STUDY QUESTIONS

Find the answers as you read.

1. What makes a wave break?
2. What happens when a wind wave breaks on shore?
3. How do *wave refraction, diffraction,* and *reflection* affect the behavior of waves?
4. What is a *standing wave*?
5. What causes storm surges?
6. What causes seiches?
7. What causes tsunamis?
8. Why are tsunamis always shallow-water waves?
9. Why don't tsunamis destroy ships in the open sea?

Surf and Breaking Waves

What makes a wave break?

What happens when a wind wave breaks on shore?

How do wave refraction, diffraction, *and* reflection *affect the behavior of waves?*

What is a standing wave?

If you've ever been to the beach, you've seen waves break and spill their energy as surf. Have you ever thought about *how* a wave breaks?

In deep water, a wave breaks when its H:L ratio exceeds 1:7. That is, when the height exceeds one-seventh of the wavelength, the wave breaks as whitecaps. The same ratio applies in shallow water, though through a different process.

Wind waves (deepwater waves) become transitional when they enter water that's shallower than half their wavelength. At this point, the bottom begins to affect the wave. As it moves shoreward, the orbital motion flattens, becoming elliptical. Interaction with the bottom slows the wave, decreasing the wavelength and packing the wave's energy into a tighter area. This causes the wave height to rise.

As the wave continues moving shoreward, the wavelength continues to decrease and the height continues to increase, moving the wave closer and closer toward an H:L ratio of 1:7. The wave passes the 1:7 ratio when the depth is 1.3 times the height. Because the crest of the wave is now traveling faster than its trough, and because its height is more than 1.7 times its length, the wave becomes unstable. The instability causes the wave to break, and its crest topples forward.

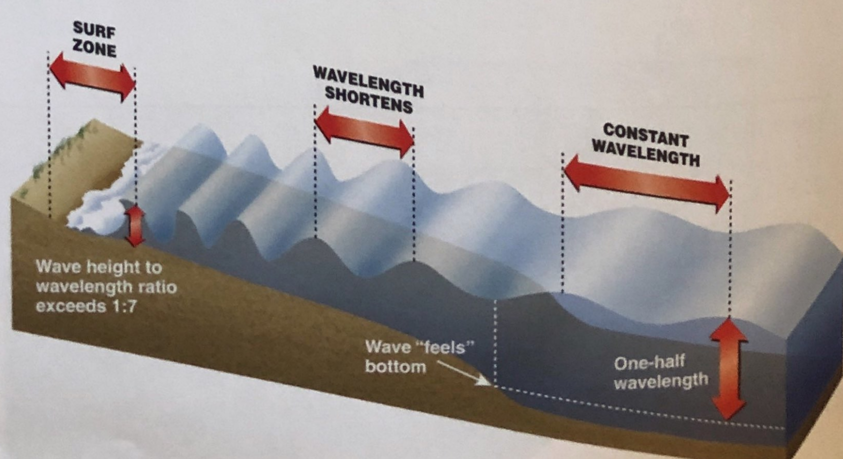

Figure 10-10

Breaking waves.

Deepwater waves become transitional when they enter water that's shallower than half their wavelength. At this point, the bottom begins to affect the wave. The trough starts to travel more slowly than the crest, decreasing the wavelength and causing the wave height to rise. As the wavelength continues to decrease and the height continues to increase, the wave's H:L ratio moves closer to 1:7. When the wave passes the 1:7 ratio, the bottom of the wave travels more slowly than the top. This topples the upper part of the wave forward, causing it to break.

There are three basic types of wave break. *Plunging breakers* are characterized by a curl as the top of the wave pitches through the air before splashing into the bottom. These occur on moderately steep beaches that decelerate the wave quickly, so the top of the wave literally flies ahead of the bottom. *Spilling breakers* occur on gentle slope beaches. The top of the wave tumbles and slides down the front of the wave as it decelerates slowly. *Surging breakers* occur on very steep beaches that are almost like walls rising out of deep water. Since there's little or no bottom contact, the waves don't slow down, but surge virtually unbroken. Surging waves can be very destructive because they don't lose much energy.

This description of surf is somewhat idealized because it assumes that waves hit the shore squarely. In reality, that rarely happens. *Refraction*, *diffraction*, and *deflection* affect wave behavior.

You may already be familiar with refraction as the bending of light rays. It also means bending ocean waves. This happens when waves approach the shore at an angle. The crest closest to shore reaches shallow water first and slows sooner than the crest away from shore. Because of this uneven slowing, the waves refract, or bend, until they face the shore more squarely and slow evenly. When the shoreline is irregular, refraction tends to concentrate wave energy toward headlands because the wave crest nearest to the headland slows first, turning the wave toward it.

Wave diffraction occurs when waves pass an obstacle, such as a jetty. Energy shifts within the wave, allowing a new wave pattern to form past the obstacle or through an opening. Diffraction is what allows very heavy seas to rock an otherwise well-protected harbor. Waves diffracted after passing through island channels

Figure 10-11a

Plunging breaker.

Figure 10-11b

Surging breaker.

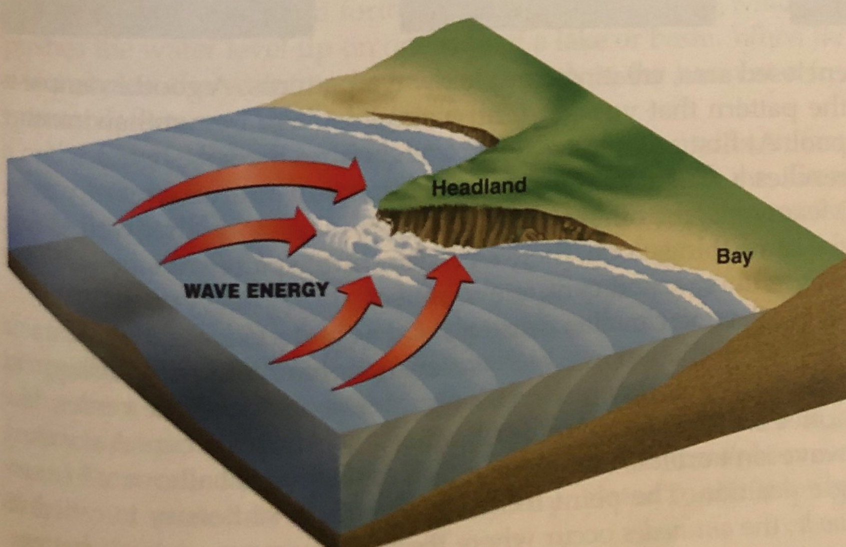

Figure 10-12

Wave refraction.
Refraction occurs when waves approach shore at an angle. When the shoreline is irregular, refraction tends to concentrate wave energy toward headlands because the wave crest nearest to the headland slows first, turning the wave toward it.

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Figure 10-13

Wave diffraction.

Wave diffraction occurs when waves pass an obstacle. Energy shifts within the wave, allowing a new wave pattern to form past the obstacle or through an opening.

can alter swell patterns well off shore. Evidence suggests that the early Polynesian seafarers you read about in Chapter 2 used this to aid navigation.

Reflection occurs when waves hit an abrupt obstacle that is nearly perpendicular in the water, such as a sea wall. The wave retains most of its energy and bounces back toward the open water. Reflected wave energy can bounce around the inside of an

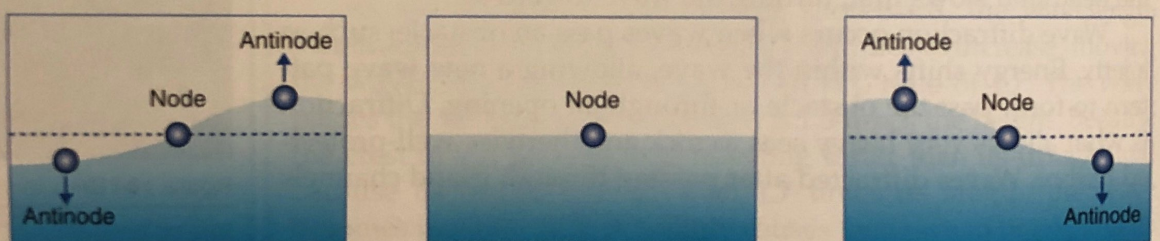

Figure 10-14

Standing wave.

A standing wave is a vertical oscillation in which water rocks back and forth, rising and falling at the ends but remaining relatively motionless near the center. The point in the wave that is stationary is called its node; the antinodes occur where there's maximum vertical change.

enclosed area, creating complex wave patterns. A good example is the pattern that you get with a single splash in a still swimming pool. At first a single wave set travels from the splash, but when it reaches a wall, it reflects in a new direction as a new set of waves. Meanwhile, the other side of the wave reaches another wall, doing the same thing. Soon, there's no discernible pattern as the reflected waves interact and continue to reflect.

Reflection can also cause a *standing wave*. A standing wave is a vertical oscillation in which water rocks back and forth, rising and falling at the ends but relatively motionless near the center, like coffee sloshing back and forth after you bump the cup. A standing wave isn't orbital, but has a trough and crest that alternate in a single position. The point in the wave that is stationary is called its *node*; the *antinodes* occur where there's maximum vertical change.