SECTION 1

Characteristics of the Atmosphere

If you were lost in the desert, you could survive for a few days without food and water. But you wouldn't last more than five minutes without the atmosphere.

The **atmosphere** is a mixture of gases that surrounds Earth. In addition to containing the oxygen you need to breathe, the atmosphere protects you from the sun's damaging rays. The atmosphere is always changing. Every breath you take, every tree that is planted, and every vehicle you ride in affects the atmosphere's composition.

READING WARM-UP

Objectives

- Describe the composition of Earth's atmosphere.
- Explain why air pressure changes with altitude.
- Explain how air temperature changes with atmospheric composition.
- Describe the layers of the atmosphere.

Terms to Learn

atmosphere	stratosphere
air pressure	mesosphere
troposphere	thermosphere

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the layers of the Earth's atmosphere.

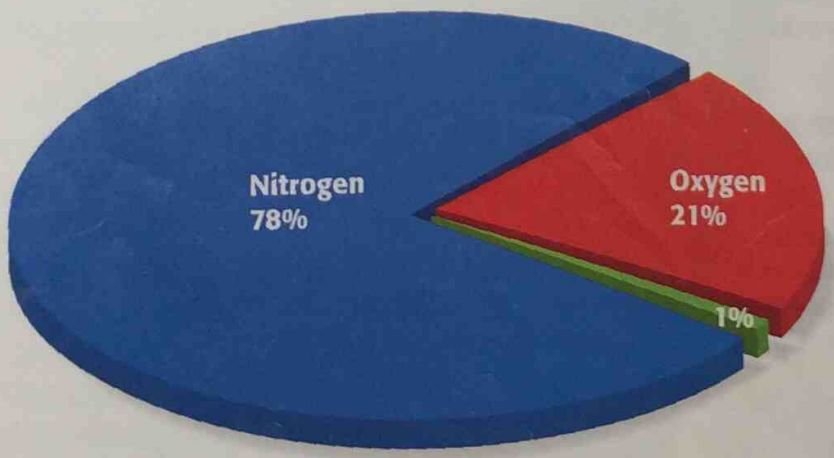
The Composition of the Atmosphere

As you can see in **Figure 1,** the atmosphere is made up mostly of nitrogen gas. The oxygen you breathe makes up a little more than 20% of the atmosphere. In addition to containing nitrogen and oxygen, the atmosphere contains small particles such as dust, volcanic ash, sea salt, dirt, and smoke. The next time you turn off the lights at night, shine a flashlight, and you will see some of these tiny particles floating in the air.

Water is also found in the atmosphere. Liquid water (water droplets) and solid water (snow and ice crystals) are found in clouds. But most water in the atmosphere exists as an invisible gas called *water vapor*. When atmospheric conditions change, water vapor can change into solid or liquid water, and rain or snow might fall from the sky.

Reading Check **Describe the three physical states of water in the atmosphere.** *(See the Appendix for answers to Reading Checks.)*

Figure 1 **Composition of the Atmosphere**



Nitrogen, the most common atmospheric gas, is released when dead plants and dead animals break down and when volcanoes erupt.

Oxygen, the second most common atmospheric gas, is made by phytoplankton and plants.

The **remaining 1%** of the atmosphere is made up of argon, carbon dioxide, water vapor, and other gases.

Atmospheric Pressure and Temperature

You may be surprised to learn that you carry a 700 km column of air every day. Although air is not heavy, at sea level, a square inch of surface area is under almost 15 lb of air.

As Altitude Increases, Air Pressure Decreases

The atmosphere is held around the Earth by gravity. Gravity acts to move gas molecules in the atmosphere toward Earth's center. The force of gravity is balanced by air pressure. **Air pressure** is the measure of the force with which air molecules push on a surface. Air pressure is strongest at the Earth's surface because more air is above you. As you move farther away from the Earth's surface, fewer gas molecules are above you. So, as altitude (distance from sea level) increases, air pressure decreases. Think of the forces of air pressure and gravity as a human pyramid, as shown in **Figure 2.** The people at the bottom of the pyramid can feel all the weight of the people on top. The people at the bottom push up to balance the weight of the people above them. In a similar way, air pressure and gravity exist near a state of balance or equilibrium.

Atmospheric Composition Affects Air Temperature

Air temperature also changes as altitude increases. The temperature differences result mainly from the way solar energy is absorbed as it moves through the atmosphere. Some parts of the atmosphere are warmer because they contain a high percentage of gases that absorb solar energy. Other parts of the atmosphere contain less of these gases and are cooler.

CONNECTION TO Physics

Air-Pressure Experiment

Does air pressure push only downward? Try this experiment to find out. Fill a plastic cup to the brim with water. Firmly hold a piece of cardboard over the mouth of the cup. Quickly invert the glass over a sink, and observe what happens. How do the effects of air pressure explain your observations?

ACTIVITY

atmosphere a mixture of gases that surrounds a planet or moon

air pressure the measure of the force with which air molecules push on a surface

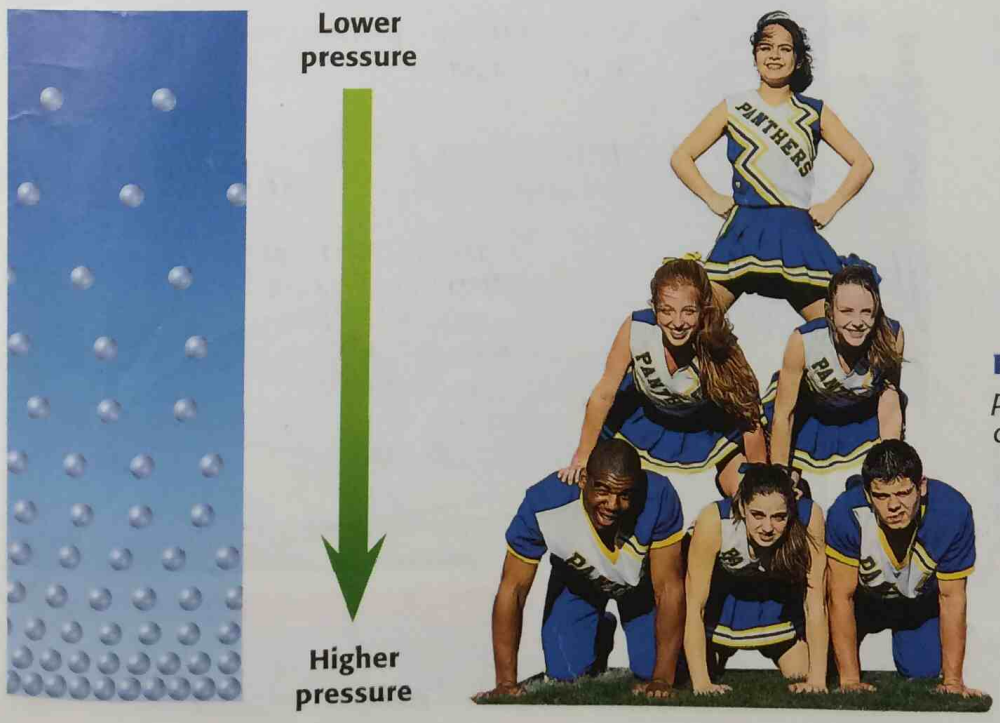


Figure 2 *As in a human pyramid, air pressure increases closer to the Earth's surface.*

Layers of the Atmosphere

Based on temperature changes, the Earth's atmosphere is divided into four layers, as shown in **Figure 3.** These layers are the *troposphere, stratosphere, mesosphere,* and *thermosphere.* Although these words might sound complicated, the name of each layer gives you clues about its features.

For example, *-sphere* means "ball," which suggests that each layer of the atmosphere surrounds the Earth like a hollow ball. *Tropo-* means "turning" or "change," and the troposphere is the layer where gases turn and mix. *Strato-* means "layer," and the stratosphere is the sphere where gases are layered and do not mix very much. *Meso-* means "middle," and the mesosphere is the middle layer. Finally, *thermo-* means "heat," and the thermosphere is the sphere where temperatures are highest.

Reading Check **What does the name of each atmospheric layer mean?**

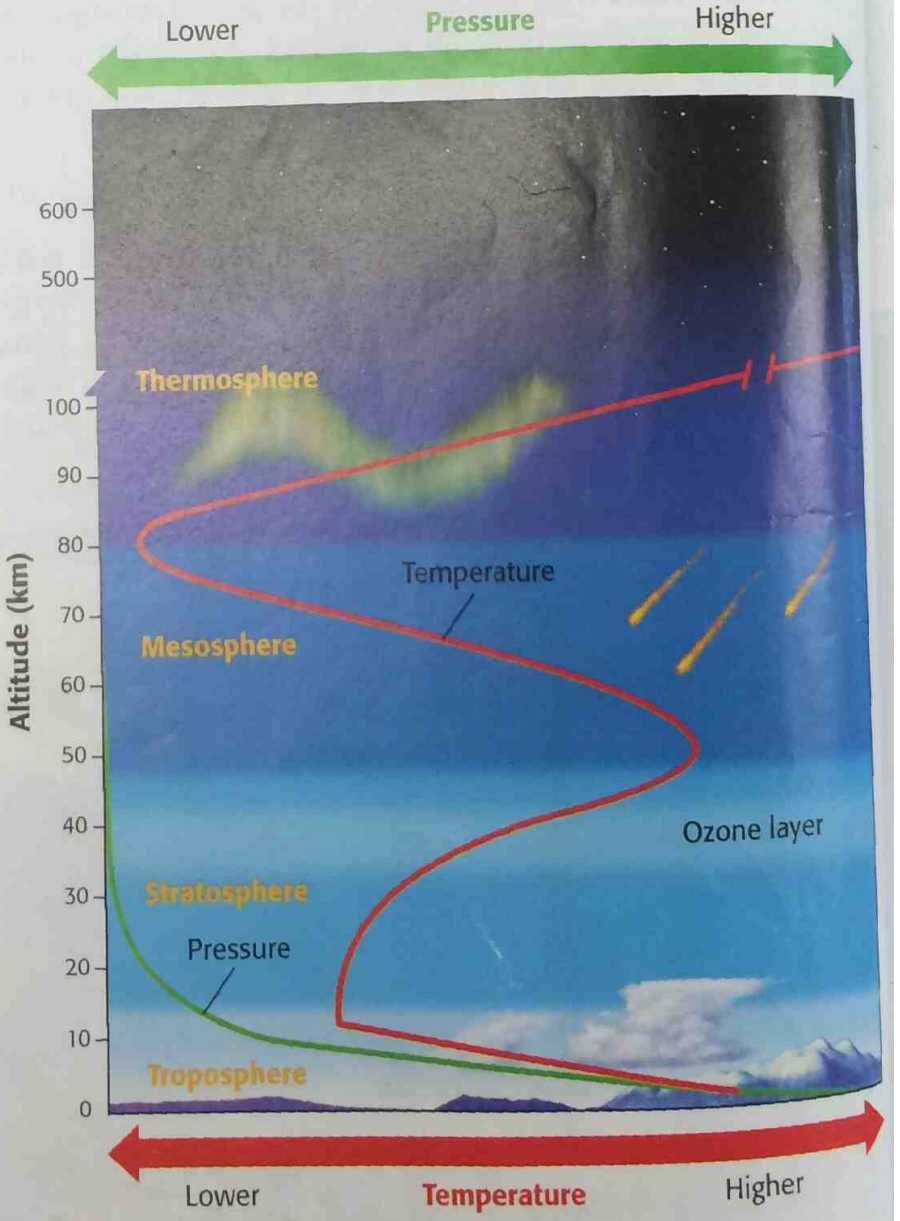


Figure 3 *The layers of the atmosphere are defined by changes in temperature.*

MATH PRACTICE

Modeling the Atmosphere

In teams, use a metric ruler to create an illustrated scale model of the atmosphere similar to the one shown on this page. Assume that the atmosphere is about 700 km high. If you reduced the height of the atmosphere by a factor of 100,000, your scale model would be 7 m long, and the troposphere would be 16 cm long. Think of a creative way to display your model. You could use sidewalk chalk, stakes and string, poster board, or other materials approved by your teacher. Do some research to add interesting information about each layer.

ACTIVITY

The Troposphere: The Layer in Which We Live

The lowest layer of the atmosphere, which lies next to the Earth's surface, is called the **troposphere.** The troposphere is also the densest atmospheric layer. It contains almost 90% of the atmosphere's total mass! Almost all of the Earth's carbon dioxide, water vapor, clouds, air pollution, weather, and life-forms are in the troposphere. As shown in **Figure 4,** temperatures vary greatly in the troposphere. Differences in air temperature and density cause gases in the troposphere to mix continuously.

The Stratosphere: Home of the Ozone Layer

The atmospheric layer above the troposphere is called the **stratosphere.** **Figure 5** shows the boundary between the stratosphere and the troposphere. Gases in the stratosphere are layered and do not mix as much as gases in the troposphere. The air is also very thin in the stratosphere and contains little moisture. The lower stratosphere is extremely cold. Its temperature averages –60°C. But temperature rises as altitude increases in the stratosphere. This rise happens because ozone in the stratosphere absorbs ultraviolet radiation from the sun, which warms the air. Almost all of the ozone in the stratosphere is contained in the ozone layer. The *ozone layer* protects life on Earth by absorbing harmful ultraviolet radiation.

The Mesosphere: The Middle Layer

Above the stratosphere is the mesosphere. The **mesosphere** is the middle layer of the atmosphere. It is also the coldest layer. As in the troposphere, the temperature decreases as altitude increases in the mesosphere. Temperatures can be as low as –93°C at the top of the mesosphere.

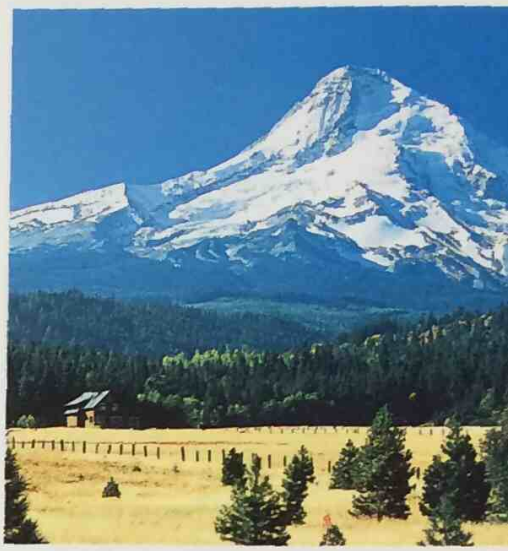


Figure 4 *As altitude increases in the troposphere, temperature decreases. Snow remains all year on this mountaintop.*

troposphere the lowest layer of the atmosphere, in which temperature decreases at a constant rate as altitude increases

stratosphere the layer of the atmosphere that is above the troposphere and in which temperature increases as altitude increases

mesosphere the layer of the atmosphere between the stratosphere and the thermosphere and in which temperature decreases as altitude increases

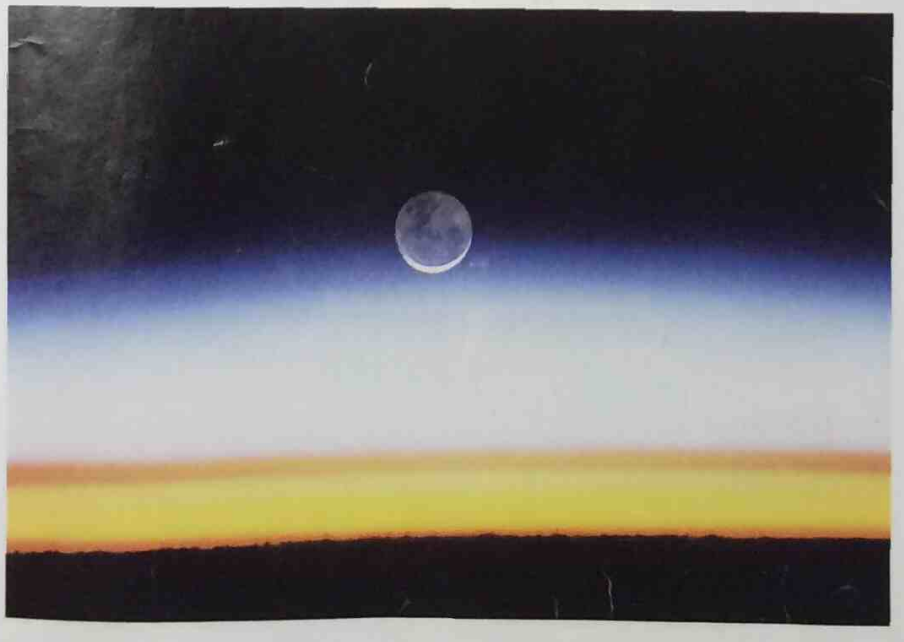


Figure 5 *This photograph of Earth's atmosphere was taken from space. The troposphere is the yellow layer; the stratosphere is the white layer.*

The Thermosphere: The Edge of the Atmosphere

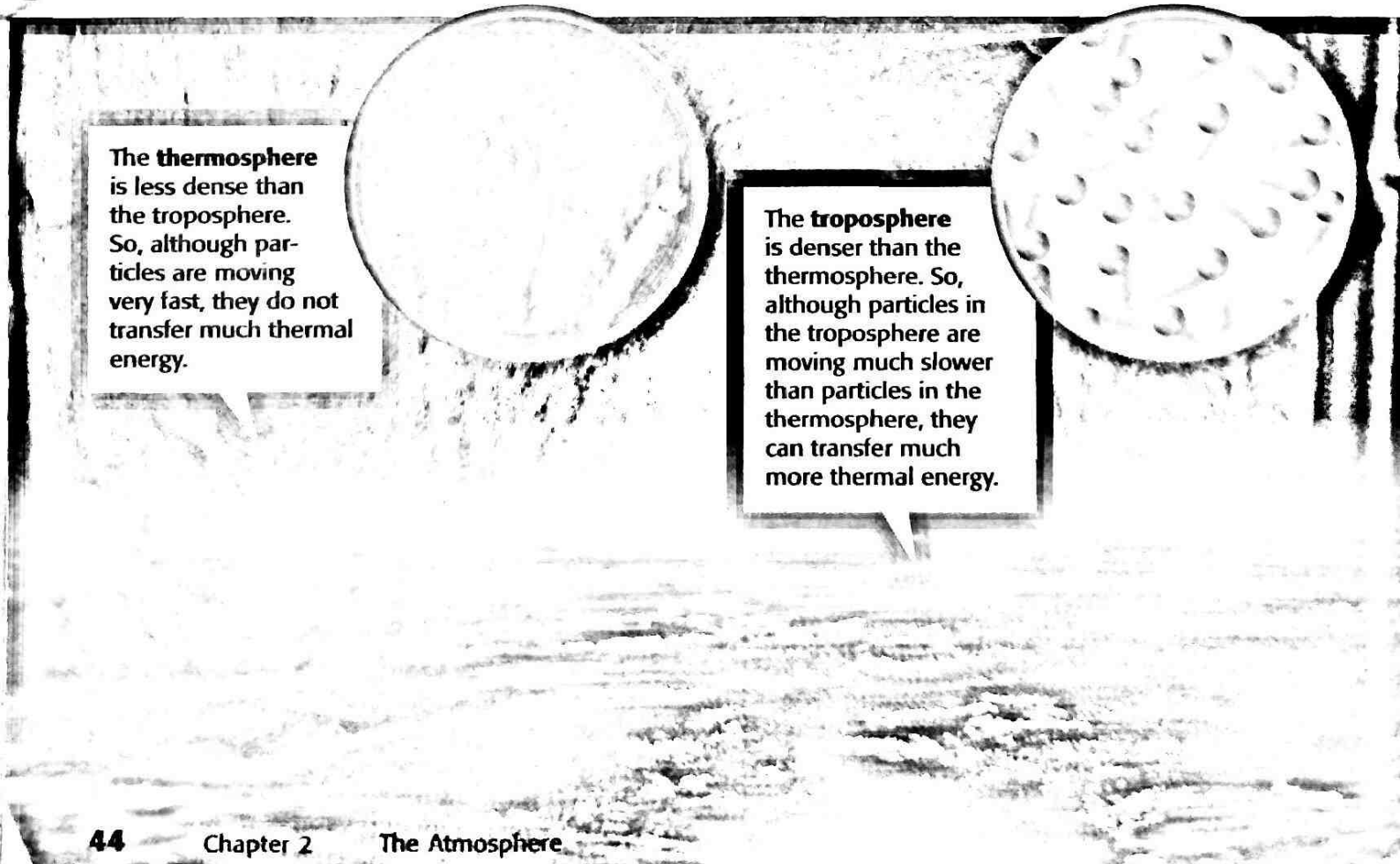
thermosphere the uppermost layer of the atmosphere, in which temperature increases as altitude increases

The uppermost atmospheric layer is called the **thermosphere.** In the thermosphere, temperature again increases with altitude. Atoms of nitrogen and oxygen absorb high-energy solar radiation and release thermal energy, which causes temperatures in the thermosphere to be 1,000°C or higher.

When you think of an area that has high temperatures, you probably think of a place that is very hot. Although the thermosphere has very high temperatures, it does not feel hot. Temperature is different from heat. Temperature is a measure of the average energy of particles in motion. The high temperature of the thermosphere means that particles in that layer are moving very fast. Heat, however, is the transfer of thermal energy between objects of different temperatures. Particles must touch one another to transfer thermal energy. The space between particles in the thermosphere is so great that particles do not transfer much energy. In other words, the density of the thermosphere is so low that particles do not often collide and transfer energy. **Figure 6** shows how air density affects the heating of the troposphere and the thermosphere.

Reading Check **Why doesn't the thermosphere feel hot?**

Figure 6 Temperature in the Troposphere and the Thermosphere



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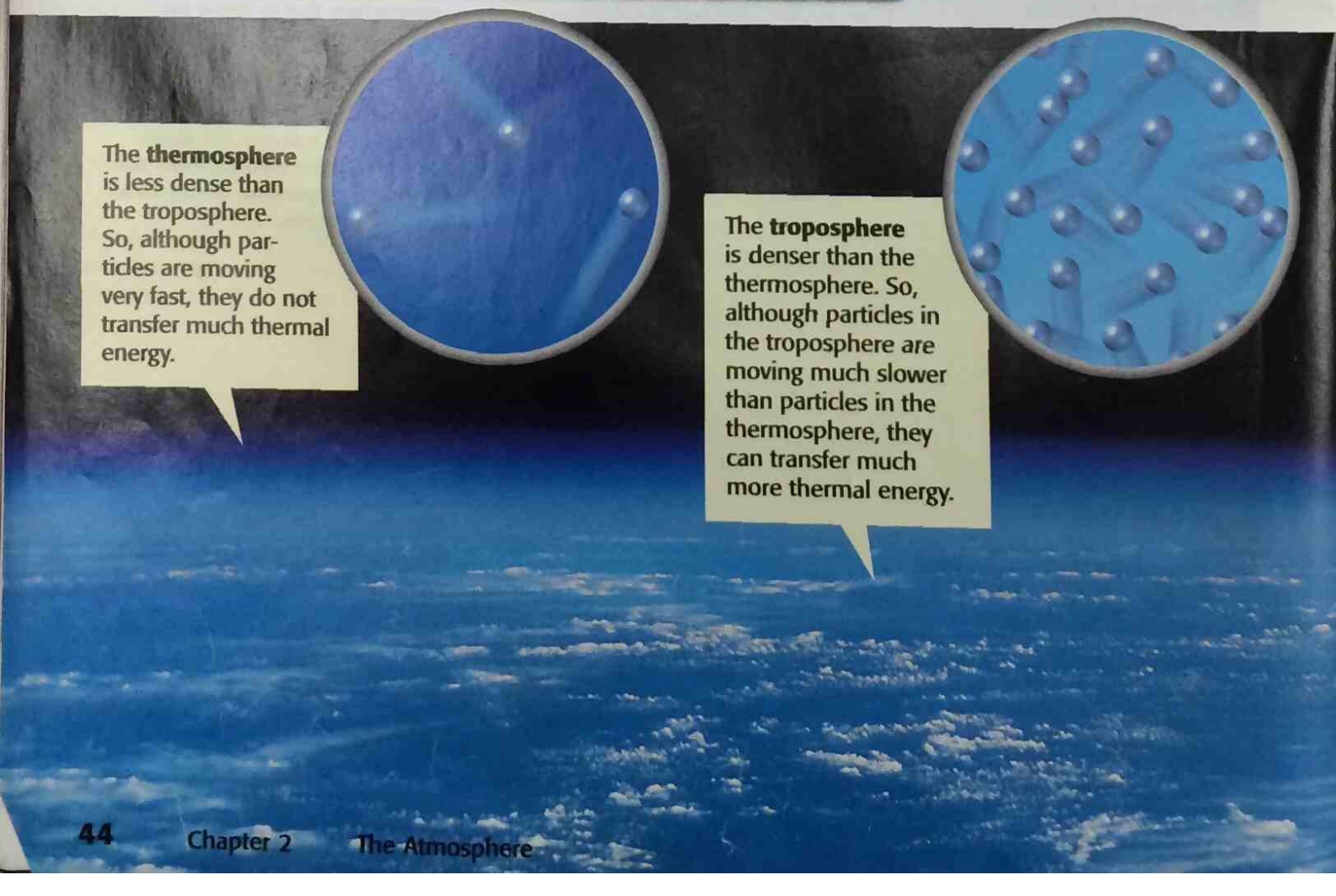

The Ionosphere: Home of the Auroras

In the upper mesosphere and the lower thermosphere, nitrogen and oxygen atoms absorb harmful solar energy. As a result, the thermosphere's temperature rises, and gas particles become electrically charged. Electrically charged particles are called *ions*. Therefore, this part of the thermosphere is called the *ionosphere*. As shown in **Figure 7**, in polar regions these ions radiate energy as shimmering lights called *auroras*. The ionosphere also reflects AM radio waves. When conditions are right, an AM radio wave can travel around the world by reflecting off the ionosphere. These radio signals bounce off the ionosphere and are sent back to Earth.

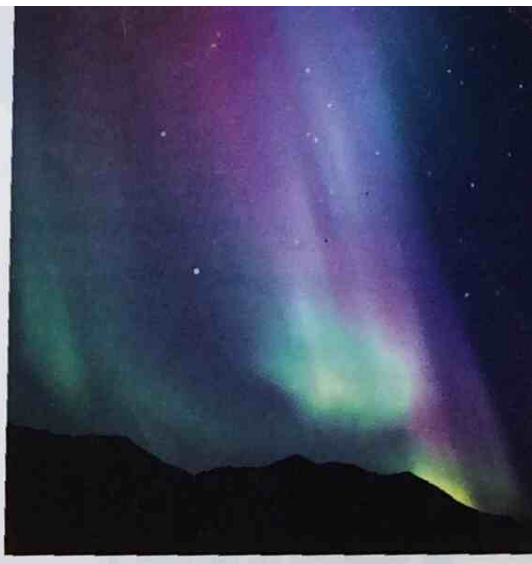

Figure 7 *Charged particles in the ionosphere cause auroras, or northern and southern lights.*

SECTION Review

Summary

- Nitrogen and oxygen make up most of Earth's atmosphere.
- Air pressure decreases as altitude increases.
- The composition of atmospheric layers affects their temperature.
- The troposphere is the lowest atmospheric layer. It is the layer in which we live.
- The stratosphere contains the ozone layer, which protects us from harmful UV radiation.
- The mesosphere is the coldest atmospheric layer.
- The thermosphere is the uppermost layer of the atmosphere.

Using Key Terms

1. Use each of the following terms in a separate sentence: *air pressure, atmosphere, troposphere, stratosphere, mesosphere,* and *thermosphere.*

Understanding Key Ideas

2. Why does the temperature of different layers of the atmosphere vary?
   a. because air temperature increases as altitude increases
   b. because the amount of energy radiated from the sun varies
   c. because of interference by humans
   d. because of the composition of gases in each layer
3. Why does air pressure decrease as altitude increases?
4. How can the thermosphere have high temperatures but not feel hot?
5. What determines the temperature of atmospheric layers?
6. What two gases make up most of the atmosphere?

Math Skills

7. If an average cloud has a density of 0.5 g/m^3 and has a volume of 1,000,000,000 m^3, what is the weight of an average cloud?

Critical Thinking

8. **Applying Concepts** Apply what you know about the relationship between altitude and air pressure to explain why rescue helicopters have a difficult time flying at altitudes above 6,000 m.
9. **Making Inferences** If the upper atmosphere is very thin, why do space vehicles heat up as they enter the atmosphere?
10. **Making Inferences** Explain why gases such as helium can escape Earth's atmosphere.