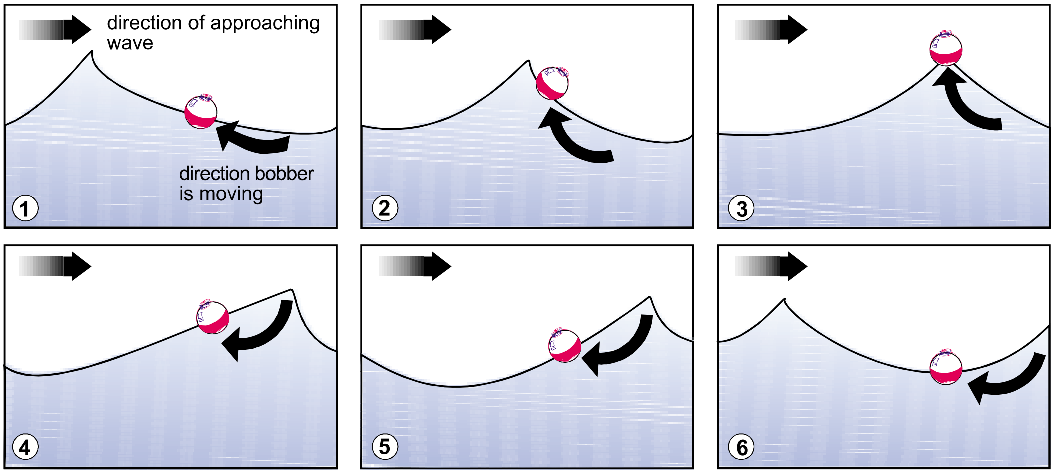
Introduction: Waves—Unpredictable Energy

If you have visited Florida's coast, you've observed the motion of the water we call **waves**. Waves seem to come from nowhere, originating from some mysterious point far out on the horizon. The waves roll toward us and the shoreline endlessly, providing us with constant changes in the surface of the water.

We also know just how destructive the force of the waves can be. Shorelines over a long period of time or even during a few hours of a passing hurricane can be eroded or even nearly wiped away. Coastal towns and cities can be destroyed by the rush of towering waves—and people living in coastal areas may be swept to their death. Like many forces of nature, waves can vary from friendly to menacing. Oceanographers study waves to help us understand their behavior and the way they affect our lives on land.

Making Waves: The Transfer of Energy



The motion or energy of water can be seen with a fishing bobber floating on the surface of a wave. As the wave approaches, the bobber moves up the crest of the wave (diagram 1-3). As the wave moves away (diagram 4-6) the bobber moves down the crest and forward toward its original position.

A *wave* is the orbital motion of water. Although this definition sounds quite simple, the cause of a wave is quite complex. There must be a force, some *form of energy*, that disturbs water and produces a wave's orbital motion. Scientists are unsure how energy is transferred in the form of waves. Scientists do, however, have some theories to explain this *transfer of energy*. The following experiment describes one of these theories.

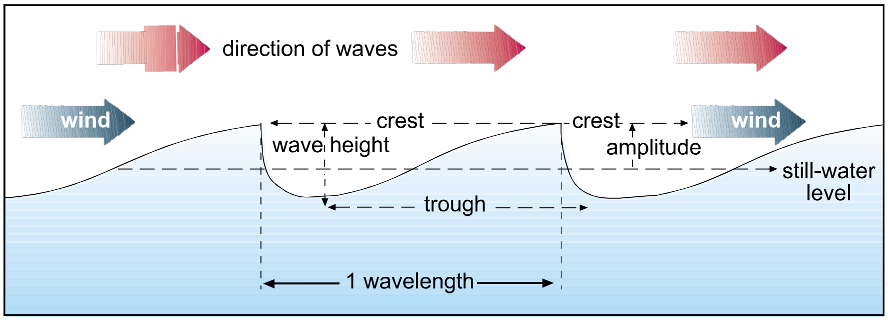
Take a tub or large container of calm water. Now sweep your hand quickly through the container so that you create a wave. You've transferred the energy produced by your body to the water in the form of a wave.

Now repeat this experiment and watch carefully as you pass your hand through the water. Note that as you push aside water along the surface, a space appears just behind—at least momentarily. Water surrounding this space instantly rushes to fill it. But as the water rushes into this space it produces a momentum—a force—that pushes it upward above the surface of the water.

This transfer of energy doesn't stop there. As the water falls back to the surface, it creates another space, which in turn is filled by surrounding water. And, again, the momentum of this rushing water produces another upward force, and so on. The harder you pass your hand through the water, the greater the energy that will be transferred, and the more numerous and powerful will be the waves you will create. Most commonly, energy that is transferred to water originates from wind. Earthquakes and the gravitational pull of the moon also produce waves.

Speaking of Waves

Oceanographers use certain terms when speaking of the features, size, and movement of the ocean's waves. The highest point on a wMfzGf the **crest**; the lowest point on a wave is called the **trough** (trawf). **Wave height** is the vertical distance between a wave's crest (high point) and its trough (low point). **Wavelength** is the distance between successive or adjacent crests. The term **wave amplitude** refers to the distance from still-water level to a wave's crest.



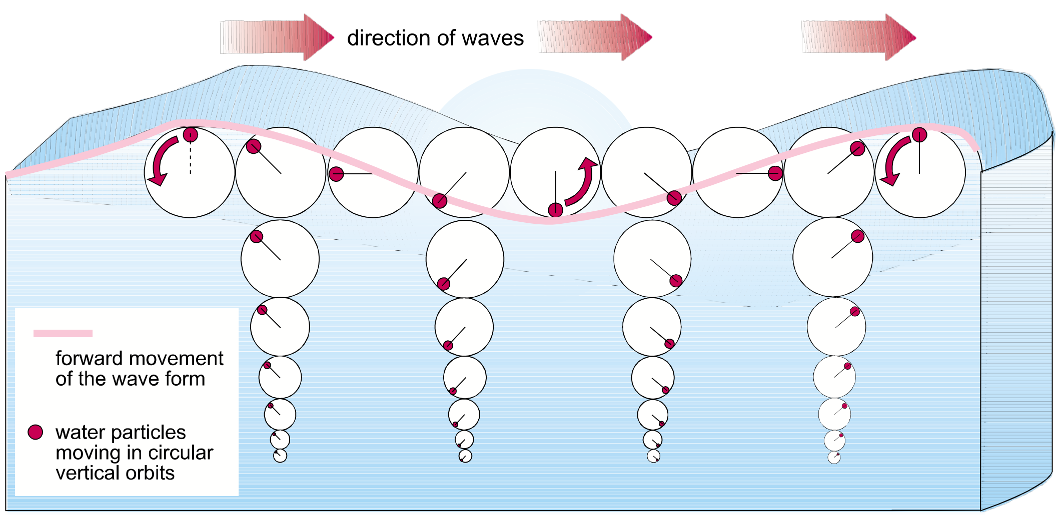
characteristics of waves

Wave Types: Deep-Water Waves and Shallow-Water Waves

Wave Types. Although *deep-water waves* occur in deep water away from the shore, they have a precise definition. Deep-water waves occur when the water's depth is deeper than one-half the wave's length. This relationship between the water's depth and the wave's length produces a wave that acts in a particular way, as described below.

Although the energy of a deep-water wave moves forward, the water it affects stays nearly in its same place in the ocean. Although this may sound hard to believe or imagine, it's true. As a drop of water moves through a wave, it follows an **orbit**, or circular path. The drop of water will rise and move forward on the wave's front slope until it reaches the crest of the wave. This drop of water will then drop down the wave's back slope and continue until it falls under the wave's trough. As you can see from this explanation, waves really refer to *forms of energy* rather than to the water itself.

Orbital Movement of Water Particles



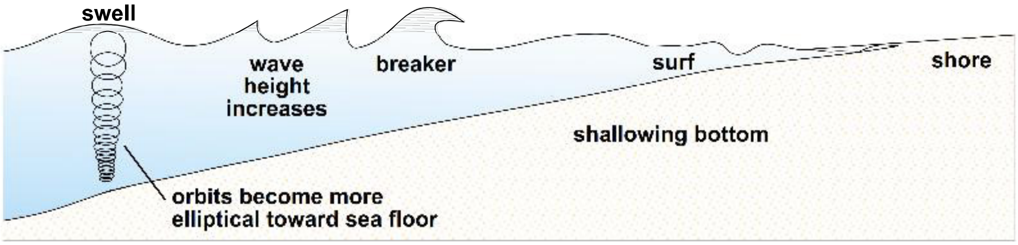
Water particles move in circular vertical orbits at the surface or beneath waves. As a drop of water moves through a wave, it moves forward on the wave's front slope until it reaches the crest of the wave. This drop of water will then drop down the wave's back slope and continue until it falls under the wave's trough.

In deep-ocean water, these waves, called *swells*, are usually long and low with rounded crests and troughs and evenly curved surfaces. The swells' wavelength, or distance between crests, stays constant.

Shallow-Water Waves. As waves near the shore, they change in size, shape, and speed. These *shallow-water waves* slow in speed; their wavelength becomes smaller, and their crests rise higher. In other words, as waves approach the shore, they become slower, higher, and more numerous. The shape of the waves becomes **trochoidal**: Their crests become pointed; their slopes grow steeper, and their troughs flatten. The wave now has begun to make its final roll.

When the depth of the water becomes less than one-half of a wave length, the wave breaks, or splashes onto the shore. When a wave breaks, energy that was stored in the wave is released.

The breaking point of the wave depends on two things: the speed of the water's orbit and the speed of the wave. As the wave climbs higher and moves more slowly, the motion of the water it affects follows an **elliptical orbit**. When the wave's water begins to flow in this oval-shaped path, the wave's crest moves slightly forward. Finally, when the depth of the water becomes less than one-half of a wave's length, the wave *breaks*, or splashes onto the shore. When a wave breaks, the energy stored in the wave is released onto the shore at impact.

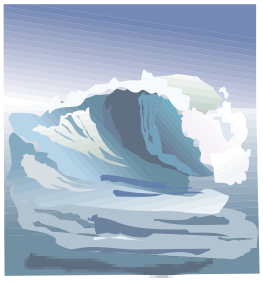


Waves do not just break when they are in shallow water. Waves can also break in deeper waters in the open ocean. Steep waves with narrow crests are produced in the open ocean by strong winds. Winds blow the narrow crests off the wave, creating a **whitecap** on the wave. A *whitecap* is a mixture of air and water on the wave. Whitecaps on the ocean or other large bodies of water are a sign that rough weather is in store.

Another wave that is encountered on the open ocean is a **rogue wave**. A *rogue wave* is a large, single wave with very high crests and low troughs. Rogue waves are very tall and are formed when two or more large waves from a storm merge or when waves meet currents that are going in the opposite direction from them. Rogue waves are dangerous and have caused many ships to be lost at sea.

Types of Breaking Waves

Breaking waves, or breakers, are affected by the shape of the ocean floor near **beaches**. The **plunging breaker** forms as a wave rolls over a steep beach slope. The **spilling breaker** develops along flatter beaches. (Spilling breakers are common along Florida's shallow and flat coast.) You can see the differences between each breaker in the lists below.



Plunging Breaker

- falls into itself
- collapses
- destroys the wave form
- produces a crashing sound

Spilling Breaker

- moves as a line of foam
- moves at the same speed as the wave form
- quiet wave

Capillary Waves

The smallest waves are **capillary waves**, or ripples, sometimes called *cat's paws*. They measure less than one inch in wavelength and affect only the top inch or so of water, whether they appear in deep or shallow waters. These little waves differ from other wind (or *gravity*) waves in several ways.

1. Larger wind waves are primarily acted on by *gravity*, which pulls the crest back to the water surface. Capillary waves, however, are small enough so that *surface tension* pulls their crest back to the water

surface. (Surface tension is the result of water molecules attracting each other.)

2. Capillary waves have crests that are rounded and troughs that are pointed or V-shaped.

capillary wave - small waves or ripples

Gravity waves have crests that are pointed and the troughs that are rounded.

gravity wave - steep waves

3. Capillary waves stop as soon as the wind stops. Capillary waves start gravity waves, and as more wind energy is transferred to the ocean, gravity waves may travel thousands of miles.

Tsunami: The Ocean's Most Powerful Wave

The most destructive wave in the ocean is caused by an undersea earthquake or volcano. Oceanographers call this wave by the Japanese term **tsunami (soo-NAM-e)**. A tsunami is also called a *seismic sea wave*.

An undersea earthquake or volcanic eruption on the seafloor can cause one of two events. If a huge crack, or fault, forms on the seafloor, gravity will force water into it. If the seafloor is raised by a quake or eruption, gravity will pull the water back down off the newly raised surface. In either event, a series of powerful waves will form and travel away from the center of the quake or eruption.

The crest of each wave in the tsunami can be 100 miles apart. These waves rush at speeds of up to 450 miles per hour and can travel as much as 2,000 miles. In the open sea, a tsunami is only a few feet high and may not be noticed; in shallow water, however, these waves become dangerously high. These fast open sea waves are forced to slow down suddenly as they reach shallower waters, pushing the waves to towering heights. The height of a tsunami can range from 30 feet to more than 100 feet. As these tremendous waves break onto shore, they flood and destroy almost anything in their path.

Waves and Erosion: Wearing Away Shorelines

Waves erode and reshape the shoreline they wash over. The rate of shoreline erosion depends upon the type of shoreline, the size and force and of waves hitting the shore, and the number and intensity of storms the shore area receives a year. During storms, wave action increases; therefore, erosion generally increases. For example, the powerful waves of Hurricane Andrew in 1992 sliced away parts of Florida's beaches and, in some cases, washed away entire beaches and buildings. Erosion that would have taken years occurred in just a few hours.

Under normal conditions, waves may erode the shore at a rate of one to one-and-a-half meters per year. Along the Florida coast, breaking waves constantly erode the sand and soft soil that compose the beaches. During moderate weather, the effects of erosion along the Florida coast are barely visible to the onlooker. Waves may also deposit sand and soft soil to form new shoreline features.

Along shorelines that are composed of rock, for example on the coast of California, erosion works in a different way. When breaking waves hit the shoreline, they chip fragments off of existing beach rock. These small rocks and sand grains are then swept by waves against other rocks on the shore, causing more beach rock to chip. Waves also cause erosion when breaking storm waves force water into the cracks of rock cliffs. The cracks grow larger and larger and, eventually, the pressure breaks the rocks apart. Erosion is also caused by the chemical action of seawater dissolving minerals from rocks. Over time, the rocks will break apart or dissolve completely.

Sea cliffs are steep faces of rock that have been eroded by waves. Eventually, the sea cliff will be worn away, often breaking off large rocks that fall into the sea. The waves will then erode the large rocks into sand.

The buildup of rock and sand at the bottom of the sea cliff form a flat platform called a **terrace**. Terraces help slow down the erosion of sea cliffs. As waves move across the terrace, they slow, striking the cliff with less energy and force. **Sea stacks** are columns of hard rock left behind by the erosion of a sea cliff. Sea cliffs consist of resistant rock and some less resistant rock. In the formation of a **sea cave**, the less resistant rock is eroded away by waves, leaving behind a hollowed-out portion of sea cliff.

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Deposits by Waves

Fast-moving waves carry sand, shell fragments, and rock particles across the ocean. As waves slow down and weaken as they approach shorelines, these particles become too heavy for waves to carry. The particles are then deposited offshore or on the shoreline. As a result of waves depositing material in different areas, various shoreline features are formed. These features include beaches, **sand bars**, and **spits**.

Beaches are the shore areas between the high-tide mark and the low tide and usually consist of sand or pebbles.

*Beache*s are the shores areas between the high-tide mark and the low tide mark. They usually consist of sand or pebbles. The type of material that composes a beach will depend upon its source. For example, the white sand on the Atlantic Coast of Florida came from the erosion of the Appalachian Mountains. The black sands on Hawaii's beaches came from the erosion of volcanic rock.

A *sand bar* is an underwater deposition of sand. Sand bars form when longshore currents (currents that move water parallel to the shore) pass across the opening of a bay or cove. The sediments carried within this current are carried inland by waves and deposited. Sand bars that are attached at one end to a mainland or island and extend into open water are called *spits*. You may have walked out on a spit of land that extended into the ocean to fish or look for shells.

Summary

Waves are formed when energy from earthquakes, the gravitational pull of the moon, or, most commonly, the wind, is transferred to the water. Special terminology is used to describe a wave. The highest point on a wave is the *crest*; the lowest point is the *trough*. The vertical distance between these two points is the *wave height*; and the distance between two adjacent waves' crests is the *wavelength*. Wave types include *deep-water* and *shallow-water waves*. Along shallow coastlines *spilling breakers* form, whereas along steeply sloped coastlines *plunging breakers* occur. In open ocean, water *whitecaps* and *rogue waves* can form. Other contrasting waves are *capillary waves* (very small ripples) and *tsunamis*, or seismic waves, which are the largest and most destructive waves.

The wave action on our beaches causes erosion *of the shoreline and changes the shape of the shoreline.*

The wave action on our beaches causes *erosion* of the shoreline and changes the shape of the shoreline. The wearing away of the coast can create *sea cliffs*, *terraces*, *sea stacks*, and *sea caves*. Erosion is countered by waves depositing sand and pebbles that form *beaches*, *sand bars*, and *spits*.