mold, and carbon monoxide. Because carbon monoxide is so deadly and so hard to detect, many homes are equipped with detectors that sound an alarm if incomplete combustion produces dangerous levels of CO. In addition, keeping rooms and air ducts clean and free of mildew and other biological pollutants will reduce potential irritants and allergens. Most of all, keeping our indoor spaces well ventilated will minimize concentrations of the pollutants among which we live.

Progress is being made worldwide in alleviating the health toll of indoor air pollution. Researchers calculate that rates of premature death from indoor air pollution dropped nearly 40 percent from 1990 to 2010. Taking steps like those described here should bring us further progress in safeguarding people's health.

**Conclusion**

Indoor air pollution poses potentially serious health hazards, but by keeping informed and taking appropriate precautions on a personal basis, we each can minimize our risks. Outdoor air pollution has been addressed more effectively by government legislation and regulation, together with pollution-control technologies. Indeed, reductions in outdoor air pollution in the United States and other industrialized nations represent some of the greatest strides made in environmental protection to date. The global depletion of stratospheric ozone has been halted thanks to our efforts, and acid deposition is gradually being addressed. Room for improvement remains, however, particularly in reducing acid deposition and photochemical smog. In the developing world, indoor and outdoor air pollutant levels are higher and take a heavy toll on people's health. Reducing pollution from indoor fuelwood burning, automobile exhaust, coal combustion in outmoded facilities, and other sources will continue to pose challenges as the world's less-wealthy nations industrialize.

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## Reviewing Objectives

You should now be able to:

1. **Describe the composition, structure, and function of Earth's atmosphere**
   - The atmosphere moderates climate, provides us oxygen, conducts and absorbs solar radiation, and transports and recycles nutrients and waste. (p. 450)
   - The atmosphere consists of 78% nitrogen gas, 21% oxygen gas, and a variety of other gases in minute concentrations. (p. 450)
   - The atmosphere includes four layers: the troposphere, stratosphere, mesosphere, and thermosphere. Temperature and other characteristics vary across these layers. Ozone is concentrated in the stratosphere. (pp. 450-451)

2. **Relate weather and climate to atmospheric conditions**
   - The sun's energy heats the atmosphere, drives air circulation, and helps determine weather, climate, and the seasons. (pp. 452-453)
   - Weather is a short-term phenomenon, whereas climate is a long-term phenomenon. Fronts, pressure systems, and the interactions among air masses influence weather. (pp. 453-454)
   - Global convective cells called Hadley, Ferrel, and polar cells create latitudinal climate zones. (p. 455)
   - Hurricanes and tornados are types of cyclonic storms that can threaten life and property. (p. 456)
Identify major pollutants, outline the scope of outdoor air pollution, and assess solutions

- Natural sources such as fires, volcanoes, and windblown dust pollute the atmosphere. Human activity can worsen some of these phenomena. (pp. 456–457)
- The pollutants we emit include primary and secondary pollutants from point and non-point sources. (p. 457)
- To safeguard public health under the Clean Air Act, the U.S. EPA and state governments monitor emissions of six major pollutants: carbon monoxide, sulfur dioxide, nitrogen oxides, volatile organic compounds, particulate matter, and lead. (pp. 458–459)
- Agencies also monitor ambient concentrations of the six criteria pollutants: carbon monoxide, sulfur dioxide, nitrogen dioxide, tropospheric ozone, particulate matter, and lead. (p. 460)
- Thanks to public policy and to pollution-control technologies, emissions in the United States have decreased substantially since 1970, and ambient air quality has improved in most respects. (pp. 459–462)
- Emissions of 187 toxic air pollutants are also declining, but they still pose health risks. (p. 462)
- The U.S. EPA is taking early steps toward regulating greenhouse gases as pollutants because they drive climate change. (pp. 462–463)
- Industrializing nations such as China and India are experiencing some of the world's worst air pollution today. (pp. 463–464)
- Industrial smog produced by fossil fuel combustion is still a problem in urban and industrial areas of many developing nations. (pp. 464–465)
- Photochemical smog is created by chemical reactions of pollutants in the presence of sunlight. It impairs visibility and human health in urban areas. (p. 465)
- Cities such as Los Angeles and Mexico City are taking bold steps to address photochemical smog. (pp. 465, 468)

Explain stratospheric ozone depletion and identify steps taken to address it

- CFCs and other persistent human-made compounds destroy stratospheric ozone. Thinning ozone concentrations pose dangers to life because they allow more ultraviolet radiation to reach Earth's surface. (pp. 468–469)
- Ozone depletion is most severe over Antarctica, where an "ozone hole" appears each spring. (p. 469)
- The Montreal Protocol and its follow-up agreements have proven remarkably successful in reducing emissions of ozone-depleting substances. (p. 472)
- The long residence time of CFCs in the atmosphere accounts for a time lag between the protocol and full restoration of stratospheric ozone. (p. 472)

Define acid deposition, illustrate its consequences, and explain how we are addressing it

- Acid deposition results when pollutants such as SO₂ and NO react in the atmosphere to produce strong acids that are deposited on Earth's surface. (p. 473)
- Acid deposition may be wet (e.g., "acid rain") or dry, and it may occur a long distance from the source of pollution. (p. 473)
- Acid deposition damages soils, water bodies, plants, animals, ecosystems, and human property and infrastructure. (pp. 473–474)
- Regulation, cap-and-trade programs, and technology are all helping to reduce acid deposition in North America. Industrializing nations will need to tackle the problem as well. (pp. 474–475)

Characterize the scope of indoor air pollution and assess solutions

- Indoor air pollution causes more deaths and health problems worldwide than outdoor air pollution. (p. 475)
- Indoor burning of fuelwood is the developing world's primary indoor air pollution risk. (pp. 475–476)
- Tobacco smoke and radon are the worst indoor pollutants in the developed world. (p. 476)
- Volatile organic compounds and living organisms can pollute indoor air. (pp. 476–477)
- Using low-toxicity materials, keeping spaces clean, monitoring air quality, and maximizing ventilation all help to enhance indoor air quality. (p. 478)

Testing Your Comprehension

1. About how thick is Earth's atmosphere? For each of the four atmospheric layers, name one characteristic.
2. Where is the "ozone layer" located? How and why is stratospheric ozone beneficial for people, whereas tropospheric ozone is harmful?
3. How does solar energy influence weather and climate? Describe how Hadley, Ferrel, and polar cells help to determine long-term climatic patterns and the location of biomes.
4. Describe a thermal inversion. Explain how inversions contribute to severe smog episodes such as the ones in London and in Donora, Pennsylvania.

5. How does a primary pollutant differ from a secondary pollutant? Give an example of each.

6. What has happened with the emissions of major pollutants in the United States in recent decades? What has happened with concentrations of “criteria pollutants” in U.S. ambient air in recent decades? Name one health risk from toxic air pollutants.

7. How does photochemical smog differ from industrial smog? How do the weather and topography influence smog formation?

8. Explain how chlorofluorocarbons (CFCs) deplete stratospheric ozone. Why is this depletion considered a long-term international problem? What was done to address this problem?

9. Why are the effects of acid deposition often felt in areas far from where the primary pollutants are produced? List three impacts of acid deposition.

10. Name three common sources of indoor pollution and their associated health risks. For each pollution source, describe one way to reduce exposure to the source.

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**Seeking Solutions**

1. Consider responses to the photochemical smog pollution that has plagued Los Angeles, Mexico City, and other metropolitan areas. Describe several ways in which major cities have tried to improve their air quality.

2. Name one type of natural air pollution, and discuss how human activity can sometimes worsen it. What potential solutions can you think of to minimize this human impact?

3. Describe how and why emissions of major pollutants have been reduced by well over 50% in the United States since 1970, despite increases in population, energy use, and economic activity.

4. International action through a treaty has helped to halt further stratospheric ozone depletion, but other transboundary pollution issues, including acid deposition, have not yet been addressed as effectively. What types of actions do you feel are appropriate for pollutants that cross political boundaries?

5. **THINK IT THROUGH** You have become the head of your county health department, and the EPA informs you that your county has failed to meet the national ambient air quality standards for ozone, sulfur dioxide, and nitrogen dioxide. Your county is partly rural but is home to a city of 200,000 people and 10 sprawling suburbs. There are several large and aging coal-fired power plants, a number of factories with advanced pollution control technology, and no public transportation system. What steps would you urge the county government to take to meet the air quality standards? Explain how you would prioritize these steps.

6. **THINK IT THROUGH** You have been elected mayor of the largest city in your state. Your city’s residents are complaining about photochemical smog and traffic congestion. Traffic engineers and city planners project that population and traffic will grow by 20% in the next decade. Some experts are urging you to restrict traffic into the city, allowing only cars with odd-numbered license plates on odd-numbered days, and those with even-numbered plates on even-numbered days. However, business owners fear losing money should these measures discourage shoppers from visiting. Consider the particulars of your city, and then decide whether you will pursue an odd-day/even-day driving program, and explain why or why not. What other steps would you take to address your city’s smog problem?

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**Calculating Ecological Footprints**

"While only some motorists contribute to traffic fatalities, all motorists contribute to air pollution fatalities." So stated a writer for the Earth Policy Institute, pointing out that air pollution kills far more people than vehicle accidents. According to EPA data, emissions of nitrogen oxides in the United States in 2012 totaled 11.3 million tons. Nitrogen oxides come from fuel combustion in motor vehicles, power plants, and other industrial, commercial, and residential sources, but fully 6.4 million tons of the 2012 total came from vehicles. The U.S. Census Bureau estimates the nation’s population to have been 313.9 million in 2012 and projects that it will reach 346.7 million in 2025. Considering these data, calculate the missing values in the table below (1 ton = 2000 lb).

<table>
<thead>
<tr>
<th>System</th>
<th>Total NO₂ emissions (lb)</th>
<th>NO₂ emissions from vehicles (lb)</th>
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