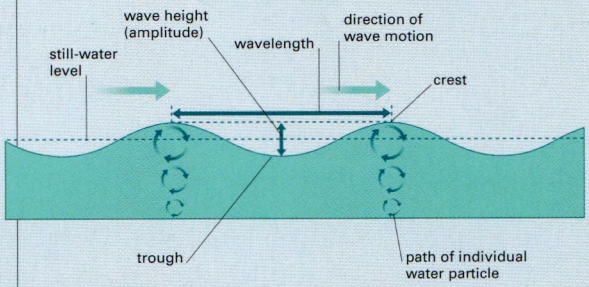
OCEAN WAVES

WAVES ARE DISTURBANCES in the ocean that transmit energy from one place to another. The most familiar types of waves—the ones that cause boats to bob up and down on the open sea and dissipate as breakers on beaches—are generated by wind on the ocean surface. Other wave types include tsunamis, which are often caused by underwater earthquakes (see p.51), and internal waves, which travel underwater between water masses. Tides (see p.78) are also a type of wave.

WAVE PROPERTIES

A group of waves consists of several crests separated by troughs. The height of the waves is called the amplitude, the distance between successive wave crests is known as the wavelength, and the time between successive wave crests is the period. Waves are classified into types based on their periods. They range from ripples, which have periods of less than 0.5 seconds, up to tsunamis and tides, whose periods are measured in minutes and hours (their wavelengths range from hundreds to thousands of miles).

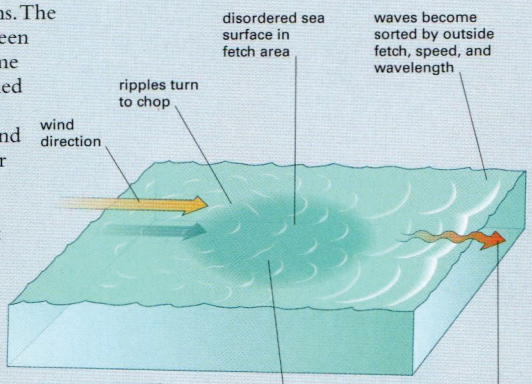
In between these extremes are chop and swell—the most familiar types of surface waves. Ocean waves behave like light rays: they are reflected or refracted by obstacles they encounter, such as islands. When different wave groups meet, they interfere—adding to, or canceling, each other.



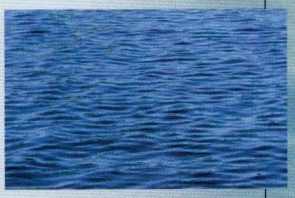
PARTICLE MOVEMENT
As waves pass over the surface, the particles of water do not move forward with the waves. Instead, they gyrate in little circles or loops. Underwater, the particles move in ever-smaller loops. At a depth below about half the distance between crests, they are quite still.

WAVE GENERATION

Wind energy is imparted to the sea surface through friction and pressure, causing waves. As the wind gains strength, the surface develops gradually from flat and smooth through growing levels of roughness. First, ripples form, then larger waves, called chop. The waves continue to build, their maximum size depending on three factors: wind speed, wind duration, and the area over which the wind is blowing, called the fetch. When waves are as large as they can get under the current conditions of wind speed and size of fetch, the sea surface is said to be "fully developed." The overall state of a sea surface can be summarized by the significant wave height—defined as the average height of the highest one-third of the waves. For example, in a fully developed sea produced by winds of about 25 mph (40 km/h), the significant wave height is typically about 8 ft (2.5 m).



BUILDING WAVES
Within the wave-generation area, the sea surface is usually quite confused—the result of groups of waves of different size and wavelength interfering with each other. Outside this area, the waves become sorted by speed to produce a more regular pattern, called a swell.



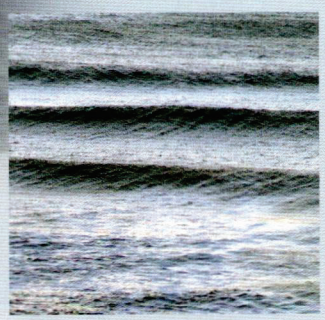
CAPILLARY WAVES (RIPPLES)
These tiny waves are a fraction of an inch high and have a wavelength of under 1½ in (4 cm).

CHOPPY SEA
In a choppy sea, the waves are 4–20 in (10–50 cm) high and have a wavelength of 10–40 ft (3–12 m).

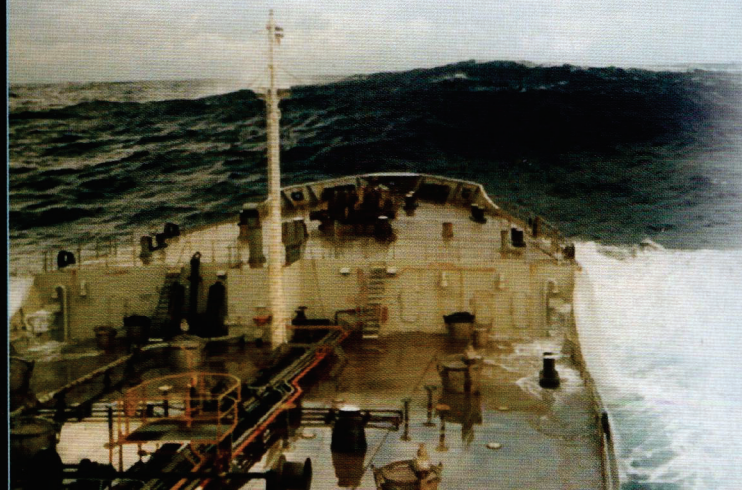
FULLY DEVELOPED ROUGH SEA
Wind speeds over 40 mph (60 km/h) can generate very rough seas with waves several yards high.

WAVE PROPAGATION

In the fetch, many different groups of waves of varying wavelength are generated and interfere. As they disperse away from the fetch, the waves become more regularly sized and spaced. This is because the speed of a wave in open water is closely related to its wavelength. The different groups of waves move at different speeds and so are naturally sorted by wavelength: the largest, fastest-moving waves at the fore, the smaller, slower-moving ones behind. This produces a regular wave pattern, or swell. Occasionally, groups of waves from separate storms interfere to produce unusually large "rogue" waves. As they propagate across the open ocean, wind-generated waves maintain a constant speed, which is unaffected by depth until they reach shallow water. Only with waves of extremely long wavelength—tsunamis—is the speed of propagation affected by water depth.



SWELL
A swell is a series of large, evenly spaced waves, often observed hundreds of miles away from the storm that spawned them. Wavelengths range from dozens to hundreds of yards.



ROGUE WAVES
Interference between two or more large waves occasionally causes a giant or "rogue" wave. This one, recorded in the Atlantic Ocean in 1986, had an estimated height of 56 ft (17 m). It broke over the ship pictured, bending its foremast back by 20°.

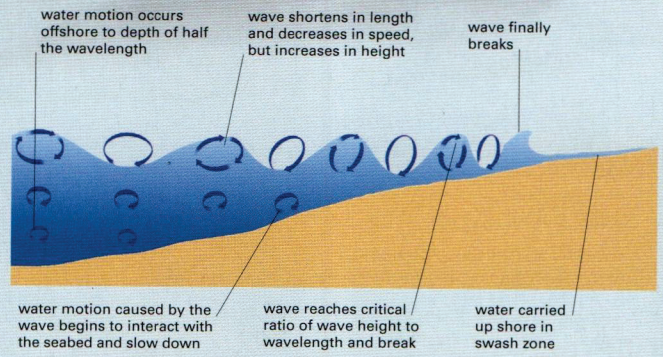
PLUNGING BREAKER
"Barrel" or "tube-forming" breakers like this occur when the waves reaching shore have large amounts of energy. The seabed must be firm and quite steep.

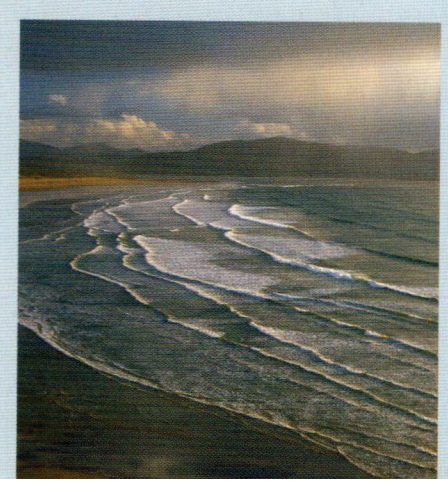
ARRIVAL ON SHORE

As waves approach a shore, the motion they generate deep down begins to interact with the sea floor. This slows the waves down and causes the crests in a series of waves to bunch up—an effect called shoaling. The period of the waves does not change, but they gain height as the energy each contains is compressed into a shorter horizontal distance, and eventually break.

There are two main types of breakers. Spilling breakers occur on flatter shores: their crests break and cascade down the front as they draw near the shore, dissipating energy gradually. In a plunging breaker, which occurs on steeper shores, the crest curls and falls over the front of the advancing wave, and the whole wave then collapses at once. Waves can also refract as they reach a coastline. This concentrates wave energy onto headlands (see p.93) and shapes some types of beaches (see p.106).

SHOALING AND BREAKING
Shoaling occurs as waves enter shallow water. The wavelength and speed both decrease, but the wave gains height. When the crest gets too steep, it curls and breaks.





WAVE REFRACTION
When waves enter a bay enclosed by headlands, they are refracted (bent) as different parts of the wavefront encounter shallow water and slow down.

HUMAN IMPACT

RIDING THE WAVES

When a swell reaches a suitably shaped beach, it can produce excellent surfing conditions. Small spilling breakers are ideal for novice surfers, while experts seek out large plunging breakers that form a "tube" they can ride along. For tube-riding, the break of the wave must progress smoothly either to the right or left. Here, a surfer rides a right-breaking wave in Hawaii—it is breaking from left to right behind the surfer.