SECTION 2

The Ozone Shield

The **ozone layer** is an area in the stratosphere where ozone is highly concentrated. *Ozone* is a molecule made of three oxygen atoms. The ozone layer absorbs most of the ultraviolet (UV) light from the sun. Ultraviolet light is harmful to organisms because it can damage the genetic material in living cells. By shielding the Earth's surface from most of the sun's ultraviolet light, the ozone in the stratosphere acts like a sunscreen for the Earth's inhabitants.

Objectives

- Explain how the ozone layer shields the Earth from much of the sun's harmful radiation.
- Explain how chlorofluorocarbons damage the ozone layer.
- Explain the process by which the ozone hole forms.
- Describe the damaging effects of ultraviolet radiation.
- Explain why the threat to the ozone layer is still continuing today.

Key Terms

ozone layer
chlorofluorocarbons (CFCs)
ozone hole
polar stratospheric clouds

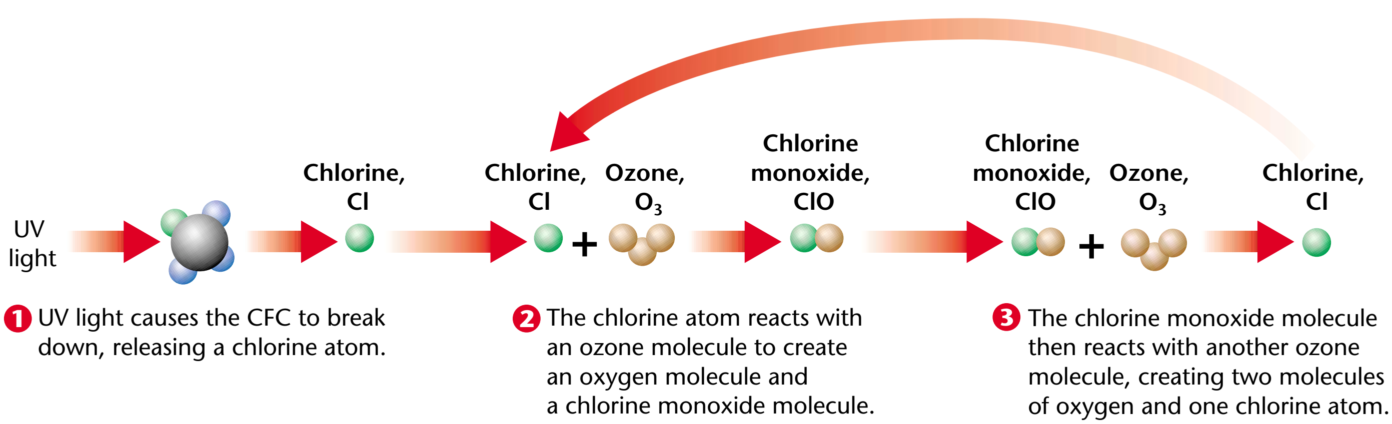
Chemicals That Cause Ozone Depletion

During the 1970s, scientists began to worry that a class of human-made chemicals called **chlorofluorocarbons (CFCs)** might be damaging the ozone layer. For many years CFCs were thought to be miracle chemicals. They are nonpoisonous and nonflammable, and they do not corrode metals. CFCs quickly became popular as coolants in refrigerators and air conditioners. They were also used as a gassy "fizz" in making plastic foams and were used as a propellant in spray cans of everyday products such as deodorants, insecticides, and paint.

At the Earth's surface, CFCs are chemically stable. So, they do not combine with other chemicals or break down into other substances. But CFC molecules break apart high in the stratosphere, where UV radiation, a powerful energy source, is absorbed. Once CFC molecules break apart, parts of the CFC molecules destroy protective ozone.

Over a period of 10 to 20 years, CFC molecules released at the Earth's surface make their way into the stratosphere. **Figure 10** shows how the CFCs destroy ozone in the stratosphere. Each CFC molecule contains from one to four chlorine atoms, and scientists have estimated that a single chlorine atom in the CFC structure can destroy 10,000 ozone molecules.

Figure 10 ▶ The CFC molecule in this illustration contains a single chlorine atom. This chlorine atom continues to enter the cycle and repeatedly destroys ozone molecules.



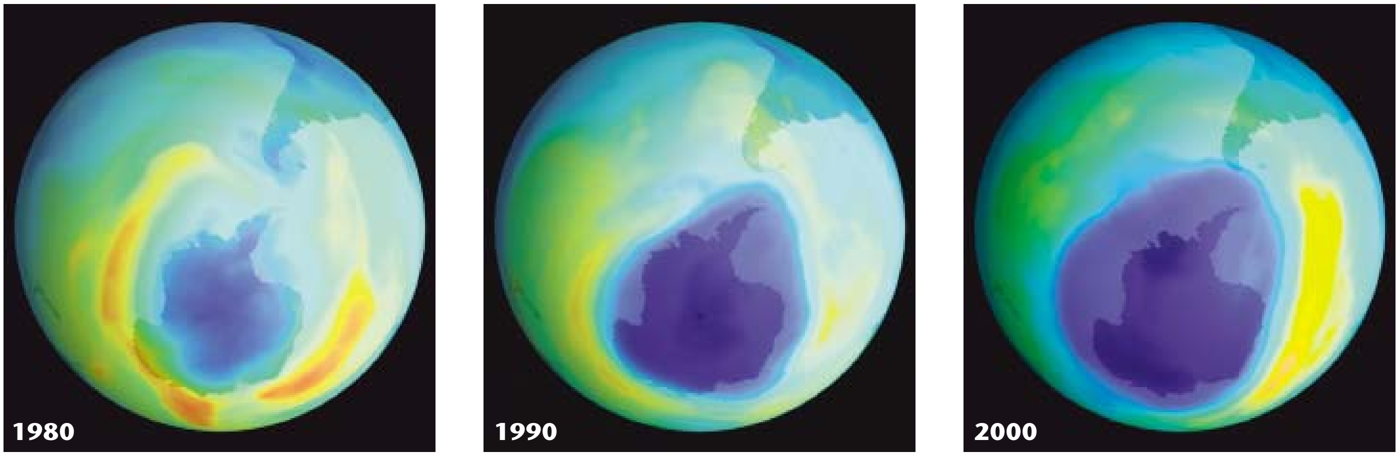


Figure 11 ▶ These satellite images show the growth of the ozone hole, which appears purple, over the past two decades.

The Ozone Hole

In 1985, an article in the scientific journal *Nature* reported the results of studies by scientists working in Antarctica. The studies revealed that the ozone layer above the South Pole had thinned by 50 to 98 percent. This was the first news of the **ozone hole,** a thinning of stratospheric ozone that occurs over the poles during the spring.

After the results from the studies from Halley Bay were published, NASA scientists reviewed data that had been sent to Earth by the *Nimbus* 7 weather satellite since the satellite's launch in 1978. They were able to see the first signs of ozone thinning in the data from 1979. Although the concentration of ozone fluctuates during the year, the data showed a growing ozone hole, as shown in **Figure 11.** Ozone levels over the Arctic have decreased as well. In fact, March 1997 ozone levels over part of Canada were 45 percent below normal.

How Does the Ozone Hole Form? During the dark polar winter, strong circulating winds over Antarctica, called the *polar vortex*, isolate cold air from surrounding warmer air. The air within the vortex grows extremely cold. When temperatures fall below about –80°C, high-altitude clouds made of water and nitric acid, called **polar stratospheric clouds,** begin to form.

On the surfaces of polar stratospheric clouds, the products of CFCs are converted to molecular chlorine. When sunlight returns to the South Pole in spring, molecular chlorine is split into two chlorine atoms by ultraviolet radiation. The chlorine atoms rapidly destroy ozone. The destruction of ozone causes a thin spot, or ozone hole, which lasts for several months. Some scientists estimate that as much as 70 percent of the ozone layer can be destroyed during this period.

Because ozone is also being produced as air pollution, you may wonder why this ozone does not repair the ozone hole in the stratosphere. The answer is that ozone is very chemically reactive. Ozone produced by pollution breaks down or combines with other substances in the troposphere long before it can reach the stratosphere to replace ozone that is being destroyed.

Connection to Meteorology

Polar Stratospheric Clouds
Because the stratosphere is extremely dry, clouds normally do not form in this layer of the atmosphere. However, during polar winters, temperatures become low enough to cause condensation and cloud formation. These clouds, which occur at altitudes of about 21,000 m, are known as polar stratospheric clouds, or PSCs. Because of their iridescence, PSCs are called mother-of-pearl or nacreous clouds. Outside of the poles, the stratosphere is too warm for these clouds to form. Because these clouds are required for the breakdown of CFCs, ozone holes are confined to the Antarctic and Arctic regions.

Effects of Ozone Thinning on Humans As the amount of ozone in the stratosphere decreases, more ultraviolet light is able to pass through the atmosphere and reach Earth's surface, as shown in **Figure 12.** UV light is dangerous to living things because it damages DNA. DNA is the genetic material that contains the information that determines inherited characteristics. Exposure to UV light makes the body more susceptible to skin cancer, and may cause certain other damaging effects to the human body.

Effects of Ozone Thinning on Animals and Plants High levels of UV light can kill single-celled organisms called *phytoplankton* that live near the surface of the ocean. The loss of phytoplankton could disrupt ocean food chains and reduce fish harvests. In addition, a reduction in the number of phytoplankton would cause an increase in the amount of carbon dioxide in the atmosphere.

Some scientists believe that increased UV light could be especially damaging for amphibians, such as toads and salamanders. Amphibians lay eggs that lack shells in the shallow water of ponds and streams. UV light at natural levels kills many eggs of some species by damaging unprotected DNA. Higher UV levels might kill more eggs and put amphibian populations at risk. Ecologists often use the health of amphibian populations as an indicator of environmental change due to the environmental sensitivity of these creatures.

UV light can damage plants by interfering with photosynthesis. This damage can result in lower crop yields. The damaging effects of UV light are summarized in **Table 1**.

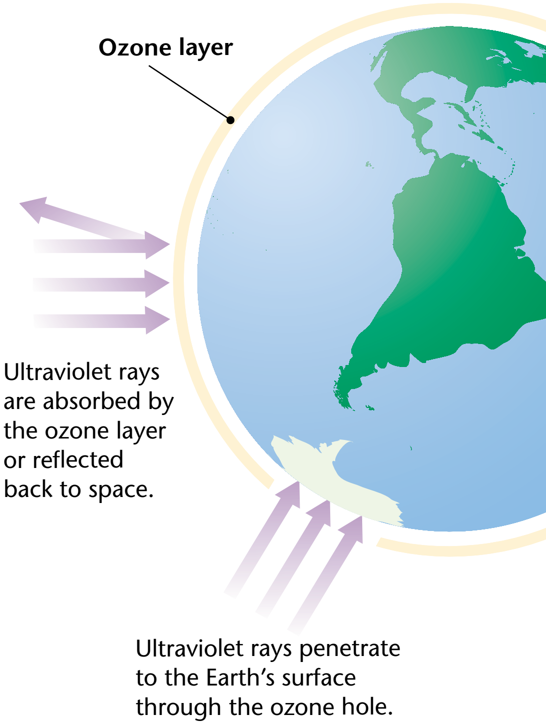


Figure 12 ▶ Depletion of the ozone layer allows more ultraviolet (UV) radiation to reach the surface of the Earth.

Table 1 ▼

Damaging Effects of UV Light	
Humans	• increased incidence of skin cancer • premature aging of the skin • increased incidence of cataracts • weakened immune response
Amphibians	• death of eggs • genetic mutations among survivors • reduction of populations
Marine Life	• death of phytoplankton in surface water • disruption of food chain • reduction in the number of photosynthesizers
Land Plants	• interference with photosynthesis • reduced crop yields

Protecting the Ozone Layer

In 1987, a group of nations met in Canada and agreed to take action against ozone depletion. Under an agreement called the Montreal Protocol, these nations agreed to sharply limit their production of CFCs. A second conference on the problem was held in Copenhagen, Denmark, in 1992. Developed countries agreed to eliminate most CFCs by 1995. The United States pledged to ban all substances that pose a significant danger to the ozone layer by 2000.

After developed countries banned most uses of CFCs, chemical companies developed CFC replacements. Aerosol cans no longer use CFCs as propellants, and air conditioners are becoming CFC free. Because many countries were involved and decided to control CFCs, many people consider ozone protection an international environmental success story. **Figure 13** illustrates the decline in world CFC production since the 1987 Montreal Protocol.

The battle to protect the ozone layer is not over. CFC molecules remain active in the stratosphere for 60 to 120 years. CFCs released 30 years ago are still destroying ozone today, so it will be many years before the ozone layer completely recovers.

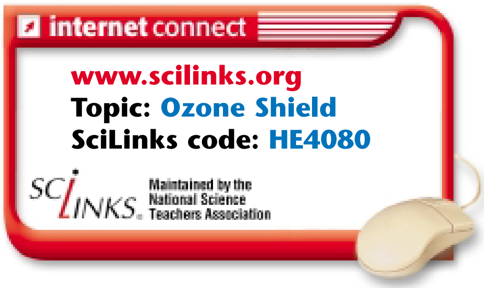
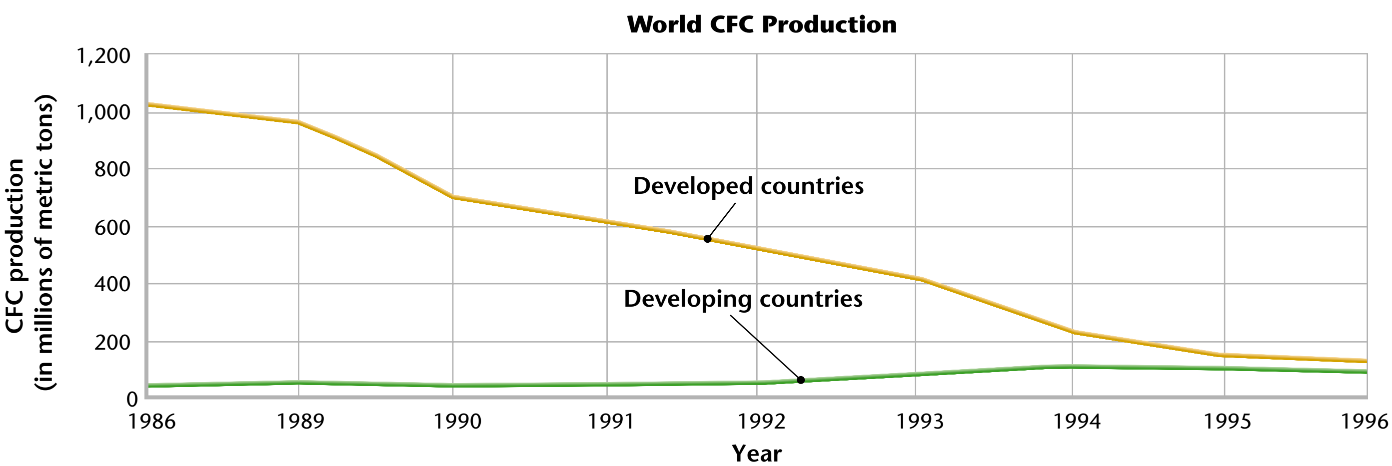


Figure 13 ▶ Chlorofluorocarbon production has declined greatly since developed countries agreed to ban CFCs in 1987.



Source: UN Environment Programme.

SECTION 2 Review

1. **Describe** the process by which chlorofluorocarbons destroy ozone molecules in the stratosphere.
2. **Describe** the process by which the ozone hole forms over Antarctica in spring.
3. **List** five harmful effects that UV radiation could have on plants or animals as a result of ozone thinning.
4. **Explain** why it will take years for the ozone layer to recover even though the use of CFCs has declined significantly. Write a paragraph that explains your answer. WRITING SKILLS

CRITICAL THINKING

5. **Making Decisions** If the ozone layer gets significantly thinner during your lifetime, what changes might you need to make in your lifestyle?
6. **Analyzing Relationships** CFCs were thought to be miracle chemicals when they were first introduced. What kinds of tests could be performed on any future miracle chemical to make sure serious environmental problems do not result from its use?