Pressure centers are among the most common features on any weather map. By knowing just a few basic facts about centers of high and low pressure, you can increase your understanding of present and forthcoming weather. You can make some weather generalizations based on pressure centers. For example, centers of low pressure are frequently associated with cloudy conditions and precipitation. By contrast, clear skies and fair weather may be expected when an area is under the influence of high pressure, as shown in Figure 6.

Key Concepts
- Describe how winds blow around pressure centers in the Northern and Southern Hemispheres.
- What are the air pressure patterns within cyclones and anticyclones?
- How does friction control net flow of air around a cyclone and an anticyclone?
- How does the atmosphere attempt to balance the unequal heating of Earth’s surface?

Vocabulary
- cyclone
- anticyclone
- trade winds
- westerlies
- polar easterlies
- polar front
- monsoon

Reading Strategy
Comparing and Contrasting
Copy the table below. As you read about pressure centers and winds, fill in the table indicating to which hemisphere the concept applies. Use N for Northern Hemisphere, S for Southern Hemisphere, and B for both.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Hemispheres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclones rotate counter-clockwise</td>
<td>?</td>
</tr>
<tr>
<td>Net flow of air is inward around a cyclone</td>
<td>?</td>
</tr>
<tr>
<td>Anticyclones rotate counter-clockwise</td>
<td>?</td>
</tr>
<tr>
<td>Coriolis effect deflects winds to the right</td>
<td>?</td>
</tr>
</tbody>
</table>

Figure 6 These sunbathers at Cape Henlopen, Delaware, are enjoying weather associated with a high-pressure center.

Highs and Lows
Lows, or cyclones (kyklon = moving in a circle) are centers of low pressure. Highs, or anticyclones, are centers of high pressure. In cyclones, the pressure decreases from the outer isobars toward the center. In anticyclones, just the opposite is the case—the values of the isobars increase from the outside toward the center.

Section Objectives
19.5 Explain how winds blow around pressure centers in the Northern and Southern Hemispheres.
19.6 Describe the air pressure patterns within cyclones and anticyclones.
19.7 Describe how friction controls the net flow of air around a cyclone and an anticyclone.
19.8 Explain how the unequal heating of Earth’s surface affects the atmosphere.

Build Vocabulary
- Concept Map Have students make a concept map using the term global winds as the starting point. All the vocabulary terms in this section except cyclone and anticyclone should be used. Have students include the definitions of the vocabulary terms in their concept maps.

Reading Focus
- a. N
- b. B
- c. S
- d. N

2 INSTRUCT

Highs and Lows
Use Models Have students use a globe to review and demonstrate the Coriolis effect. One student can rotate the globe while the other uses a pointer to show a flow of air moving straight down from a pole to the equator. Students can also use the model to compare the direction in which airflow is deflected in the Northern and Southern Hemispheres.

Ask: Seen from Earth’s orbit, what is the relationship between Earth’s surface and the line along which the air is flowing? (Earth rotates beneath the line of airflow.) Seen from Earth’s surface, what appears to be happening? (Earth’s rotation makes it appear that the airflow is deflected to one side—to the right in the Northern Hemisphere, to the left in the Southern Hemisphere.)

Visual, Verbal

Air Pressure and Wind 537
Cyclonic and Anticyclonic Winds  You learned that the two most significant factors that affect wind are the pressure gradient and the Coriolis effect. Winds move from higher pressure to lower pressure and are deflected to the right or left by Earth’s rotation. When the pressure gradient and the Coriolis effect are applied to pressure centers in the Northern Hemisphere, winds blow counterclockwise around a low. Around a high, they blow clockwise. Notice the wind directions in Figure 7.

In the Southern Hemisphere, the Coriolis effect deflects the winds to the left. Therefore, winds around a low move clockwise. Winds around a high move counterclockwise. In either hemisphere, friction causes a net flow of air inward around a cyclone and a net flow of air outward around an anticyclone.

Weather and Air Pressure  Rising air is associated with cloud formation and precipitation, whereas sinking air produces clear skies. Imagine a surface low-pressure system where the air is spiraling inward. Here the net inward movement of air causes the area occupied by the air mass to shrink—a process called horizontal convergence. Whenever air converges (or comes together) horizontally, it must increase in height to allow for the decreased area it now occupies. This increase in height produces a taller and heavier air column. A surface low can exist only as long as the column of air above it exerts less pressure than does the air in surrounding regions. This seems to be a paradox—a low-pressure center causes a net accumulation of air, which increases its pressure.

With what type of weather is rising air associated?

Customize for Inclusion Students

Visually Impaired  Help visually impaired students compare cyclones and anticyclones by using their hands to model the motions of these phenomena. Explain that, in the Northern Hemisphere, cyclonic winds blow inward and counterclockwise around a low-pressure center. Have students use one hand to represent Earth’s surface. This hand remains stationary. They can use the other hand to make the counterclockwise, inward motion of a cyclonic wind. Then have students use the same hand to make the clockwise, outward motion of an anticyclonic wind in the Northern Hemisphere.
In order for a surface low to exist for very long, converging air at the surface must be balanced by outflows aloft. For example, surface convergence could be maintained if divergence, or the spreading out of air, occurred above the low at a rate equal to the inflow below. Figure 8 shows the relationship between surface convergence (inflow) and divergence (outflow) needed to maintain a low-pressure center. Surface convergence around a cyclone causes a net upward movement. Because rising air often results in cloud formation and precipitation, a low-pressure center is generally related to unstable conditions and stormy weather.

Like cyclones, anticyclones also must be maintained from above. Outflow near the surface is accompanied by convergence in the air above and a general sinking of the air column, as shown in Figure 8.

**Weather Forecasting** Now you can see why weather reports emphasize the locations and possible paths of cyclones and anticyclones. The villain in these reports is always the low-pressure center, which can produce bad weather in any season. Lows move in roughly a west-to-east direction across the United States, and they require a few days, and sometimes more than a week, for the journey. Their paths can be somewhat unpredictable, making accurate estimation of their movement difficult. Because surface conditions are linked to the conditions of the air above, it is important to understand total atmospheric circulation.

**Facts and Figures**

Accurate forecasts require that meteorologists not only predict the movement of low-pressure centers, but also determine if the airflow aloft will intensify an embryo storm or act to suppress its development. Surface cyclones would quickly eradicate themselves—not unlike the incoming rush of air that occurs when a vacuum-packed can is opened—without divergence in the air above. As a result, meteorologists must base their forecasts on data from upper and lower atmospheric conditions. Because of the close relationship between conditions at the surface and aloft, understanding of total atmospheric circulation, particularly in the mid-latitudes, is very important.
Global Winds

The underlying cause of wind is the unequal heating of Earth’s surface. In tropical regions, more solar radiation is received than is radiated back to space. In regions near the poles the opposite is true—less solar energy is received than is lost. The atmosphere balances these differences by acting as a giant heat-transfer system. This system moves warm air toward high latitudes and cool air toward the equator. On a smaller scale, but for the same reason, ocean currents also contribute to this global heat transfer. Global circulation is very complex, but you can begin to understand it by first thinking about circulation that would occur on a non-rotating Earth.

Non-Rotating Earth Model

On a hypothetical non-rotating planet with a smooth surface of either all land or all water, two large thermally produced cells would form, as shown in Figure 9. The heated air at the equator would rise until it reached the tropopause—the boundary between the troposphere and the stratosphere. The tropopause, acting like a lid, would deflect this air toward the poles. Eventually, the upper-level airflow would reach the poles, sink, spread out in all directions at the surface, and move back toward the equator. Once at the equator, it would be reheated and begin its journey over again. This hypothetical circulation system has upper-level air flowing toward the pole and surface air flowing toward the equator.

Rotating Earth Model

If the effect of rotation were added to the global circulation model, the two-cell convection system would break down into smaller cells. Figure 10 illustrates the three pairs of cells that would carry on the task of redistributing heat on Earth. The polar and tropical cells retain the characteristics of the thermally generated convection described earlier. The nature of circulation at the middle latitudes, however, is more complex.

Near the equator, rising air produces a pressure zone known as the equatorial low—a region characterized by abundant precipitation. As shown in Figure 10, the upper-level flow from the equatorial low reaches 20 to 30 degrees, north or south latitude, and then sinks back toward the surface. This sinking of air and its associated heating due to cooling results in the formation of a high-pressure region, or cell, that then moves back toward the equator.

Facts and Figures

George Hadley, an English meteorologist of the eighteenth century, first proposed the simple convection system pictured in Figure 9. Because Earth rotates, however, meteorologists had to develop a more complex global circulation model. This model is pictured in Figure 10 and has three cells on each side of the equator. The Hadley cells, named after George Hadley and also called tropical cells, are shown north and south of the equator. The next cell, which is unlabeled on the diagram, is the mid-latitude cell. It is also called a Ferrel cell after William Ferrel, a nineteenth century American meteorologist who helped explain atmospheric circulation at mid-latitudes. The third type of cell, also unlabeled, is the polar cell.
to compression produce hot, arid conditions. The center of this zone of sinking dry air is the subtropical high, which encircles the globe near 30 degrees north and south latitude. The great deserts of Australia, Arabia, and the Sahara in North Africa exist because of the stable dry conditions associated with the subtropical highs.

At the surface, airflow moves outward from the center of the subtropical high. Some of the air travels toward the equator and is deflected by the Coriolis effect, producing the trade winds. Trade winds are two belts of winds that blow almost constantly from easterly directions. The trade winds are located between the subtropical highs and the equator.

The remainder of the air travels toward the poles and is deflected, generating the prevailing westerlies of the middle latitudes. The westerlies make up the dominant west-to-east motion of the atmosphere that characterizes the regions on the poleward side of the subtropical highs. As the westerlies move toward the poles, they encounter the cool polar easterlies in the region of the subpolar low. These winds are not constant winds like the trade winds. The polar easterlies are winds that blow from the polar high toward the subpolar low. These winds are not constant winds like the trade winds. In the polar region, cold polar air sinks and spreads toward the equator. The interaction of these warm and cool air masses produces the stormy belt known as the polar front.

This simplified global circulation is dominated by four pressure zones. The subtropical and polar highs are areas of dry subsiding (sinking) air that flows outward at the surface, producing the prevailing winds. The low-pressure zones of the equatorial and subpolar regions are associated with inward and upward airflow accompanied by clouds and precipitation.

What is the polar front?

Use Visuals

**Figure 10** After students have read Rotating Earth Model and examined the illustration, ask: What happens to warm equatorial air that has risen into the upper atmosphere? (It moves toward the poles until it reaches latitudes of 20 or 30 degrees, then sinks downward.) What kind of weather is characteristic of regions around 20 to 30 degrees latitude? (dry, hot) What factor is primarily responsible for the trade winds? (Coriolis effect) What factors create the polar front? (meeting of the warmer, subpolar westerlies with the colder polar easterlies) What kind of weather is characteristic of the polar front? (stormy)

Visual, Logical

**Address Misconceptions**

Students may think that heat is “lost” from air as it sinks toward Earth’s surface in a high-pressure center. Explain to students that the term adiabatic refers to the cooling or warming of air caused when air is allowed to expand or is compressed, not because heat is added to or subtracted from the system. In other words, no heat enters or leaves the system. Compression of air as it sinks creates adiabatic heating. Expansion of air as it rises creates adiabatic cooling. The air continues to cool as it rises until it reaches its dew point. Then condensation takes place and clouds begin to form. Ask: How does adiabatic cooling help explain why precipitation is associated with low-pressure centers but not high-pressure centers? (Rising air in a low-pressure center becomes cool enough for condensation. Sinking air in a high-pressure system is heated adiabatically, preventing condensation.)

Verbal
Section 19.2 (continued)

Build Science Skills

Applying Concepts Use a world map to help students visualize the movement of monsoons in south Asia. Have them picture a high-pressure system above the land that pushes air out to sea. Then have them picture how heat from the land during summer causes air to rise, producing a low-pressure system that pulls in moist air from the ocean.

Visual, Logical

3 ASSESS

Evaluate Understanding

Have students write a paragraph comparing and contrasting cyclonic and anticyclonic winds. Have students write a second paragraph explaining how each of the following global winds is formed: trade winds, westerlies, and polar easterlies.

Reteach

Draw a globe on the board or use a laminated world map. On the map, draw in each type of global wind while explaining its formation to students. Use Figure 10 as a reference.

Math Practice

Solutions

8. 992 (−) to 1020 (+) millibars. In other words, the map includes pressures a bit less than 992 millibars and a bit more than 1020 millibars. Isobar interval equals 4 millibars.

Influence of Continents

The only truly continuous pressure belt is the subpolar low in the Southern Hemisphere. Here the ocean is uninterrupted by landmasses. At other latitudes, particularly in the Northern Hemisphere where landmasses break up the ocean surface, large seasonal temperature differences disrupt the pressure pattern. Large landmasses, particularly Asia, become cold in the winter when a seasonal high-pressure system develops. From this high-pressure system, surface airflow is directed off the land. In the summer, landmasses are heated and develop low-pressure cells, which permit air to flow onto the land as shown in Figure 11. These seasonal changes in wind direction are known as the monsoons. During warm months, areas such as India experience a flow of warm, water-laden air from the Indian Ocean, which produces the rainy summer monsoon. The winter monsoon is dominated by dry continental air. A similar situation exists to a lesser extent over North America.

Section 19.2 Assessment

Reviewing Concepts

1. Describe how winds blow around pressure centers in the Northern Hemisphere.
2. Compare the air pressure for a cyclone with an anticyclone.
3. How does friction control the net flow of air around a cyclone and an anticyclone?
4. Describe how the atmosphere balances the unequal heating of Earth’s surface.
5. What is the only truly continuous pressure belt? Why is it continuous?
6. In general, what type of weather can you expect if a low-pressure system is moving into your area?

Critical Thinking

7. Identifying Cause and Effect What must happen in the air above for divergence at the surface to be maintained? What type of pressure center accompanies surface divergence?

8. Examine Figure 7. What is the approximate range of barometric pressure indicated by the isobars on the map? What is the pressure interval between adjacent isobars?