Lesson: Water, Seawater, Ocean Circulation and Dynamics

In this lesson, you will learn about the composition of water, seawater, and ocean circulation and dynamics. You will also have a better understanding of the causes and effects of motion and force.

The oceans, the big blue, source of life, the hallmark of Earth. We hold the oceans within us, both physically and mentally. Vast, blue, tranquil, and treacherous, the oceans are the signature of our planet. The only planet in the solar system blessed with a liquid medium for life to evolve in.

The motions of the atmosphere, traced out by clouds, and the size of the oceans dominate the view of earth from space. So vast are the oceans, in fact, that they take up almost 71% of the entire surface of the globe (139 million square miles). The oceans have an average depth of 12,230 feet (3730 m) and reach the deepest point in the Mariana Trench of the northwester Pacific Ocean, at 36,204 feet (11,038m) below sea level. The ocean basins hold at vast quantity of water, over 285 million cubic miles of water (1185 million cu. km.). This vast quantity of water arose from the Earth's interior as it cooled.

The oceans are the largest repository of organisms on the planet, with representatives from all phylum's. Life is extremely abundant in the sea, from the obvious large whales, fish, corals, shrimp, krill and seaweed, to the microscopic bacteria floating freely in the seas. The bacteria is so abundant that just one spoonful of ocean water contains from 100 - 1,000,000 bacteria cells per cubic centimeter!

The oceans contain the largest repository of organisms on the planet, and all the organisms in the ocean are subject to the properties of the seawater surrounding them. Water surrounds all marine organisms, composes the greater bulk of their bodies, and is the medium by which various chemical reactions take place, both inside and outside of their bodies.

Water itself is very simple. Each molecule of water is composed of two hydrogen atoms and one oxygen atom. The hydrogen atoms bond to the oxygen atom asymmetrically by sharing electrons (Each hydrogen atoms shares its only electron with the oxygen atom. The oxygen atoms receives the two electrons needed to complete its outer shell, making it a stable molecule.)
Important interactions occur because of the electron sharing. The oxygen atoms tend to draw the electrons furnished by the Hydrogen atoms closer to its nucleus, creating an electrical separation and a polar molecule.

The polar nature results in the hydrogen end (which has a positive charge) attracting the oxygen end (with a negative charge) of other adjacent water molecules. This forms Hydrogen Bonds between adjacent water molecules. These bonds are weak compared to the electron sharing bonds (6% as strong) and are easily broken and reformed.

The hydrogen bonding and polarity of water molecules is responsible for many of the unique characteristics and physical properties of water.

- If water was not polar, it would be a gas at room temperature and have an extremely low freezing point, making life impossible.
- At the air-water interface, the sticky polar nature of water allows it to form a 'skin' over the water surface, strong enough to support small objects. This phenomenon is known as surface tension, and water has the highest surface tension of all common liquids.
- Water has a great capacity to hold heat energy, with the highest heat of vaporization of most common substances (thus a high boiling point--allowing it to be liquid on the surface of the relatively warm Earth). When water evaporates, it absorbs considerable amounts of heat.
- Water has a high latent heat of fusion; when ice is formed, considerable amounts of heat energy is released. Water therefore acts as a buffer against temperature changes and keeps the earths climate from rapidly fluctuating.
- When water freezes, it becomes less dense-- hence ice floats (a lucky thing as if it were not so, the oceans would be frozen solid)
- Possibly most important for the chemical processes of life-- water is a universal solvent. It has the ability to dissolve more substances than any other liquid (due, once again, to its polar characteristics and hydrogen bonding). When dissolved in water, salts turn into their ions (Sodium chloride, table salt, NaCl becomes Na+ and Cl--.) This allows for many free radicals to be available to the chemistry of life.
- Water is very dense, some 800 times denser than air. The density allows large and small organisms to float along effortlessly for long periods of time (compared to land, where terrestrial organisms must fight gravity with each step in order to move around.)
- Water absorbs light rays very quickly (important to photosynthetic life, which is only possible where light penetrates, and all light is absorbed by 600 feet beneath the surface of the oceans)
- Water absorbs light differentially. The red end of the light spectrum is absorbed in shallow water while the blues and greens penetrate the deepest (important for plants because different plants use different parts of the light spectrum for photosynthesis, and the differential absorption can determine the vertical distribution of marine plants).

Seawater is pure water plus dissolved solids and gases. The dissolved solids come from 'weathering' processes of the continental land masses rocks being dissolved by rain water and flowing out to sea with the rivers. The gases come from the atmosphere. As water is a universal solvent, many different compounds are dissolved in it.

A 1kg sample of saltwater contains 35 g of dissolved compounds, including inorganic salts, organic compounds from living organisms, and dissolved gasses. The solid substances are known as 'salts' and their total amount in the water is referred to by a term known as **Salinity** (expressed as parts per thousand).

Oceanic salinities generally range from 34 to 37 parts per thousand. Variations from place to place are due to factors such as rainfall, evaporation, biological activity and radioactive decay. Salinities are higher in the tropics due to high evaporation rates. Fresh supplies of salts are now being added to the oceans from the rivers at roughly the same rate that they are being removed by various physical, chemical and biological processes.

Temperature is a very important physical parameter in the marine environment. It limits the distribution and ranges of ocean life by affecting the density, salinity, and concentration of dissolved gasses in the oceans, as well as influencing the metabolic rates and reproductive cycles of marine organisms.

The seasonal range of temperature in the ocean is affected by latitude , depth, and proximity to the shore. Marine temperatures change gradually because of the heat capacity of water. In the abyssal zone, water temperatures are remarkably stable and remain virtually constant throughout the year. Similarly, in equatorial and polar marine regions, ocean temperatures change very little with season.

Because the surface of the ocean is heated by sunlight, the depths are cooler. There is a minimum of vertical mixing, because the warm water cannot displace the dense, colder deep water.

The waters of the ocean are in constant motion. Its movement ranges from strong currents such as the Gulf Stream, down to small swirls or eddies.

What causes all of this motion?

The short answer is: energy from the Sun, and the rotation of the Earth.

The Sun drives oceanic circulation in two primary ways:

Circulation of the atmosphere--this is, **winds**.

Energy is transferred from atmospheric winds to the upper layers of the ocean through frictional coupling between the ocean and the atmosphere at the sea-surface. Causing variations in the temperature and salinity of seawater, which in turn control its **density**. Changes in temperature are caused by fluxes of heat across the air-sea boundary

Changes in salinity are brought about by the addition or removal of freshwater (mainly through evaporation and precipitation, but also, in polar regions, by the freezing and melting of ice.

If surface water becomes more dense than underlying waters, an unstable situation develops and the denser surface water will sink. This vertical, density-driven circulation is known as thermohaline circulation.

The rotation of the Earth contributes to ocean circulation patterns. The frictional coupling between the oceans waters and the solid Earth is very weak. The same is true for air masses. Only very close to the surface of the Earth is frictional coupling significant. In the extreme case of a projectile moving above the surface of the Earth, the frictional coupling is effectively zero.

The Earth rotates at a constant rate. Consider the following: A missile fired due northwards from a launch pad at the equator. When it leaves the launch pad, the missile is moving eastwards at the same velocity as the Earth's surface, as well as moving northwards at its firing velocity. Initially, because it has the same eastwards velocity as the surface of the Earth, the missile appears to travel in a straight line; however, as the eastward velocity at the surface of the earth is greatest at the Equator and decreases towards the poles, as the missile travels north, the eastward velocity of the Earth below the missile becomes less and less.

As a result, in relation to the Earth, the missile is moving not only northwards but also eastwards, at a progressively greater rate. The apparent deflection of objects which move over the surface of the Earth without being frictionally bounds to it (such as missiles, or water and air), is explained in terms of an apparent force known as the **Coriolis force**.

A missile launched from the Equator has both its northerly firing velocity and an eastward velocity relative to the surface of the Earth at the equator.

Its actual relative travel follows a resultant vector which is a combination of the two.

The path taken by a missile has a deflection attributed to the Coriolis force. The coriolis force increases with increasing latitude.

The magnitude of the Coriolis force increases from zero at the Equator to a maximum at the poles.

The Coriolis force acts at right angles to the direction of motion, so as to cause a deflection to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Because a missile is moving so fast, the amount that the Earth has 'turned beneath" it during its short flight is small. Winds and ocean currents, on the other hand, are slow moving, and so are significantly affected by the Coriolis force. Consider an ocean current flowing at 1 knot at 45 degrees north latitude. The mater will travel about 1800 meters in an hour, and during that hour the Coriolis force will have deflected it about 300m from its original path! The Coriolis force therefore has a significant effect deflecting oceans.