Chapter 7

Global Change

With an increasing number of people inhabiting this planet, the atmosphere is experiencing rapid changes, which impacts all life. In this chapter, the focus is on global change, starting with the protective ozone layer and followed by global warming, climate change, and the greenhouse effect. Finally, the impacts on other species and biodiversity are presented, along with conservation efforts. Each of these components of the Earth has been altered by human activities. Although changes in the ozone, climate, and biodiversity all occur naturally, human involvement has increased the rate at which destruction and alteration is occurring.

Stratospheric Ozone

Formation of Stratospheric Ozone

Stratospheric ozone shields life on Earth from the sun's ultraviolet (UV) radiation. There are three forms of UV radiation: UVA (long wavelength), UVB (medium wavelength), and UVC (short wavelength). Ozone (O_3) is formed in the upper stratosphere by a photochemical reaction between an existing oxygen molecule (O_2) and an additional oxygen atom (O), with the catalyst of ultraviolet (UV) radiation. UVC, the strongest of the three types of UV radiation, has enough energy to **photolyze** (break apart with light) the oxygen molecule.

The UVC splits apart the oxygen molecule into atomic oxygen.	$O_2 + UVC \rightarrow O + O$
Atomic oxygen then reacts with the oxygen molecule to form ozone.	$O + O_2 \rightarrow O_3$

This is a reversible reaction. When UVC strikes the ozone molecule, atomic oxygen and molecular oxygen are formed. Atomic oxygen can react with an ozone molecule to form two oxygen molecules.

The UVC splits apart the ozone molecule into atomic oxygen and the oxygen molecule.	$O_3 + UVC \rightarrow O + O_2$
Atomic oxygen now reacts with an ozone molecule to form two oxygen molecules.	$O + O_3 \rightarrow 2\ O_2$

For millions of years, the formation and destruction of ozone remained balanced so that the amount of ozone in the atmosphere stays fairly constant. It filters out much of the UV radiation reaching to the Earth from the sun. Keeping the UV radiation relatively constant for millions of years, has allowed life to evolve on Earth that is equipped to handle this (and only this) level of UV radiation.

The layer of the Earth's atmosphere known as the **stratosphere** extends from about 6 miles to about 31 miles above the Earth's surface. The highest part of the stratosphere houses 97 percent to 99 percent of the atmosphere's ozone molecules; thus, it is often referred to as the **ozone layer.** The remaining small percentage of ozone in the ground-level atmospheric layer known as the **troposphere** is considered a pollutant. The majority of ozone is formed above the tropics near the equator where the sun is almost directly overhead most of the year. Ozone is produced above the temperate and polar regions, too, but in less volume and concentration. As you would expect, there are strong seasonal variations in the production of ozone (more in the summer months and less in the winter months).

Ozone does not necessarily remain in the area where it is produced. Air currents distribute the ozone away from the tropics toward the North Pole and South Pole. Generally, winds carry ozone toward the North Pole during the Northern Hemisphere's winter and toward the South Pole during the Southern Hemisphere's winter. Ozone above the poles builds slowly over time because, while little is generated in the polar regions, a correspondingly small amount is destroyed, so the ozone that moves in from more tropical regions accumulates. Ozone reaches its highest concentration and thickness during the spring. As the spring moves into summer, the ozone layer starts to thin, becoming its thinnest in the fall.

Ultraviolet (UV) Radiation

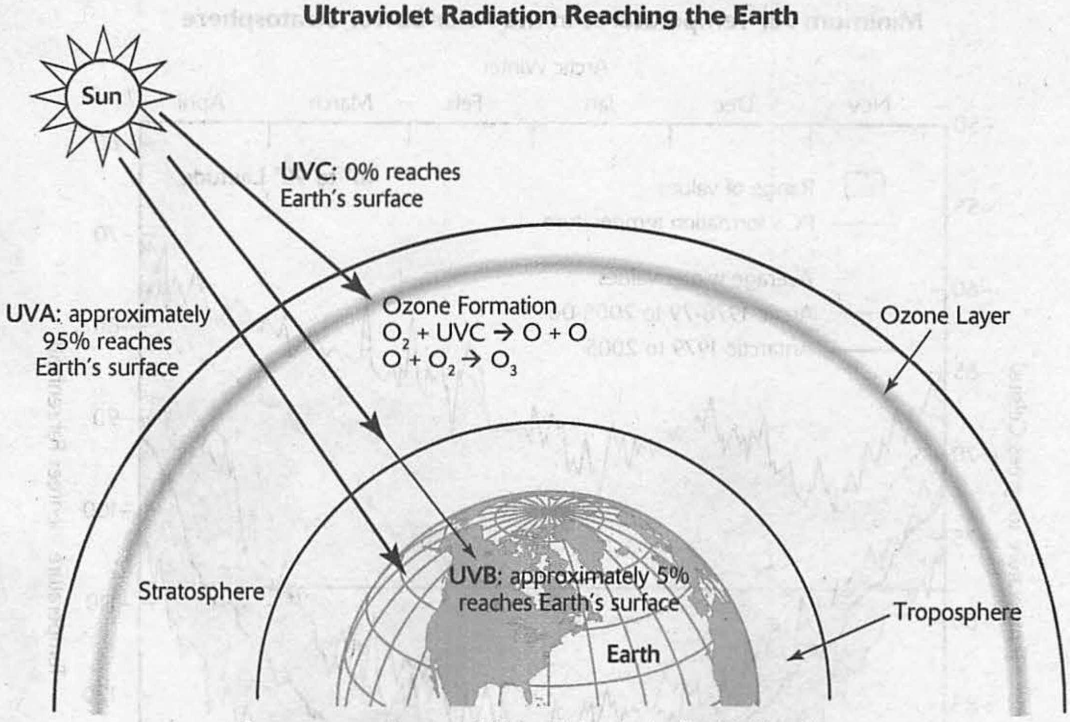
While all light is electromagnetic radiation, radiation comes in different wavelengths, frequencies, and energies. The higher the frequency and shorter the wavelength, the higher the energy. **Ultraviolet radiation (UV)** is light on the electromagnetic spectrum with wavelengths shorter than the minimum that the human eye is designed to see. However, some insects can see UV light. In fact, the sun emits many kinds of electromagnetic radiation we cannot see, including radio, microwave, infrared, ultraviolet, X-ray, and gamma radiations. The three most common bands of energy are **visible light, infrared,** and **ultraviolet**.

The three types of ultraviolet radiation (UV) are labeled by their wavelengths: **UVA** (long wavelength), **UVB** (medium), and **UVC** (short). UVA is not absorbed by ozone, and UVB is absorbed only partially by ozone, with some reaching the Earth's surface. UVC (short wavelength) is completely absorbed by ozone and normal oxygen. In the case of UVA and UVB, the more ozone, the more absorption. If there is less ozone, more of these types of radiation reach the Earth. Additional factors that affect how much radiation reaches the Earth include the amount of cloud cover and the angle at which the Earth faces the sun (which varies seasonally). The following table illustrates the amount of radiation that reaches the Earth's surface.

Types of UV Radiation

	Wavelength	How Much Reaches the Earth's Surface	Description
UV-A	Long Wavelength (320 to 400 nm)	Most	UVA is closest to blue/violet in the visible light spectrum. UVA absorption through human skin plays an essential role in the formation of natural vitamin D and is also responsible for tanning. That said, overexposure can be harmful and cause sunburn and premature aging. Many species of birds, insects, and reptiles can see UVA.
UV-B	Medium Wavelength (290 to 320 nm)	About 5 percent	The power of UVB radiation can alter human DNA. Over-exposures also can cause "snow blindness" (photokeratitis), cataracts, immune deficiencies, and skin tumors. The strongest risk to human health of overexposure to UVB radiation is non-melanoma skin cancer. Many animals as well as humans are harmed if exposed to high doses of UVB radiation.
UV-C	Short Wavelength (100 to 290 nm)	None	UVC is found only in the stratosphere and is completely absorbed by the ozone. UVC radiation drives the reactions that both form and destroy ozone.

Ultraviolet Radiation Reaching the Earth

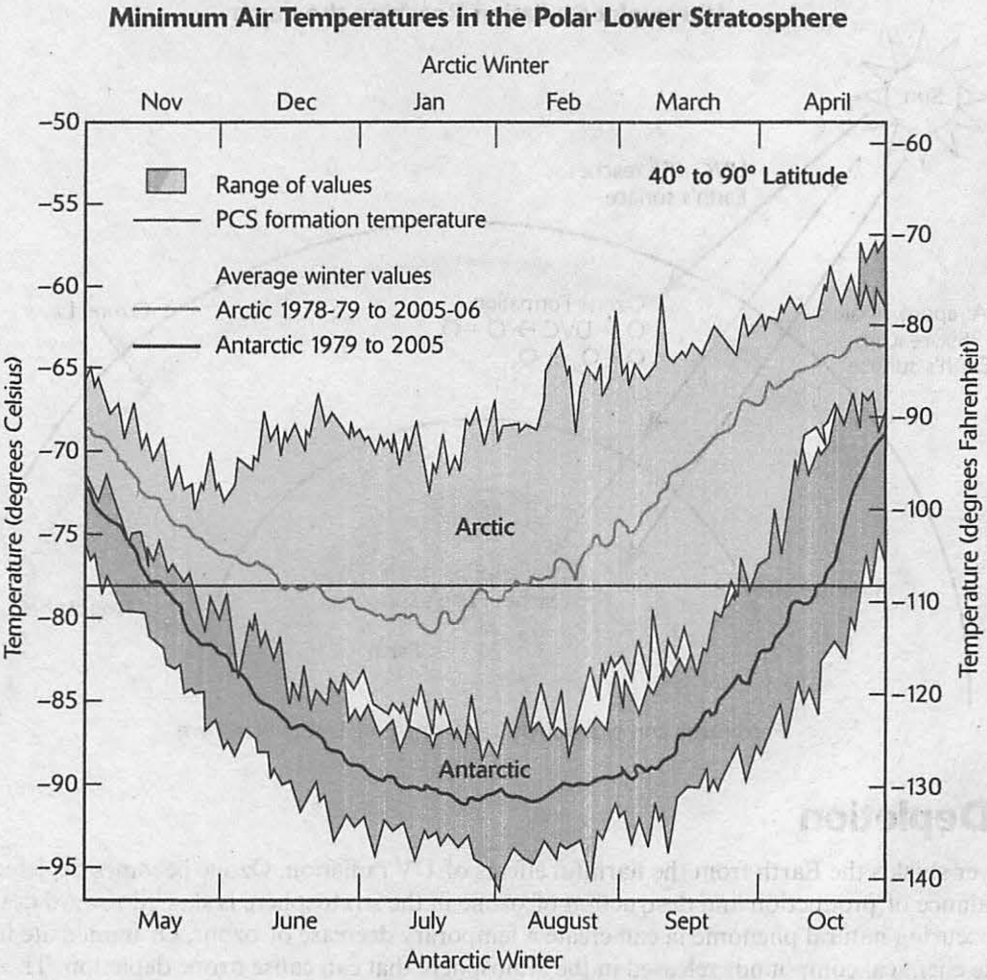


Percentage and types of UV radiation in the Earth's biosphere

Ozone Depletion

The ozone layer shields the Earth from the harmful effects of UV radiation. Ozone becomes depleted when the natural balance of production and destruction of ozone in the stratosphere is skewed toward destruction. Periodically occuring natural phenomena can create a temporary decrease of ozone. Of immediate importance are man-made chemical compounds released in the atmosphere that can cause ozone depletion. These compounds contain halogens (chlorine, bromine, iodine, and fluorine) and are known as **ozone-depleting substances,** such as chlorofluorcarbons (CFCs).

The global awareness and concern of ozone depletion started in 1985 with the discovery of a thinning of the ozone layer above the Antarctic by British scientists Joesph Farman, Brian Gardiner, and Jonathan Shanklin. Further research revealed that this thinning is twofold: First, overall levels of ozone in Antarctica have dropped 30 percent since the 1970s. This depletion continues at a rate of about 3 percent per year. The second depletion has been commonly described as the **ozone hole.** The ozone hole is not technically a "hole" devoid of ozone; it is an area of seasonal depletion over Antarctica that, once formed, tends to travel northward toward the equator and may linger over landmasses such as Australia, New Zealand, South America, and South Africa. When present, this ozone hole increases the UVB levels in affected areas by 3 percent to 10 percent, and in some years, by as much as 20 percent. The severe depletion of ozone above the Antarctic occurs because of special weather conditions. Very low temperature in the Antarctic winter months of below –78°C create ice clouds called **polar stratospheric clouds (PSCs).** Consolidation of greenhouse gases in these clouds helps drive ozone-depletion reactions. The more extremely cold days, the more PSCs and the larger that year's ozone hole will likely be.



Source: National Oceanic and Atmospheric Administration

In 1988, a similar but less severe hole was found in the ozone layer above the Arctic, occurring between February and June. The Arctic hole caused an 11 percent to 38 percent ozone loss (as compared to the 50 percent seasonal loss in Antarctica). As the ozone hole breaks up, it may move and linger over North America, Europe, and Asia. However, because the hole is not yet as thin as that in Antarctica, the increase in UVB radiation will not be nearly as extreme, so the effect on humans and local ecosystems will be less dramatic.

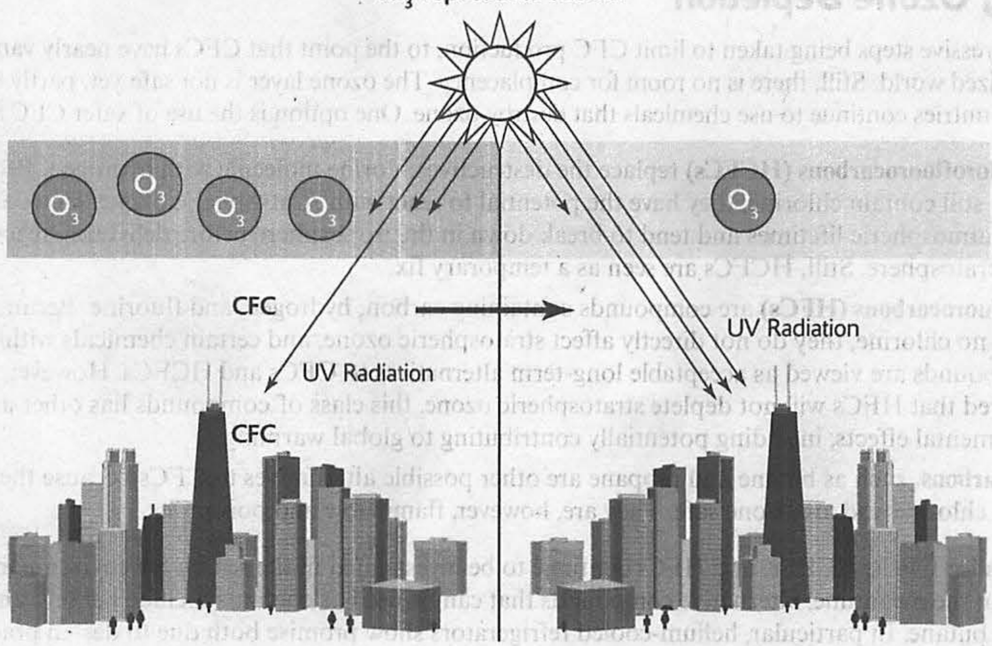
Chlorofluorocarbons (CFCs) are the primary man-made compounds involved in the depletion of ozone. They have commonly been used as refrigerants in air conditioners, refrigerators, and aerosol propellants. CFCs also are used as cleaning solvents for electrical parts and in the manufacturing of insulation. Prior to the 1980s, at least one million tons of CFCs were manufactured for consumer use every year, and the production and distribution of CFCs was a billion-dollar industry. The largest sources of environmental CFCs were leaks from car air conditioners and aerosols used in spray paints, deodorants, hairspray products, and other aerosol cans. Today, the use of CFCs as propellants is forbidden in the United States and most developed countries due to the strong link between CFCs and ozone depletion.

How Do CFCs Destroy Ozone?

When CFCs are released into the atmosphere, they rise through the troposphere and into the stratosphere. UV radiation breaks down the CFC molecule, releasing atomic chlorine (Cl). The released chlorine then detaches an oxygen molecule from ozone (O_3) to create **chlorine monoxide** (ClO) and molecular oxygen (O_2). Then the chlorine monoxide further reacts with another ozone molecule to produce two molecular oxygen molecules, freeing the chlorine to react with another ozone molecule and continue the cycle of ozone destruction. One freed atomic chlorine molecule from CFCs can destroy over 100,000 ozone molecules. The CFC may take many years to reach the stratosphere, where it can stay for 20 to 120 years, depending upon the exact compound. CFCs were first manufactured in 1931 as safer substitutes for ammonia and sulfur dioxide, the toxic refrigerants used at the time. The CFCs currently in the stratosphere may have been released any time since the development of CFCs.

Bromine levels in the stratosphere are about 150 times less than chlorine levels, but bromine is 10 to 100 times more influential in destroying ozone. This is because there is no stable, binding form of bromine in the stratosphere, and it is very easily photolyzed so that almost all the atmospheric bromine remains in a form that reacts with ozone. Approximately 20 percent of observed ozone depletion is caused by bromine. Bromine compounds are found in halons that are often used in dry-cleaning and fire-suppression equipment. Bromomethane (commonly known as methyl bromide [CH_3Br]) is produced industrially and naturally. It was used extensively as a pesticide until it was phased out in most countries in the early 2000s due to its being recognized as an ozone-depleting chemical. Methyl bromide is also produced by phytoplankton in the world's oceans and is found in the smoke plumes of burning biomass.

Ozone Depletion Process
(O_3 represents ozone)



Environmental Effects of Ozone Depletion

Ozone depletion and the resulting increase in ultraviolet radiation harm the Earth, humans, plants, and animals. Some of these adverse effects include the following:

- Changes in weather patterns
- Increased cooling of the stratosphere and warming of the troposphere due to less ozone to absorb the UV radiation, allowing more to reach the Earth's surface
- Increased formation of ground-level smog
- Increased damage to the skin (for example, sunburns)
- Increased UV radiation (UVB), which plays a major role in malignant melanoma skin cancer
- Increase of eye diseases (for example, cataracts)
- Increased damage to plants (including hardwood forests)
- Increased damage to agricultural crops, reducing food availability
- Increased harmful effects on animals, which may threaten the extinction of some species
- Disruption of productivity of ecosystem food chains, such as reduced growth of phytoplankton (tiny floating algae in the ocean, which are the base of the marine food chain)
- Weakening the efficiency of humans immune system
- Increased rate of mutations in human and nonhuman DNA, which are damaged by UVB radiation

Reducing Ozone Depletion

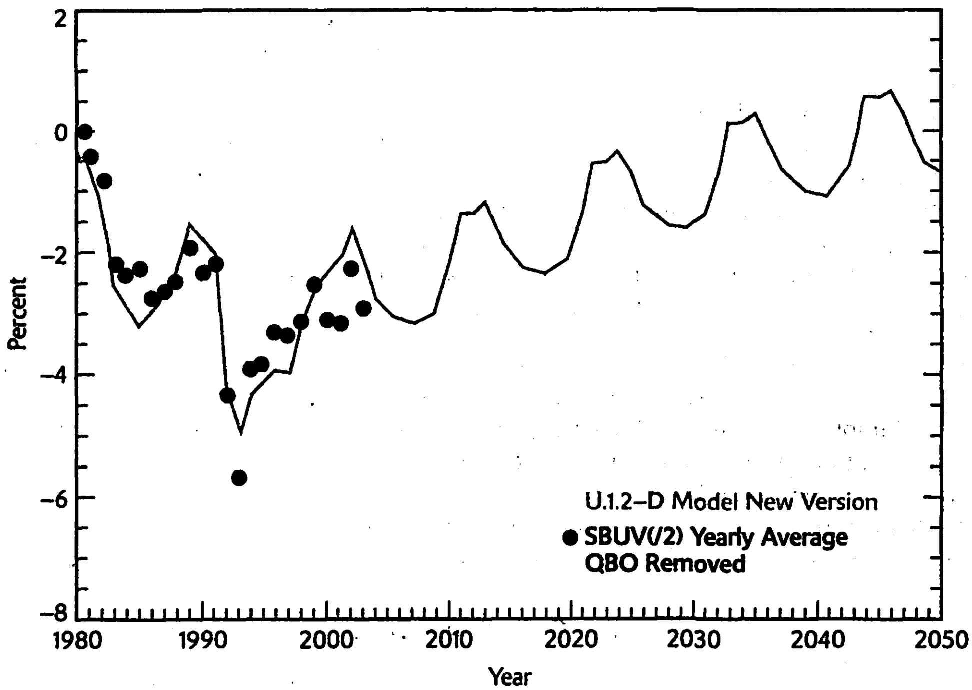
There are aggressive steps being taken to limit CFC production, to the point that CFCs have nearly vanished from the industrialized world. Still, there is no room for complacency. The ozone layer is not safe yet, partly because some developing countries continue to use chemicals that destroy ozone. One option is the use of safer CFC alternatives:

- **Hydroclorofluorocarbons (HCFCs)** replace the destructive chlorine molecule with hydrogen. Because HCFCs still contain chlorine, they have the potential to react with stratospheric ozone. However, they have shorter atmospheric lifetimes and tend to break down in the troposphere before delivering reactive chlorine to the stratosphere. Still, HCFCs are seen as a temporary fix.
- **Hydrofluorocarbons (HFCs)** are compounds containing carbon, hydrogen, and fluorine. Because HFCs contain no chlorine, they do not directly affect stratospheric ozone, and certain chemicals within this class of compounds are viewed as acceptable long-term alternatives to CFCs and HCFCs. However, though it is believed that HFCs will not deplete stratospheric ozone, this class of compounds has other adverse environmental effects, including potentially contributing to global warming.
- **Hydrocarbons,** such as butane and propane are other possible alternatives to CFCs because they do not contain chlorine and are ozone-safe. They are, however, flammable and poisonous.

Replacements for CFCs, HCFCs, and HFCs continue to be investigated in the search for environmentally safe alternatives. In the meantime, alternative compounds that can be used as coolants include helium, ammonia, propane, and butane. In particular, helium-cooled refrigerators show promise both due to design practicality and to the fact that helium is a noble gas and, thus, nonreactive (meaning that it will not deplete the ozone layer).

Amendments to the **Clean Air Act** include requirements for the disposal of old refrigerators and air-conditioner units and may require that older units be modified to use newer, environmentally safer coolants. Home air conditioners are designed to have a lifetime of 20 years or more, so many older units still use the ozone-depleting Freon (R12). New products continue to be developed that are less harmful to the stratospheric ozone layer and less harmful to the environment.

Percent of Ozone Change (50°N–50°S) Since 1980 and Projected to 2050



Source: Environmental Protection Agency

Relevant Laws and Treaties

There are many laws and treaties pertaining to the cleanliness and safety of the air and to the protection of Earth's atmosphere and ozone layer. Those relating to ozone depletion are the Clean Air Act and Montreal Protocol.

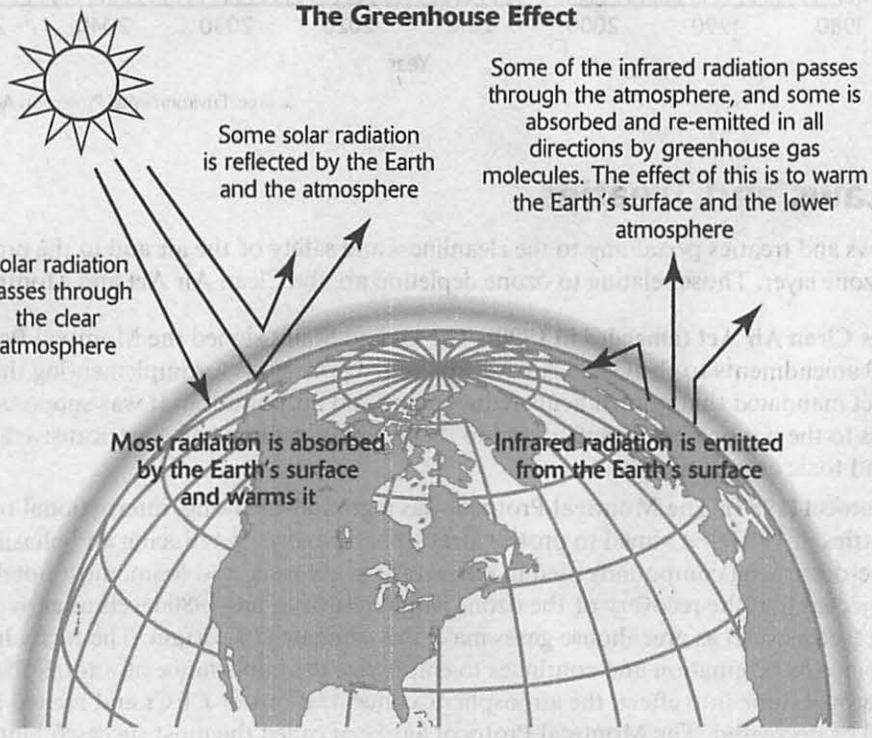
- **United States Clean Air Act (amended in 1990):** The United States signed the Montreal Protocol in 1987, and the 1990 amendments to the Clean Air Act contained provisions for implementing the protocol. The Clean Air Act mandated that governments reduce smog and air pollution. It was supposed to curb three major threats to the nation's environment and to the health of millions of Americans: acid rain, urban air pollution, and toxic air emissions.
- **Montreal Protocol (1987):** The Montreal Protocol was a ground-breaking, international treaty signed by several countries in 1987 that aimed to protect stratospheric ozone by reducing and phasing out the production of ozone-destroying compounds used in refrigeration, aerosols, and foam, most notably CFCs. The protocol projected that the recovery of the ozone would return to pre-1980 levels as early as 2050; however, contributing factors such as greenhouse gases make this estimate less certain. The treaty has been modified seven times since its origination and continues to emphasize the importance of a total phase-out of CFCs. Since the protocol came into effect, the atmospheric concentrations of CFCs and related hydrocarbons have either leveled or decreased. The Montreal Protocol has been called the most successful international environmental agreement in history.

Global Warming and Climate Change

The terms *global warming* and *climate change* often are used interchangeably, but they have different meanings. **Global warming** is the steady increase in the average temperature of the Earth's surface that may be caused by man-made greenhouse emissions, which lead to increased infrared and thermal radiation near the Earth's surface. Global warming has been observed since the 1980s and continues to be at the forefront of international environmental research and debate. This debate is generally centered on whether the steady temperature increase of the Earth's surface is a natural occurrence or whether it has been accelerated as a result of human activity. **Climate change** is any change in the state of the climate (for example, temperature) that persists steadily for many years—decades or longer. Global climate change is a natural process and is best illustrated by the five known ice ages. Questions about global climate change and the contributions of human activities will continue to be discussed and evaluated, but regardless of its origins, the Earth is warming.

Global warming is widely associated with an increased concentration of **greenhouse gases** that soak up infrared radiation and trap heat in the atmosphere. However, a **natural greenhouse effect** is necessary to keep the Earth's climate warm and habitable. When the Earth's atmosphere traps solar radiation, it heats up, distributing this heat to the Earth. Without our atmosphere, the Earth would be uninhabitably hot during the day and uninhabitably cold at night. Thus, the atmosphere is much like an insulting blanket that traps the heat to keep the planet at a relatively constant temperature. About 80 percent to 90 percent of the Earth's natural greenhouse effect is due to water vapor in the atmosphere, which is a greenhouse gas.

The Greenhouse Effect

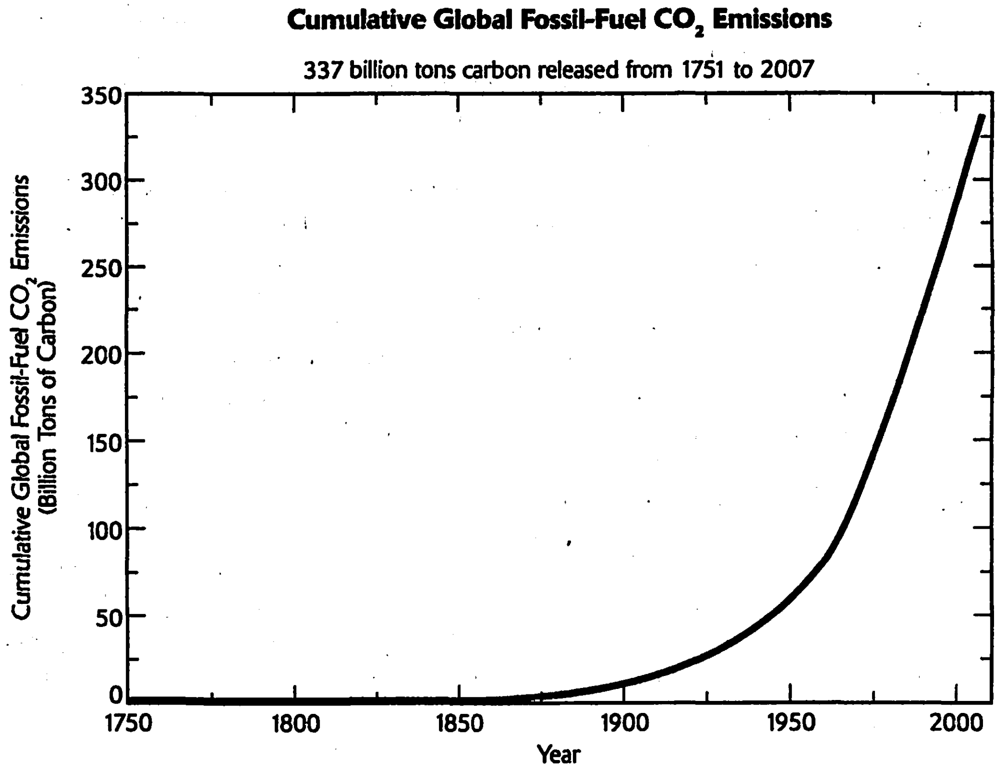


Source: Environmental Protection Agency

Other gases found naturally in the atmosphere also are considered greenhouse gases, insulating and acting as positive factors in the atmosphere in moderate concentrations and having a negative impact at increasing concentrations. Here are some of the most prominent of the greenhouse gases:

- **Carbon dioxide (CO_2)** is the most prominent greenhouse gas in the Earth's atmosphere. The primary sources of CO_2 are the burning of fossil fuels, decomposition, deforestation, and cellular respiration. This means that burning fires, motor vehicles, and smokestacks of factories that burns coal all emit carbon dioxide. Without carbon dioxide in the air, the Earth would be very cold. Carbon dioxide can spend an average of 50 to 100 years (or more) in the troposphere.
- **Carbon tetrachloride (CCl_4)** was primarily used in the production of cleaning fluids, especially in the manufacture of military airplanes and spacecrafts. It has an average time in the troposphere of about 50 years.
- **Chlorofluorocarbons (CFCs)** spend a relatively short 15 years in the troposphere but a much longer time in the stratosphere, where they damage ozone (as previously discussed). Historically, the primary sources of CFCs included coolants used in air conditioners and refrigerators, foam and insulation production, and aerosol spray cans. For the most part, these sources have been eliminated or are in the process of being eliminated.
- **Halons** are used in fire suppression and dry-cleaning supplies. Halons also are found naturally in the smoke plumes of burning biomass and in phytoplankton in the world's oceans. The relative warming effects of halons is 6,000 times that of carbon dioxide.
- **Hydrochlorofluorocarbons (HCFCs)** are modified CFCs, having fewer chlorine atoms and are considered less dangerous than CFCs. HCFCs tend to stay in the troposphere longer than CFCs. HCFCs are used as replacement coolants in air conditioners and refrigerators and in foam and insulation production.
- **Hydrofluorocarbons (HFCs)** are modified CFCs, having no chlorine atoms. HFCs like HCFCs tend to stay in the troposphere longer than CFCs—in the case of HFCs, 15 to 400 years. HFCs are used as coolants in air conditioners and refrigerators and in production of foam and insulation. HFCs tend to be less effective than CFCs as coolants.
- **Methane** is a naturally occurring gas with a lifespan of approximately 15 years in the troposphere and a warming factor of 25 times that of carbon dioxide. There are many sources of methane, including the production of rice, cattle, and coal, as well as natural gas leaks, especially during the transporting of natural gas in pipelines. Interestingly, organisms currently frozen in permafrost produce methane if thawed, and as the tundra melts due to global warming, these organisms will begin to contribute their methane, increasing the rate of warming.
- **Nitrous oxide (N_2O)** can stay in the troposphere for about 115 years. Its relative warming potential is 300 times greater than carbon dioxide. The sources of nitrous oxide include the burning of fossil fuels, livestock waste, fertilizers, and the manufacturing of plastics.
- **Sulfur hexafluoride (SF_6)** is used largely in heavy industry to insulate high-voltage equipment and to assist in the manufacture of cable cooling systems. It is used as a replacement for the highly carcinogenic pollutant PCBs. Of the ten greenhouse gases described here, it has the longest potential time in the troposphere at 3,200 years and the highest relative warming potential (24,000 times that of carbon dioxide).
- **Water vapor** concentrations fluctuate by geographic regions, but human activity does not significantly affect water vapor concentrations except in local areas of large agricultural irrigation. Although as temperatures increase on the planet, more water evaporates and can cause additional water vapor to rise into the atmosphere. Water vapor is naturally occurring.

The **man-made greenhouse effect** is the process by which manmade, "greenhouse" gases are released into atmosphere, where they act like an insulating blanket, trapping heat in the troposphere that would otherwise reflect into space. The majority of the scientific community believes that human activities contribute to global warming, but the topic is widely debated, partly due to the fact that many businesses produce greenhouse gases and reducing the emission of these gases costs money. Most of the greenhouse effect takes place in the troposphere, where levels of several greenhouse gases have increased since large-scale industrialization began 150 years ago. Carbon dioxide is increasing due to the burning of fossil fuels and deforestation. Nitric oxide is increasing due to the burning of fossil fuels. Part of the methane increase is due to the decomposition of organic material in the permafrost, increased cattle production, and the melting of methyl hydrates as ocean temperatures rise (scientists are searching for additional causes of increased methane). CFCs were not manufactured until the 1930s so all atmospheric CFCs are human-made.



Source: Boden, T.A., G. Marland, and R.J. Andres. 2010. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2010

The natural concentration of carbon dioxide in the Earth's atmosphere is constantly changing due to seasonal variations. Plants take in carbon dioxide for photosynthesis and then release it during cellular respiration and decomposition. The world's oceans absorb slightly more than they release. This natural waxing and waning of carbon dioxide concentrations is known as the **carbon cycle.** However, humans have altered the carbon cycle by contributing excess carbon dioxide from the burning of fossil fuels in power plants and for transportation, excessive deforestation and through other carbon-dioxide-producing activities. Plants and the world's oceans can absorb some of this excess, but the imbalance between emissions and absorption leads to a net increase in atmospheric CO_2 over time. The amount of carbon dioxide in the atmosphere has increased almost 39 percent since 1750, shortly before the beginning of the Industrial Revolution (see the following table).

Increase in Greenhouse Gases

Greenhouse Gas	Preindustrial Levels (ppm)	Current Level (ppm)	Increase Since 1750 (ppm)	Percent Increase
Carbon dioxide	280	388	108	38.6
Methane	700	1,745	1,045	149.3
Nitric oxide	270	314	44	16.3
CFCs	0*	533	533	

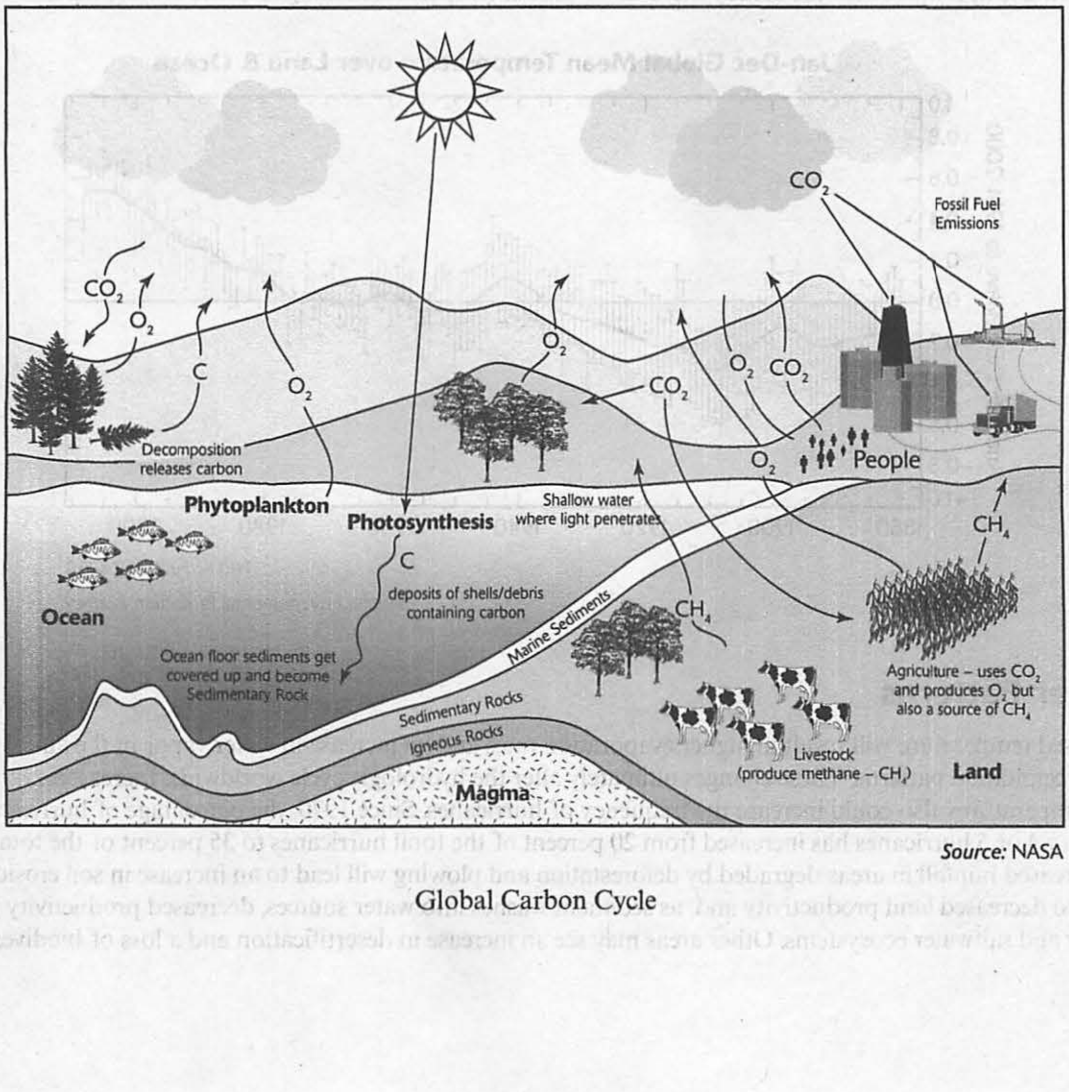
* CFCs were first manufactured in 1931.

One factor accelerating the amount of carbon dioxide that humans add to the atmosphere is the increased contributions of developing nations, especially China and India. As these countries undergo industrialization, they burn more fossil fuels, especially in coal-burning power plants (though many newer coal power plants are somewhat cleaner than the older designs). The overall increase of CO_2 emissions between 2003 and 2008 was over 30 percent for the world and over 61 percent for China. The following table shows the change in coal production from 2003 to 2008 for the larger coal producers. To date, humans have developed no way to successfully capture carbon dioxide once it is emitted into the atmosphere.

Production of Coal (in million tonnes, 1 tonne = 1,000 kg)					
	2003	**2008**	**Change**	**% Change**	**Reserves (years)**
World	5,187.6	6781.2	1,593.6	30.7	142
China	1,722	2782	1,060	61.6	41
United States	972.2	1062.8	90.5	9.3	224
European Union	638	587.7	–50.3	–7.9	51
India	375.4	521.7	146.3	39	114

Impacts and Consequences of Global Warming

Atmospheric levels of carbon dioxide (CO_2) have increased steadily since the Industrial Revolution and continue to rise at a pace consistent with the steady increase of the global economy. Historically, natural climate changes have caused large-scale geographical shifts in weather patterns and in the habitats of all living organisms. However, the current pace of global climate change is unprecedented. If greenhouse gases continue on pace to double in the next 65 years, the global temperature could rise at least 1°C to 5°C. If this rise continues into the next century, the global average temperature may reach higher values than have occurred in the last million years. This rapid environmental change can cause glaciers to melt, surface temperature changes, alteration of weather patterns, rising sea levels, changes in biodiversity, and the extinction of species.



Source: NASA

Global Carbon Cycle

Oceans

Carbon dioxide reacts with water in a reversible reaction to form carbonic acid (H_2CO_3). As the carbon dioxide increases in the atmosphere, the ocean absorbs more carbon dioxide, and more carbonic acid is formed, lowering the pH of seawater. This affects all the living organisms in the world's oceans, both plant and animal.

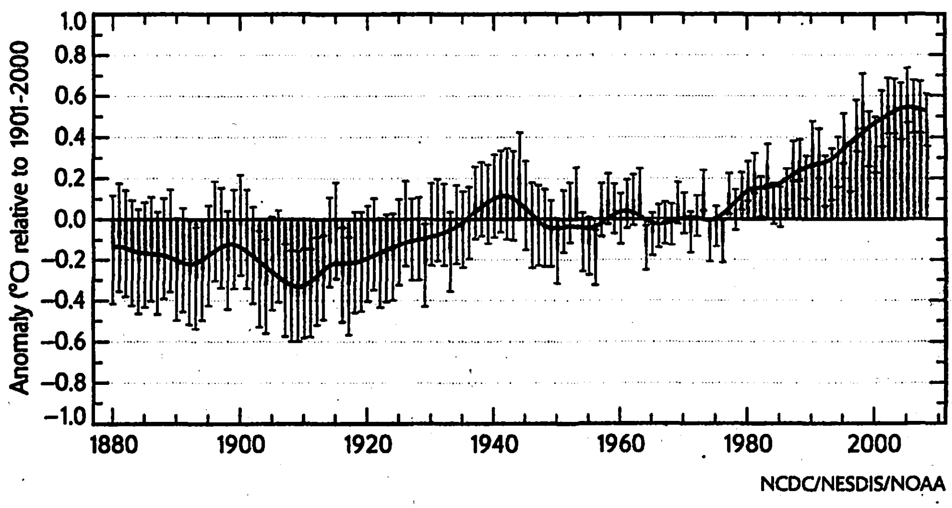
Temperature

Determining changes in the Earth's temperature is difficult because accurate temperature data only dates back to about 1850. One way to measure historic air temperatures is to study ice cores. Ice core samples are often collected on ice sheets in Antarctica, in Greenland, or on glaciers found in higher elevations. As ice forms, it traps gases found in the atmosphere, allowing analysis of historic levels of atmospheric gases. Collected ice core samples range from just a few years old, to as old as 800,000 years. Analysis of these samples shows that historic increases in air temperature have averaged less than 2°C per 1,000 years. However, since the Industrial Revolution, we've seen a dramatic increase in the concentration of greenhouse gases in the Earth's atmosphere. And since the Industrial Revolution, the average air temperature on Earth has increase between 3°C and 5°C. The temperature increase in the past 260 years is double the amount we have historically seen in any 1,000-year period.

There are many possible consequences of higher air temperatures, including changes in weather patterns, a decrease in glaciers and polar ice caps, and rising sea levels. Additionally, as the polar regions warm, there will be an increase in greenhouse gases released from organisms currently frozen in permafrost and from the decomposition of organic matter currently preserved in permafrost. In ocean water, recent studies show that CO_2 dissolved in the water is released into the atmosphere as the oceans warm. This action is similar to the release of carbon dioxide when opening a bottle of warm soda.

The following graph illustrates the steady increase of global temperature changes in the atmosphere.

Jan-Dec Global Mean Temperature over Land & Ocean



Source: Environmental Protection Agency

Weather Patterns

An increased temperature will result in higher evaporation rates and an increase in water vapor in the atmosphere, altering precipitation patterns. These changes ultimately alter the hydrologic cycle worldwide. Increased evaporation and sea temperatures also could increase the frequency of hurricanes. Since 1970, the percentage of hurricanes that are category 4 or 5 hurricanes has increased from 20 percent of the total hurricanes to 35 percent of the total hurricanes. Increased rainfall in areas degraded by deforestation and plowing will lead to an increase in soil erosion, which may lead to decreased land productivity and, as sediment washes into water sources, decreased productivity in both freshwater and saltwater ecosystems. Other areas may see an increase in desertification and a loss of biodiversity.

Rise in Sea Level

The most obvious contribution to rising sea levels due to global warming is from the melting of ice, most notably in the polar regions. Additionally, warmer water expands, and with higher temperatures, the existing ocean waters would take up more space. Increased hurricanes also could cause seasonal swelling of the oceans. Oceans cover approximately 70 percent of the Earth's surface, and the sea level is currently rising at a rate of 1/10 inch per year. Due to the CO_2 already in the atmosphere, the sea level is projected to continue rising for many centuries.

The impacts of a rising sea level include loss of coastal ecosystems, flooding of cities (such as New Orleans and Venice), disappearing islands, disappearing wetlands, displacement of coastal inhabitants, and increased vulnerability to storm surges because coral reefs and barrier islands, which protect the coastland, may be submerged. Some of these effects could be magnified if the frequency of severe storms increases. Bangladesh, for example, is an impoverished nation that is projected to lose 17.5 percent of its land if the sea level rises 40 inches. Louisiana would lose its freshwater wetlands. Economic challenges of a rising sea include decreased tourism and reduced local agriculture.

El Niño and La Niña

El Niño and La Niña patterns also have been altered by global climate change. El Niño events produce increased warming of the Pacific Ocean every two to seven years, while La Niña events produce cooling of surface waters near the equatorial region of the Pacific Ocean every two to seven years. During the last several decades, the frequency of El Niño events has increased while the frequency of La Niña has decreased. Studies of historic data show that the recent increase in the El Niño variation is most likely linked to global warming. However, these cycles are still not fully understood, so future changes in these cycles are difficult to predict. For example, stronger El Niño events may occur in the early stages of global warming but may become weaker as the lower layers of the ocean get warmer. Some scientists believe these patterns will stabilize on their own.

Melting Glaciers

Over time, in areas where more snow falls than melts, the accumulation of snow compresses the lower layers into glacial ice. This ice slowly slides toward lower elevations like an ice river, and at a certain elevation, the ice starts to melt. Many people worldwide depend upon melting glaciers for survival. However the warming Earth means that over the past century, Earth's glaciers have increased their melt rate, decreasing in total land coverage by 50 percent. Glacial melting in areas unaccustomed to water causes landslides, flash flooding, and increased variation of water flows into rivers. Much of Asia relies on the waters from seasonal melting of the glaciers in the Himalayan Mountains, where global warming has increased the overall flow of water, which has, in turn, increased flooding and disease. Once the source glaciers are depleted, it is expected that the flow of water to much of Asia will decrease, leading to droughts and decreased potential to produce hydroelectric power.

Current estimates put the number of people living within 1 vertical meter of the coastline at about 150 million, and current estimates predict a rise in sea level of between 0.5 and 1.5 meters by the end of the century. The resulting worldwide flooding of islands and coastal areas will force these 150 million people to relocate.

Since the end of the last ice age 18,000 years ago, the sea level has risen 122 meters, most of that in the first 15,000 years. It is estimated that the rate of ocean rise for the 3,000 years prior to the Industrial Revolution had slowed to about 0.2 mm per year. Since the Industrial Revolution, the pace of ocean rise has increased to about 3 mm per year.

If all the glaciers, the ice sheets, and the polar ice cap melted in the Northern Hemisphere, combined with the thermal expansion of water, the sea level would rise 6.5 to 7.5 meters. If the ice cap and ice sheets in Antarctica melted, the sea level would rise another 61 meters. (However, extreme melting in Antarctica is unlikely as the mean air temperature of –37°C is still much below the melting point of water at 0°C.)

Biodiversity

Humans are not the only organisms affected by global warming. A decrease in polar ice in the Northern Hemisphere has decreased both the food supply and the hunting areas of polar bears. Plants and animals have moved their ranges towards the poles. Grasses have become established in Antarctica for the first time. Bird migration patterns have changed, with migrations starting an average of two days earlier per decade. As the thermal temperature of the water increases, phytoplankton, krill, and fish populations have been affected, changing population size and location. It is interesting to note that many migratory patterns have evolved with codependence on other species. For example, a migratory bird population may depend on the timing of seasonal food sources along its route. With global climate change, many of these coevolved behaviors are altered. Birds may arrive to find plant or animal food sources nonexistent, which, in turn, can impact reproduction and offspring. Current research is exploring the ways in which interdependent populations are likely to be affected by continuing climate change.

Global warming and the resultant rise in sea levels will affect not only land ecosystems, but also sea life. Corals are dependent on a narrow temperature range for survival and are sensitive to temperate variations. Therefore, small increases in temperature can kill corals. In recent years, we have seen this happen, as corals die in warmed seas. Also, increasing acidification of the oceans due to changing CO_2 concentrations can harm and kill coral. Other marine life may be forced to migrate northward or southward to find the same water temperature. These displaced animals may find that, while their migration allows them to keep a constant water temperature, many of the habitats and food sources on which they depend are scarce.

Sea water circulation patterns also are disturbed by global warming. Cold water moves along the sea floor toward the equator, and warm water around the equator moves toward the poles across the surface of the ocean. This is known as *thermohaline circulation.* One result of this circulation process is the delivery of oxygenated water to the sea floor and nutrient-rich waters to the surface. Without this circulation, oxygen levels in the deeper parts of the ocean and on the sea floor would be depleted and nutrient upwellings on the surface would decrease.

Fish, such as salmon, are also sensitive to water temperature. During the summer, when the water is warm, salmon have a higher metabolic rate. During the winter months, their metabolism slows down, an adaptation that allows them to survive longer on less food (like a bear's hibernation when food is scarce). With global warming and increased water temperatures, salmon would be forced to maintain a higher metabolic rate, even in the winter months of food shortage. Many salmon would starve.

Reducing Climate Change

In the 1990s, CO_2 emissions increased 1.3 percent per year, but with the current rate of global growth and industrialization, scientists predict that the annual growth rate of CO_2 emissions is likely to climb to approximately 1.9 percent to 2.5 percent annually. According to the EPA, total emissions from the developing world are expected to exceed those from the developed world by the year 2015. Asia is leading the way in the growth rate of CO_2 emissions, with an increase in a consumer-oriented economic middle class and new coal power plants. The rise in carbon dioxide is also due to the inability of natural **carbon sinks** such as plants and oceans to absorb carbon dioxide at the rate at which it is being produced.

This means that before we can achieve a true reduction in carbon dioxide levels, we have to first stabilize the rate of the current emissions *increase.* The three gases specifically targeted for stabilization and then reduction are carbon dioxide, methane, and nitrous oxide.

Since cars currently produce almost 30 percent of carbon dioxide emissions in the United States, increasing efficiency measured in miles per gallon will help decrease emissions. Another way to reduce carbon dioxide emissions is switching electricity production from fossil-fuel-based power plants to renewable sources such as wind, solar, and hydroelectric. Methane emissions can be reduced by repairing leaks in pipelines and by reducing the world dependency on rice and livestock production. Other ideas to reduce global warming include supporting laws, treaties, and protocols that reduce the emissions of greenhouse gases, and slowing down the rate of deforestation while encouraging the replanting of forests.

Laws and Treaties

Enacted by the United Nations Framework Convention on Climate Change, the goal of the **Kyoto Protocol (1997)** is to achieve stabilization of greenhouse-gas concentrations in the atmosphere at a level that would prevent climate change. The protocol was adopted in 1997 and signed by 187 nations. Under the protocol, 39 industrialized countries and the European Union are committed to the reduction of four greenhouse gases (carbon dioxide, methane, nitrous oxide, and sulfur hexafluoride), along with two groups of gases (hydrofluorocarbons and perfluorocarbons). They agreed to a reduction of their greenhouse gas emissions by 5.2 percent from 1990 levels. The United States is one of the few countries in the world that has not signed the Kyoto Protocol.

Loss of Biodiversity

Massive Extinctions from Human Activity

Biodiversity is the variety of organisms found within a specific geographic area. Increased biodiversity allows an ecosystem to remain stabile when pressured. A variety of species, for example, provides ecosystems and humans with many benefits and services.

In addition to diversity of species, biodiversity includes genetic diversity within any single species. For example, wild cheetahs have very low gene diversity, so they may be at risk for population decimation by one kind of pathogen. As each species in an ecosystem finds its role in a community, its **niche,** then a complex ecosystem structure is formed. This promotes ecosystem stability and provides a variety of food sources and habitat for flora and fauna. An example of biodiversity is found in Yosemite National Park, which is home to one-third of all the bird species represented in North America.

As humans have interfered with ecosystems, we have caused biodiversity to decline. The factors that make an area's biodiversity likely to decline are represented by the acronym HIPPCO, used by many conservation biologists. HIPPCO stands for Habitat destruction, degradation, and fragmentation; Invasive species (nonnative, exotic); Population and resource use increases; Pollution; Climate change; and Overexploitation.

Issues Related to Loss of Biodiversity

Issues related to loss of biodiversity as described by the World Resource Institute (2005) are linked to human activity:

- Overuse and overexploitation
- Pollution and sedimentation
- Introduced species
- Endangered and extinct species
- Habitat loss

Losses Due to Overuse and Overexploitation

Overexploitation of species creates loss of biodiversity. Among the most common overused and overexploited groups of species are marine fish and invertebrates. Overexploitation, including overfishing and over-harvesting, has resulted in 75 percent of the world's marine species being depleted. Several species—including cod off Newfoundland in Canada, anchovy off the coast of Peru, sole in the Irish Sea, and deep-sea fish such as orange roughy and sablefish—have been depleted to such an extent that they are no longer a viable food or economic resource. Nearly 100 million tons of fish and shellfish are removed from the world's oceans every year. As the world's population grows and as diets increasingly shift from beef and pork to more fish and shellfish, even more fish and shellfish will be removed. Overfishing also impacts species, such as dolphins and seals, which are caught unintentionally as part of netting or long-lining techniques. So-called **bycatch** is thrown away when fish are harvested. For every pound of shrimp catch, over 5 pounds of bycatch is discarded. The loss of marine life impacts the world's coastal populations (nearly 2 billion people), many of whom depend upon marine life for food and other products.

Aquatic species are not alone in their growing use. Worldwide beef consumption doubled from 1950 to 2000, from approximately 44 pounds per capita to nearly 88 pounds per capita. The acreage needed to grow beef is immense. Land is needed to grow food (usually corn) to feed the cattle, and land is needed to house the cattle until they are taken to market. Many corporations that use beef in their fast-food restaurants have cut down large areas of trees in the tropical rain forest to meet the needs of beef production.

Losses Due to Pollution

Pollution comes in five primary forms: air, soil, water, noise, and light. Humans release pollutants into the Earth's atmosphere, soil, or natural water systems, causing degradation in both local areas and sources to which pollution can be transported. Light and noise pollution can interfere with the natural cycles of species and adversely affect behavior. A sixth form of pollution, genetic pollution, is still under investigation.

Pollutants can have many negative affects on **animal species:** interfering with metabolic and endocrine functions, impairing development, shortening life spans, and compromising immune systems. Pollutants also can alter species' reproductive function, causing changes in mating behaviors, genetically affecting offspring, or causing an organism to become sterile. Pollution is often a contributing factor in the decline or ultimate extinction of a species. The loss of one species then has a ripple effect throughout an ecosystem.

There are many mechanisms by which pollutants enter species: through the air they breathe, the water they drink, the food they digest, or through their skin percutaneously. Marine fish and other aquatic species are especially defenseless when exposed to pollutants in the water. Air pollutants include carbon monoxide, sulfur dioxide, and oxides of nitrogen. Water and soil pollutants include heavy metals, pesticide and herbicide compounds, and the thermal pollution of man-made heat sources.

Plant species also can be adversely affected by pollutants. **Lichen** is especially fragile and, thus, susceptible to destruction by **air pollutants.** Therefore, the presence of lichen is often a good indicator of clean air. Air pollutants also can cause damage to the water and soil, frequently in the form of adjusting the pH level. When an air pollutant, such as sulfuric acid, combines with the water droplets that make up clouds, the water droplets become acidic. **Acid rain** causes harm to living organisms. When those droplets fall to the ground as rain or snow, the acidity of the water can have damaging effects on plants and the environment. Acid rain can destroy leaves on plants (reducing photosynthesis) and trees, and can harm animals, fish, and other wildlife. When acid rain penetrates into the soil, it can change soil chemistry, making it unfit for many living things that rely on soil as a habitat or for nutrition. Acidified soil can leach out nutrients that plants need for their development, growth, or maintenance. Plants exposed to pollutants can deteriorate from disease and insect infiltration.

Light pollution (luminous pollution) is excessive artificial lighting of the type often seen in any major industrialized city. This artificial lighting interferes with animal species that depend on natural lighting phenomena (such as the stars and moon) to find their way in the night. Lights may interfere with mating and nesting of species, migration patterns, and hunting for food. In some satellite photos of sections of the Earth at night, it is difficult to identify specific cities due to the overall glow of light pollution—especially in Europe, the east and west coasts of the United States, Japan, China, and India.

Noise pollution is another pollutant that is especially prevalent in urban areas. Noise pollution adversely affects the health and lives of millions of people and is related to sleep disruption, hearing loss, high blood pressure, and stress-related illnesses. The constant drone of vehicles on the roads, the flight of airplanes in and out of airports, manufacturers, power plants, and others man-made sources produce noises that can impair animal species. In animals, noise can cause stress, alter the delicate balance of detection and avoidance of predators and prey, and interfere with animals' use of sounds in communication and reproduction.

Genetic pollution is a term popularized by environmentalist Jeremy Rifkin in his 1998 book *The Biotech Century.* Biologists have used the term to describe the flow of genes from two genetically distinct organisms resulting in a genetically modified organism (GMO). For example, the flow of genes from domestic, feral, nonnative, and invasive species into wild, native species. Today, the term *genetic pollution* is associated with the genetic exchange of undesirable genes from GMOs to wild native species. In addition, genetic pollution often refers to crops and aquaculture. Several GMO animal products have been developed, but none has yet been approved for market by the U.S. Food and Drug Administration (FDA).

Losses Due to Introduced Species

Introduced species originate in one location and end up in another, either by chance or by human intervention. There are several words used to describe introduced species including *nonnative, invasive, alien,* and *exotic.* There are more than 4,500 *nonnative* species in North America. *Invasive* species infest an area and can do harm to it. They may kill other species, drive them out of the area, or cause economic damage for humans. Examples of invasive species include kudzu, zebra mussels, the Mediterranean fruit fly, and sudden oak death. The spread of invasive species has caused widespread damage to native habitats, including the elimination of native species. Invasive species have interfered with crop production, causing losses of crops and money.

There are many ways an invasive species can be transported to new areas. Some are left over from farming and animal raising (such as feral pigs), others arrive by accident (for example, the zebra mussel in the ballast water of ships), and some are introduced intentionally to provide a service but then grow out of control (such as kudzu in the southeastern United States and cane toads in Australia). Their adverse effects are many. The zebra mussel can clog the openings to water intakes for water filtration plants. Kudzu, sometimes referred to as "the vine that ate the South," was planted along freeways to prevent erosion. Unfortunately, kudzu can grow up to 3 feet in a single day, and since there are no known organisms that keep kudzu in check in its invasive habitat, it has grown rampant. Invasive species' case studies are further discussed in Appendix B.

Losses Due to Endangered and Extinct Species

An **endangered species** is a population of organisms that is at risk of becoming extinct. Many species become endangered due to habitat loss, changes in environment, hunting/poaching, introduction of a nonnative species, disease, pollution, or a combination of factors. Many countries have established their own criteria for labeling a species "endangered." In the United States, these criteria are put forth in the Endangered Species Act, which describes two categories of danger:

- **Endangered:** Plants and animals that are so rare that they are in danger of becoming extinct.
- **Threatened:** Plants and animals that are projected to become endangered within the foreseeable future.

The International Union for Conservation of Nature (IUCN) was established to promote natural resource conservation. The IUCN has developed its Red List, which has three broad categories and smaller breakdowns within those categories. The categories are:

- **Extinct**
  - Extinct: The last remaining member of the species has died or is presumed to have died.
  - Extinct in the wild: Only captive individuals of the population remain; no individuals of the species are known to live in the wild.
- **Threatened**
  - Critically endangered: The species faces an extreme risk of becoming extinct.
  - Endangered: The species faces a high risk of extinction in the near future.
  - Vulnerable: The species faces a high risk of extinction in the medium term.
- **At Low Risk**
  - Near threatened: The species may be considered threatened in the near future.
  - Least concern: There is no immediate threat to the survival of the species.

Three hundred known plant and animal species have gone extinct in North America since European colonization. Approximately 750 North American plants and 1,200 animals are listed as endangered, with another 3,000 species proposed for listing. Only a few species have been removed from the list. As of May 2007, the populations of endangered species have increased from historic lows and several species that were once endangered have been removed from the list, while others have been moved from endangered to threatened. Five species had recovered and been removed from the list entirely, including bald eagles, peregrine falcons, American alligators, gray whales, and grizzly bears. However, as of 2007, seven species had also been removed from the list after becoming extinct, including Florida's dusky seaside sparrow, the Santa Barbara song sparrow, the Tecopa pupfish, the Sampson's pearly mussel, the blue pike, the longjaw cisco, and the Amistad gambusia.

Losses Due to Habitat Destruction

According to researchers, the greatest threat to species is the loss, degradation, and fragmentation of habitats. Perhaps the greatest loss is the deforestation of the tropical areas. Large areas of forest have been cut down for their timber, or to plant grasses and corn for cattle production. Additionally, the destruction and degradation of coral reefs resulting especially from harvesting for home aquariums and coral bleaching has created devastating habitat loss. The draining and filling of the world's coastal wetlands including mangrove swamps and saltwater marshes has resulted in an over 50 percent loss of these habitats. Many countries' inland wetlands have experienced a loss of more than 80 percent.

Large areas of grasslands have been plowed to grow food for animal and human consumption, to house large farms to raise cattle and other farm animals, and, most recently, for the development of large cities. These grasslands include the prairie in the United States, the pampas in Argentina, the steppes of Eurasia, and the veldt in Africa. Less than 1 percent of the original prairie is left in the United States.

Pollution of land and water also can result in habitat destruction. And this destruction is not limited to the areas in which pollution first occurs. For example, cities have storm drains that collect pollutants from a variety of sources, including oils and other fluids from cars; feces from pets; fertilizers from our yards, playing fields, and golf courses; and trash such as plastic bottles and bags. These pollutants flow downstream to the oceans, destroying habitats and harming species along the way.

Historically, the lack of development in the majority of the Earth's tropical biomes has kept them relatively safe from habitat destruction (in comparison with the greater habitat destruction born of development in temperate biomes in the United States, Canada, most of Europe, Japan, and elsewhere). However, the recent increase in development in tropical biomes has resulted in the accelerated habitat destruction in these regions.

Island species are especially vulnerable, because they have no place to go when their habitat is destroyed, degraded, or fragmented, and many face extinction as the island is developed. Many of those species are endemic to their island (meaning, they are found nowhere else on Earth).

Maintenance through Conservation

As described in *Sustaining the Earth: An Integrated Approach,* by G. Tyler Miller and Scott Spoolman, there are two major approaches to maintaining and protecting wildlife:

- **Species approach:** Protecting individual endangered species, usually by laws and international treaties, or by establishing breeding programs to help sustain these species and reintroducing them back into the wild. The California condor is a good example of this approach.
- **Ecosystem approach:** Increasingly, scientists and conservationists are finding that the best way to preserve species is to preserve the ecosystem they inhabit. The ecosystem approach employs a four-point plan:
  - Locate and map the ecosystem. Develop an inventory of its species and the role they play in the ecosystem.
  - Protect the most endangered ecosystems and their species.
  - Repair degraded ecosystems.
  - Design biodiversity-friendly developments that help protect endangered ecosystems.

One place this ecosystem approach has been especially effective is on California's Santa Cruz Island, within Channel Islands National Park. On Santa Cruz Island, two native species were close to extinction. But instead of working directly to increase these species through breeding or species-specific protection, conservation efforts focused on returning the environment to conditions in which these endangered species formerly thrived. On Santa Cruz Island, the introduced golden eagle had decimated the rodent population on which the endemic Channel

Island fox depended for survival. Conservationists reintroduced the bald eagle, which had become nearly extinct on the island due to the historic use of DDT as a pesticide. The bald eagle greatly displaced the invasive golden eagles, allowing rodent and, thus, fox populations to rebound. Additionally, conservationists worked to eradicate the island's introduced and invasive wild pig population, which had been decimating both plant and terrestrial animal populations. It took 26 months to eradicate the introduced wild pigs on the island, but after focusing on habitat and restoring native species while eradicating invasive ones, the ecosystem of Santa Cruz Island was overwhelmingly restored.

Another strong example of an ecosystem approach to habitat and species restoration was in Yellowstone National Park, where a rampant elk population was over-grazing aspen trees, leading to overall ecosystem degradation. With the reintroduction of gray wolves to the park, the elk was soon culled to a population size the ecosystem could sustainably support.

Other ideas to slow habitat destruction include expanding current wildlife refuges and sanctuaries and adding new ones, expanding federal public lands to preserve and protect habitats of endangered species, managing existing habitats and monitoring their use for changes, expanding breeding programs for additional plant and animal species, and passing new laws and international treaties to protect threatened and endangered species and protect their habitats.

However, many of these initiatives cost money either directly or through the decreased ability to make money. The economic challenges, combined with a general lack of knowledge about the benefits of habitats and biodiversity and the ways they can be protected or saved, makes conservation challenging. Much of the money needed to save species such as the California Condor, Santa Cruz Kit Fox, and the Giant Panda comes from governments, private donations, grants, and zoos. For example, it has cost an average of $5 million per year to help the condors recover from 22 birds in 1987, when all the condors were in captivity, to over 350 birds today, with approximately 150 in the wild.

Practice

1. What type of radiation is involved in the formation of ozone?

   A. Visible radiation
   B. UVA
   C. UVB
   D. UVC
   E. Infrared radiation

2. Which of the following human conditions can be caused by UVB radiation?

   I. Blistering of the skin with severe sunburns
   II. Skin cancer
   III. Cataracts

   A. I only
   B. II only
   C. III only
   D. I and III
   E. I, II, and III

3. Which of the following gases is involved in the destruction of the ozone layer?

   A. NO
   B. CFCs
   C. CO_2
   D. CH_4
   E. H_2O

4. Which of the following is NOT an effect of ozone depletion?

   A. An increase in sunburns and other damage to the skin that may result in more cases of skin cancer
   B. Higher UV radiation causing damage to the leaves of plants and reducing the crop production
   C. Cooling of the troposphere as less UV radiation reaches the Earth's surface
   D. Harmful effect to the skin of animals (even animals with fur) and to their eyes
   E. Increase in the rate of mutations as UVB damages DNA in living organisms

5. Which of the following is NOT a source of CFCs?

   A. Aerosol cans
   B. Air conditioners
   C. Foam production
   D. Cleaning solutions
   E. Refrigerators

6. Which greenhouse gas is the cause of 80 percent to 90 percent of the natural greenhouse effect?

   A. Water vapor
   B. Carbon dioxide
   C. Methane
   D. Nitrous oxide
   E. Halons

7. Which of the following is the greatest overall threat to species survival?

   A. Climate change
   B. Pollution
   C. Overuse
   D. Invasive species
   E. Habitat loss

8. Which of the following are examples of habitat fragmentation?

   I. A large area is cut into smaller patches by the development of ranches.
   II. Farms are removed to reconnect land areas.
   III. Major highways divide the land, making it difficult for species to cross.

   A. I only
   B. II only
   C. III only
   D. I and III
   E. I, II, and III

9. Which of the following is NOT a reason for the huge loss of species in the world's oceans?
   - A. Over 60 percent of the world's population living near a coastal area
   - B. Two billion people relying on the world's oceans for the majority of their protein
   - C. Bycatch, the unintended capture of fish that are not the target species
   - D. The high number of fish caught for sport fishing
   - E. People changing their diets to include more fish and less beef and pork

10. Which of the following is NOT a form of pollution that may result in the loss of biodiversity?
    - A. Air
    - B. Food
    - C. Land
    - D. Noise
    - E. Water

11. Which of the following is NOT a reason why invasive species cause the loss of biodiversity?
    - A. Invasive species may kill native species.
    - B. Invasive species outcompete native species for food.
    - C. Invasive species may drive out native species.
    - D. Invasive species may be food for native species.
    - E. Invasive species may damage the habitat and make it uninhabitable for native species.

12. Which of the following is an example of the ecosystem approach to maintaining biodiversity?
    - A. Protect individual species by passing laws to help sustain the species.
    - B. Develop breeding programs to increase the population of the species.
    - C. Map an ecosystem and develop an inventory of the species and the role they play in the ecosystem.
    - D. Manage the species for sustainable yield through national laws and international treaties.
    - E. Develop quotas for the capture of fisheries and game species.

13. Which U.S. act was created to protect species that are threatened or endangered?
    - A. Endangered Species Act
    - B. Fish and Wildlife Act
    - C. Fur Seal Act
    - D. Marine Mammal Protection Act
    - E. Migratory Bird Treaty Act

14. Which of the following is NOT true about UVA?
    - A. UVA has a frequency of 320 nm to 400 nm.
    - B. UVA causes tanning in humans.
    - C. Most UVA reaches the Earth's surface.
    - D. UVA is involved in the formation of ozone.
    - E. Many species of birds, bees, and reptiles can see UVA.

15. Which of the following treaties controls international trade in endangered species?
    - A. Endangered Species Act
    - B. CITES
    - C. Montreal Protocol
    - D. Kyoto Protocol
    - E. Basel Convention

Answers

1. **D** UVC is the form of UV radiation that is involved in the formation of ozone.
2. **E** All three are the result of UVB radiation.
3. **B** All five are greenhouse gases, but only CFCs destroy ozone and cause the thinning of the ozone layer.
4. **C** The troposphere will see an increase of UV radiation and, thus, should heat up, not cool down.
5. **D** Cleaning solutions do not contain CFCs, unless they were used with aerosols; most cleaning supplies are either poured out of a container or sprayed from pump-type bottles.
6. **A** Water vapor is the cause of 80 percent to 90 percent of the natural greenhouse effect. Halons are not part of the natural greenhouse gases.
7. **E** Based on multiple studies, scientists suggest that habitat loss is the greatest threat to species survival.
8. **D** Removing farms allows segmented land to come together, thus reversing habitat fragmentation.
9. **D** Most fish that are sold at a market are caught by commercial fishing boats, not by sport fishing. All the other answers are reasons why fisheries have declined.
10. **B** Food is not considered a form of pollution. Air, land, noise, and water are forms of pollution that may result in the loss of biodiversity.
11. **D** If an invasive species happened to be food for a native species, the population of the native species would be likely to increase rather than decrease.
12. **C** Choices A and B demonstrate the species approach to saving biodiversity. Choices D and E are part of the wildlife management approach. Choice C, mapping an ecosystem, is part of the ecosystem approach to maintaining biodiversity.
13. **A** Although the other four acts may be used to protect specific species, the Endangered Species Act encompasses all endangered and threatened species.
14. **D** UVC is not involved in the formation of ozone, while UVA is not included.
15. **B** The Convention on International Trade in Endangered Species of Wild Fauna and Flora, often called CITES, is the international treaty that was designed to regulate international trade in endangered species.