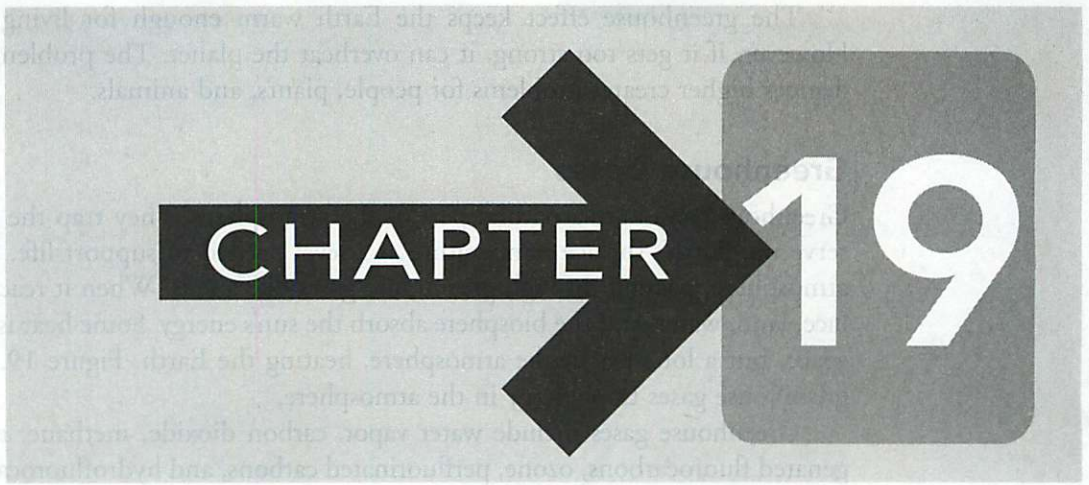



# Global Change and Economics

IN THIS CHAPTER

**Summary:** Greenhouse gases are measurable. Global warming takes place when heat is retained near the Earth. The Earth is a living, recycling, and changing system.


**Keywords**

✪ Ozone, greenhouse gases, global warming, aerosols, carbon dioxide, nitrous oxide, methane, volatile organic compounds, carbon sequestration

## Greenhouse Effect

Greenhouses, sometimes called hothouses, work by trapping the sun's heat. Their glass sides and roof let sunlight in, but keep heat from escaping, like a car parked in the sun with the windows rolled up. Similarly, greenhouses offer plants (e.g., tropical orchids) warm, humid environments, even when outside weather is dry, windy, or cold.

In Chapter 6, we saw how the atmosphere surrounds our planet like a blanket. It protects us from harmful cosmic radiation, regulates temperature and humidity, and controls the weather. The atmosphere is critical to life on this planet and provides the air we breathe.

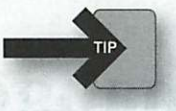

The *greenhouse effect* describes how atmospheric gases prevent heat from being released back into space, allowing it to build up in the Earth's atmosphere.

The greenhouse effect keeps the Earth warm enough for living *things* to survive. However, if it gets too strong, it can overheat the planet. The problem is that even a few degrees higher creates problems for people, plants, and animals.

## Greenhouse Gases

Greenhouse gases are a natural part of the atmosphere. They trap the sun's heat and preserve the Earth's surface temperature at a level needed to support life. Sunlight enters the atmosphere, passing through greenhouse gases like a lens. When it reaches the Earth's surface, land, water, and the biosphere absorb the sun's energy. Some heat is reflected back into space, but a lot stays in the atmosphere, heating the Earth. Figure 19.1 shows how these greenhouse gases trap energy in the atmosphere.

Greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, halogenated fluorocarbons, ozone, perfluorinated carbons, and hydrofluorocarbons. Water vapor is the most important greenhouse gas, and human activity doesn't have much direct impact on its natural atmospheric level.




*Global warming* is caused by an increase in the levels of these gases. The greatest impact on the greenhouse effect has come from industrialization, which has increased the amounts of carbon dioxide, methane, and nitrous oxide in the atmosphere. Land clearing and fossil fuel burning have raised atmospheric concentrations of soot and other *aerosols* (air particles) as well.

According to climatic models (programmed with the volume of gases released into the atmosphere yearly), the planet is warming at a steep rate. Consequences of global

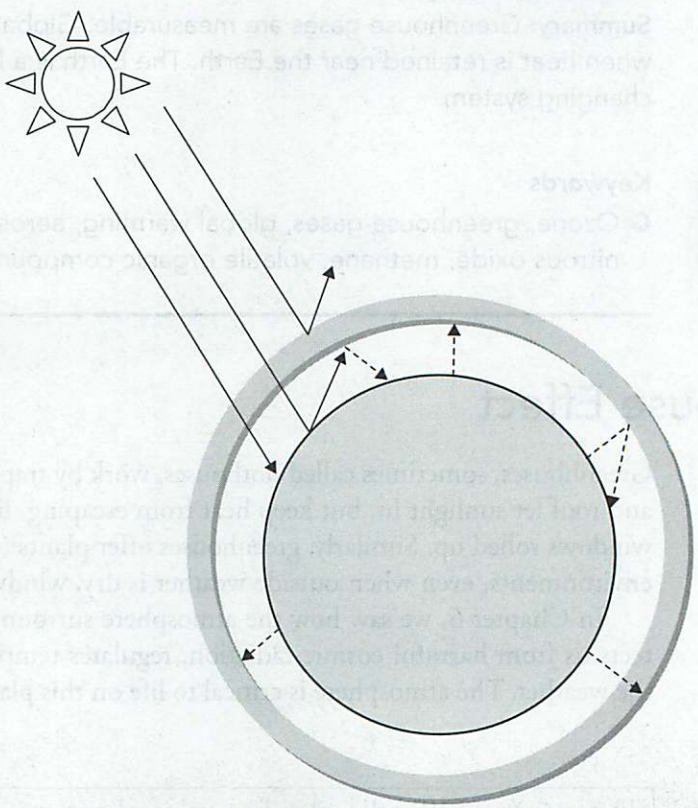
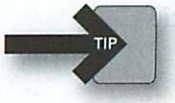


**Figure 19.1 Greenhouse gases trap energy from the sun in the atmosphere, causing it to heat up.**

warming (e.g., melting of polar ice and rising sea levels) are already taking place. Since 1991, the National Academy of Sciences has found clear evidence of global warming and recommends immediate greenhouse gas reductions. Depending on whether or not changes are made, temperature increases of between −16°C and −13°C in the next 100 to 200 years, with sea level increases of 1–8 meters are predicted.




Since greenhouse gases are long lasting, even if everyone stopped using their cars *today*, global warming would continue for another 150 years. Think of it like a speeding train; even when the engineer hits the brakes, the train's total speed and mass cause it to take a long time to stop. For this reason, it's important to speed up the use of alternative energy sources and curb and/or stop the release of greenhouse gases into the atmosphere.

## Formation of Greenhouse Gases

Many industrial processes create greenhouse gases. When organic matter (e.g., table scraps, garden waste, and paper) is left in landfills, its decomposition forms methane and carbon dioxide. Sewage and water treatment plants also release these gases when breaking down wastes. Cement production, used in building roads and laying of building foundations, requires chemical processes that produce an assortment of greenhouse gases.

### Carbon Dioxide


*Carbon dioxide* ($CO_2$) is a natural greenhouse gas and the biggest human-supplied contributor to the greenhouse effect (about 80%). A heavy, colorless gas, carbon dioxide is the main gas we exhale during breathing. It dissolves in water to form carbonic acid, is formed in animal respiration, and comes from the decay or combustion of plant and animal matter. Carbon dioxide is also used to carbonate drinks and is absorbed from the air by plants in photosynthesis.

The Earth's inhabitants don't have the option to stop breathing. However, the amount of carbon dioxide in the atmosphere is about 30% higher today than it was in the early 1800s. Figure 19.2 shows carbon dioxide concentration trends over the past 250 years.

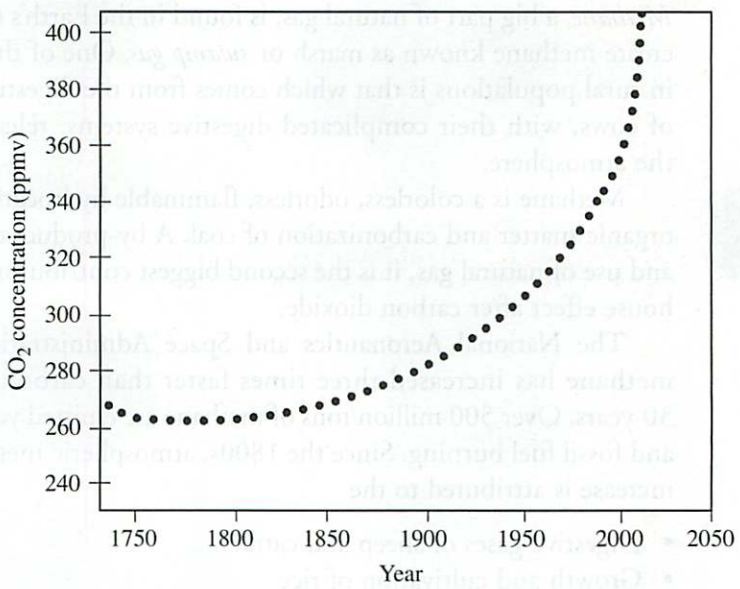
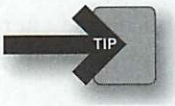



**Figure 19.2 Carbon dioxide trends over the past 250 years.**
*Source: Oak Ridge National Laboratory (2002).*

The industrial revolution is responsible for this jump. Ever since fossil fuels such as oil, coal, and natural gas were first burned to create energy for electricity and transportation fuel, carbon dioxide levels started to climb. Additionally, when farmers clear and burn weeds and crop stubble, carbon dioxide is produced.

Carbon dioxide gases also come from the Earth. When volcanoes explode, about 90–95% of the spewed gases are made up of water vapor and carbon dioxide.

### Nitrogen Oxides




The colorless gas known as nitrous oxide is an atmospheric pollutant produced by combustion (e.g., 14% of total U.S. emissions in 2007), which traps heat much more efficiently than carbon dioxide. There are several ways nitrogen and oxygen team up in the atmosphere, including *nitrogen dioxide, nitric oxide,* and *nitrous oxide.* Since nitrogen oxides are stable gases and do not break down quickly, they build up in the atmosphere in greater and greater concentrations. In the sky, nitrogen dioxide creates a yellow-brown haze called smog.

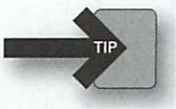
Nitrogen combines with moisture in the atmosphere to form nitric acid. This comes down as rain and acidifies lakes and soils, killing fish and small animal populations and damaging forests. Acid particulates are precipitated, along with the leaching out of heavy metals, into water supplies. Scientists believe this increase comes from crop burning, industrial releases, and excess of nitrogen fertilizers used in agriculture.

Besides fossil fuel burning, nitrogen oxides are also produced by kerosene heaters, gas ranges and ovens, incinerators, and deforestation and leaf burning, as well as by aircraft engines and cigarettes. Lightning and natural soil sources also produce nitrogen oxides. Scientists estimate vehicles produce 40% of the pollution due to nitrogen oxide, with electric utilities and factories responsible for 50% of industrial emissions. The remaining 10% comes from other sources.

At high altitudes, nitrogen oxides are responsible for some ozone depletion. When ozone is thin or absent, the amount of solar ultraviolet radiation reaching the ground increases. This causes plant damage and injury to animals and humans in the form of skin cancers and other problems.

### Methane

*Methane,* a big part of natural gas, is found in the Earth's crust. Underwater decaying plants create methane known as marsh or *swamp gas.* One of the best known sources of methane in rural populations is that which comes from the digestive tract of farm animals. Millions of cows, with their complicated digestive systems, release large amounts of methane to the atmosphere.




Methane is a colorless, odorless, flammable hydrocarbon released by the breakdown of organic matter and carbonization of coal. A by-product of the production, transportation, and use of natural gas, it is the second biggest contributor (i.e., 35% in 2007) to the greenhouse effect after carbon dioxide.

The National Aeronautics and Space Administration (NASA) reports atmospheric methane has increased three times faster than carbon dioxide and tripled in the past 30 years. Over 500 million tons of methane are emitted yearly from bacterial decomposition and fossil fuel burning. Since the 1800s, atmospheric methane levels have risen 145%. This increase is attributed to the

- Digestive gases of sheep and cattle
- Growth and cultivation of rice
- Release of natural gas from the Earth
- Decomposition of garbage and landfill waste

In the atmosphere, naturally occurring hydroxyl radicals combine with and remove methane, but as hydroxyl concentrations drop and methane emissions rise, overall methane concentrations will get higher.

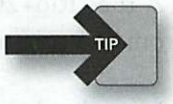
Burning fossil fuels for energy creates greenhouse gases. When oil, gas, or coal burns, carbon in the fuel mixes with atmospheric oxygen to form carbon dioxide. Methane is produced from coal mining and certain natural gas pipelines. Rice production in paddy fields generates methane under water.

### Enhanced Greenhouse Effect

Solar cycles and changes in the sun's radiation affect local climate and allow the sun's energy to reach the Earth's surface, keeping heat from escaping. The Earth gets slowly hotter. Industrial activity produces greenhouse gases, which serve as additional blankets to heat the Earth even more.


The *enhanced greenhouse effect* caused by the burning of fossil fuels (oil, coal, and natural gas) increases global warming and changes the environment.

Global warming effects differ around the world and make it hard to predict exactly how the climate may change. Temperature increases are expected to be higher in polar areas than around the equator. Land temperatures might be higher than those over oceans. Rainfall might be heavier in some areas and lower in others.




Major climatic change greatly affects local weather through the frequency and intensity of storms. Some scientists fear the high number of major Atlantic hurricanes in recent years may be the beginning of severe climate change. Ranching, crops, pests, diseases, ocean levels, and native plant and animal populations would all be impacted.

Increasing global warming has also motivated people in different cities, states, industries, and countries to step up their work on developing "clean" energy options.

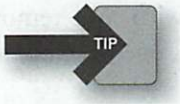
## Carbon

Carbon is essential to life, but increasingly a problem as fossil fuel burning increases atmospheric carbon dioxide. However, unless you live in a polluted city or near industrial plants, it's hard to believe the Earth's immense atmospheric layers can't handle industrial pollutants. Global warming is often dismissed as a knee-jerk reaction of environmentalists.

In 2004, scientists reported in *Science* that the ocean had taken up nearly half of the carbon dioxide gas released into the air since the 1800s. This was good news, since less greenhouse gases means less global warming. However, oceans will reach their carbon dioxide limit.

Carbon uptake starts with plankton. These tiny organisms, drifting along on ocean currents, perform photosynthesis to produce energy and draw carbon out of the atmosphere. While building intricate calcium carbonate shells, they bind carbon as well. Eventually, these organisms die and sink to the bottom of the ocean dropping out of the carbon cycle. The rest dissolve in the low-calcium carbonate conditions of deep waters. Either way, their carbon doesn't return to the atmosphere for a very long time.


*Carbon sequestration* removes and stores atmospheric carbon in carbon sinks (e.g., oceans, forests) through physical and biological processes like photosynthesis.




The amount of human-produced carbon dioxide being absorbed into the ocean is important. If carbon dioxide levels get high enough, the ocean's top layer will become more acidic, reducing calcium carbonate's availability to plankton. Then, as human-produced carbon dioxide sinks into the ocean, calcium carbonate dissolution may speed up.

This becomes especially significant when shell-making is impacted. In the last decade, scientists found that even small calcium carbonate decreases in seawater limited plankton's and coral's ability to build exoskeletons. If this continues over more centuries, organisms' ability to create shells may be compromised. If sinking shells from dead organisms dissolve in this shallower ocean water and their carbon returns into the atmosphere a lot sooner, the greenhouse effect will accelerate dramatically. The take home message is: if oceans become less effective as a sink for human-produced carbon dioxide, the buildup of atmospheric carbon dioxide will accelerate.

## Greenhouse Gas Inventories

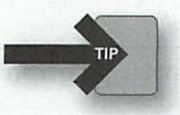
We've seen how the combustion of coal, oil, and natural gas cause global $CO_2$ levels to rise. Less well known is how trees absorb $CO_2$ during photosynthesis and then release it when they are cut down. The 34 million acres of tropical forests destroyed annually, about the size of New York state, release between 20–25% of total global $CO_2$ emissions.

In 1992, at the United Nations' Earth Summit in Rio de Janeiro, the international community first acknowledged the threat of climate instability. Over 185 nations agreed to reduce greenhouse gas emissions to their 1990 levels by 2012. More importantly, the participants agreed to stabilize atmospheric concentrations of greenhouse gases to prevent dangerous human interference with the global climate system. In June 2012, the "Rio+20" summit was held for nations to tackle unresolved environmental issues from the original Earth Summit conference in 1992 and plan future strategies.


The U.S. Environmental Protection Agency's Clean Air Markets Division developed the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. This EPA atmospheric inventory estimates, documents, and evaluates greenhouse gas emissions and sinks for all source categories. To update the report, the Inventory Program polls dozens of federal agencies, academic institutions, industry associations, consultants, and environmental organizations for up-to-date information. It also gets data from a network of continuous carbon dioxide emission monitors installed at most U.S. electric power plants.

In December 2008, the Department of Energy reported total U.S. greenhouse gas emissions of $CO_2$ levels rose by 17% from 1990 to 2007. If business-as-usual industrial output doesn't change, global $CO_2$ levels will double by the end of the 21st century. In 2012, however, scientists were surprised to record a total decrease in $CO_2$ levels since 1992. The drop was thought to be due to lower-priced natural gas and its impact (>10% drop) in coal burning.

Under the umbrella of the *Intergovernmental Panel on Climate Change* (*IPCC*), over 200 scientists and national experts worked together to develop guidelines to help countries create atmospheric inventories across international borders. Since then, scientists determined that stabilizing atmospheric levels of carbon dioxide will mean reducing $CO_2$ emissions and other heat-trapping gases to 80% of the 1990 global levels. According to some models, this means decreasing or stopping the release of 1.2 trillion tons of $CO_2$ by 2050. This isn't an impossible mission. Better energy efficiency throughout the global economy could prevent one-third of emissions while cutting energy costs.




Scientists use natural and industrial emission inventories as tools to develop atmospheric models. Policy makers and regulatory agencies use these inventories to check policy compliance and emission rates. Most inventories contain the following information:

- Chemical and physical identity and properties of pollutants
- Geographical area affected

- Time period when emissions were generated
- Types of activities that cause emissions
- Description of methods used
- Data collected

About 25% of the needed greenhouse gas decreases, about 370 billion tons, could be achieved by stopping tropical deforestation, restoring degraded lands, and improving land productivity worldwide through the use of best practices in agriculture and forestry. At local and regional levels, individuals have an important role.

International climate policy usually focuses on lowering emissions by adopting alternative energy options. Options without negative climate and biodiversity impacts (e.g., solar and wind power) are crucial to lowering energy-related emissions.

Environmental leaders and organizations are working with industries to reduce their carbon dioxide emissions, as well as enhance their competitive advantage. Industry has also turned to solar or wind power to cut costs, along with seeking new methods (e.g., nanotechnology) for energy transmission.

## Ozone

*Ozone* ($O_3$) has a distinctive odor and blue color, while normal oxygen is odorless and colorless. Concentrated in a thin upper stratospheric layer, ozone is a very reactive form of oxygen. Constantly created and destroyed in the stratosphere, ozone levels are relatively constant and affected naturally by sunspots, the seasons, and latitude. There are also yearly and geographical drops in ozone levels, followed by a recovery.


Ozone is an atmospheric bodyguard with a crucial role in protecting life on Earth. It is largely responsible for absorbing the sun's ultraviolet (UV) radiation. Most importantly, it absorbs the fraction of ultraviolet light called *UVB radiation*. Table 19.1 lists UV radiation types and effects.

Ultraviolet radiation is a bad, bad thing! It causes breaks in the body's nuclear proteins (DNA) leaving the door open for associated health problems. UVB is connected with skin cancer and cataracts. It is also harmful to crops, materials, and marine organisms. Atmospheric ozone blocks intense UV radiation from reaching the surface of Earth and the plants and animals living there. However, with an ever-increasing human population, atmospheric changes prevent ozone recovery.

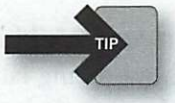
### Ozone Depletion

For the past 50 years, *chlorofluorocarbons* (CFCs) held the answer to many material problems. They were stable, nonflammable, not too toxic, and cheap to produce. They had a variety of uses including applications as refrigerants, solvents, and foam blowing agents. Chlorine formulations did everything from disinfect water to serve as solvents (e.g., methyl chloroform

**Table 19.1 Ultraviolet radiation has many negative effects on living organisms.**

| UV RADIATION TYPE | WAVELENGTHS (NM) | EFFECTS ON LIFE |
|---|---|---|
| UVA | 400–320 | Fairly safe; tanning but not burning |
| UVB | 320–290 | Harmful; sunburn, skin cancer, other problems |
| UVC | 290–200 | Very harmful, but mostly absorbed by ozone |

and carbon tetrachloride) in chemistry labs. Roughly 84% of stratospheric chlorine comes from human-made sources, while only 16% comes from natural sources. Unfortunately, these compounds don't just break down in the atmosphere and disappear. They linger and are carried by winds into the stratosphere to destroy ozone faster than it is naturally created.




CFCs break down only by exposure to strong UV radiation. When that happens, CFC releases chlorine, which damages the ozone layer. Scientists have found that 1 atom of chlorine can destroy over 100,000 ozone molecules.

In the 1950s, a "hole" or thinning of the ozone layer over Antarctica was first reported. This annual event of extremely low ozone levels showed drops of over 60% during bad years. Further research found ozone also thinned over North America, Europe, Asia, Australia, South America, and Africa. In fact, since the first reports, Earth observation satellites, such as the European Space Agency's *Envisat*, track the yearly arrival and shape of the ozone hole.

Scientific outcry over ozone depletion led to a 1978 ban on aerosol CFCs in several countries, including the United States. In 1985, the Vienna Convention was tasked to gather international cooperation in reducing CFC levels by half.

The good news is that atmospheric chlorine stopped rising in 1997–98, and if this trend continues, natural ozone recovery should occur in about 50 years.

The ozone layer will recover over time, but other problem gases (e.g., sulfur hexafluoride) are released during aluminum smelting, electricity production, magnesium processing, and semiconductor manufacturing and need to be addressed as well.

### Nature's Part

Green plants use the sun's energy and carbon dioxide from the air for photosynthesis. This is a good thing, because they soak up carbon dioxide in the process. Plants are considered to be carbon dioxide storehouses. During the photosynthetic cycle, they form carbohydrates, which make up the foundation of the food chain.

Forests absorb carbon dioxide in a big way. We have learned how forests build up a significant supply of stored carbon in their tree trunks, roots, stems, and leaves. Then, when the land is cleared, this stored carbon is converted back to carbon dioxide by burning or decomposition.

The oceans are another big player in this process of carbon dioxide absorption. They also absorb carbon dioxide from the atmosphere and act as a moderating influence on temperature ranges.

## Climate Change

Climate change includes temperature increases, rising sea levels, rainfall changes, and more extreme weather events. Scientific data discussed at the *2002 World Summit on Sustainable Development* and the *2004 United Nations' Convention on Biological Diversity* suggest global warming is causing shifts in species habitat and migrations by an average of 6.1 kilometers per decade toward the poles. This shift, predicted by climate change models, notes that spring arrives 2.3 days earlier per decade, on average, in temperate latitudes. Entire boreal and polar ecosystems are also showing the effects of global warming.


*Climate change* describes the difference in either the average state of the climate, or its variability, taking place over an extended period of time.

Past changes in global climate resulted in major shifts in species' ranges and a huge reorganization of biological communities, landscapes, and biomes during the last 1.8 million years. These changes took place in a much simpler world than today, and with little or no pressure from human activities. Species biodiversity is impacted by climate changes, as well as human pressure and adaptation.

Global warming is not just a theory anymore. Data confirm it is definitely happening, and we are our own biggest enemy. Environmental biologists and chemists calculated that in terms of equivalent units of carbon dioxide, humans are releasing roughly the same amount of greenhouse gases into the atmosphere as that of a Mount St. Helens eruption every two days. Not a good thing.


Global scientific agreement within the past 5 years is that the growing levels of heat-trapping gases are definitely affecting global climate and regional weather patterns. Those changes are causing a domino effect and impacting biodiversity.

Scientists have already seen regular and extensive effects on many species and ecosystems. In the past 30 years alone, climate change has resulted in large shifts in the distribution and abundance of many species. These impacts range from the disappearance of toads in Costa Rica's cloud forests to the death of coral reefs throughout the planet's tropical marine environments.

## Global Economics

The World Bank was established in 1945 to aid war-torn Europe and Japan, but in the 1950s, its emphasis shifted to helping third-world countries. Unfortunately, many of its loans ended up being shortsighted. For example, in Botswana, a multimillion dollar loan was awarded to increase beef production for export, even though severe overgrazing on delicate grasslands was a known problem. This environmentally ill-considered project and others like it failed. Consequently, the United States and other concerned countries insisted future World Bank loans be subject to thorough environmental impact reviews before being granted. Only time will tell if the World Bank, global policy makers, or economists will work together for the environment.

# › Review Questions

## Multiple-Choice Questions

**1.** Greenhouses work

(A) by trapping the sun's heat
(B) when the walls and ceiling are painted green
(C) by cooling hot house plants to the dew point
(D) best when arctic mosses are grown
(E) when generators are used to maintain temperature

**2.** Natural and industrial emission inventories contain

(A) geographical data
(B) the time period when emissions were generated
(C) types of activities causing emissions
(D) the chemical and physical identity of pollutants
(E) all of the above

**3.** Greenhouse gases include all the following, except

(A) water vapor
(B) nitrous oxide
(C) carbon dioxide
(D) methane
(E) butyric acid

**4.** Climate change includes all the following except

(A) a rise in sea levels
(B) changes in rainfall patterns
(C) cooling of the Earth's core
(D) rising temperatures
(E) increased incidence of extreme weather

**5.** When fossil fuels are burned, adding to greenhouse gases and creating global warming, it is known as

(A) biodiversity lithification
(B) gasification
(C) deforestation
(D) dissolution
(E) enhanced greenhouse effect

**6.** Important decreases in greenhouse gas could be achieved by all the following except

(A) stopping tropical deforestation
(B) mining and burning more coal
(C) increasing agricultural and forestry best practices
(D) restoring and conserving degraded lands
(E) improving land productivity worldwide

**7.** The 2004 United Nations' Convention on Biological Diversity suggests that global warming is causing

(A) poor television reception
(B) an increase of mosquitoes in southern climates
(C) species habitat and migration shifts averaging 6.1 kilometers per decade toward the poles
(D) developing countries to use much more energy per person than developed countries.
(E) coastal areas to support increased numbers of mollusc species

**8.** Stabilizing atmospheric levels of carbon dioxide will mean reducing carbon dioxide emissions and other heat-trapping gases to what percent of 1990 global levels?

(A) 20%
(B) 35%
(C) 50%
(D) 80%
(E) 95%

**9.** Which of the following does not describe nitrogen oxides?

(A) They are stable gases.
(B) They are blue in color.
(C) They do not break down quickly.
(D) They build up in the atmosphere.
(E) They appear as a yellow-brown haze.

**10.** If the amount of human-produced carbon dioxide being absorbed into the oceans gets high enough, the ocean's top layer may become increasingly

(A) acidic
(B) basic
(C) opaque
(D) neutral
(E) murky

**11.** What organisms perform photosynthesis to produce energy and draw carbon out of the atmosphere?

(A) Whales
(B) Tulips
(C) Plankton
(D) Algae
(E) Deep sea tube worms

**12.** Ranching, crops, number of pests and diseases, and native plants and animals will be impacted by

(A) greater number of vegetarians
(B) new farming subsidies
(C) lower levels of carbon dioxide
(D) climate change
(E) weaker environmental policies

**13.** Removal and storage of atmospheric carbon in carbon sinks (e.g., oceans, forests) through physical and biological processes is called

(A) acid rain
(B) carbon sequestration
(C) lithification
(D) dissolution
(E) green energy

**14.** Compared to carbon dioxide, how do nitrogen oxides trap heat in the atmosphere?

(A) They don't trap heat at all.
(B) They trap heat about 1% less efficiently.
(C) They trap heat much more efficiently.
(D) They trap heat about 10% less efficiently.
(E) They trap heat much less efficiently.

**15.** What group developed guidelines to help countries create atmospheric inventories across international borders?

(A) EPA
(B) IPCC
(C) NASA
(D) CDC
(E) USDA

**16.** What percent of total greenhouse gases comes from carbon dioxide?

(A) 10%
(B) 30%
(C) 50%
(D) 70%
(E) 80%

**17.** Depending on the level of greenhouse gases in the next 100 to 200 years, scientists predict temperature increases between −16°C and −13°C, with sea levels rising up to

(A) 2 meters
(B) 5 meters
(C) 8 meters
(D) 9 meters
(E) 15 meters

## Answers and Explanations

1. **A**—Greenhouse gases trap the sun's heat and keep the Earth's surface temperature at a level needed to support life. Sunlight passes through these gases like a lens.
2. **E**—The Intergovernmental Panel on Climate Change developed a set of guidelines to help countries create atmospheric inventories across international borders.
3. **E**—Butyric acid is a building block of lipids (fats) and not a greenhouse gas.
4. **C**—The Earth's core has not cooled measurably in human history.
5. **E**—These gases are added to existing natural atmospheric gases.
6. **B**—Fossil fuel burning increases greenhouse gases as well as soot and aerosols.
7. **C**—Since many species have narrow temperature tolerances, they must move to cooler average temperature areas to survive.
8. **D**
9. **B**—They are colorless unless combined with other gases.
10. **A**—As carbon dioxide sinks into the ocean, it can reduce total calcium carbonate levels and cause greater acidity.
11. **C**—Drifting along on ocean currents, plankton perform photosynthesis, producing energy and drawing carbon out of the atmosphere.
12. **D**—Major climatic change greatly affects local weather through the frequency and intensity of storms.
13. **B**—While building intricate calcium carbonate shells, plankton bind further carbon.
14. **C**—Since nitrogen oxides are stable gases and don't break down quickly, they build up in the atmosphere.
15. **B**—The Intergovernmental Panel on Climate Change included 200 scientists and experts.
16. **E**
17. **C**—Large water volumes stored as ice are poured back into the oceans as ice melts.

## Free-Response Questions

1. Oceanographers mapped the ocean's carbon chemistry. They compared what the ocean looked like before the industrial revolution (i.e., subtracting out carbon from fossil fuels) to current carbon values. Their findings, reported in the July 16, 2004, issue of *Science*, show that where human-produced carbon dioxide has sunk deep enough, the layer of carbonate-dissolving ocean water is now roughly 200 meters closer to the surface.
   (a) What effects can too much $CO_2$ have on the ocean's chemistry?
   (b) Why are policy makers looking for a way to pull carbon out of the atmosphere?
2. In a National Science Foundation Report on Global Warming, Anthony Leiserowitz at the University of Oregon Survey Research Laboratory asked Americans their opinions on global warming. Some of the survey results showed that
   - Of 92% of Americans who had heard of global warming, over 90% thought the United States should reduce its greenhouse gas emissions.
   - 77% support government regulation of carbon dioxide as a pollutant and investment in renewable energy (71%).
   - 76% want the United States to reduce greenhouse gas emissions regardless of what other countries do.

(a) Why is it important to raise public awareness about global warming?
(b) Should the population be aware of the risk to health if the hole in the ozone stops recovering yearly?

## Free-Response Answers and Explanations

1.
   a. Too much carbon dioxide dissolved into our oceans can acidify it, harming marine life. Overburdening any environment's capacity to manage levels of greenhouse gases places a stress on the ecosystem and biome, which can result in a loss of organisms and habitats. When carbon dioxide dissolves in water, it forms carbonic acid which releases hydrogen atoms. These hydrogen atoms combine with carbonate in seawater forming bicarbonate, which does not escape back into the atmosphere easily.
   b. Carbon sequestration removes and stores atmospheric carbon in carbon sinks (e.g., oceans, forests) through physical and biological processes like photosynthesis. Policy makers want to find ways to sequester carbon until clean alternate energy sources can provide the bulk of the world's energy needs.

2.
   a. Rather than instill anxiety or panic in a population, raising public awareness is an important step in finding a better way to scale back harmful human behavior. This is especially true in a country like the United States, which greatly contributes increased levels of carbon dioxide around the world. Raising public awareness is also a key step in holding policy makers, and society at large, to standards of accountability.
   b. Ozone, an atmospheric bodyguard, has a crucial role in protecting life on Earth. It is largely responsible for absorbing the sun's harmful ultraviolet (UV) radiation. Without it, skin cancer and other health problems would become much more prevalent and affect large percentages of the world's population. People need to know their choices (i.e., chlorofluorocarbon use as a propellant in spray cans) have consequences, and each person can make a difference (e.g., using a pump sprayer) if they are informed.

## Rapid Review

- Greenhouse gases (e.g., roughly 79.1% nitrogen, 20.9% oxygen, 0.03% carbon dioxide, and trace amounts of others) are a natural part of the atmosphere.
- The term *greenhouse effect* describes how atmospheric gases prevent heat from being released back into space, allowing it to build up in the Earth's atmosphere.
- Greenhouse gases also include water vapor, methane, nitrous oxide, halogenated fluorocarbons, ozone, perfluorinated carbons, and hydrofluorocarbons.
- Water vapor is the most important greenhouse gas, but human activity doesn't have much direct impact on its natural atmospheric level.
- Global warming is caused by an increase in greenhouse gas levels.
- The greatest impact on the greenhouse effect has come from industrialization and increases in the amounts of carbon dioxide, methane, nitrous oxide, soot, and aerosols.
- Carbon dioxide ($CO_2$) is a natural greenhouse gas and the biggest human-supplied contributor to the greenhouse effect (about 70%).

- The 34 million acres of tropical forests destroyed annually release between 20–25% of total global $CO_2$ emissions.
- Nitrous oxide is a stable atmospheric pollutant produced by combustion.
- Nitrogen and atmospheric moisture form nitric acid, which comes down as acid rain and acidifies lakes and soils, kills fish and animals, and damages forests.
- Ozone, an atmospheric bodyguard, has a crucial role in protecting life on Earth by absorbing the sun's ultraviolet (UV) radiation.
- Ultraviolet radiation breaks down the body's DNA and causes skin cancer and cataracts.
- The enhanced greenhouse effect caused by the burning of oil, coal, and natural gas increases global warming and changes the environment.
- Drifting on ocean currents, plankton use photosynthesis to produce energy and draw carbon out of the atmosphere. While building intricate calcium carbonate shells, they bind carbon as well.
- Major climatic change greatly affects local weather through the frequency and intensity of storms.
- Carbon sequestration removes and stores atmospheric carbon in carbon sinks (e.g., oceans, forests) through physical and biological processes like photosynthesis.
- If oceans become less effective in serving as a sink for human-produced carbon dioxide, atmospheric carbon dioxide buildup will accelerate.
- Global warming is causing shifts in species habitat and migrations averaging 6.1 kilometers per decade toward the poles.
- The EPA atmospheric inventory estimates, documents, and evaluates greenhouse gas emissions and sinks for all source categories.
- If business-as-usual industrial output doesn't change, global $CO_2$ levels will double by the end of the 21st century.
- Roughly 84% of stratospheric chlorine comes from human-made sources, while only 16% comes from natural sources.
- Ozone reduction allows harmful UV radiation through the atmosphere, causing skin cancer, eye damage, and other harmful effects.