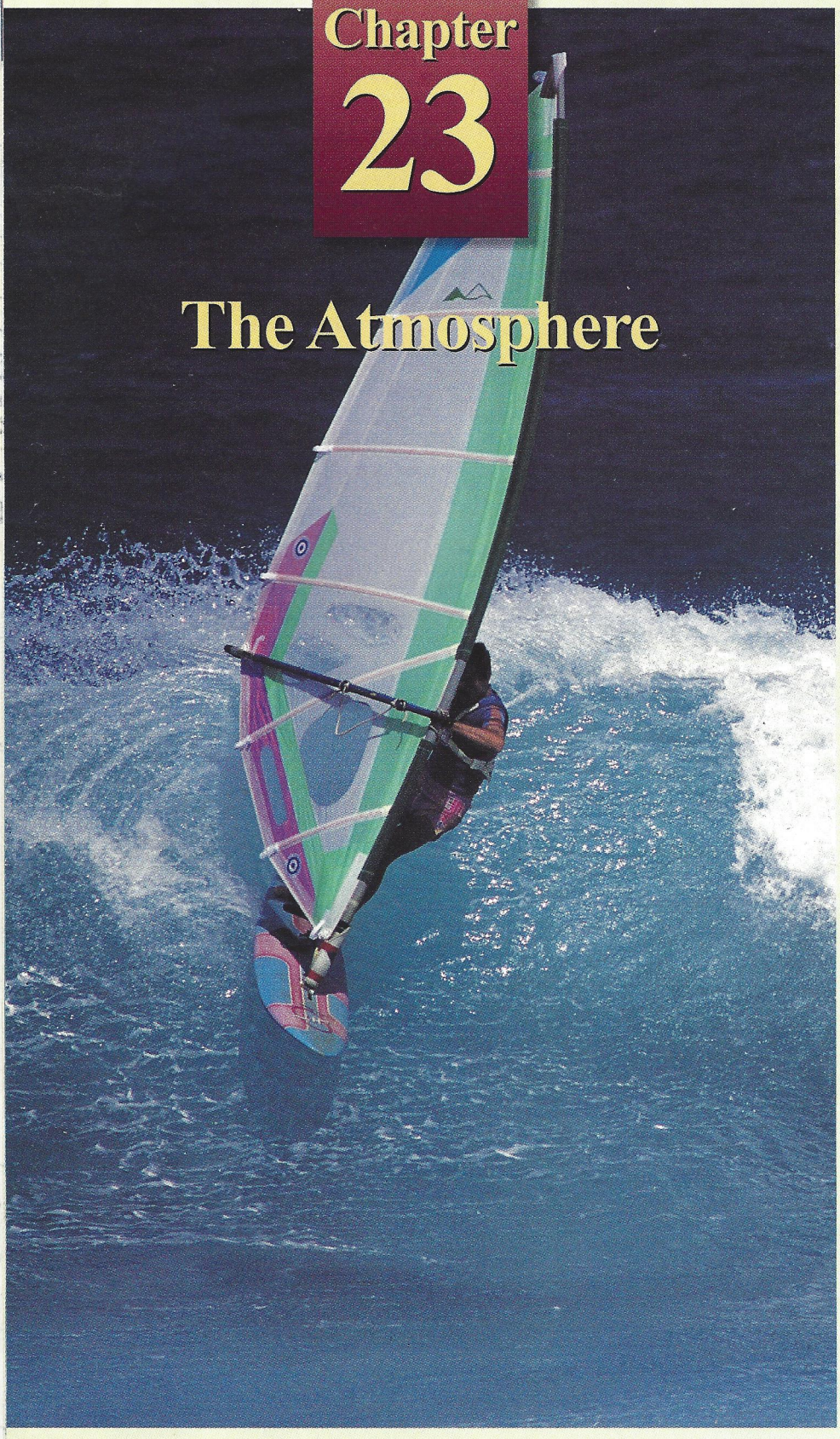
Chapter 23

The Atmosphere



Have you ever thought of yourself as an organism that lives in a sea of gases, as a fish lives in water? People live within a narrow zone where the earth's atmosphere meets the land. The conditions within this thin layer have a major effect on peoples' lives.

In this chapter, you will learn how natural forces and processes act on this narrow zone to influence conditions such as air pressure, wind, and air pollution.

Chapter Outline

The wind provides energy to move this windsurfer over the water.

23.1 Characteristics of the Atmosphere

Section Objectives

- **Discuss the composition of the earth's atmosphere.**
- **Explain how two types of barometers work.**
- **Describe the layers of the atmosphere.**
- **Identify the weather conditions that increase the effects of air pollution.**

The atmosphere is a layer of gases and tiny particles that surrounds the earth. The atmosphere influences almost every living thing. You breathe the gases of the atmosphere. The temperature of the atmosphere determines how you dress and what many of your daily activities will be.

As explained in Chapter 1, the study of the atmosphere is called *meteorology*. Meteorologists study all the characteristics of the atmosphere. They also study **weather** and **climate.** Weather is the general condition of the atmosphere at a particular time and place; it includes temperature, air movements, and moisture content. The general weather conditions over many years is climate. Meteorology, however, is not limited to weather and climate changes. Meteorologists may specialize in a particular area such as agriculture, aviation, forestry, or health.

Composition of the Atmosphere

The atmosphere, or air, is a mixture of chemical elements and compounds. As Figure 23–1 shows, the most abundant elements in air are the gases nitrogen, oxygen, and argon. The most abundant compounds in air are the gases carbon dioxide and water vapor. However, the graph does not include water vapor because the amount of water vapor varies greatly under different conditions.

Water vapor is added to air by evaporation. Most water vapor comes from the oceans, but some also comes from lakes, ponds, streams, and the soil. Plants give off water vapor during transpiration, one of their life processes. At the same time that water vapor is being added to the atmosphere by evaporation, it is being removed by condensation and precipitation. The percentage of water vapor in air varies, depending on factors such as time of day, location, and season. Moist air may contain as much as 4 percent water vapor. Dry air has less than 1 percent water vapor. Because the amount of water vapor in air is variable, the composition of air is usually given for dry air.

Another important substance in the upper atmosphere is a form of oxygen called **ozone,** although it is present only in very small amounts. Oxygen (O_2) has two atoms per molecule, whereas ozone has three. What would the chemical formula for ozone be?

The ozone in the upper atmosphere is important because it protects the earth's inhabitants by absorbing harmful ultraviolet rays of the sun. Without ozone in the atmosphere, people would be severely sunburned by ultraviolet rays. Unfortunately, a number of human activities damage the ozone layer. Gases from aerosol spray cans, coolant used in refrigerators and air conditioning, and hydrocarbons from the burning of supersonic aircraft fuel break down ozone.

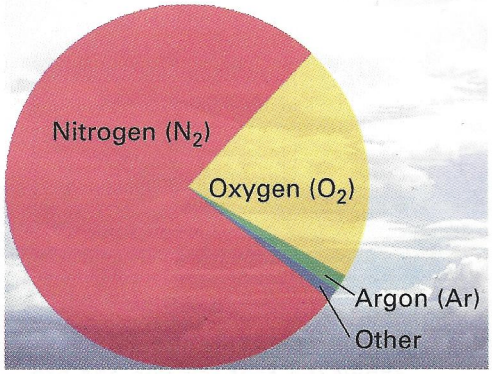


Figure 23–1. The pie chart shows the composition of dry air by volume. Other gases included in the 0.1% are neon (Ne), helium (He), xenon (Xe), and carbon dioxide (CO_2).

In addition to gases, the atmosphere usually contains various kinds of tiny solid particles, which are called *atmospheric dust*. Atmospheric dust includes mineral particles lifted from soil by winds, ash from fires, volcanic dust, and microscopic organisms. It may also include particles from meteors that have vaporized. When tiny drops of ocean water are tossed into the air as sea spray, the drops evaporate. Left behind in the air are tiny crystals of salt, another component of atmospheric dust. Large dust particles remain in the atmosphere only briefly because their weight causes them to fall. However, many particles that are so small they cannot be seen remain suspended in the atmosphere for months or years.

All over the earth and up to an altitude of about 100 km, the composition of dry air is nearly the same. Although nitrogen and oxygen are always being added to, as well as removed from, the atmosphere, the relative amounts of these gases do not change significantly.

Oxygen in the Atmosphere

The amount of oxygen in the atmosphere is the result of natural processes that maintain the chemical balance of the atmosphere. Animals, bacteria, and plants remove oxygen from the air as part of their life processes. Forest fires, the burning of fuels, and the weathering of some rocks also use up oxygen. Living things, burning, and weathering would quickly use up most atmospheric oxygen if it were not for various processes that add oxygen to air. Land and ocean plants produce large quantities of oxygen in daylight. During photosynthesis plants use sunlight, water, and carbon dioxide to produce their food. Oxygen is released as a product of photosynthesis. The amount of oxygen produced by plants each year equals that consumed by all processes. Thus, the oxygen content of the air is in a state of balance. It has not changed significantly over hundreds or even thousands of years.

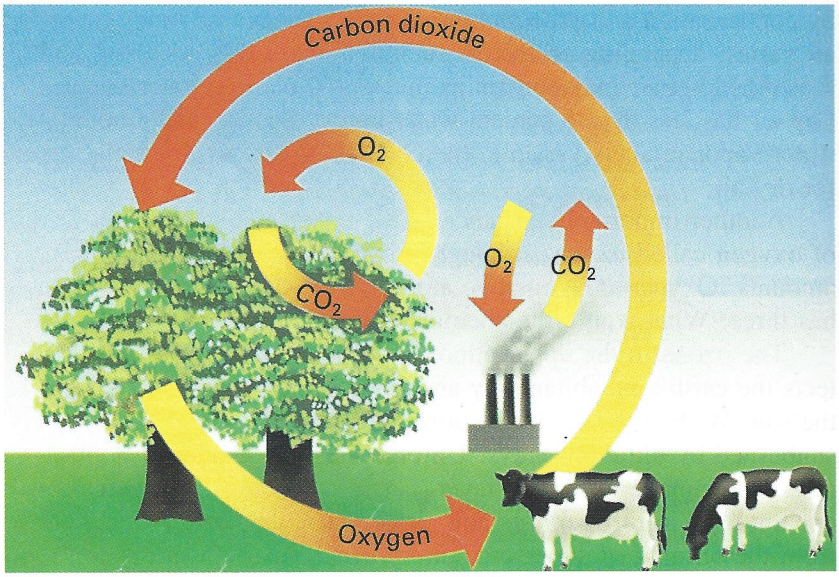


Figure 23–2. This illustration shows the consumption and production of oxygen (O_2) and carbon dioxide (CO_2) in the atmosphere. The oxygen–carbon dioxide cycle maintains a stable amount of oxygen and carbon dioxide in the atmosphere.

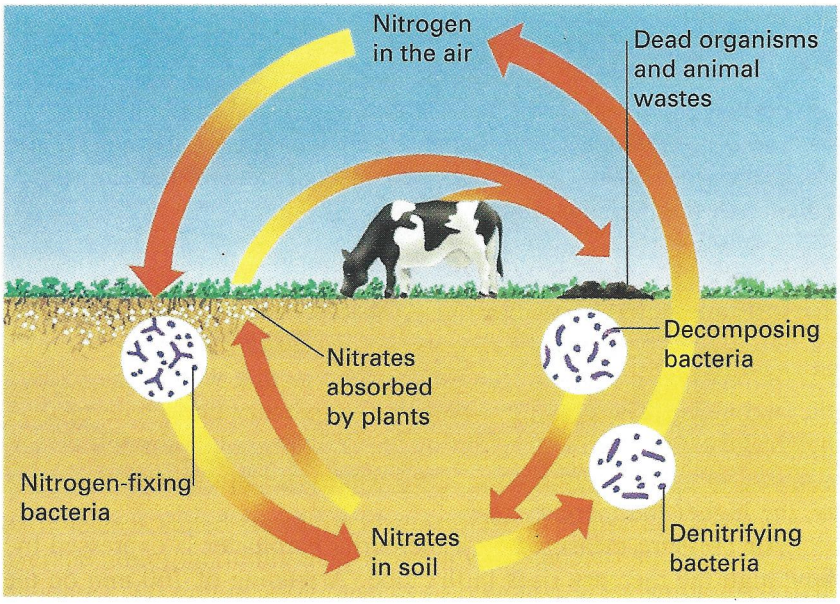


Figure 23–3. The nitrogen cycle maintains a stable amount of nitrogen in the air.

Nitrogen in the Atmosphere

The amount of nitrogen in the atmosphere is maintained through the **nitrogen cycle.** During the cycle, nitrogen moves from air to the soil, to plants and animals, and back again to the air. As Figure 23–3 shows, nitrogen is removed from the air mainly by the action of nitrogen-fixing bacteria. These microscopic organisms live in the soil and on the roots of certain plants. The bacteria chemically change nitrogen from the air into nitrogen compounds, which are vital to the growth of all plants. When animals eat plants, nitrogen compounds enter their bodies. These compounds are then returned to the soil through animal excretions or by the decay of dead organisms. In the soil, the processes involved in denitrification release nitrogen and return it to the atmosphere. A similar nitrogen cycle takes place among water-dwelling plants and animals.

Atmospheric Pressure

Gravity pulls the gases of the atmosphere toward the earth's surface and holds them there. Due to the pull of gravity, 99 percent of the total mass of atmospheric gases is found within 32 km of the earth's surface. The remaining 1 percent extends upward for hundreds of kilometers but gets increasingly thinner at high altitudes. In other words, there is less air at these higher altitudes.

A 1-cm^2 column of air that reaches from sea level to the top of the atmosphere has a mass of 1.03 kg and exerts a force of 10.1 newtons (N). In other words, at sea level, on every square centimeter of the earth's surface, the atmosphere presses down with a force of 10.1 N, which is about 2 lb. The ratio of the weight of the air to the area of the surface on which it presses is called **atmospheric pressure.** Since there is less air at higher altitudes, there is less weight pressing down on surfaces at those altitudes. Thus, the atmospheric pressure is lower at higher altitudes.

You have probably experienced the effects of changes in air pressure. If you have ever driven through the mountains or flown in

an airplane, you may have had a popping sensation in your ears. This sensation is due to the decreased air pressure on the outside of your eardrum. When the air pressure on both sides of the eardrum is equalized, the popping stops.

Mercurial Barometer

An instrument that measures atmospheric pressure is called a **barometer.** One type of barometer is the *mercurial barometer.* Atmospheric pressure presses on the liquid mercury in a well at the base of the barometer. The pressure squeezes the mercury up to a certain height inside a tube. The height of the mercury inside the tube varies with the atmospheric pressure. The greater the atmospheric pressure is, the higher the mercury rises.

Air pressure measured by a mercurial barometer is expressed by how high the mercury rises in the tube. A reading of 760 mm on the

SMALL-SCALE INVESTIGATION

Barometric Pressure

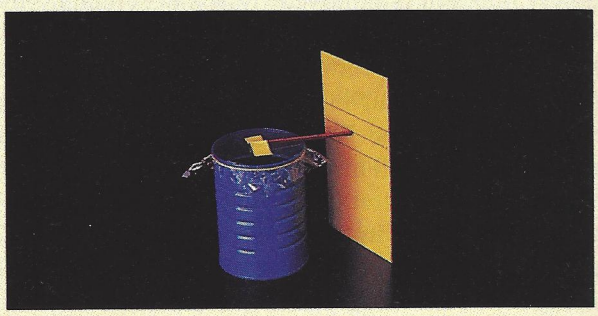
A barometer measures changes in atmospheric pressure. You can construct a simple aneroid barometer with some common objects.

Materials

plastic wrap; coffee can with a diameter of about 10 cm, open at one end; rubber band; drinking straw, about 10 cm long; masking or adhesive tape; cardboard, 10 cm wide and at least 8 cm taller than the can; metric ruler

Procedure

1. Refer to the photo in making your barometer.
2. Secure plastic wrap tightly over the open end of the can with the rubber band.
3. Tape one end of the straw onto the plastic wrap near the center, as shown in the photo.
4. Fold the cardboard so that it stands upright and extends at least 3 cm above the top of the can.
5. Place the cardboard so that the free end of the straw just touches the front of the cardboard. Mark an *X* where the straw touches.
6. Draw three horizontal lines on the cardboard: level with the *X,* 2 cm above the *X,* and 2 cm below the *X.*



7. Position the cardboard so that the straw touches the *X* again. Tape the base of the cardboard in place so that it does not shift.
8. Observe the level of the straw at least once a day over a 5-day period. Record any changes.

Analysis and Conclusions

1. What factors affect how your model works? Explain your answer.
2. What does an upward movement of the straw indicate? a downward movement?
3. Compare your results with the barometric pressures listed in your local newspaper. What kind of weather was associated with high pressure? with low pressure?