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Objectives

- **Describe** how wind patterns, the rotation of Earth, and continental barriers affect surface currents in the ocean.
- **Identify** the major factor that determines the direction in which a surface current circulates.
- **Explain** how differences in the density of ocean water affect the flow of deep currents.

Ocean Currents

current in geology, a horizontal movement of water in a well-defined pattern, such as a river or stream

- Oceanographers identify ocean currents by studying the physical and chemical characteristics of the ocean water.
- Scientists place ocean currents into two major categories: surface currents and deep currents.

Factors That Affect Surface Currents

surface current a horizontal movement of ocean water that is caused by wind and that occurs at or near the ocean's surface

- Surface currents are controlled by three factors: air currents, Earth's rotation, and the location of the continents.
- Because *wind* is moving air, wind has kinetic energy.
- As energy is transferred from the air to the ocean, the water at the ocean's surface begins to move.

Factors That Affect Surface Currents, *continued*

Global Wind Belts

- Global wind belts, such as the trade winds and westerlies, are a major factor affecting the flow of ocean surface water.
- In both hemispheres, trade-wind belts push currents westward across the tropical latitudes of all three major oceans.
- Westerlies push ocean currents eastward in the higher latitudes of the Northern and Southern Hemispheres.

Factors That Affect Surface Currents, *continued*

Continental Barriers

- The continents are another major influence on surface currents.
- The continents act as barriers to surface currents.
- When a surface current flows against a continent, the current is deflected and divided.

End Of Slide

Factors That Affect Surface Currents, *continued*

The Coriolis Effect

Coriolis effect the apparent curving of the path of a moving object from an otherwise straight path due to Earth's rotation

- Wind belts and ocean currents follow a curved or circular pattern that is caused by Earth's rotation.

Factors That Affect Surface Currents, *continued*

The Coriolis Effect, *continued*

gyre a huge circle of moving ocean water found above and below the equator

- Wind belts and the Coriolis effect cause huge circles of moving water, called gyres, to form.
- In the Northern Hemisphere, water flow in gyres is to the right, or clockwise. In the Southern Hemisphere, the flow is to the left, or counterclockwise.

Major Surface Currents

Equatorial Currents

- Warm equatorial currents are located in the Atlantic, Pacific, and Indian Oceans.
- Each of these oceans has two warm-water equatorial currents that move in a westward direction.
- Between these westward-flowing currents lies a weaker, eastward-flowing current called the *Equatorial Countercurrent.*

Major Surface Currents, *continued*

Currents in the Southern Hemisphere

- In the most southerly regions of the oceans, constant westward winds produce the world's largest current, the *Antarctic Circumpolar Current*, also known as *West Wind Drift*.
- No continents interrupt the movement of this current that completely circles Antarctica and crosses all three major oceans.

End Of Slide

Reading Check

What is the world's largest ocean current?

End Of Slide

Reading Check

What is the world's largest ocean current?

Because no continents interrupt the flow of the Antarctic Circumpolar Current, also called the *West Wind Drift*, it completely encircles Antarctica and crosses three major oceans. All other surface currents are deflected and divided when they meet a continental barrier.

Major Surface Currents, *continued*

Currents in the North Atlantic

Gulf Stream the swift, deep, and warm Atlantic current that flows along the eastern coast of the United States toward the north

- South of Greenland, the Gulf Stream widens and slows until it becomes a vast, slow-moving warm current known as the *North Atlantic Current*.
- Near western Europe, the North Atlantic Current splits.

Major Surface Currents, *continued*

Currents in the North Atlantic, *continued*

- The Gulf Stream, the North Atlantic Current, the Canary Current, and the North Equatorial Current form the North Atlantic Gyre.

- At the center of this gyre lies a vast area of calm, warm water called the *Sargasso Sea*.

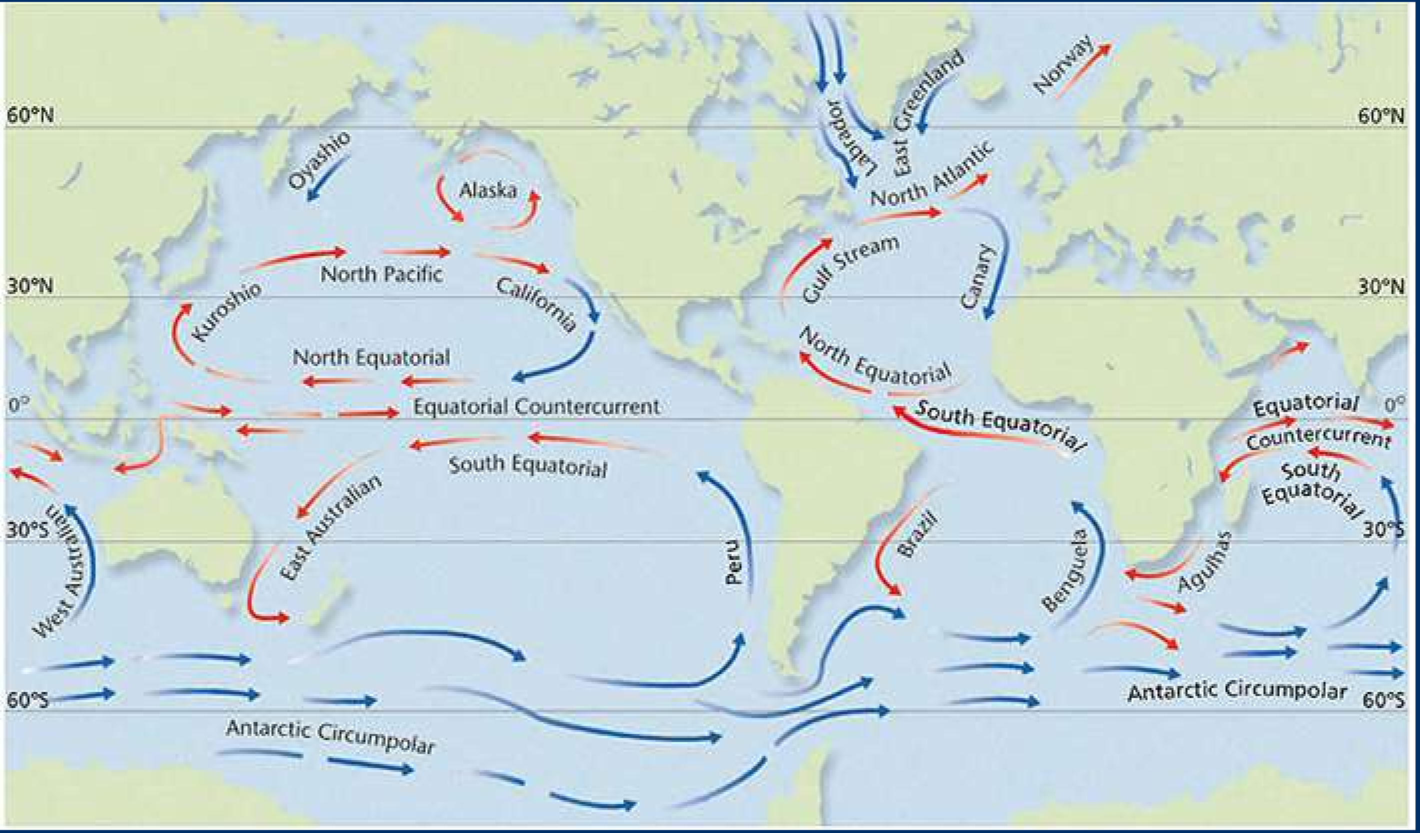
Major Surface Currents, *continued*

Currents in the North Pacific

- The patterns of currents in the North Pacific is similar to that in the North Atlantic.
- The warm Kuroshio Current, the Pacific equivalent of the Gulf Stream, flows northward along the east coast of Asia. This current then flows toward North America as the North Pacific Drift.
- It eventually flows southward along the California coast as the cool California Current.

Major Surface Currents, *continued*

The diagram below shows the major surface currents of Earth's oceans.



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Deep Currents

deep current a streamlike movement of ocean water far below the surface

- Deep currents form as cold, dense water of the polar regions sinks and flows beneath warmer ocean water.
- The movement of polar waters is a result of differences in density.
- Temperature determines density. Salinity, too, determines the density of water.

Deep Currents, *continued*

Antarctic Bottom Water

- The temperature of the water near Antarctica is very cold, –2°C. The water's salinity is high. These two factors make the water off the coast of Antarctica the densest and coldest ocean water in the world.
- This dense, cold water sinks to the ocean bottom and forms a deep current called the *Antarctic Bottom Water*.

Reading Check

Why is Antarctic Bottom Water the densest in the world?

End Of Slide

Reading Check

Why is Antarctic Bottom Water the densest in the world?

Antarctic Bottom Water is very cold. It also has a high salinity. The extreme cold and high salinity combine to make the water extremely dense.

Deep Currents, *continued*

North Atlantic Deep Water

- In the North Atlantic, south of Greenland, the water is very cold and has a high salinity. This cold, salty water forms a deep current that moves southward under the northward flowing Gulf Stream.

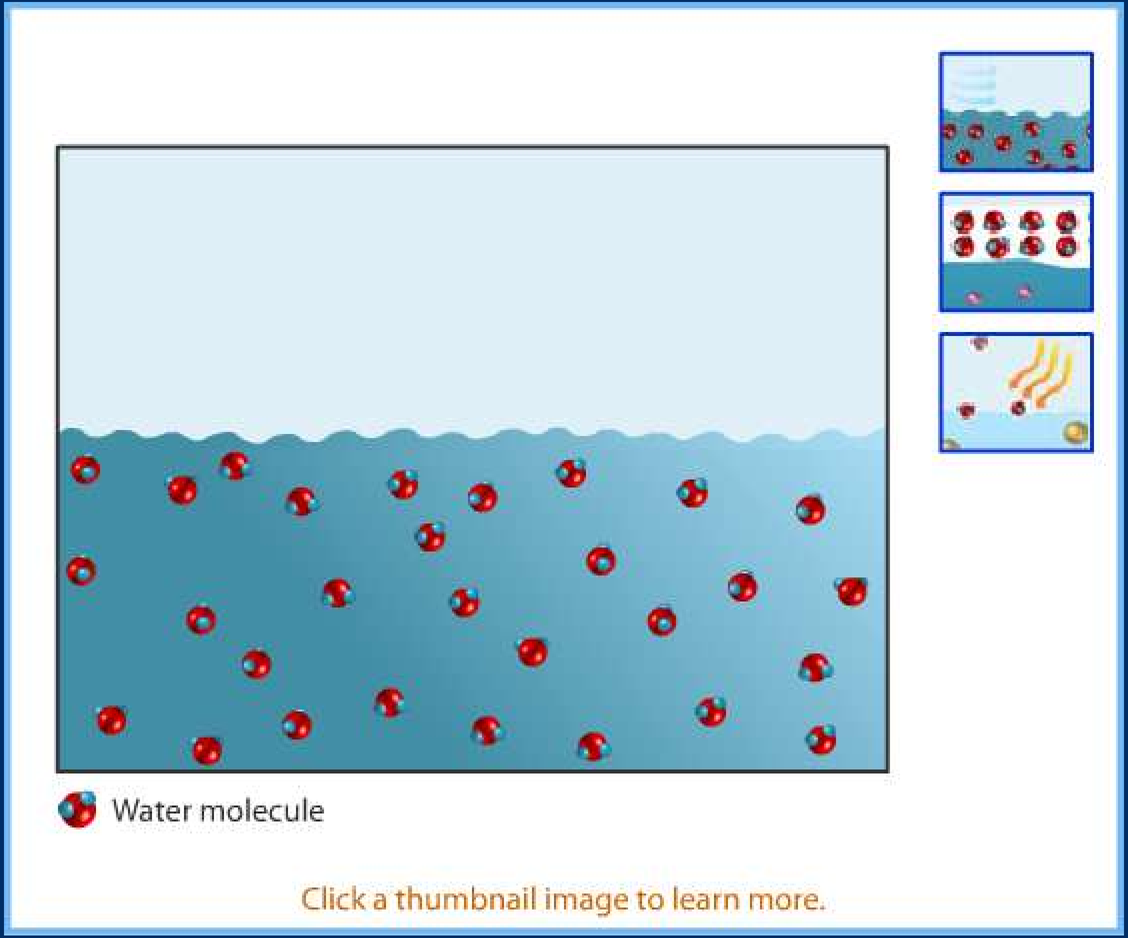
- The dense, highly saline water of the Mediterranean Sea forms a deep current as it flows through the strait of Gibraltar and into the less dense Atlantic Ocean.

Deep Currents, *continued*

Turbidity Currents

- A turbidity current is a strong current caused by an underwater landslide.
- The sediment causes the water to become cloudy, or turbid, and denser than the surrounding water.
- The dense water mass of the turbidity current moves beneath the less dense, clear water.

Formation of Deep Ocean Currents



Objectives

- **Describe** the formation of waves and the factors that affect wave size.
- **Explain** how waves interact with the coastline.
- **Identify** the cause of destructive ocean waves.

Ocean Waves

wave a periodic disturbance in a solid, liquid, or gas as energy is transmitted through a medium

- One kind of wave is described as the periodic up-and-down movement of water.
- Such a wave has two basic parts—a *crest* and a *trough*.
- The crest is the highest point of a wave. The trough is the lowest point between two crests.

Ocean Waves, *continued*

wave period the time required for two consecutive wave crests to pass a given point

- The *wave height* is the vertical distance between the crest and the trough of a wave.
- The *wavelength* is the horizontal distance between two consecutive crests or between two consecutive troughs.

$$\text{wave speed} = \frac{\text{wave length}}{\text{wave period}}$$

Wave Energy

- The longer that wind blows from a given direction, the more energy is transferred from wind to water and the larger the wave becomes.
- Because of their large surface area, larger waves receive more energy from the wind than smaller waves do.
- Thus, larger waves grow larger, and smaller waves die out.

End Of Slide

Wave Energy, *continued*

Water Movement in a Wave

- Although the energy of a wave moves from water molecule to water molecule in the direction of the wave, the water itself moves very little.

- As a wave moves across the surface of the ocean, only energy of the wave, not the water, moves in the direction of the wave.

Wave Energy, *continued*

Water Movement in a Wave, *continued*

- The water molecule within the wave move in a circular motion. During a single wave period, each water particle moves in one complete circle.
- As a wave passes a given point, the circle traced by a water particle on the ocean surface has a diameter that is equal to the height of the wave.

Wave Energy, *continued*

Water Movement in a Wave, *continued*

- Because waves receive their energy from wind pushing against the surface of the ocean, the energy received decreases as the depth of the water increases.
- Thus, the diameter of a water molecule's circular path decreases as water depth increases. Below a depth of about one-half the wavelength, there is almost no circular motion of water molecules.

Reading Check

Why does the diameter of a water molecule's circular path in a wave decrease as depth increases?

End Of Slide

Reading Check

Why does the diameter of a water molecule’s circular path in a wave decrease as depth increases?

Because waves receive energy from wind that pushes against the surface of the water, the amount of energy decreases as the depth of water increases. As a result, the diameter of the water molecules’ circular path also decreases.

Wave Energy, *continued*

Wave Size

fetch the distance that wind blows across an area of the sea to generate waves

- Three factors determine the size of a wave. These factors are the speed of the wind, the length of time the wind blows, and fetch.

- The size of a wave will increase to only a certain height-to-length ratio before the wave collapses.

Wave Energy, *continued*

Whitecaps

- When winds blow the crest of a wave off, *whitecaps* form.
- Because whitecaps reflect solar radiation, they allow less radiation to reach the ocean.
- Scientists have been studying how this characteristic may affect climate.

Waves and the Coastline

- In shallow water near the coastline, the bottom of a wave touches the ocean floor.

- A wave touches the ocean bottom where the depth of the water is about half the wavelength.

Waves and the Coastline, *continued*

Breakers

- The height of a wave changes as the wave approaches the coastline.
- As the wave moves into shallow water, the bottom of the wave is slowed by friction. The top of the wave, however, continues to move at its original speed.
- Finally, the top of the wave topples over and forms a *breaker,* a foamy mass of water that washes onto the coastline.

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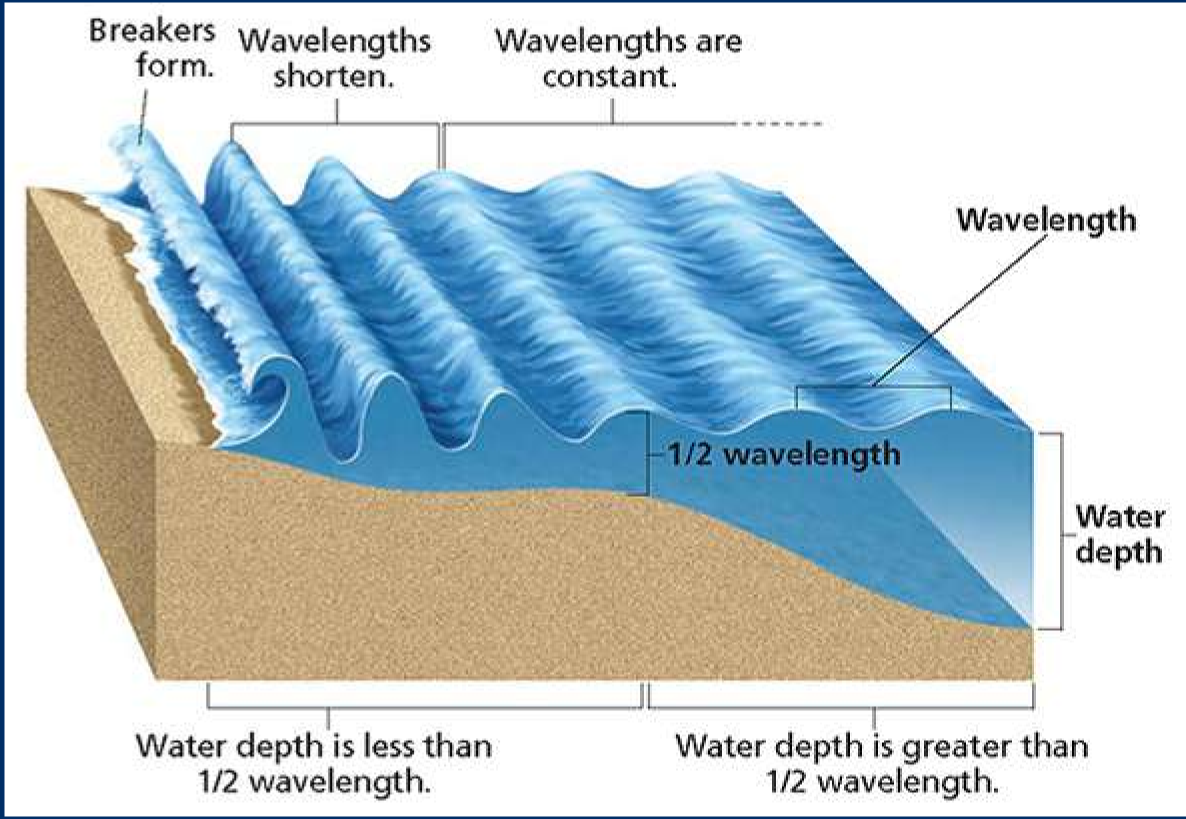
Waves and the Coastline, *continued*

The diagram below shows how breakers form.



Reading Check

As a wave moves into shallow water, what causes the top of the wave to break and topple over?

Reading Check

As a wave moves into shallow water, what causes the top of the wave to break and topple over?

Contact with the ocean floor causes friction, which slows down the bottom of the wave but not the top of the wave. Because of the difference in speed between the top and bottom of the wave, the top gets farther ahead of the bottom until the wave becomes unstable and falls over.

Waves and the Coastline, *continued*

Refraction

refraction the process by which ocean waves bend directly toward the coastline as they approach shallow water, the part of the wave that is traveling in shallow water travels more slowly than the part of the wave that is still advancing in deeper water.

- The wave gradually bends toward the beach and strikes the shore head-on.

Waves and the Coastline, *continued*

Undertows and Rip Currents

- Water carried onto a beach by breaking waves is pulled back into deeper water by gravity. This motion forms an irregular current called an *undertow.*
- The generally weak undertow is often confused with the more dangerous *rip current*.
- Rip currents form when water from larger breakers returns to the ocean through channels that cut through underwater sandbars that are parallel to the beach.

Waves and the Coastline, *continued*

Longshore Currents

- *Longshore currents* form when waves approach the beach at an angle.
- Longshore currents flow parallel to the shore. Great quantities of sand are carried by longshore currents.
- These sand deposits form low ridges of sand called *sandbars*.

Tsunamis

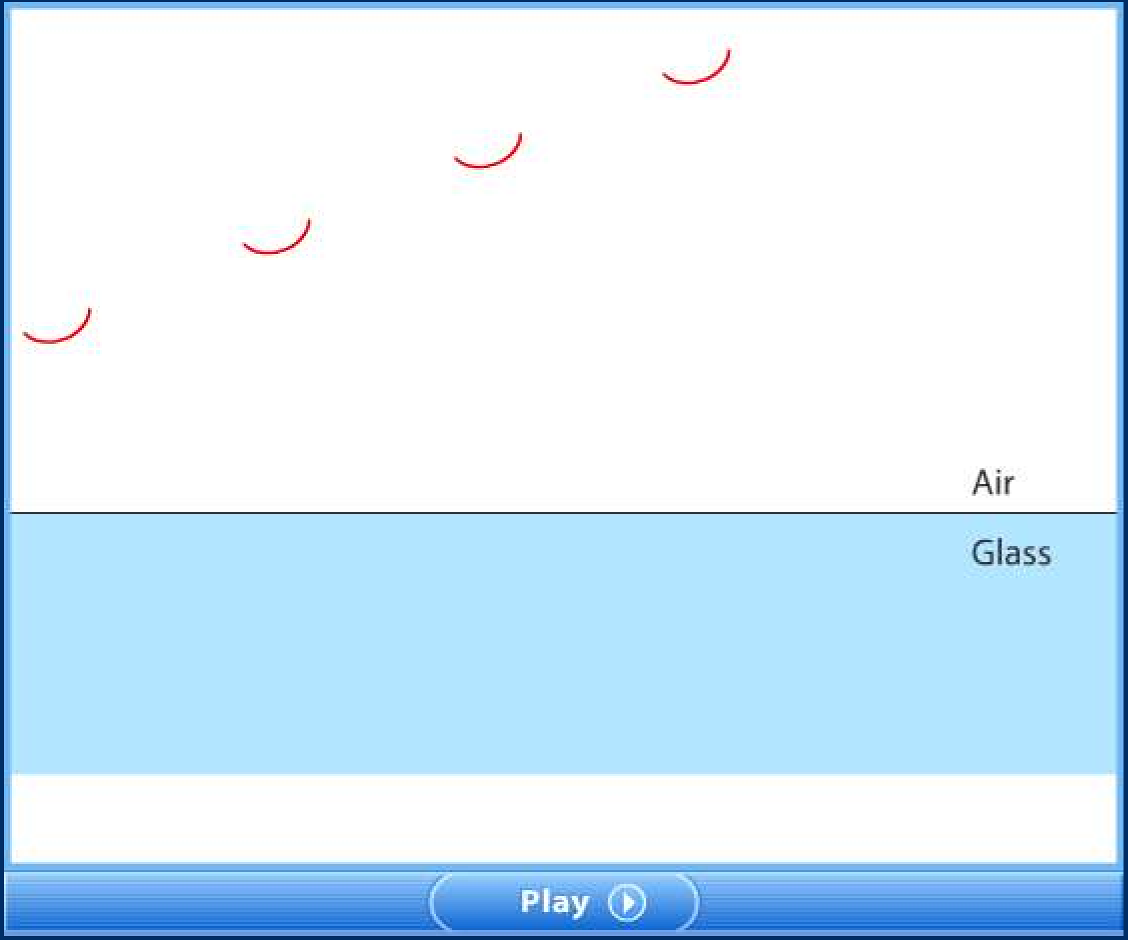
- *Tsunamis* are giant seismic ocean waves.
- Most tsunamis are caused by earthquakes on the ocean floor, but some can be caused by volcanic eruptions and underwater landslides.
- Tsunamis are commonly called *tidal waves*, which is misleading because tsunamis are not caused by tides.

Tsunamis, *continued*

Tsunami as a Destructive Force

- A tsunami has a tremendous amount of energy.
- All of the energy of this mass of water is released against the shore and causes a great deal of destruction.
- The arrival of a tsunami may be signaled by the sudden pulling back of the water along the shore.

Wave Model of Refraction



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Objectives

- **Describe** how the gravitational pull of the moon causes tides.
- **Compare** spring tides and neap tides.
- **Describe** how tidal oscillations affect tidal patterns.
- **Explain** how the coastline affects tidal currents.

Tides

tides the periodic rise and fall of the water level in the oceans and other large bodies of water

- *High tide* is when the water level is highest.
- *Low tide* is when the water level is lowest.

The Causes of Tides

- The gravitational effects of the moon and, to a lesser extent, the sun causes tides.
- Because the force of the moon's gravity decreases with distance from the moon, the gravitational pull of the moon is strongest on the side of Earth that is nearest to the moon.

The Causes of Tides, *continued*

- As a result, the ocean on Earth’s near side bulges slightly, which causes a high tide within the area of the bulge.

- Low tides form halfway between two high tides. Low tides form because as ocean water flows toward areas of high tide, the water level in other areas of the oceans drop.

Behavior of Tides

tidal range the difference in levels of ocean water at high tide and low tide

- Because there are two tidal bulges, most locations in the ocean have two high tides and two low tides daily.
- The tidal range can vary widely from place to place.
- Because the moon rises about 50 minutes later each day, the times of high and low tides are about 50 minutes later each day.

Behavior of Tides, *continued*

Spring Tides

- The sun's gravitational pull can strengthen or weaken the moon's influence on the tides.
- During the new moon and the full moon, Earth, the sun, and the moon are aligned. The combined gravitational pull of the sun and the moon results in higher high tides and lower low tides.
- During these two monthly periods, tides are called *spring tides.*

Behavior of Tides, *continued*

Neap Tides

- During the first- and third-quarter phases of the moon, the moon and the sun are at right angles to each other in relation to Earth.
- The gravitational forces of the sun and moon work against each other.
- As a result, the daily tidal range is small. Tides that occur during this time are called *neap tides.*

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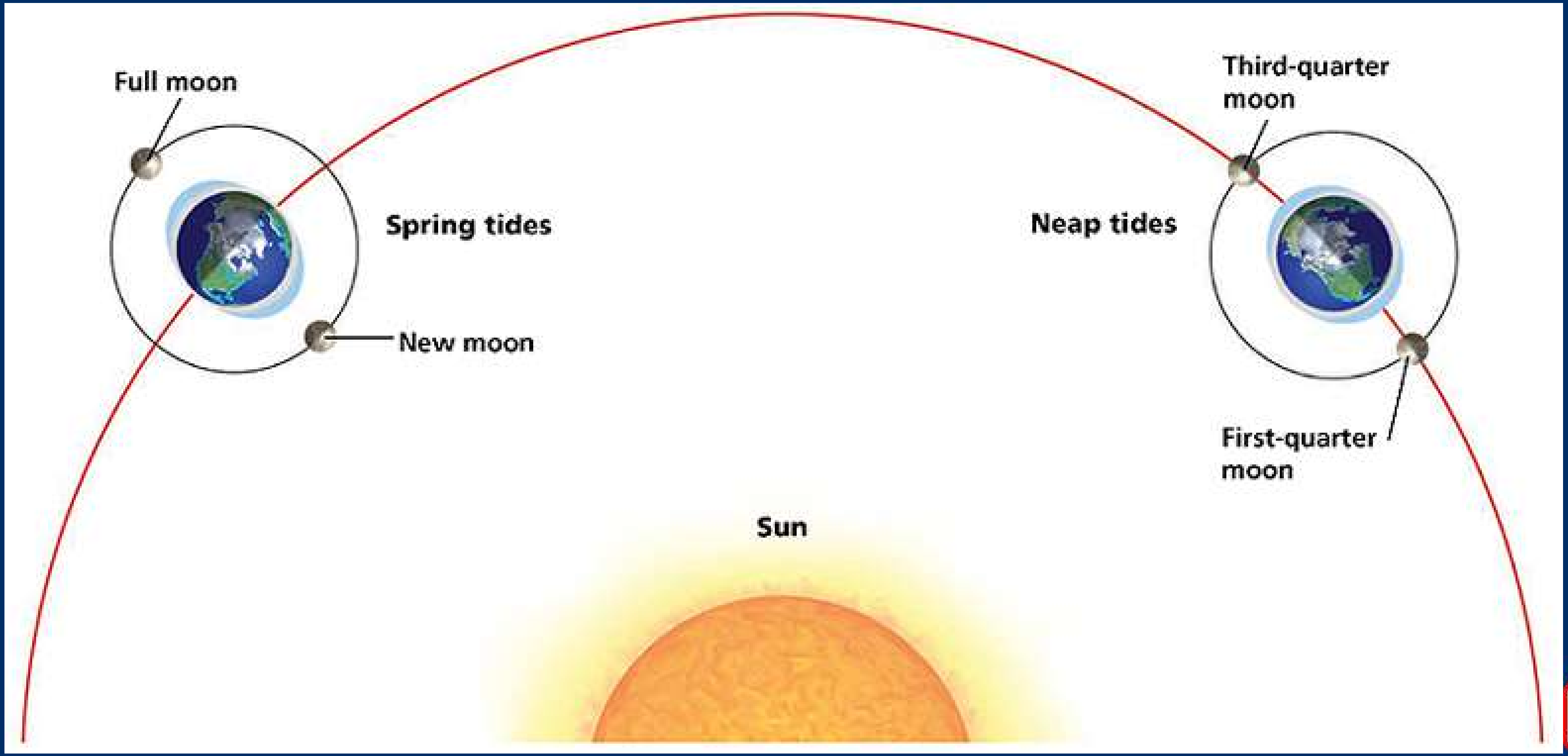
Behavior of Tides, *continued*

The diagram below shows spring tides and neap tides.



Reading Check

Describe the location of the sun and moon in relation to Earth when the tidal range is small.

End Of Slide

Reading Check

Describe the location of the sun and moon in relation to Earth when the tidal range is small.

When the tidal range is small, the sun and the moon are at right angles to each other relative to Earth's orbit.

End of Slide

Tidal Variations

- Tidal patterns are greatly influenced by the size, shape, depth, and location of the ocean basin in which the tides occur.
- Along the Atlantic Coast of the United States, two high tides and two low tides occur each day and have a fairly regular tidal range.
- Along the shore of the Gulf of Mexico, however, only one high tide and one low tide occur each day.

Tidal Variations, *continued*

Tidal Oscillations

tidal oscillation the slow, rocking motion of ocean water that occurs as the tidal bulges move around the ocean basins

- In some enclosed seas tidal oscillations reduce the effects of the tidal bulges.
- However, in small basins and narrow bays located off major ocean basins, tidal oscillations may amplify the effects of the tidal bulges.

Tidal Currents

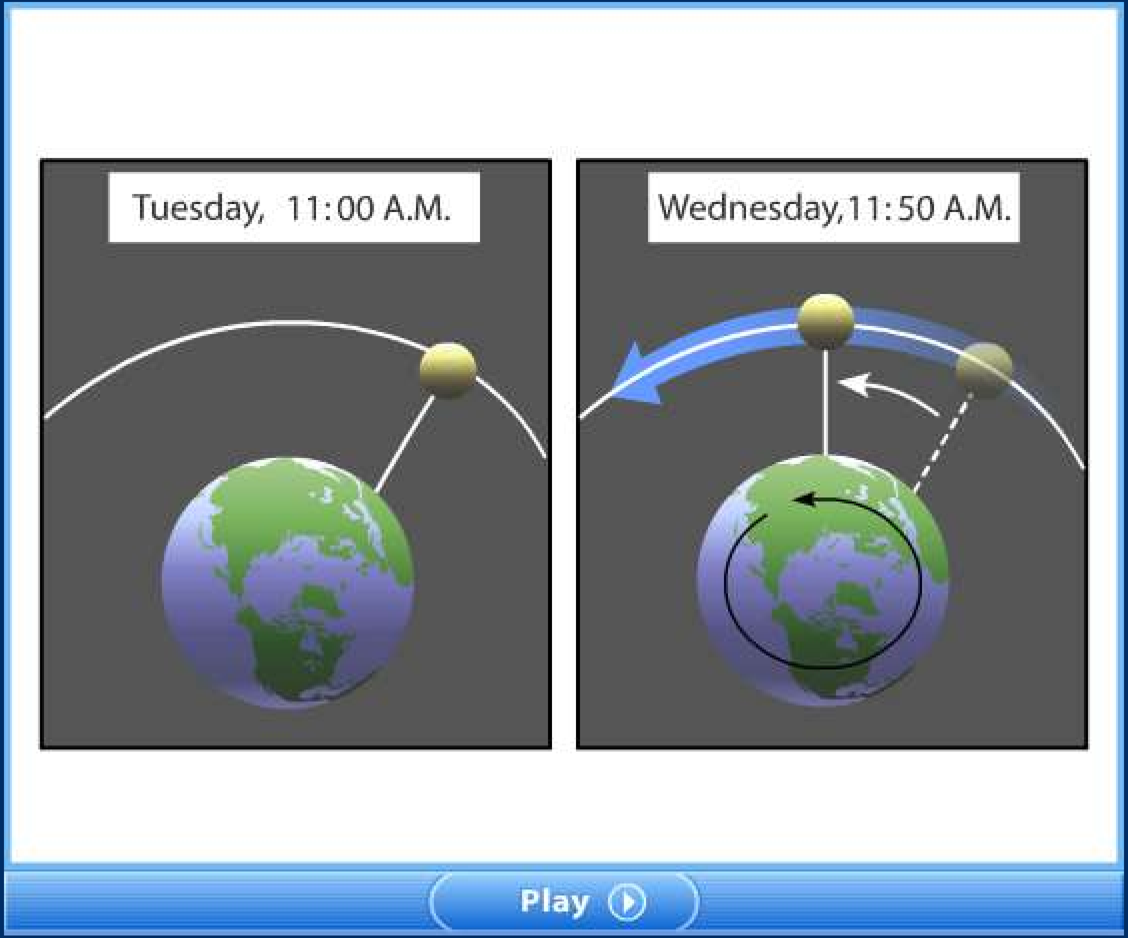
tidal current the movement of water toward and away from the coast as a result of the rise and fall of the tides

- When the tidal current flows toward the coast, it is called *flood tide*.
- When the tidal current flows toward the ocean, it is called *ebb tide*.

Tidal Currents, *continued*

- When there are no tidal currents, the time period between flood tide and ebb tide is called *slack water*.
- Tidal currents in the open ocean are much smaller than those at the coastlines.
- Tidal currents are strongest between two adjacent coastal regions that have large differences in the height of the tides.

Timing of the Tides



Brain Food Video Quiz

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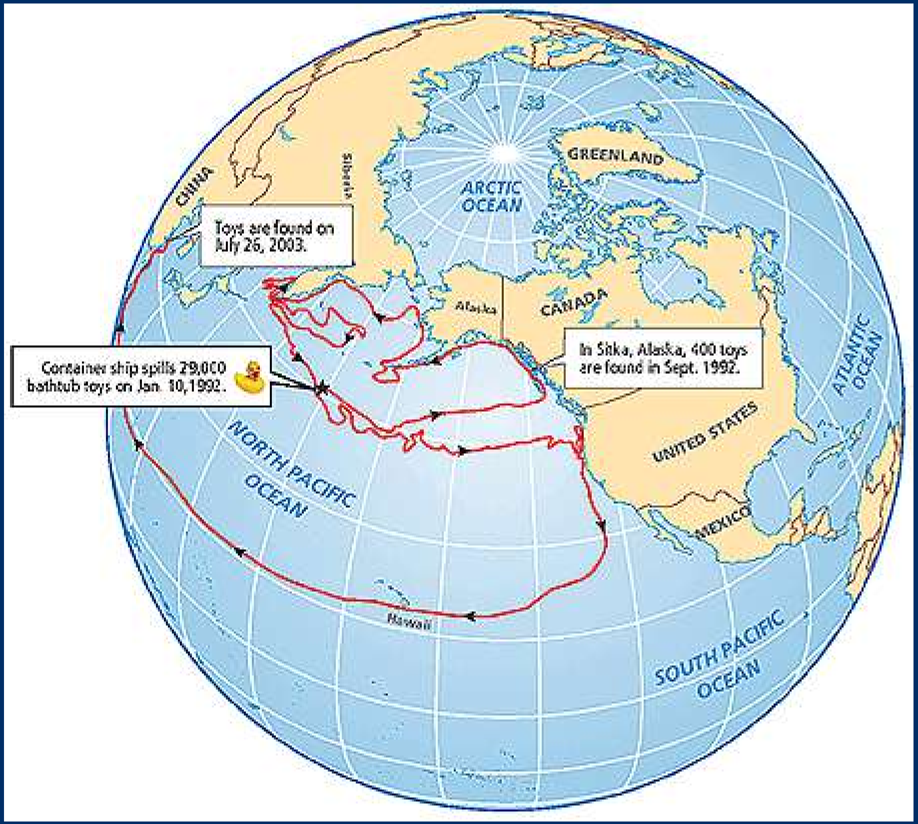
Maps in Action

Roaming Rubber Duckies



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Multiple Choice

1. Which of the following factors is a cause of surface currents?

A. Earth's rotation on its axis
B. water salinity
C. human activity
D. sea-floor spreading

Multiple Choice, *continued*

1. Which of the following factors is a cause of surface currents?

A. Earth's rotation on its axis

B. water salinity

C. human activity

D. sea-floor spreading

Multiple Choice, *continued*

2. What is the speed of an ocean wave that has 12 s between crests and a wavelength of 36 m?

F. 6 m/s

G. 3 km

H. 3 m/s

I. 12 m

Multiple Choice, *continued*

2. What is the speed of an ocean wave that has 12 s between crests and a wavelength of 36 m?

F. 6 m/s

G. 3 km

H. 3 m/s

I. 12 m

Multiple Choice, *continued*

3. When an ocean wave travels 100 m west, which of the following also travels 100 m west?

A. the energy in the wave

B. the water molecules in the wave

C. both the water molecule and the energy

D. neither the water molecule nor the energy

Multiple Choice, *continued*

3. When an ocean wave travels 100 m west, which of the following also travels 100 m west?

A. the energy in the wave

B. the water molecules in the wave

C. both the water molecule and the energy

D. neither the water molecule nor the energy

Multiple Choice, *continued*

4. What role do convection currents in the ocean and atmosphere have in regulating climate?

F. They set up atmospheric circulation.
G. They prevent deep-water currents.
H. They restrict energy to local use.
I. They ensure a balance of precipitation.

Multiple Choice, *continued*

4. What role do convection currents in the ocean and atmosphere have in regulating climate?

F. They set up atmospheric circulation.

G. They prevent deep-water currents.

H. They restrict energy to local use.

I. They ensure a balance of precipitation.

Multiple Choice, *continued*

5. The vertical distance from the trough of a wave to the crest of a wave is called the

A. wave height

B. wave length

C. wave speed

D. wave distance

Multiple Choice, *continued*

5. The vertical distance from the trough of a wave to the crest of a wave is called the

A. wave height
B. wave length
C. wave speed
D. wave distance

Short Response, *continued*

6. What is a main factor that causes the movements of deep-water currents?

Short Response, *continued*

6. What is a main factor that causes the movements of deep-water currents?

water density differences

Short Response, *continued*

7. What happens to a wave's height as the wave approaches the shore?

Short Response, *continued*

7. What happens to a wave's height as the wave approaches the shore?

Its height increases.

Short Response, *continued*

8. Most waves are generated by energy transferred to water from what?

Short Response, *continued*

8. Most waves are generated by energy transferred to water from what?

wind

Reading Skills

Read the passage below. Then, answer questions 9-11.

Tsunamis

Tsunamis are the most destructive waves in the ocean. Most tsunamis are caused by earthquakes on the ocean floor, but some can be caused by volcanic eruptions and underwater landslides. Tsunamis are sometimes called *tidal waves*, which is misleading because tsunamis have no connections to tides.

Tsunamis commonly have a wave period of about 1 hour and a wave speed of about 890 km/h, which is about as fast as a commercial airplane. By the time the tsunami reaches the shore, the tsunami's height may be 40 m.

Tsunamis can travel thousands of kilometers. One tsunami was triggered by an earthquake off the coast of South America in 1960. The tsunami was so powerful that it crossed the Pacific Ocean and hit the city of Hilo, on the coast of Hawaii, approximately 10,000 km away. The same tsunami then continued and struck Japan.

Reading Skills, *continued*

9. Why is the word *misleading* used to describe the use of the term *tidal waves* in the reading passage?

A. Tsunamis are really large tides.

B. Tsunamis can cause extensive damage to coastal areas.

C. Tsunamis are related to earthquakes.

D. Tsunamis are not related to tides.

Reading Skills, *continued*

9. Why is the word *misleading* used to describe the use of the term *tidal waves* in the reading passage?

A. Tsunamis are really large tides.

B. Tsunamis can cause extensive damage to coastal areas.

C. Tsunamis are related to earthquakes.

D. Tsunamis are not related to tides.

Reading Skills, *continued*

10. Which of the following statements is a fact from the passage?

F. All tsunamis are caused by earthquakes.

G. A tsunami can travel as fast as an airplane.

H. The tsunami of 1960 only struck Japan.

I. Tsunamis are caused by surface currents.

Reading Skills, *continued*

10. Which of the following statements is a fact from the passage?

F. All tsunamis are caused by earthquakes.

G. A tsunami can travel as fast as an airplane.

H. The tsunami of 1960 only struck Japan.

I. Tsunamis are caused by surface currents.

Reading Skills, *continued*

11. Once triggered, how far can a tsunami travel?

A. Tsunamis are short-lived and usually dissipate within just a few kilometers.

B. Tsunamis travel about 100 km before dissipating in the ocean.

C. Tsunamis travel about 1,000 km before dissipating in the ocean.

D. Tsunamis can travel thousands of kilometers before dissipating or striking land.

Reading Skills, *continued*

11. Once triggered, how far can a tsunami travel?

A. Tsunamis are short-lived and usually dissipate within just a few kilometers.

B. Tsunamis travel about 100 km before dissipating in the ocean.

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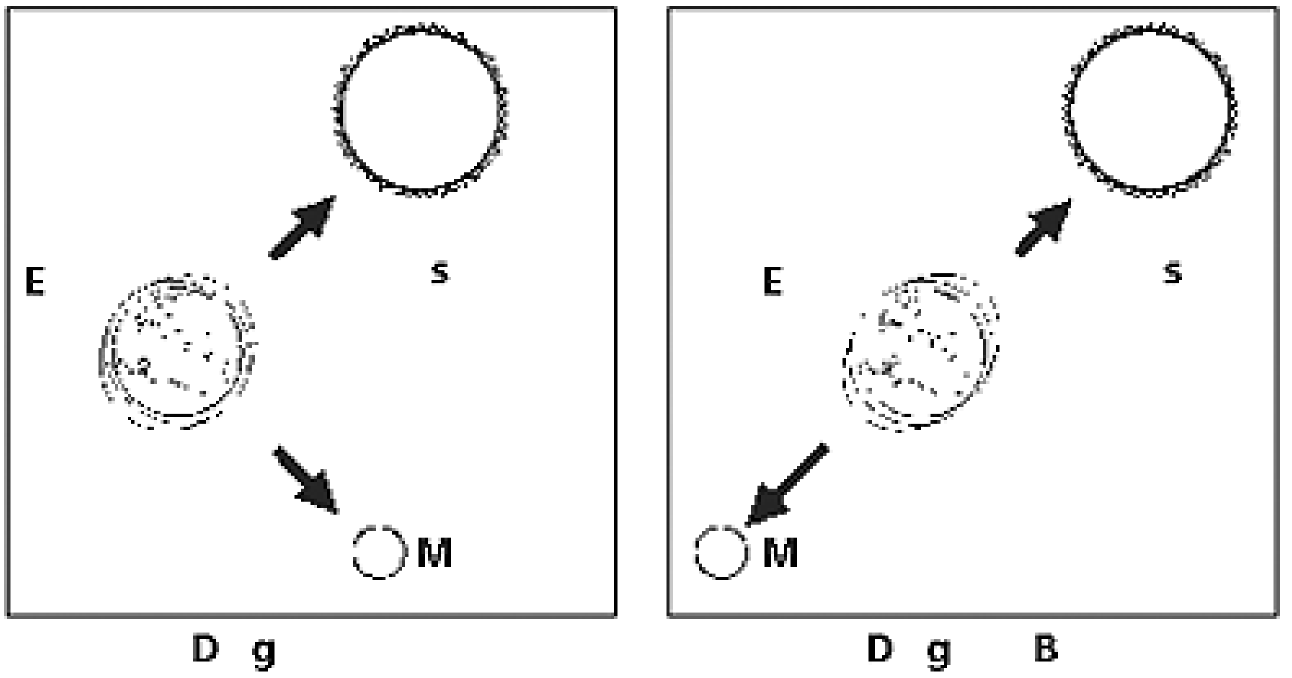
D. Tsunamis can travel thousands of kilometers before dissipating or striking land.

Interpreting Graphics

Use the diagram below to answer questions 12 and 13.

Effect of Sun and Moon on Earth's Tides



Interpreting Graphics, *continued*

12. What type of tide is produced by the arrangement in Diagram B?

F. spring tide

G. neap tide

H. winter tide

I. weak tide

Interpreting Graphics, *continued*

12. What type of tide is produced by the arrangement in Diagram B?

F. spring tide

G. neap tide

H. winter tide

I. weak tide

Interpreting Graphics, *continued*

13. Using the diagrams above, explain in general terms how the gravitational effects of astronomical bodies cause tides on Earth.

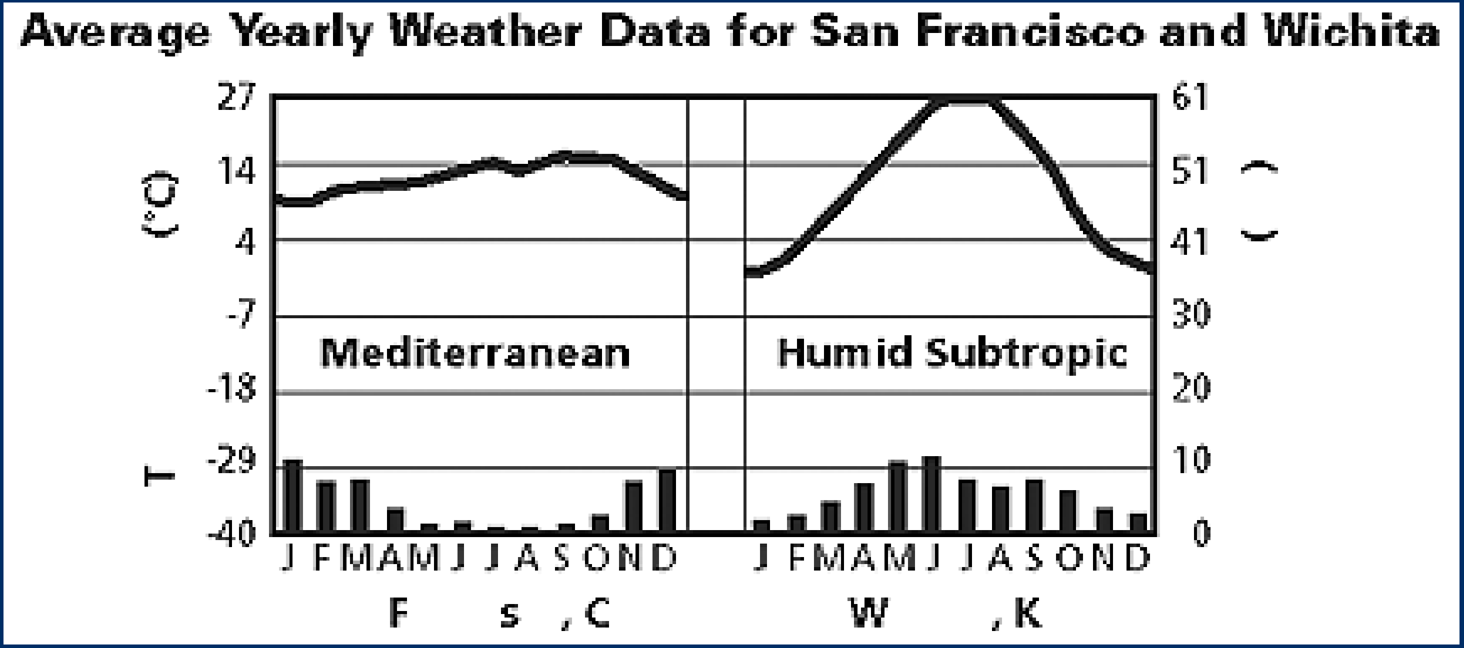
Interpreting Graphics, *continued*

13. Using the diagrams above, explain in general terms how the gravitational effects of astronomical bodies cause tides on Earth.

Answers should include: the moon’s gravity, and to a lesser extent the sun’s gravity, tugs on the surface of Earth and its waters; as the moon revolves around Earth, the moon exerts a gravitational pull on Earth’s surface and its ocean waters; two high tidal bulges are created on opposite sides of the planet as the moon’s gravity affects Earth. Low tides occur in between these bulges; because the waters flow more easily they are more affected than the solid Earth is.

Interpreting Graphics, *continued*

Use the climate graphs below to answer questions 14 and 15.



Interpreting Graphics, *continued*

14. Which location shows the most extreme climate variation?

A. Wichita, Kansas shows the most extreme climate variation.

B. San Francisco, California shows the most extreme climate variation.

C. Both climates are equally mild.

D. Both climates are equally variable.

Interpreting Graphics, *continued*

14. Which location shows the most extreme climate variation?

A. Wichita, Kansas shows the most extreme climate variation.

B. San Francisco, California shows the most extreme climate variation.

C. Both climates are equally mild.

D. Both climates are equally variable.

Interpreting Graphics, *continued*

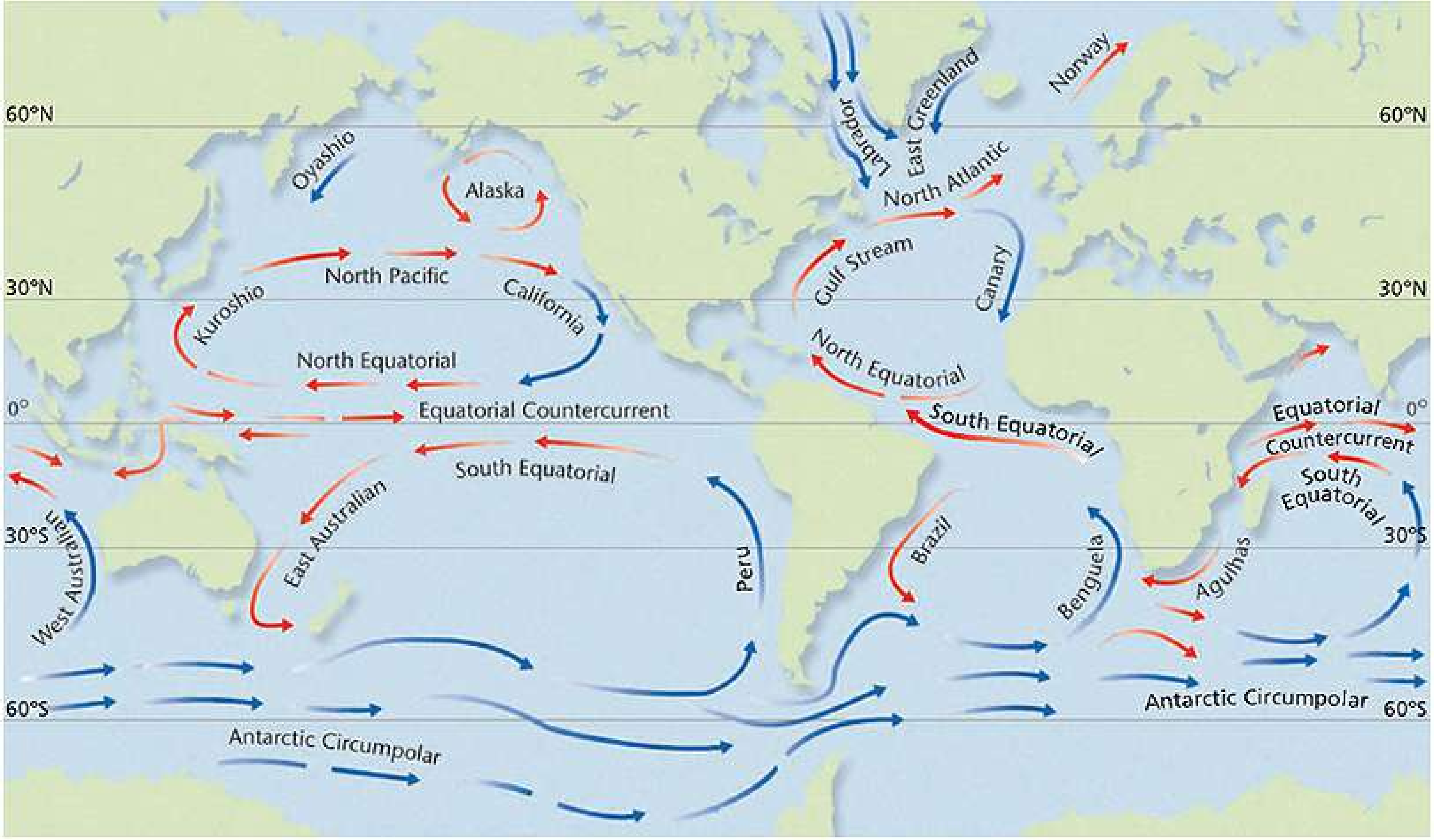
15. How do the location of these cities and the nearby currents help explain the differences in their climates?

Interpreting Graphics, *continued*

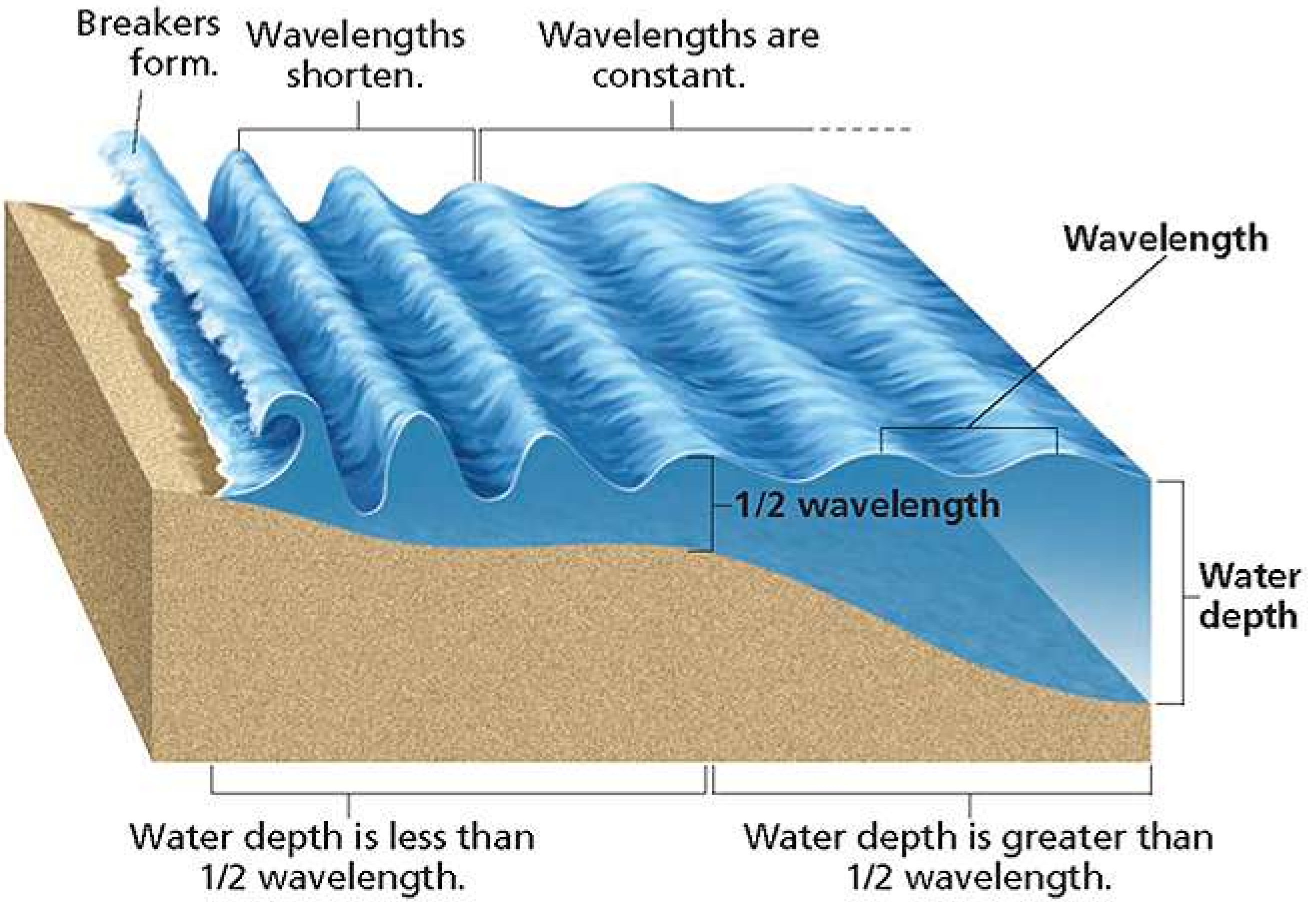
15. How do the location of these cities and the nearby currents help explain the differences in their climates?

Answers should include: concepts of the differential energy absorption patterns of water and land to explain the observed differences in climate; an understanding that water heats and cools more slowly than does land; cities that are located near large bodies of water have fewer temperature variations because of the mediating effect of the water.

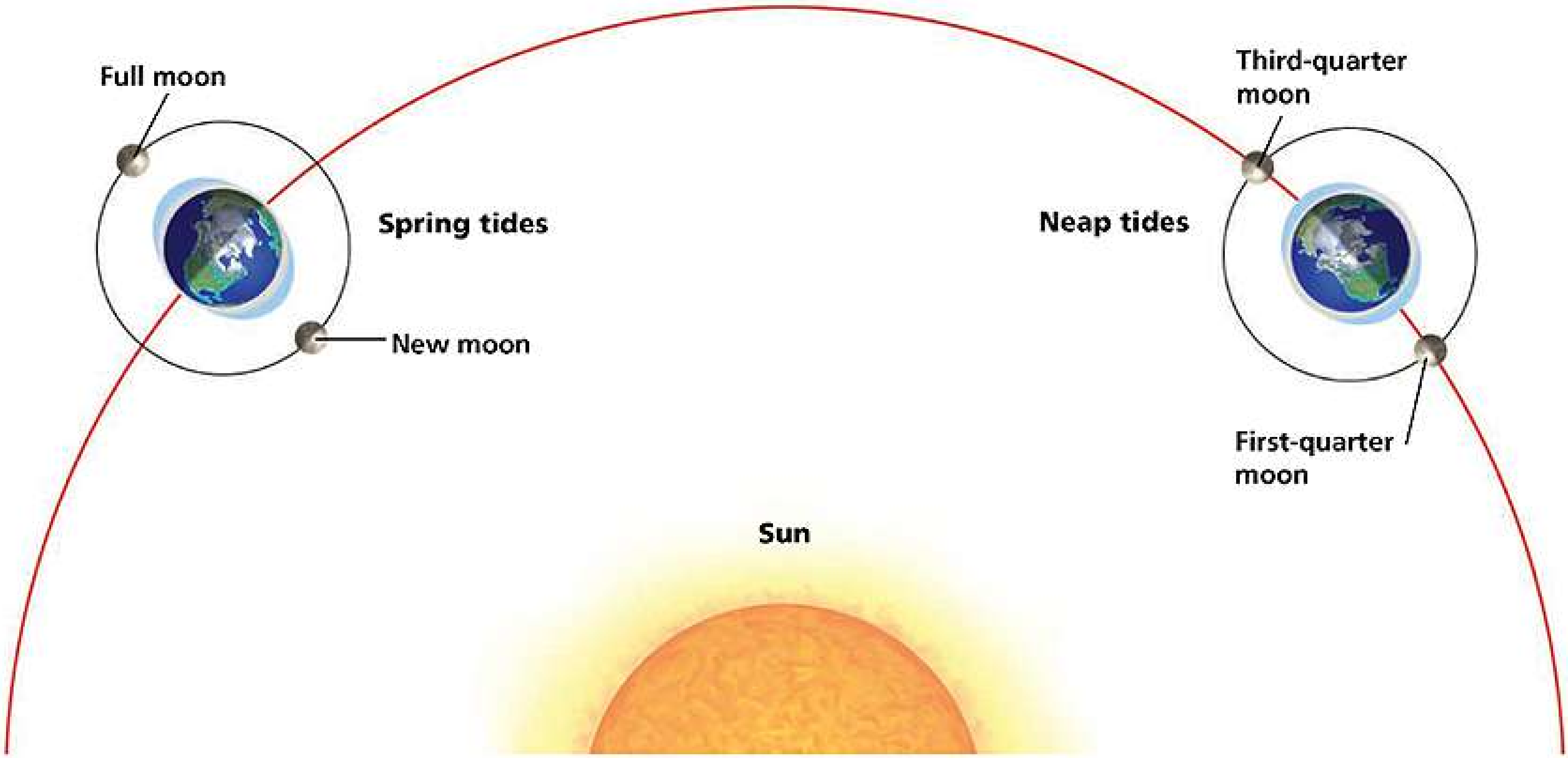
Major Surface Currents



The Formations of Breakers



Spring Tides and Neap Tides



Roaming Rubber Duckies