds

 [Science Daily](#)

 [CNN](#)

 [BBC](#)



Careers

Bio Bytes

Opinion Poll

Strange Biology



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

Climate Change— Changing the Planet

Polar bears are on the move. The area of arctic sea ice on which these carnivores hunt seals has declined 34 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 cannot make it, and they drown. Now polar bears must compete with grizzly bears. If climate change is changing the shape of one of Earth's coldest regions, how will it affect the rest of our planet?

(tr) ©Thomas Misen/Photo Researchers, Inc.; (bl) ©Tom Van Sant/Photo Researchers, Inc.

Ecosystems at Risk **TEKS 12F**

In the 20th century, the average global temperature rose by 0.6°C (1°F). The difference may seem small, but it is an average for the entire globe. Near the poles, the effects of climate change are more dramatic. Since 1949, average annual temperatures in Alaska have risen 1.8°C (3°F)—enough to lengthen the summer melting season for sea ice and glaciers. From 1979 to 2007, Arctic sea ice retreated enough to expose an additional one million square miles of open water—the equivalent of six Californias.

Good and Bad News? **TEKS 11B, 12F**

In the rest of the world, the impact of climate change on Earth's species may be mixed. Many animal species, such as birds and butterflies, can move to cooler areas as the climate warms. But insects and microorganisms that cause infectious diseases, such as malaria and yellow fever, are also spreading toward the poles. Some plant species cannot move as quickly as the climate is expected to change, and may become extinct.

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, some researchers have predicted 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.

In addition, studies show that this increase in global temperatures is linked to a four percent increase in ocean humidity and a six to eight percent increase in rainfall, leading to stronger hurricanes.

TECHNOLOGY **STEM.**

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.

Read More >> [at HMDScience.com](http://HMDScience.com)

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 climate change by simulating different temperature increases.

But the news may not be all bad. Some of the same research shows that the same factors that increase the strength of a hurricane also make it less likely that the hurricane will ever make landfall. The retreat of Arctic sea ice may someday make it possible to open a shipping lane through the Arctic Ocean.

Scientists theorize that climate change has been accelerated 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 CO₂. They can absorb the CO₂ 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 TEKS 3D, 12F

Scientists have little doubt that Earth’s climate is changing. It is impossible to predict exactly how any ecosystem will be affected by climate change. However, biologists and climatologists are collecting data about processes, including solar radiation, precipitation, evaporation, the transfer of heat by winds and by ocean currents, and the ways in which plants affect climate. They interpret this information using computer models and try to answer questions about how climate change will affect Earth.

- Could climate change alter certain ocean currents, changing Earth’s temperatures further?
- How quickly might the polar ice caps melt?

CAREERS

Oceanographer in Action

RUTH CURRY

TITLE Oceanographer, Woods Hole Oceanographic Institution

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.

[Read More >>](#) [at HMDSscience.com](http://at.HMDSscience.com)

- How have global climate changes affected Earth’s ecosystems in the past?
- Is there a way to preserve biodiversity on mountain tops and polar areas where animals and plants have no cooler places to migrate to?

[Read More >>](#) [at HMDSscience.com](http://at.HMDSscience.com)