SECTION 3

Global Warming

Have you ever gotten into a car that has been sitting in the sun for a while with all its windows closed? Even if the day is cool, the air inside the car is much warmer than the air outside. On a hot summer day, opening the door to the car can seem like opening the door of an oven.

The reason heat builds up inside the car is that the sun's energy streams into the car through the clear glass windows in the form of sunlight. The carpets and upholstery in the car absorb the light and change it into heat energy. Heat energy does not pass through glass as easily as light energy does. Sunlight continues to stream into the car through the glass, but heat cannot get out. The heat continues to build up and is trapped inside the car. A greenhouse works the same way. By building a house of glass, gardeners trap the sun's energy and grow delicate plants in the warm air inside the greenhouse even when there is snow on the ground outside.

Objectives

- Explain why Earth's atmosphere is like the glass in a greenhouse.
- Explain why carbon dioxide in the atmosphere appears to be increasing.
- Explain why many scientists think that the Earth's climate may be becoming increasingly warmer.
- Describe what a warmer Earth might be like.

Key Terms

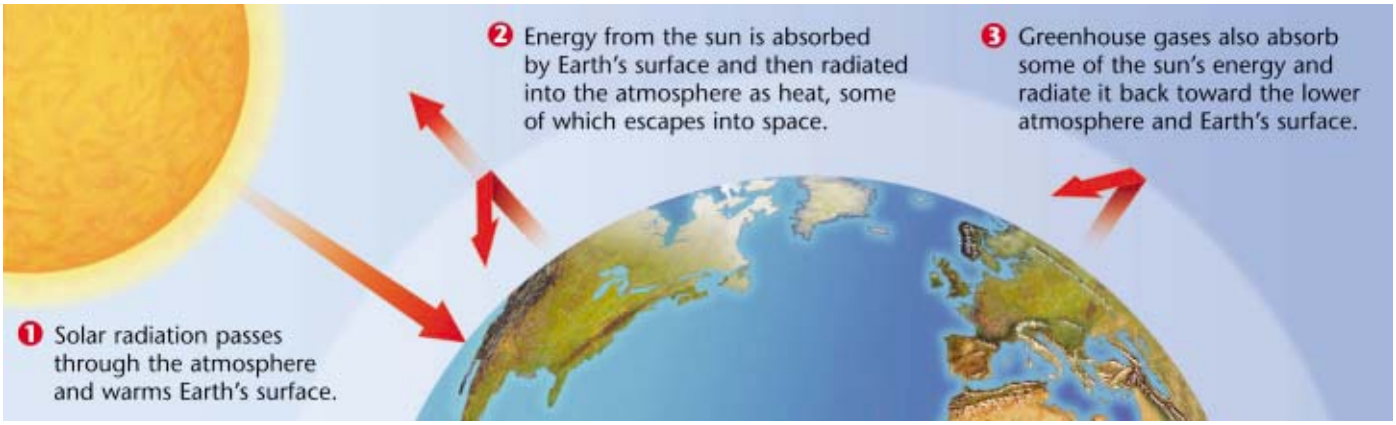
greenhouse gases
global warming
Kyoto Protocol

The Greenhouse Effect

The Earth is similar to a greenhouse. The Earth's atmosphere acts like the glass in a greenhouse. As shown in **Figure 14,** sunlight streams through the atmosphere and heats the Earth. As this heat radiates up from Earth's surface, some of it escapes into space. The rest of the heat is absorbed by gases in the troposphere and warms the air. This process of heat absorption is called the *greenhouse effect.*

Not every gas in our atmosphere absorbs heat in this way. The gases that do absorb and radiate heat are called **greenhouse gases.** The major greenhouse gases are water vapor, carbon dioxide, chlorofluorocarbons, methane, and nitrous oxide. Of these, water vapor and carbon dioxide account for most of the absorption of heat that occurs in the atmosphere.

Figure 14 ▶ How the Greenhouse Effect Works



FIELD ACTIVITY

Carbon Dioxide Create a question dealing with carbon dioxide or carbon dioxide levels in the atmosphere. Investigate the FAQ section of the Carbon Dioxide Information Analysis Center's Web site to see if your question has already been answered. If not, click on "Ask Us a Question," and e-mail your question to the center. Report your findings to the class.

Measuring Carbon Dioxide in the Atmosphere In 1958, a geochemist named Charles David Keeling installed an instrument at the top of a tall tower on the volcano Mauna Loa in Hawaii. Keeling wanted to precisely measure the amount of carbon dioxide in the air, far away from forests and cities. In a forest, carbon dioxide levels rise and fall with the daily rhythms of photosynthesis. Near cities, carbon dioxide from traffic and industrial pollution raises the local concentration of the gas. The winds that blow steadily over Mauna Loa have come thousands of miles across the Pacific Ocean, far from most forests and human activities, swirling and mixing as they traveled. Keeling reasoned that at Mauna Loa, the average carbon dioxide levels for the entire Earth could be measured.

Keeling's first measurement, in March of 1958, was 314 parts per million of carbon dioxide in the air, or 0.0314 percent. The next month the levels rose slightly. By summer the levels were falling, but in the winter they rose again. During the summer, growing plants use more carbon dioxide for photosynthesis than they release in respiration. This causes carbon dioxide levels in the air to decrease in the summer. In the winter, dying grasses and fallen leaves decay and release the carbon that was stored in them during the summer. So, carbon dioxide levels rise.

Rising Carbon Dioxide Levels After only a few years of measuring carbon dioxide, it became obvious that the levels were changing in ways other than just the seasonal fluctuations. Each year, the high carbon dioxide levels of winter were higher, and each year, the summer levels did not fall as low. **Figure 15** shows the carbon dioxide measured from 1958 to 2000. By 2000, the average level of carbon dioxide was about 368 parts per million. Thus, in 42 years, carbon dioxide has gone from 314 to 368 parts per million, an increase of 54 parts per million or 17 percent. This increase may be due to the burning of fossil fuels.

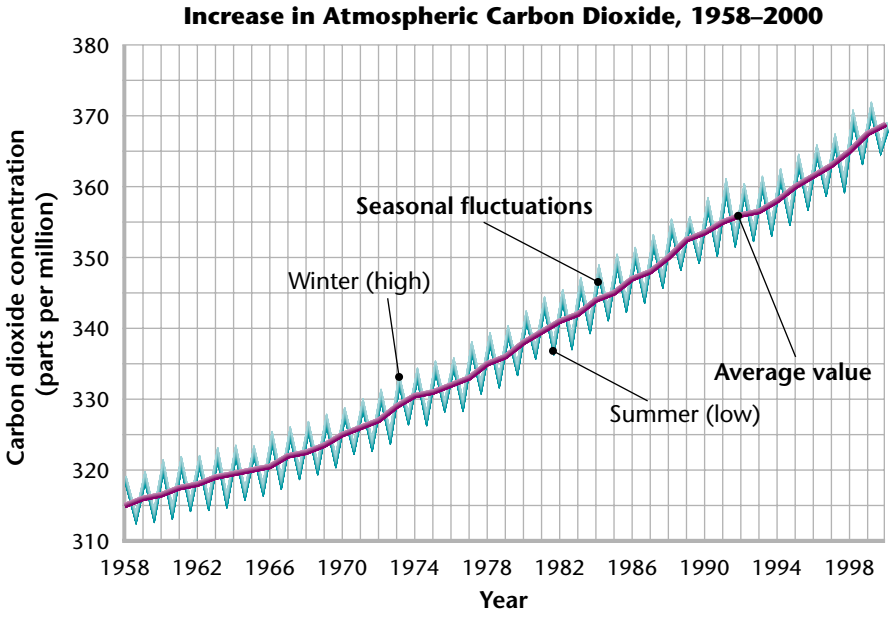


Figure 15 ▶ The graph shows that the average yearly concentration of carbon dioxide in the atmosphere has increased since 1958.

Greenhouse Gases and the Earth's Temperature Many scientists think that because greenhouse gases trap heat near the Earth's surface, more greenhouse gases in the atmosphere will result in an increase in global temperature. A comparison of carbon dioxide in the atmosphere and average global temperatures for the past 400,000 years supports that view.

Today, we are releasing more carbon dioxide than any other greenhouse gas into the atmosphere. Millions of tons of carbon dioxide are released into the atmosphere each year from power plants that burn coal or oil and from cars that burn gasoline. Millions of trees are burned in tropical rain forests to clear the land for farming. Thus, the amount of carbon dioxide in the atmosphere increases. We are also releasing other greenhouse gases, such as CFCs, methane, and nitrous oxide, in significant amounts. **Table 2** shows the sources of some major greenhouse gases.

Table 2 ▼

Major Greenhouse Gases and Their Sources

Carbon dioxide, CO_2: burning fossil fuels and deforestation

Chlorofluorocarbons (CFCs): refrigerants, aerosols, foams, propellants, and solvents

Methane, CH_4: animal waste, biomass burning, fossil fuels, landfills, livestock, rice paddies, sewage, and wetlands

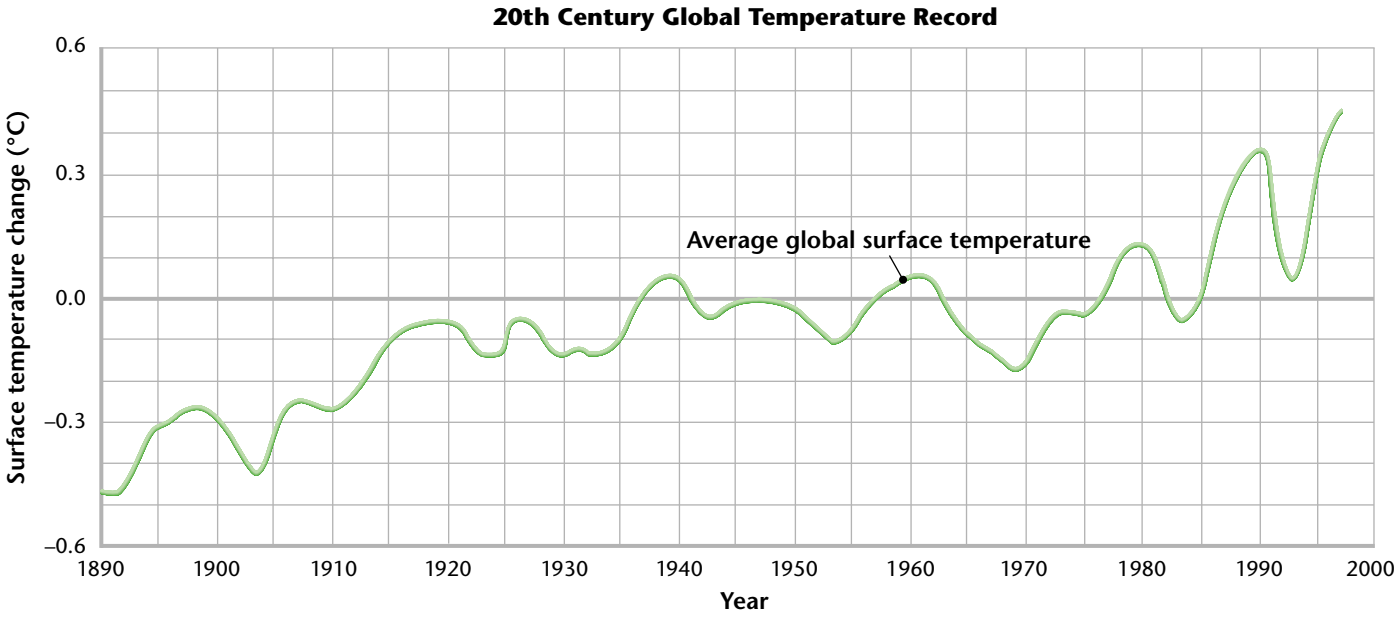
Nitrous Oxide, N_2O: biomass burning, deforestation, burning of fossil fuels, and microbial activity on fertilizers in the soil

Water vapor, H_2O: evaporation, plant respiration

How Certain Is Global Warming?

Many scientists think that the increasing greenhouse gases in our atmosphere result in increasing the average temperature on Earth. The result, they believe, will be a warmer Earth. This predicted increase in global temperature is known as **global warming.** As is shown by the graph in **Figure 16**, Earth's average global temperature increased during the 20th century. Many scientists project that the warming trend that began in the 20th century will continue throughout the 21st century. However, not all scientists agree that the observed global warming is due to greenhouse gases. Some scientists believe that the warming is part of natural climatic variability. They point out that widespread fluctuations in temperature have occurred throughout geologic time.

Figure 16 ▶ As shown by the graph, the surface of the Earth warmed during the 20th century.



Source: National Center for Atmospheric Research.

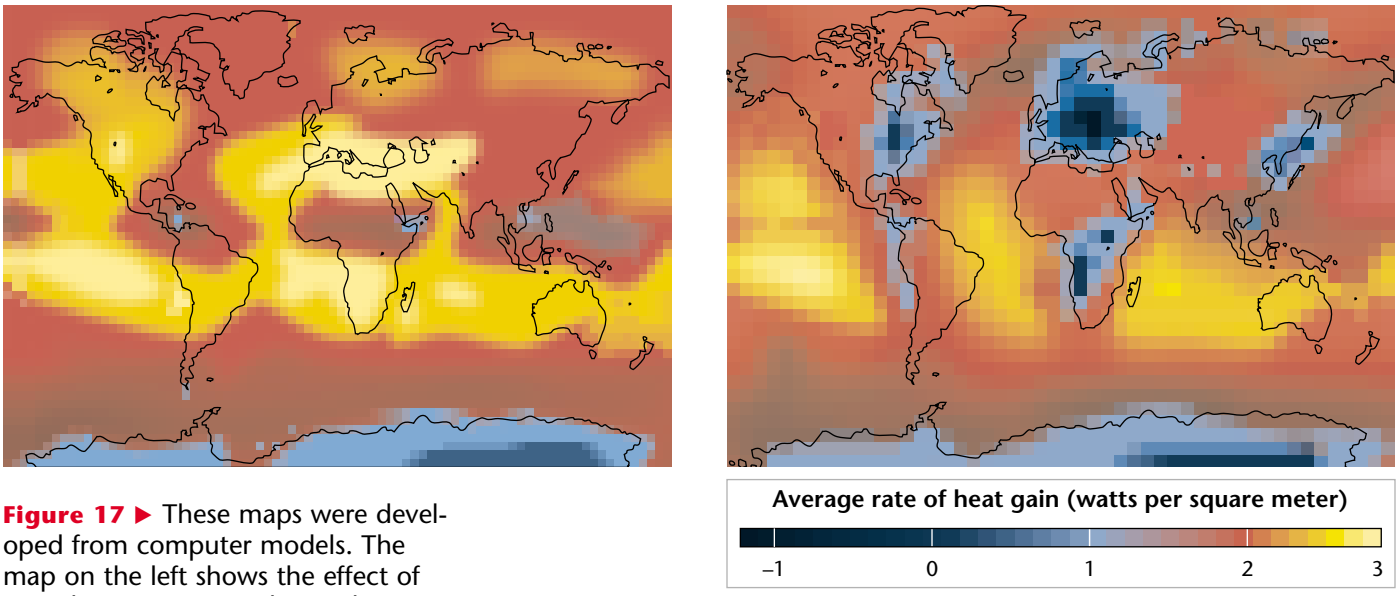


Figure 17 ▶ These maps were developed from computer models. The map on the left shows the effect of greenhouse gases on the Earth before sulfur pollution was added. The map on the right shows how the addition of the sulfur pollution variable shows a cooling effect.

Modeling Global Warming Scientists are currently unable to make accurate predictions about the rate of global warming because climatic patterns are complex and too many variables must be taken into account to be solved even using today's fastest computers. Predictions about climate change are based on computer models, such as the models shown in **Figure 17.** Scientists write equations representing the atmosphere and oceans. Scientists also enter data about carbon dioxide levels, prevailing winds, and many other variables. The computer models predict how phenomena such as temperature, rainfall patterns, and sea level will be affected. Computer modeling is complicated by the Earth's feedback processes that sometimes make it necessary to use different equations under changing simulated environments. These feedback processes are related to clouds, water vapor, ice, circulation changes within the oceans, changes in ocean chemistry, and changes in vegetation. Computer models of Earth's climate are becoming more reliable as more data are available, as additional factors are taken into consideration, and as faster computers are built.

Connection to Biology

Ocean Warming Commercial fishing in the northern Atlantic Ocean depends heavily on a fish called a *cod*. In recent years, the numbers of cod in the North Atlantic have greatly decreased. In 2001, English scientists embarked on a research project to find out if the decline in the numbers of cod was linked to the changing global climate. They sailed the ocean waters between Greenland and Iceland collecting samples of zooplankton. The scientists found that zooplankton levels have drastically decreased since 1963, the date of the last survey. The scientists believe that slowly warming ocean-water temperatures have in some way affected zooplankton in the North Atlantic Ocean and have in turn impacted the animals such as the cod that rely on the zooplankton as food.

The Consequences of a Warmer Earth

The Earth's climate has changed dramatically in the past. Many of those changes, however, occurred over thousands or millions of years. Scientists are not sure how quickly the Earth will warm or how severe the effects of global warming might be. Different computer models give different answers to these questions.

The impacts of global warming could include a number of potentially serious environmental problems. These problems range from the disruption of global weather patterns and global rise in sea level to adverse impacts on human health, agriculture, and animal and plant populations. Other impacts on the environment that could not be predicted by computer models might also arise.

Figure 18 ▶ This is a satellite map of a 11,000 km² iceberg—the size of Connecticut!—that split off from the Ross Ice Shelf in Antarctica in March of 2000. Many scientists believe that scenarios like this would become more common if the poles grow warmer.

Melting Ice and Rising Sea Levels If the global temperature increased, the amount of ice and snow at the poles would decrease. The melting of ice and snow at the poles would cause sea levels around the world to rise. The rise in sea level might affect coastal areas in a number of ways. Coastal wetlands and other low-lying areas might be flooded. Enormous numbers of people who live near coastlines could lose their homes and sources of income. Beaches could be extensively eroded. The salinity of bays and estuaries might increase, which could adversely affect marine fisheries. Also, coastal freshwater aquifers could become too salty to be used as sources of fresh water.

Global Weather Patterns If the Earth warms up significantly, the surface of the oceans will absorb more heat, which may make hurricanes and typhoons more common. Some scientists are concerned that global warming will also cause a change in ocean current patterns, such as shutting off the Gulf Stream. Such a change could significantly affect the world's weather. For instance, some regions might have more rainfall than normal, whereas other regions might have less. Severe flooding could occur in some regions at the same time that droughts devastate other regions.

Human Health Problems Warmer average global temperatures could pose threats to human health. Greater numbers of heat-related deaths could occur as a result of global warming. Both very young people and very old people would have the greatest risk of heat exhaustion during periods of high temperatures. Concentrations of ground-level ozone could increase as air temperatures rise. Consequently, respiratory illnesses could increase, especially in urban areas. Furthermore, global warming could cause insectborne diseases to spread. Warmer temperatures might enable mosquitoes, which carry diseases such as malaria and encephalitis, to greatly increase in number.

Figure 19 ▶ If climate change caused extreme weather to become more frequent, global agriculture would become severely impacted.

Agriculture Agriculture would be most severely impacted by global warming if extreme weather events, such as droughts, became more frequent. The effects of drought are shown in **Figure 19.** Higher temperatures could result in decreased crop yields. The demand for irrigation could increase, which would further deplete aquifers that have already been overused.

Effects on Plants and Animals Climate change could alter the range of plant species and could change the composition of plant communities. A warmer climate could cause trees to colonize northward into cooler areas. Forests could shrink in area in the southern part of their range and lose diversity.

Global warming may cause a shift in the geographical range of some animals. For example, birds that live in the Northern Hemisphere may not have to migrate as far south during the winter. Warming in the surface waters of the ocean might cause a reduction of zooplankton, tiny, shrimplike animals, that many marine animals depend on for food. The crabeater seal, shown in **Figure 20,** would be just one of the animals affected by a reduction in zooplankton. Warming in tropical waters may kill the microscopic algae that nourish corals, thus destroying coral reefs.

Figure 20 ▶ In spite of its name, the crabeater seal actually feeds on zooplankton. This seal is a resident of Antarctica.

Recent Findings

The Intergovernmental Panel on Climate Change (IPCC) is a network of approximately 2,500 of the world's leading climatologists from 70 countries. In 2001, the IPCC issued its Third Assessment Report (TAR). TAR describes what is currently known about the global climate system and provides future estimates about the state of the global climate system. Some of the findings of the IPCC included that the average global surface temperature increased by 0.6°C during the 20th century, that snow cover and ice extent have decreased, and that the average global sea level has risen. The IPCC has also reported that concentrations of atmospheric greenhouse gases have continued to increase as a result of human activities. It has also predicted that human influences will continue to change the composition of the Earth's atmosphere and continue to warm the Earth throughout the 21st century.

Reducing the Risk

In 1997, representatives from 160 countries met and set timetables for reducing emissions of greenhouse gases. These timetables will go into effect when a treaty called the *Kyoto Protocol* is ratified by 55 percent of the attending nations. The **Kyoto Protocol** requires developed countries to decrease emissions of carbon dioxide and other greenhouse gases by an average of 5 percent below their 1990 levels by 2012. In March of 2001, the United States decided not to ratify the Kyoto Protocol. Most developed nations are going ahead with the treaty.

The need to slow global warming has been recognized by the global community. Some nations and organizations have engaged in reforestation projects to reduce carbon dioxide, such as the project shown in **Figure 21.** However, the attempt to slow global warming is made difficult by the economic, political, and social factors faced by different countries. Conflict has already arisen between developed and developing countries over future CO_2 emissions, the projections of which are shown in **Figure 22.**

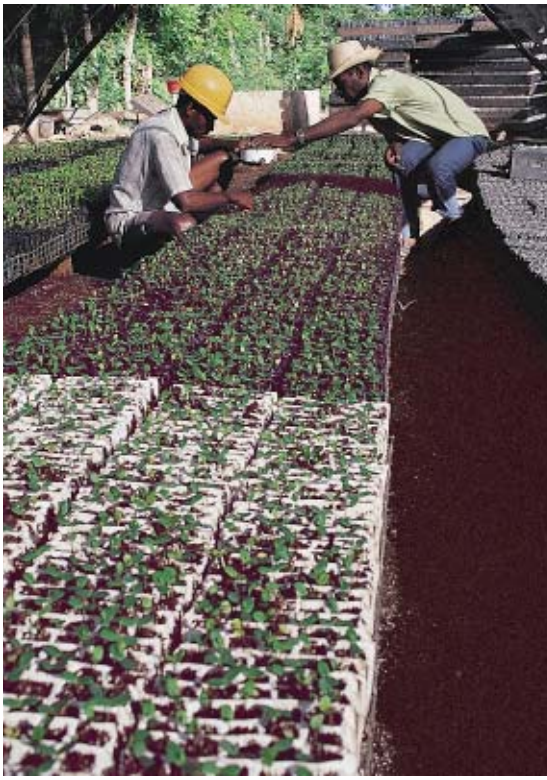
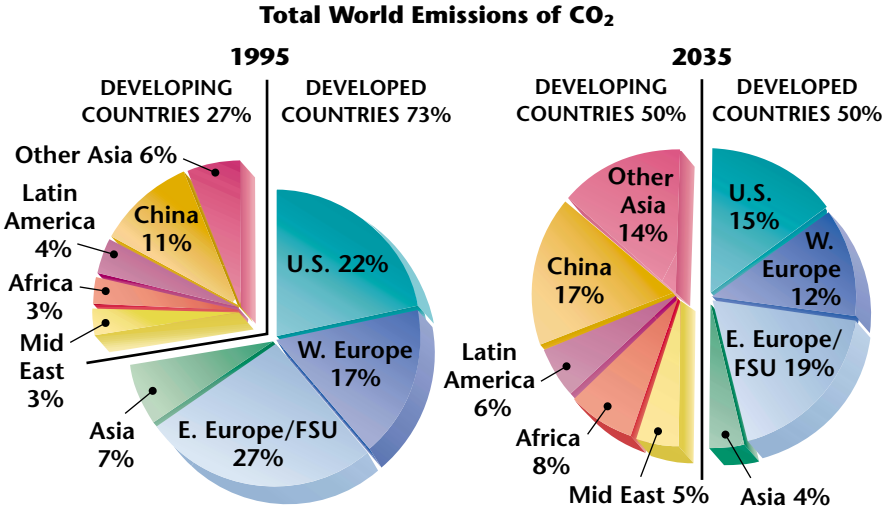


Figure 21 ▶ Because plants take in carbon dioxide during photosynthesis, reforestation projects such as this project in Haiti may help to offset a portion of global carbon dioxide emissions.



Source: U.S. Environmental Protection Agency.

Figure 22 ▶ Developing countries are projected to make up half of all CO_2 emissions by 2035. In 1995, total carbon released as CO_2 was 6.46 billion tons (5.86 billion metric tons). In 2035, total carbon emissions are projected to be 11.71 billion tons (10.62 billion metric tons).

SECTION 3 Review

1. **Explain** why Earth's atmosphere is like the glass in a greenhouse.
2. **Explain** why carbon dioxide in the atmosphere appears to be increasing.
3. **Explain** why many scientists believe Earth's climate may be getting increasingly warmer.
4. **Name** some of the possible consequences of a warmer Earth.

CRITICAL THINKING

5. **Making Predictions** Read the text under the heading "Modeling Global Warming." What difficulties do scientists face when they attempt to construct models that accurately predict the rate of global warming? READING SKILLS
6. **Analyzing Relationships** How could environmental problems in developing countries that result from global climate change affect the economies of developed countries, such as the United States?