Chapter 23 The Earth's Atmosphere

On most days, you can look up into the sky and see clouds. They do not always look like the ones shown in the photo. How would you describe other kinds of clouds that you have seen?

Learning Objectives

- Identify the layers of the atmosphere.
- Explain air pressure.
- Describe how winds are formed.
- Explain how convection currents work.
- Compare different types of precipitation.
- List the different cloud forms.
- LAB ACTIVITY: Observe how a cloud forms.
- SCIENCE IN YOUR LIFE: Use a chart to find wind chill temperatures.

Words to Know

atmosphere	the air that surrounds the Earth or another body in space
troposphere	the layer nearest the Earth in the atmosphere, where we live and where most weather takes place
stratosphere	the second layer in the atmosphere
ozone	a thin layer of gas found in the stratosphere that filters out much of the harmful radiation from the sun
mesosphere	the third layer in the atmosphere
ionosphere	the fourth layer in the atmosphere, where there are many electrically charged particles
thermosphere	the outermost layer in the atmosphere
air pressure	the weight of the gases pressing down on the Earth
barometer	an instrument that measures air pressure
humidity	the amount of water vapor in the air at any given time
precipitation	any form of water that falls from the air
dew point	the temperature at which water vapor turns into liquid water
cirrus cloud	a high-altitude cloud made of ice crystals
stratus cloud	a low-lying gray cloud that covers a wide area
cumulus cloud	a big, puffy low-altitude cloud that usually signals good weather

23-1 Air All Around Us

Words to Know

atmosphere	the air that surrounds the Earth or another body in space
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mesosphere	the third layer in the atmosphere
ionosphere	the fourth layer in the atmosphere, where there are many electrically charged particles
thermosphere	the outermost layer in the atmosphere

What Is the Atmosphere?

Take a deep breath. You just filled your lungs with air. The air that surrounds the Earth or another body in space is called the **atmosphere.** The pull of gravity holds the atmosphere to the Earth. The atmosphere travels with the Earth as it moves through space.

Some people do not think of the air as anything at all. However, air is matter. Air has mass, even though you cannot see it. Air is made up mostly of gases, including the gas water vapor. There is also a certain amount of fine dust always floating in the air. Sometimes the air is heavy, and sometimes it is light. Air is also affected by gravity and heat from the sun.

The Earth's atmosphere is about 78 percent nitrogen. Oxygen makes up about 21 percent. There are also small amounts of water vapor, argon, carbon dioxide, and other gases in the atmosphere.

The higher up you go in the atmosphere, the thinner the air is. Mountain climbers gasp for air on top of high mountains. Climbers need to breathe in more air to get enough oxygen. People who climb the highest peaks in the world carry oxygen in tanks with them.

The atmosphere does not suddenly end. It becomes thinner and thinner as you go farther from the Earth. At about 600 miles (960 kilometers), there is almost no atmosphere left.

✓ **What two gases make up most of the atmosphere?**

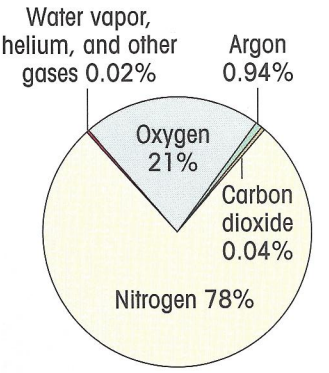


Figure 23-1 *This chart shows what the atmosphere is made up of.*

Layers in the Atmosphere

Scientists often divide the atmosphere into five layers. Some of these layers overlap.

Troposphere

The layer nearest the Earth is called the **troposphere.** This is the layer in which we live and where most weather takes place. Planes fly in the troposphere.

The troposphere is warmest near the Earth. It is cooler farther away from the Earth. The air is most dense near the bottom of the troposphere. Here, air molecules are packed close together by the weight of the air above.

Stratosphere

The second layer is called the **stratosphere.** Within the stratosphere is a thin layer of the gas **ozone.** Ozone is a form of oxygen. This layer is very important to living things. Ozone filters out much of the harmful radiation from the sun.

Air pollution may be breaking down the ozone layer. Without protection from ozone, more ultraviolet light can get through to the Earth's surface. Ultraviolet light, which is invisible, is the cause of sunburn and some skin cancers. Scientists say an increase in this radiation could cause an increase in skin cancer in humans.

Mesosphere and Ionosphere

The third layer in the atmosphere around the Earth is called the **mesosphere.** The fourth layer is called the **ionosphere.** The ionosphere actually begins in the mesosphere and goes upward through the fifth layer. The ionosphere contains many electrically charged particles. These particles are important in radio communications. They reflect radio signals.

Thermosphere

The outermost layer is called the **thermosphere.** The air in the thermosphere is very thin.

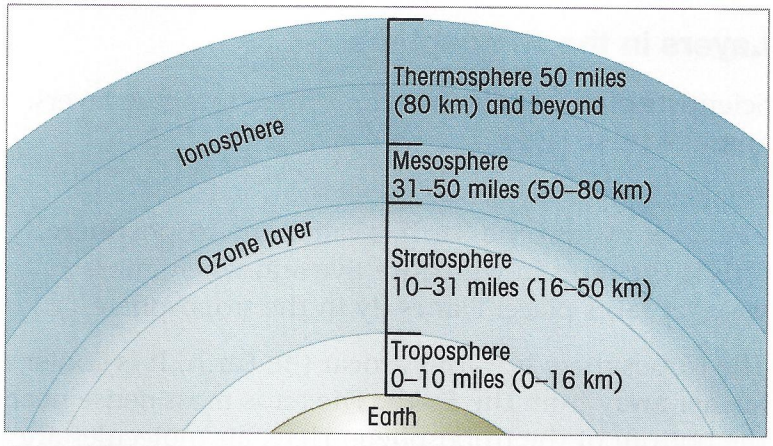


Figure 23-2 *These are the layers of the atmosphere.*

✓ **How many layers are in the atmosphere, and what are they called?**

Lesson Review

1. What substances make up the atmosphere?
2. About how far does the atmosphere go above the surface of the Earth?
3. What layer of the atmosphere helps radio communication? Explain how.
4. **CRITICAL THINKING** Suppose the Earth had much less gravity. How would that change the atmosphere?

23-2 Properties of Air

Words to Know

air pressure	the weight of the gases pressing down on the Earth
barometer	an instrument that measures air pressure

Science Fact

Barometers are used to help predict the weather. A change in barometric pressure usually means a change in the weather.

Air Has Weight

Gravity keeps the Earth's atmosphere from flying off into space. Gravity is strongest near the Earth's surface. Therefore, the atmosphere closest to the Earth is pulled the most by gravity. This causes the air molecules to pack together more tightly. So, the air close to the Earth's surface is heavier, or denser. The air farther away is less dense, or lighter.

Air pressure is the weight of the gases pressing down on the Earth. Air pressure changes all the time. A **barometer** is an instrument that measures air pressure.

✓ **Why is the air close to the Earth's surface very dense?**

Air Has Heat

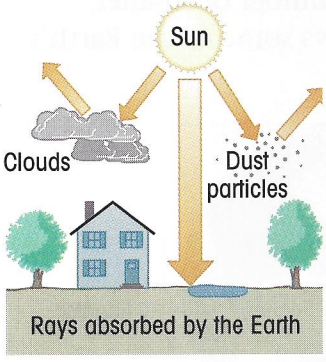


Figure 23-3 *Energy from the sun warms the surface of the Earth. The Earth's surface warms the atmosphere.*

Energy from the sun reaches the Earth as radiation. Once radiation strikes the ground, it changes to heat energy. Then the ground radiates the heat back into the atmosphere. At that point, water vapor and other gases in the air absorb some of the warmth.

Clouds often block the sun's energy. They also reflect sunlight back into the outer atmosphere. At night, though, clouds around the Earth act as a blanket. They trap the heat and keep it from escaping into space.

✓ **How do clouds affect sunlight striking the Earth?**

Air Can Move

Wind is moving air. Remember that heat causes the molecules in all matter to move. The warmer air is, the faster it moves and the more the molecules spread out. In other words, heat causes matter to become less dense. When air becomes less dense, it moves up, or rises. Colder air sweeps into the empty space left by the warmer air. This action sets up a circular motion of air called a *convection current*.

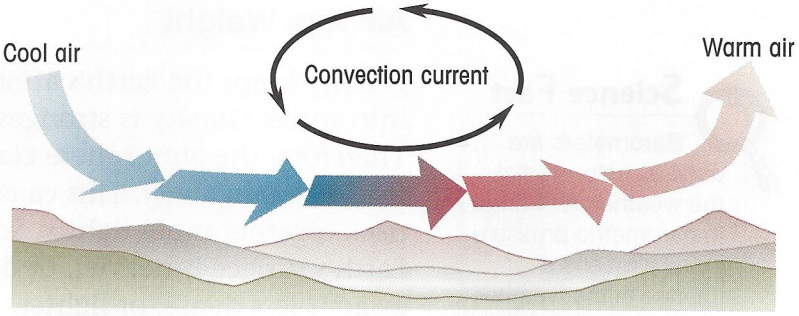


Figure 23-4 *Convection currents result from the uneven heating of the atmosphere. Warm air rises. Cool air takes its place.*

The Earth's Wind Systems

Convection currents form large wind systems. Warm air at the equator rises and moves toward the poles. Cooler air flows toward the equator from the north and south to replace the rising warm air. This causes a huge convection current. However, the rotation of the Earth breaks up this big wind into a number of smaller, circular winds. This picture shows some of the Earth's large wind systems.

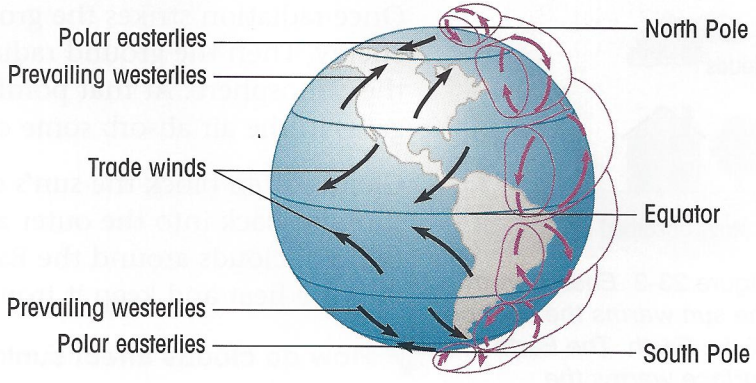


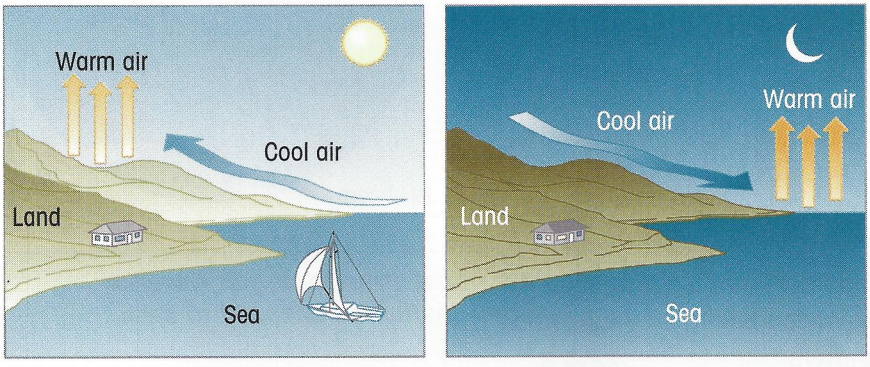
Figure 23-5 *Convection currents cause most of the large wind systems on Earth.*

Local Winds

As you just read, the Earth has several major wind systems. However, the Earth's surface features, such as mountains, valleys, and big bodies of water, create local winds. Local winds are smaller wind systems. For example, cold mountain breezes blow down mountain slopes at night. Warm valley breezes blow up mountain slopes on sunny days.

Winds over the land and water also change between day and night. Land heats up faster than oceans or large lakes. So, during the day, the air over land becomes warmer than the air over large bodies of water. When the warm air over the land rises, the cold air over the ocean or lake rushes in. This kind of wind is called a *sea breeze*.

At night, the opposite happens. The land cools off faster than the ocean. So, the air over land gets cooler than the air over the ocean. The ocean air rises and the land air rushes out. This creates a *land breeze*.



Sea Breeze **Land Breeze**

Figure 23-6 *Sea breezes and land breezes are local winds.*

Local winds are always named for the direction from which they come. So a *westerly* is blowing from the west. It blows toward the east. A *north wind* is blowing from the north. It blows toward the south.

What causes most of the Earth's winds?

Lesson Review

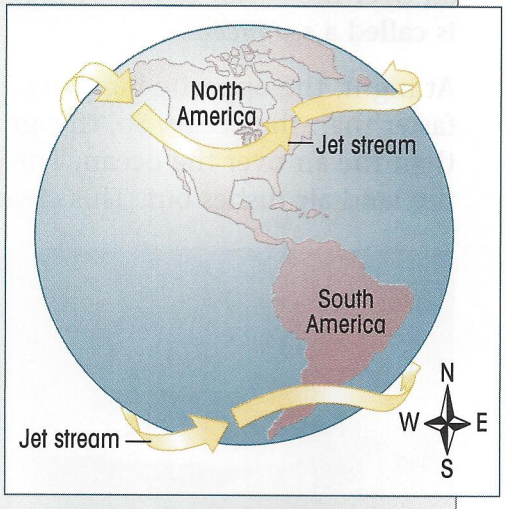
1. What are three properties of air?
2. How does sunlight heat the air?
3. What is a convection current?
4. **CRITICAL THINKING** On a hot day, why is it often cooler near the shore of an ocean than farther inland?

A Closer Look

JET STREAMS

Have you ever tried to ride a bicycle against the wind? If so, you probably had to work hard to overcome the moving air. Airplanes also have to use more energy to overcome very strong moving streams of air. That is why the routes many airplanes take are designed with the *jet streams* in mind. Jet streams are narrow rivers of fast-moving air.

Two major jet streams flow from west to east across the Earth. The winds of the jet streams move at an average of 35 miles (56 kilometers) per hour in the summer. In the winter, the winds move at an average of 75 miles (120 kilometers) per hour. Airplanes that are moving eastward try to fly along a jet stream. The powerful winds push the airplane through the atmosphere. The airplane gains speed and uses less fuel.



Jet streams flow in wavelike patterns from west to east.

CRITICAL THINKING Why do you think pilots flying west try to avoid the jet streams?

23-3 Water and Air

Words to Know

humidity	the amount of water vapor in the air at any given time
precipitation	any form of water that falls from the air
dew point	the temperature at which water vapor turns into liquid water
cirrus cloud	a high-altitude cloud made of ice crystals
stratus cloud	a low-lying gray cloud that covers a wide area
cumulus cloud	a big, puffy low-altitude cloud that usually signals good weather

Remember
When water evaporates, it turns from a liquid into a gas.

Precipitation

There is always some water in the air. Water enters the air by evaporating off the ground, lakes, oceans, rivers, plants, and animals. The amount of water in the air at any given time is the level of **humidity.** When the humidity is high, water may fall from the air. **Precipitation** is any form of water that falls from the air. The form the water takes depends partly on the temperature of the air.

Rain

Liquid water falls as rain. Warming can change rain into the gas water vapor. Cooling can turn water vapor back into a liquid. The temperature at which water vapor turns back into a liquid is called the **dew point.** If air is cooled below the dew point, some of the water vapor in the air forms tiny droplets of water. These droplets collect to make clouds. Fog is a low-lying layer of cloud. When the droplets become large enough and heavy enough, they fall as rain.

Sleet, Snow, and Hail

If the temperature in a cloud is below freezing, the water vapor may form ice crystals. These then fall as snow.

Sleet is rain that freezes as it falls through a layer of cold air near the ground. Hail is made up of lumps of ice. These lumps form as winds toss ice crystals up and down in a rain cloud. Each time the crystals move up, water freezes around them. Heavy lumps of ice form and fall to the ground. Hail usually occurs during strong thunderstorms.

✓ **What are three frozen forms of precipitation?**

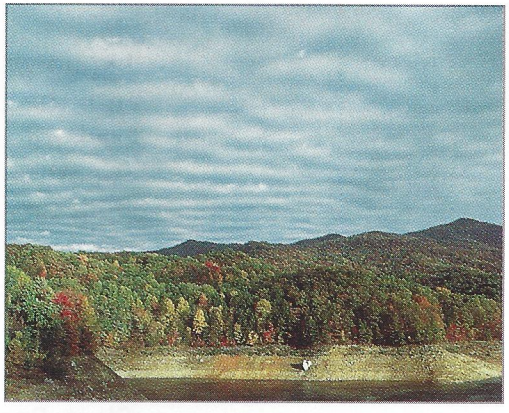
How Clouds Form

Clouds form whenever water droplets or ice particles collect in the atmosphere. A lot of moisture in the air and cold temperatures help clouds to form.

There are three main kinds of clouds. A **cirrus cloud** is a high-altitude cloud made of ice crystals. *Cirrus* means "curled." Cirrus clouds are thin and feathery. They are usually bright white.

A **stratus cloud** is a low-lying gray cloud that covers a wide area. Stratus clouds are made of water droplets. *Stratus* means "spread out." Stratus clouds form broad, flat layers. They float low in the sky and usually appear as an unbroken cloud cover. Stratus clouds are often a sign of rainy weather.

Cirrus clouds usually contain ice crystals because the surrounding air is very cold.



Stratus clouds often look like a blanket in the sky.

A **cumulus cloud** is a big, puffy low-altitude cloud that usually signals good weather. Cumulus clouds are made of water droplets. *Cumulus* means "heaped up." A *thunderhead* is a special kind of cumulus cloud. Thunderheads usually bring storms.

What do the three main kinds of clouds look like?

Cumulus clouds can grow very tall.

Lesson Review

1. How does water enter the air?
2. What causes rain?
3. How do clouds form?
4. **CRITICAL THINKING** Sometimes water drops fall through the air without ever reaching the ground. What happens to them?

On the Cutting Edge

CLOUD SEEDING

Some places never get a steady supply of rain. Months can go by without rain. This causes problems for plants and animals in the area.

Sometimes rain can be brought to a dry place through a process called *cloud seeding*. An airplane flies into clouds with tops colder than 23 degrees Fahrenheit (°F). The airplane drops tiny crystals of a chemical called silver iodide onto the clouds. Water vapor in the clouds condenses around the crystals. Droplets form. If the droplets reach a certain size, they fall to the ground as rain. Sometimes cloud seeding is used to clear away fog over airports. Cloud seeding is not always successful. However, in some situations, it is worth trying.

An airplane drops crystals of silver iodide to try to make rain.

CRITICAL THINKING In what situations would cloud seeding be worth trying?

LAB ACTIVITY
Making a Cloud

BACKGROUND
Cooling can cause water vapor to condense into liquid water. But the vapor needs a surface to condense onto. Water vapor condenses onto tiny particles of dust in the air. This forms the droplets that make up clouds.

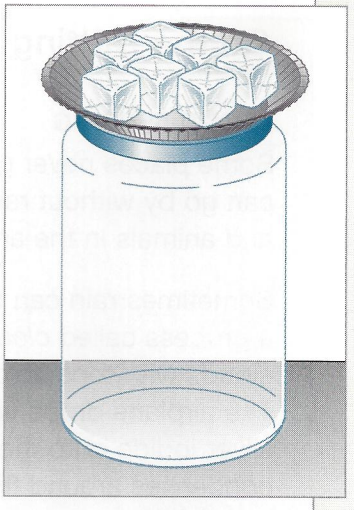
PURPOSE
You will observe how particles in the air help clouds to form.

Safety Alert

Always keep hair and clothing away from an open flame.

MATERIALS
paper, pencil, safety goggles, jar with lid, pitcher of warm water, aluminum foil tray, ice, matches, wooden splint

WHAT TO DO
1. Put on your safety goggles.
2. Fill the jar with warm water. Put the lid on and let the jar stand for 2 minutes.
3. Empty the jar and replace the cover. Immediately place a tray of ice cubes on the lid. Observe the jar for 1 minute. Record your observations.
4. Rinse the jar and repeat Step 2.
5. Ask your teacher to use a match to light the splint. Blow out the splint immediately.
6. Hold the smoldering splint inside the jar so that some smoke enters it.
7. Replace the lid and cover it with the tray of ice cubes. Observe the jar again for 1 minute and record your observations.



Step 3

DRAW CONCLUSIONS
- Did you see a thicker cloud in Step 3 or in Step 7?
- What caused the thicker cloud to form?
- What three things are needed for clouds to form?

SCIENCE IN YOUR LIFE
Wind Chill Temperature

A cold day feels a lot colder if there is a strong wind. To dress for the weather on a cold day, you need to know more than air temperature. You also need to know the *wind chill temperature*. The faster the wind blows, the quicker your body will lose heat. So, the faster the wind blows, the colder you will feel.

Wind Chill Temperatures

Actual Temperature	Wind Speed (miles per hour) 5	10	15	20	25
50°F	48°	40°	36°	32°	30°
40°F	37°	28°	22°	18°	16°
30°F	27°	16°	9°	4°	0°
20°F	16°	4°	−5°	−10°	−15°
10°F	6°	−9°	−18°	−25°	−29°
0°F	−5°	−21°	−36°	−39°	−44°
−10°F	−15°	−33°	−45°	−53°	−59°
−20°F	−26°	−46°	−58°	−67°	−74°
−30°F	−36°	−58°	−72°	−82°	−87°

The chart shows wind chill temperatures. The first column lists the actual air temperatures. The other columns show how air at that temperature feels when it is moving at a certain speed. For example, look at the third row. It shows wind chill temperatures when the actual air temperature is 30°F. When the air is moving 5 miles per hour, the air feels as if is 27°F. When the air is moving 25 miles per hour, the air feels as if it is 0°F. So, when you go outside, you should dress for the wind chill temperature, not the actual temperature.

Use the chart to answer these questions.

1. What is the wind chill temperature if the actual temperature is 20°F with a wind of 15 miles per hour?
2. If the wind is 25 miles per hour and the wind chill temperature is −44°F, what is the actual temperature?
3. What would you wear to go outside if the actual temperature was 40°F with a wind of 10 miles per hour? Why?

Critical Thinking

It is 50°F outside. The weather forecast calls for winds to increase from 5 miles per hour to 25 miles per hour. How would you explain to friends going outside that it will be colder than they think?

Chapter

23 Review

Summary

The Earth's atmosphere is divided into layers. It also has properties such as air pressure, winds, and clouds that affect our daily life.

Lesson 23.1

The atmosphere is a mixture of gases, including water vapor. The atmosphere has five layers.

Lesson 23.2

Air pressure is the weight of gases pressing down on the Earth. Warm air rises. Cold air sweeps in to fill the space. This sets up a convection current. Convection currents cause most winds. There are also local winds caused by the Earth's surface features.

Lesson 23.3

There is always some moisture in the air. Precipitation is any kind of moisture that falls to the ground. Rain, snow, hail, and sleet are forms of precipitation. Clouds are made of water droplets or ice.

Vocabulary Review

air pressure
atmosphere
barometer
dew point
humidity
precipitation
stratosphere
troposphere

Complete each sentence with a term from the list.

1. Water vapor turns to liquid water at the _____.
2. Ozone is a thin layer of gas found in the _____.
3. The weight of gases pressing down on the Earth is _____.
4. A _____ is used to measure air pressure.
5. Any water that falls from the air is _____.
6. Air that surrounds the Earth makes up the _____.
7. Water in the air is called _____.
8. We live in the layer of the atmosphere called the _____.

Chapter Quiz

Write your answers on a separate sheet of paper.

1. What are the layers of the atmosphere, starting from the nearest to the Earth?
2. What causes air pressure?
3. What happens when sunlight hits clouds?
4. How does uneven heating of the atmosphere cause winds?
5. What are three surface features that can cause local winds?
6. What kind of wind occurs when the warm air over land rises and the cold air over the ocean rushes in?
7. What happens to air cooled below the dew point?
8. How are sleet, snow, and hail different from each other?
9. What are the three main groups of clouds?
10. What kind of cloud is a thunderhead?

Test Tip
Review the pictures and captions in the chapter. Try explaining to a friend what each picture shows.

Research Project

The Beaufort scale is a scale of wind speed. Do research and write a report on the Beaufort scale. The report should describe the scale and explain how it is used. Use the Beaufort scale to estimate the wind speed near your home each day for a week. Include this information in your report.