Lesson: Currents

The continents may be far apart, but highways of moving water called ocean currents connect these separate landmasses. If you were to catch one of these currents while onboard a sailboat, you would be able to travel a great distance as did explorer Thor Heyerdahl on his journey across the Pacific Ocean. But it is not necessary to set sail to find ocean currents.

The evidence for far-ranging currents can be found on a beach, perhaps in the form of a coconut from distant islands, driftwood from an offshore wreck, or even a bottle with a message in it from a potential pen pal across the sea.

A **current** is a large mass of continuously moving ocean water. The largest currents that move across the ocean are called **global ocean currents**. These currents are like rivers that travel great distances. The Gulf Stream is a global ocean current and was first described in detail by the American statesman Benjamin Franklin. The Gulf Stream flows up from the Gulf of Mexico along the East Coast of the United States and then moves across the Atlantic Ocean. The average surface speed of the Gulf Stream is about 8 km per hour. It is approximately 160 km wide and more than 100 meters deep.

The surface temperature of the Gulf Stream is about 24°C, warm enough to significantly affect the climate of two countries that are along its path, England and Ireland. Without the warm Gulf Stream, England and other places in Europe would be as cold as Canada. Where the warm Gulf Stream flows across the Atlantic toward Europe, it becomes known as the North Atlantic Current.

On reaching the shores of England and Ireland, the North Atlantic Current warms the coastal water temperature of these two countries by as much as 15°C. This produces a moderate climate of warm summers and not very cold winters. The warm, moist air brought in by the current meets the colder air coming from the north and condenses to produce the rain and fog that are typical of this region.

Another global ocean current is the California Current. The California Current and the Gulf Stream Current move in opposite directions. The Gulf Stream flows from south to north, and the California Current flows north to south. Which one is warmer?

The Gulf Stream is warmer because it originates in tropical waters; and the California Current is cold because it comes from the north. The Gulf Stream warms the beaches along the East Coast from Florida to Massachusetts, making it possible to swim comfortably during the summer. However, because of the cold California Current, bathers encounter colder ocean water from Washington to California.

Ocean currents are deflected to the east in the northern hemisphere and to the west in the southern hemisphere. What causes ocean currents to move in these directions? This circular drift of the oceans was first studied by the French physicist Gaspard Coriolis (1792-1843) and has come to be known as the **Coriolis effect**.

The Coriolis effect states that the spinning Earth causes the winds and surface waters to move in a clockwise direction in the northern hemisphere and in a counter¬clockwise direction in the southern hemisphere. (The winds help drive the movement of the ocean's surface waters.) The continents deflect the ocean currents, causing them to move in giant circles called gyres. These wind-driven ocean currents are also called **surface currents**. Such currents are important to marine life because they move the drifting plankton thousands of kilometers across the ocean.

The Role of Wind

Surface ocean currents are mainly caused by wind. The winds that most affect the oceans' currents are:

The Westerlies (40-50 degree latitudes) blow west to east.
The Trade Winds (20 degree latitudes) blow east to west.

Both of these winds are a result of warm air from the tropics moving to the poles and the Coriolis effect (that due to the rotation of the Earth, water moves clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere). Because these huge circular currents are blocked by continents, smaller (though still giant) ocean current circles called gyres are formed.

The Role of Density

Differences in water density affect vertical ocean currents (movement of surface ocean water to the bottom of the ocean and movement of deep ocean water to the surface).

Variations in water density are caused by variations in salinity (the amount of salt in water) and temperature. Saltier water is more dense than less salty water; cold water is more dense than warm water. Denser water tends to sink, while less dense water tends to rise. **Cold-water currents** occur as the cold water at the poles sinks and slowly moves toward the equator. Warm-water currents travel out from the equator along the surface, flowing toward the poles to replace the sinking cold water.

As these currents mix the oceans surface and deep waters, they help replenish the oxygen in the water.

Other Causes of Currents

Other causes of currents include tides, rain, runoff, and ocean bottom topography. Topography is the surface features of a place. Ocean topography includes slopes, ridges, valleys, and mountains! All these things are found at the bottom of the ocean, and can influence currents.

Global ocean currents move horizontally across the ocean's surface. There are also subsurface currents, parts of which may move in a vertical direction. There is a salinity difference between the two bodies of water. The Mediterranean Sea has a higher salinity (about 3.9 percent) than does the Atlantic Ocean (about 3.5 percent).

Why is the Mediterranean saltier? The climate in the Mediterranean region is hot and dry; so, the sea, which is enclosed by land, is warmer than the Atlantic and its water evaporates faster. When water evaporates, salt is left behind, which increases salinity. The saltier water in the Mediterranean is denser, so it sinks below the cold waters of the Atlantic Ocean and flows out as a subsurface current. The less salty (and thus less dense) waters of the Atlantic flow into the Mediterranean at the surface.

Temperature differences also can produce vertical water currents. Warm water rises and cold water sinks (unless the salinity differences are great, as in the case of the Mediterranean subsurface current). Cold water sinks because its molecules are closer together, making the water denser.

Warm water rises because its molecules are in motion and are spaced farther apart, making the water less dense. Picture the ocean as a giant pool that is heated by the sun. At the equator, the water is warmer, so it rises. At the poles, the water is colder, so it sinks. As the warmer water rises at the equator, the colder water from the poles flows in to take its place. This creates giant cycles of flowing water from the poles to the equator.

The spreading of heat energy that results from the rising of warm water and the sinking of cold water is an example of a convection current. These currents also bring oxygen from the surface waters to the deeper waters. (Recall that convection currents also occur when warm air rises and cool air sinks, and when magma flows within Earth's mantle.)

Warm water rises at the equator, flows until it cools, and sinks at the poles. Cold-water currents (from the poles) that replace the rising currents at the equator flow below the surface. In recent years, scientists have found evidence for deep countercurrents, which are slow horizontal ocean currents that flow in a direction generally opposite to the wind-driven currents at the surface.

Not all subsurface currents are slow. One of the fastest types is called a **turbidity current**. Turbidity currents are found along the continental slope, where the sea floor around a continent drops off steeply. Turbid means "cloudy," and the cloudiness is due to the presence of silt, mud, and clay in the current as it rushes down a slope like an underwater avalanche.

The great speed of a turbidity current, as high as 80 km per hour, is due to the steepness of the slope. Turbidity currents are powerful enough to carve out many V-shaped depressions (canyons) on the floor of a slope. Turbidity currents off the mid-Atlantic coast produced the Hudson and Baltimore canyons.

Every time a wave breaks on the beach, it dislodges sand. Waves that break at an angle produce a current that moves parallel to the beach, called a **longshore current** (or littoral current). The movement of beach sand along the shore, pushed by waves and currents, is called littoral drift. During storms, when waves and currents have much more energy, littoral drift increases significantly.

When vertical currents rise to the surface from the depths, they often contain nutrient-rich sediments from the bottom. The rising of such waters from deep in the ocean is called an upwelling. Upwellings are significant because nutrients such as phosphates and nitrates are important for the growth of plankton. Plankton are an important food source for a variety of marine animals.

Areas of significant coastal upwellings make excellent fishing grounds. Peru has traditionally been one of the leading fishing nations in the world because of the upwelling that occurs along its coast. The tiny anchovy (Engraulis sp.), which feeds on the plankton that thrive in upwellings, was the backbone of the fishing industry in Peru.

In good years, millions of metric tons of this fish were harvested. Unfortunately, a combination of over fishing and El Niños has caused a crash in the anchovy population since the 1970s and a reduction in catch to about 100,000 metric tons per year. Humans are not the only ones to suffer. Millions of ocean fish, invertebrates, seabirds, and marine mammals also have suffered from the loss of this food source.

After a wave breaks on a beach, the forward momentum transports water up the slope of the beach. The returning current or backwash is called the undertow. An undertow is an example of a current caused by wave action. As you may know from experience, an undertow has enough force to cause someone standing in the surf zone to lose his or her footing.

On beaches with heavy surf, sand eroded by wave action gets deposited a short distance from shore in a long hill called a **sandbar**. A sandbar forms parallel to the beach and acts like a dam by holding accumulated water from breaking waves. If water accumulation is too great, the pressure causes the sandbar to break, producing a rush of water seaward. This fast, narrow current of water seaward is called a rip current. If you get caught in a rip current, do not caught it. Let the current carry you out a short distance, where its energy is dissipated. You can then swim back to the beach, but do so diagonally to avoid swimming into another rip current.

Tides also produce currents. When the tide enters and leaves bays and inlets, the tidal change produces swift-moving tidal currents, which run parallel to the shore. These currents are swiftest when the tide is changing from high to low or from low to high. Tidal currents slow during a period called slack water, which usually occurs at the end of each high tide and low tide. Tidal currents are important to marine life along the coasts because they carry nutrients and small organisms back and forth between the bays and the offshore waters.

An interesting, and potentially dangerous, phenomenon usually caused by tidal currents that move past each other in coastal waters is a whirlpool. A whirlpool (also called an eddy) is the rapid movement of surface waters in a circle. Whirlpools, which often form between islands, may also result from strong winds or when ocean currents flow against tides or unusual coastal features. At the center of the whirling water is a depression. Larger whirlpools can pose a danger to boats and people, because the water's movement is strong enough to draw large objects into the whirlpool's center.

The land and sea are always involved in a game of give and take. Tides, waves, and currents remove sediments from the shore, a process called erosion. These same movements of ocean water also deposit sand along beaches, a process called deposition. Along every shoreline, these two dynamic processes occur. When people choose to live along the shore, they must contend with the natural forces that may cause a beach to grow in one area, while it erodes in another.

Each year, government agencies spend billions of dollars trying to decrease erosion and preserve beachfronts by constructing barriers. One kind of barrier, called a groin, is made of wood or rock and extends straight out from the sand into the water at regular intervals. Although groins cause a build-up of sand on one side, erosion still occurs on the other side. Another barrier, called a jetty, traps sand and prevents it from accumulating in a channel. Other barriers, called breakwaters, are placed offshore to reduce the erosive power of wave action on the shore.

The image above is an example of erosion in Port Campbell National Park in Australia. The Twelve Apostles are a landmark for Victoria and Australia. The limestone stacks are formed naturally: by erosion. In July 2005, an 'Apostle' (50 meter tall) collapsed. There are now only eight left.

Pumping sand from a nearby sea floor and dumping it onto the beach, a process called dredging, also can be used to slow beach erosion. However, dredging is just a temporary solution to beach erosion because, in time, the ocean will reclaim the sand. Structures called seawalls are also built along shores to prevent property from being flooded during storms. But, eventually, wave action undermines seawalls, causing them to collapse into the water.