CHAPTER 13 The Nature of Storms

BIG Idea The exchange of thermal energy in the atmosphere sometimes occurs with great violence that varies in form, size, and duration.

13.1 Thunderstorms
MAIN Idea The intensity and duration of thunderstorms depend on the local conditions that create them.

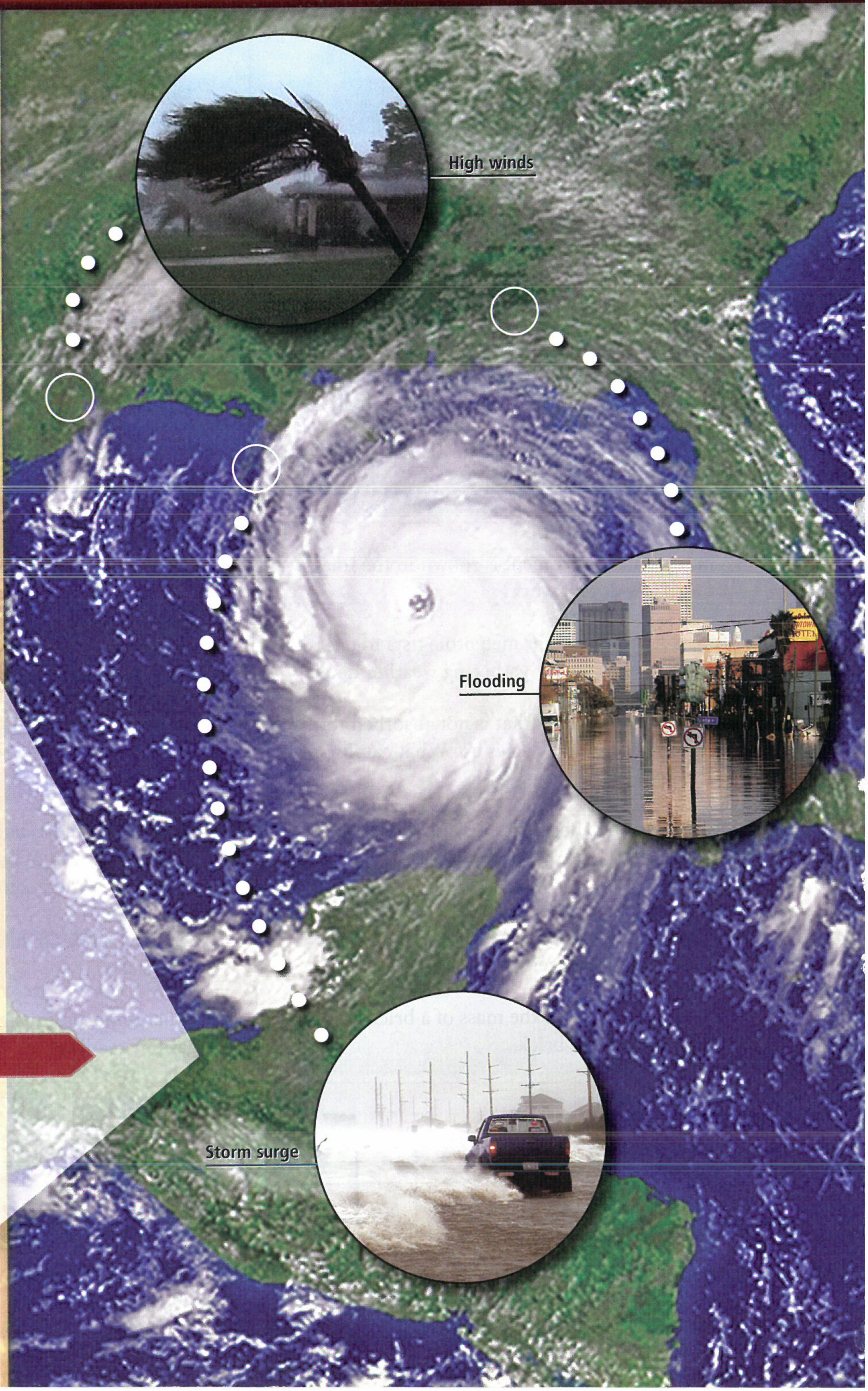
13.2 Severe Weather
MAIN Idea All thunderstorms produce wind, rain, and lightning, which can have dangerous and damaging effects under certain circumstances.

13.3 Tropical Storms
MAIN Idea Normally peaceful, tropical oceans are capable of producing one of Earth's most violent weather systems—the tropical cyclone.

13.4 Recurrent Weather
MAIN Idea Even a relatively mild weather system can become destructive and dangerous if it persists for long periods of time.

GeoFacts

- Hurricanes, tornadoes, and everyday thunderstorms follow the same life cycles.
- The largest hailstone measured was nearly 18 cm in diameter.
- An F5 tornado can pack winds that will flatten a building.



LAUNCH Lab

Why does lightning form?

You have probably felt the shock of static electricity when you scuff your feet on a rug and then touch a doorknob. Your feet pick up additional electrons, which are negatively charged. These electrons are attracted to the positively charged protons of the doorknob metal, causing a small electrical current to form. The current causes you to feel a small shock.

Procedure

1. Read and complete the safety lab form.
2. With a **paper punch,** create 10 **paper circles.**
3. Place the circles in two piles of 5 on your desk.
4. Blow up a small **balloon** and mark one side with an *X*.
5. Rub the *X* side of the balloon on some **fabric.**
6. Hold the *X* side of the balloon 2 cm above one pile of paper circles.
7. Turn the balloon over, opposite the *X*, and hold it 2 cm above the other pile of paper circles.

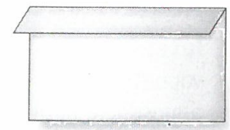
Analysis

1. **Describe** what happened to the paper circles.
2. **Explain** what happened when you rubbed the balloon on the fabric.
3. **Infer** how the static attracting the paper is similar to the static electricity you produced on a rug.
4. **Infer** what causes lightning to jump from spot to spot.

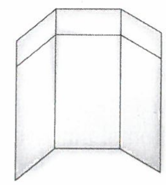
FOLDABLES™ Study Organizer

Thunderstorm Development Make the following Foldable to summarize the stages of thunderstorm development.

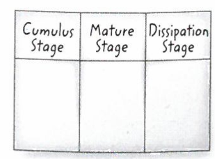
STEP 1 Make a 3-cm fold along the long side of a sheet of paper and crease.



STEP 2 Fold the sheet into thirds.



STEP 3 Unfold the paper and draw lines along the fold lines. Label the columns *Cumulus Stage, Mature Stage,* and *Dissipation Stage.*



FOLDABLES **Use this Foldable with Section 13.1.** As you read this section, diagram the air movement, and describe the conditions at each stage.

Earth Science Online

Visit glencoe.com to

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- explore Concepts In Motion animations:
  - Interactive Time Lines
  - Interactive Figures
  - Interactive Tables
- access Web Links for more information, projects, and activities;
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Section 13.1

Objectives

- **Identify** the processes that form thunderstorms.
- **Compare and contrast** different types of thunderstorms.
- **Describe** the life cycle of a thunderstorm.

Review Vocabulary

latent heat: stored energy in water vapor that is not released to warm the atmosphere until condensation occurs

New Vocabulary

air-mass thunderstorm
mountain thunderstorm
sea-breeze thunderstorm
frontal thunderstorm
stepped leader
return stroke

Thunderstorms

MAIN Idea The intensity and duration of thunderstorms depend on the local conditions that create them.

Real-World Reading Link Think about how an engine processes fuel to produce energy that powers an automobile. Thunderstorms are atmospheric engines that use heat and moisture as fuel and expend their energy in the form of clouds, rain, lightning, and wind.

Overview of Thunderstorms

At any given moment, nearly 2000 thunderstorms are in progress around the world. Most do little more than provide welcome relief on a muggy summer afternoon, or provide a spectacle of lightning. Some, however, grow into atmospheric monsters capable of producing hail the size of baseballs, swirling tornadoes, and surface winds of more than 160 km/h. These severe thunderstorms can also provide the energy for nature's most destructive storms—hurricanes. These severe thunderstorms, regardless of intensity, have certain characteristics in common. **Figure 13.1** shows which areas of the United States experience the most thunderstorms annually.

How thunderstorms form In Chapter 11, you read that the stability of the air is determined by whether or not an air mass can lift. Cooling air masses are stable and those that receive warming from the land or water below them are not. Under the right conditions, convection can cause a cumulus cloud to grow into a cumulonimbus cloud. The conditions that produce cumulonimbus clouds are the same conditions that produce thunderstorms. For a thunderstorm to form, three conditions must exist: a source of moisture, lifting of the air mass, and an unstable atmosphere.

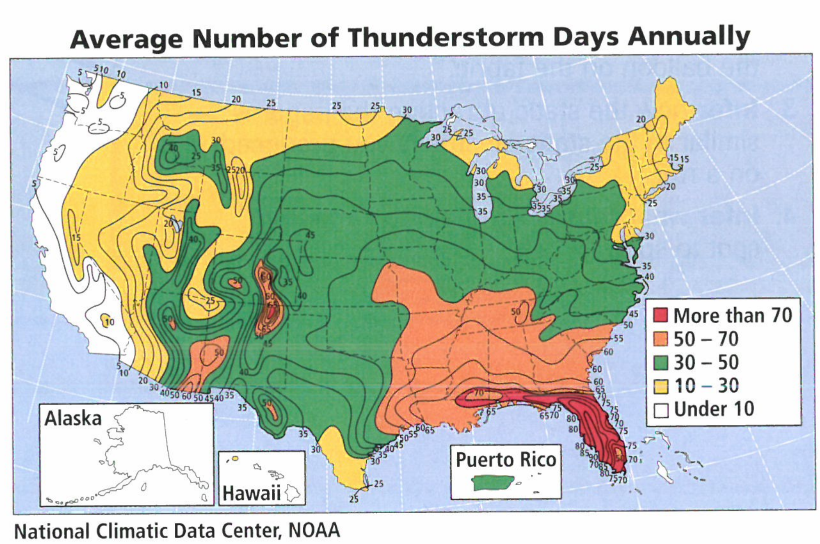


Figure 13.1 Both geography and air mass movements make thunderstorms most common in the southeastern United States.
Predict *why the Pacific Coast has so few thunderstorms and Florida has so many.*

Figure 13.2 This cumulus cloud is growing as a result of unstable conditions. As the cloud continues to develop into a cumulonimbus cloud, a thunderstorm might develop.

Moisture First, for a thunderstorm to form, there must be an abundant source of moisture in the lower levels of the atmosphere. Air masses that form over tropical oceans or large lakes become more humid from water evaporating from the surface below. This humid air is less dense than the surrounding dry air and is lifted. The water vapor it contains condenses into the droplets that constitute clouds. Latent heat, which is released from the water vapor during the process of condensation, warms the air causing it to rise further, cool further, and condense more of its water vapor.

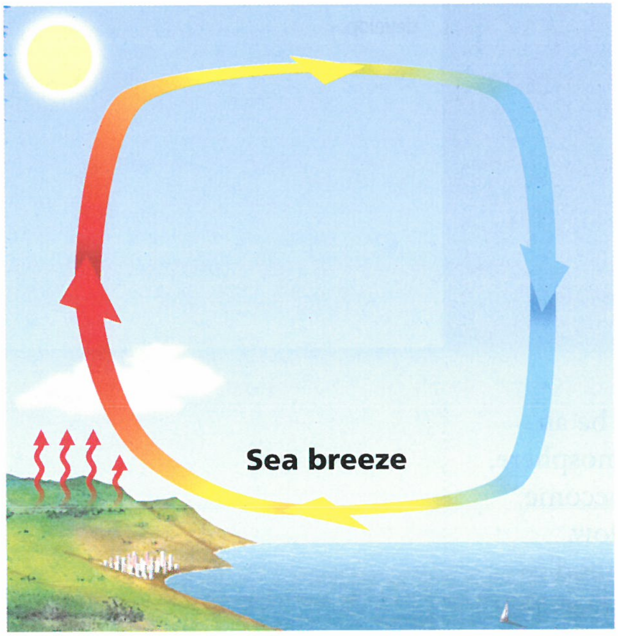
Lifting Second, there must be some mechanism for condensing moisture to release its latent heat. This occurs when a warm air mass is lifted into a cooler region of the atmosphere. Dense, cold air along a cold front can push warmer air upward, just like an air mass does when moving up a mountainside. Warm land areas, heat islands such as cities, and bodies of water can also provide heat for lifting an air mass. Only when the water vapor condenses can it release latent heat and keep the cloud rising.

Stability Third, if the surrounding air remains cooler than the rising air mass, the unstable conditions can produce clouds that grow upward. This releases more latent heat and allows continued lifting. However, when the density of the rising air mass and the surrounding air are nearly the same, the cloud stops growing. **Figure 13.2** shows a cumulus cloud that is on its way to becoming a cumulonimbus cloud that can produce thunderstorms.

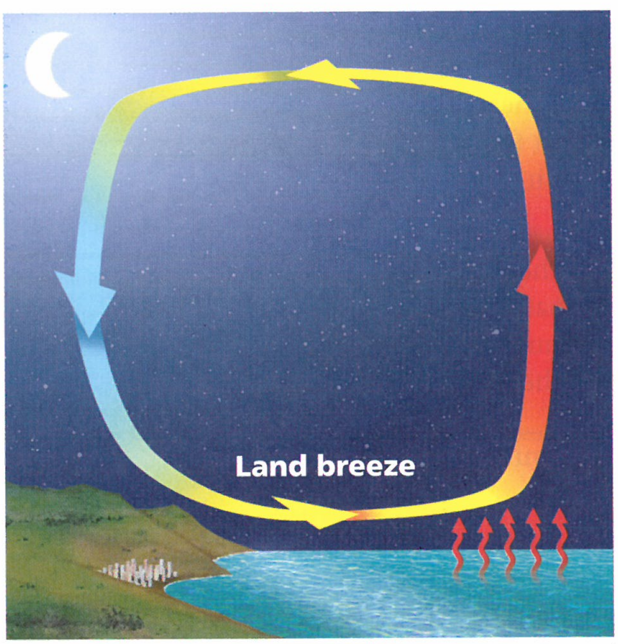
Reading Check **Describe** the three conditions for thunderstorm growth.

Limits to thunderstorm growth The conditions that limit thunderstorm growth are the same ones that form the storm. Conditions that create lift, condense water vapor, and release latent heat keep the air mass warmer than the surrounding air. The air mass will continue to rise until it reaches a layer of equal density that it cannot overcome. Because atmospheric stability increases with height, most cumulonimbus clouds are limited to about 12,000 m. Thunderstorms are also limited by duration and size.

Figure 13.3 Temperature differences exist over land and water and vary with the time of day.
Infer *why water is warmer than the land at night.*



During the day, the temperature of land increases faster than the temperature of water. The warm air over land expands and rises, and the colder air over the sea moves inland and replaces the warm air. These conditions can produce strong updrafts that result in thunderstorms.



At night, conditions are reversed. The land cools faster than water, so the warmer sea air rises, and cooler air from above land moves over the water and replaces it. Nighttime conditions are considered stable.

Types of Thunderstorms

Thunderstorms are often classified according to the mechanism that causes the air mass that formed them to rise. There are two main types of thunderstorms: air-mass and frontal.

Air-mass thunderstorms When air rises because of unequal heating of Earth's surface within one air mass, the thunderstorm is called an **air-mass thunderstorm.** The unequal heating of Earth's surface reaches its maximum during mid-afternoon, so it is common for air-mass thunderstorms, also called pop-up storms, to occur.

There are two kinds of air-mass thunderstorms. **Mountain thunderstorms** occur when an air mass rises by orographic lifting, which involves air moving up the side of a mountain. **Sea-breeze thunderstorms** are local air-mass thunderstorms that occur because land and water store and release thermal energy differently. Sea-breeze thunderstorms are common along coastal areas during the summer, especially in the tropics and subtropics. Because land heats and cools faster than water, temperature differences can develop between the air over coastal land and the air over water, as shown in **Figure 13.3.**

Frontal thunderstorms The second main type is **frontal thunderstorms,** which are produced by advancing cold fronts and, more rarely, warm fronts. In a cold front, dense, cold air pushes under warm air, which is less dense, rapidly lifting it up a steep cold-front boundary. This rapid upward motion can produce a thin line of thunderstorms, sometimes hundreds of kilometers long, along the leading edge of the cold front. Cold-front thunderstorms get their initial lift from the push of the cold air. Because they are not dependent on daytime heating for their initial lift, cold-front thunderstorms can persist long into the night. Flooding from soil saturation is common with these storms. Floods are the main cause of thunderstorm-related deaths in the United States each year.

Less frequently, thunderstorms can develop along the advancing edge of a warm front. In a warm-front storm, a warm air mass slides up and over a gently sloping cold air mass. If the warm air behind the warm front is unstable and moisture levels are sufficiently high, a relatively mild thunderstorm can develop.

Thunderstorm Development

A thunderstorm usually has three stages: the cumulus stage, the mature stage, and the dissipation stage. The stages are classified according to the direction the air is moving.

Cumulus stage In the cumulus stage, air starts to rise vertically, as shown in **Figure 13.4.** The updrafts are relatively localized and cover an area of about 5–8 km. This creates updrafts, which transport water vapor to the cooler, upper regions of the cloud. The water vapor condenses into visible cloud droplets and releases latent heat. As the cloud droplets coalesce, they become larger and heavier until the updrafts can no longer sustain them and they fall to Earth as precipitation. This begins the mature stage of a thunderstorm.

Mature stage In the mature stage, updrafts and downdrafts exist side by side in the cumulonimbus cloud. Precipitation, composed of water and ice droplets that formed at high, cool levels of the atmosphere, cools the air as it falls. The newly cooled air is more dense than the surrounding air, so it sinks rapidly to the ground along with the precipitation. This creates downdrafts. As **Figure 13.4** shows, the updrafts and downdrafts form a convection cell which produces the surface winds associated with thunderstorms. The average area covered by a thunderstorm in its mature stage is 8–15 km.

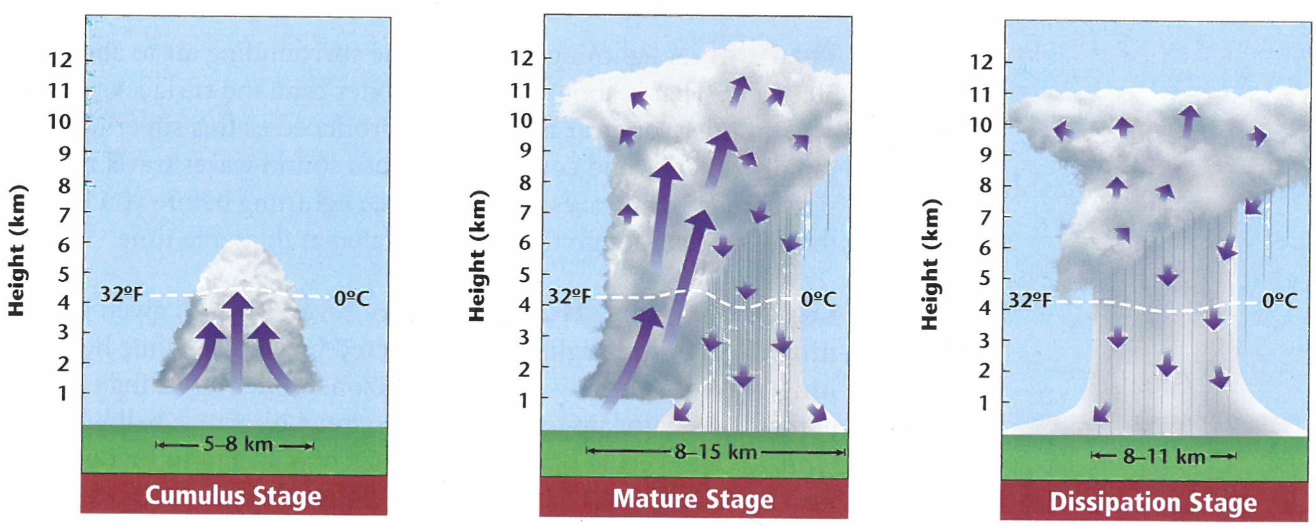
Dissipation stage The convection cell can exist only if there is a steady supply of warm, moist air at Earth's surface. Once that supply is depleted, the updrafts slow down and eventually stop. In a thunderstorm, the cool downdrafts spread in all directions when they reach Earth's surface. This cools the areas from which the storm draws its energy, the updrafts cease, and clouds can no longer form. The storm is then in the dissipation stage shown in **Figure 13.4.** This stage will last until all of the previously formed precipitation has fallen.

FOLDABLES Incorporate information from this section into your Foldable.

Concepts In Motion

Interactive Figure To see an animation of thunderstorm development, visit glencoe.com.

■ **Figure 13.4** The cumulus stage of a thunderstorm is characterized mainly by updrafts. The mature stage is characterized by strong updrafts and downdrafts. The storm loses energy in the dissipation stage.



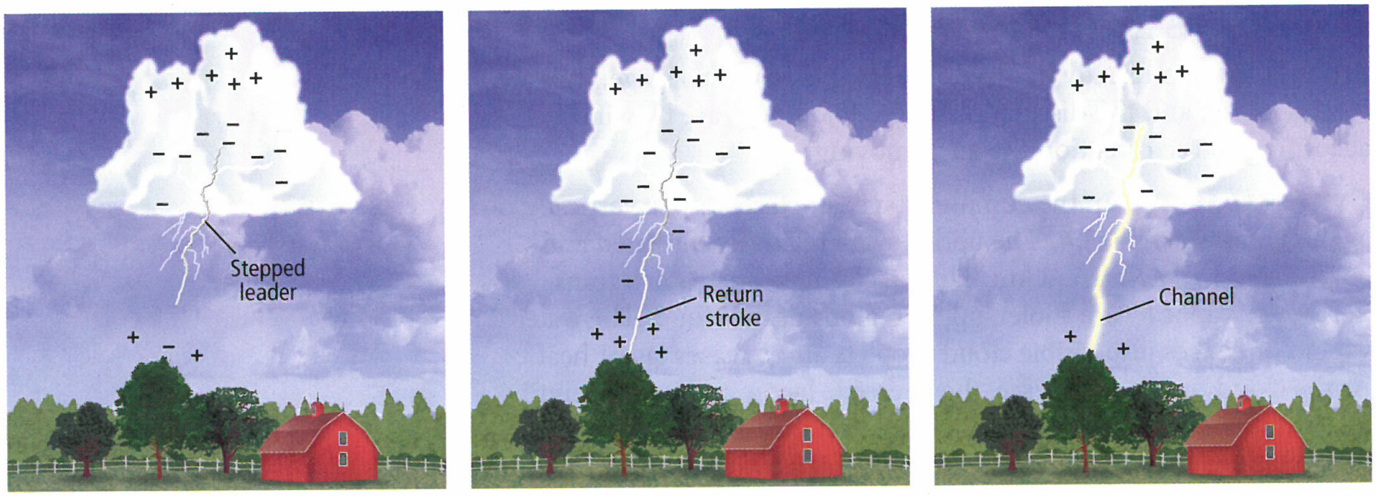


Figure 13.5 When a stepped leader nears an object on the ground, a powerful surge of electricity from the ground moves upward to the cloud and lightning is produced.
Sequence ***Make an outline sequencing the steps of lightning formation.***

Lightning

Have you ever touched a metal object on a dry winter day and been zapped by a spark from static electricity? The static electricity was generated from friction, and the spark is similar to lightning. Lightning is the transfer of electricity generated by the rapid rushes of air in a cumulonimbus cloud. Clouds become charged when friction between the updrafts and downdrafts removes electrons from some of the atoms in the cloud. The atoms that lose electrons become positively charged ions. Other atoms receive the extra electrons and become negatively charged ions. As **Figure 13.5** shows, this creates regions of air with opposite charges. Eventually, the differences in charges break down, and a branched channel of partially charged air is formed between the positive and negative regions. The channel of partially charged air is called a **stepped leader,** and it generally moves from the center of the cloud toward the ground. When the stepped leader nears the ground, a branched channel of positively charged particles, called the **return stroke,** rushes upward to meet it. The return stroke surges from the ground to the cloud, illuminating the connecting channel with about 100 million volts of electricity. That illumination is the brightest part of lightning.

Thunder A lightning bolt heats the surrounding air to about 30,000°C. That is about five times hotter than the surface of the Sun. The thunder you hear is the sound produced as this superheated air rapidly expands and contracts. Because sound waves travel more slowly than light waves, you might see lightning before you hear thunder, even though they are generated at the same time.

Lightning variations There are several names given to lightning effects. Sheet lightning is reflected by clouds, while heat lightning is sheet lightning near the horizon. Spider lightning can crawl across the sky for up to 150 km. The most bizarre is ball lightning which is a hovering ball about the size of a pumpkin that disappears in a fizzle or a bang. Blue jets and red sprites originate in clouds and rise rapidly toward the stratosphere as cones or bursts.