

MODULE #1: The Oceans of Our Planet

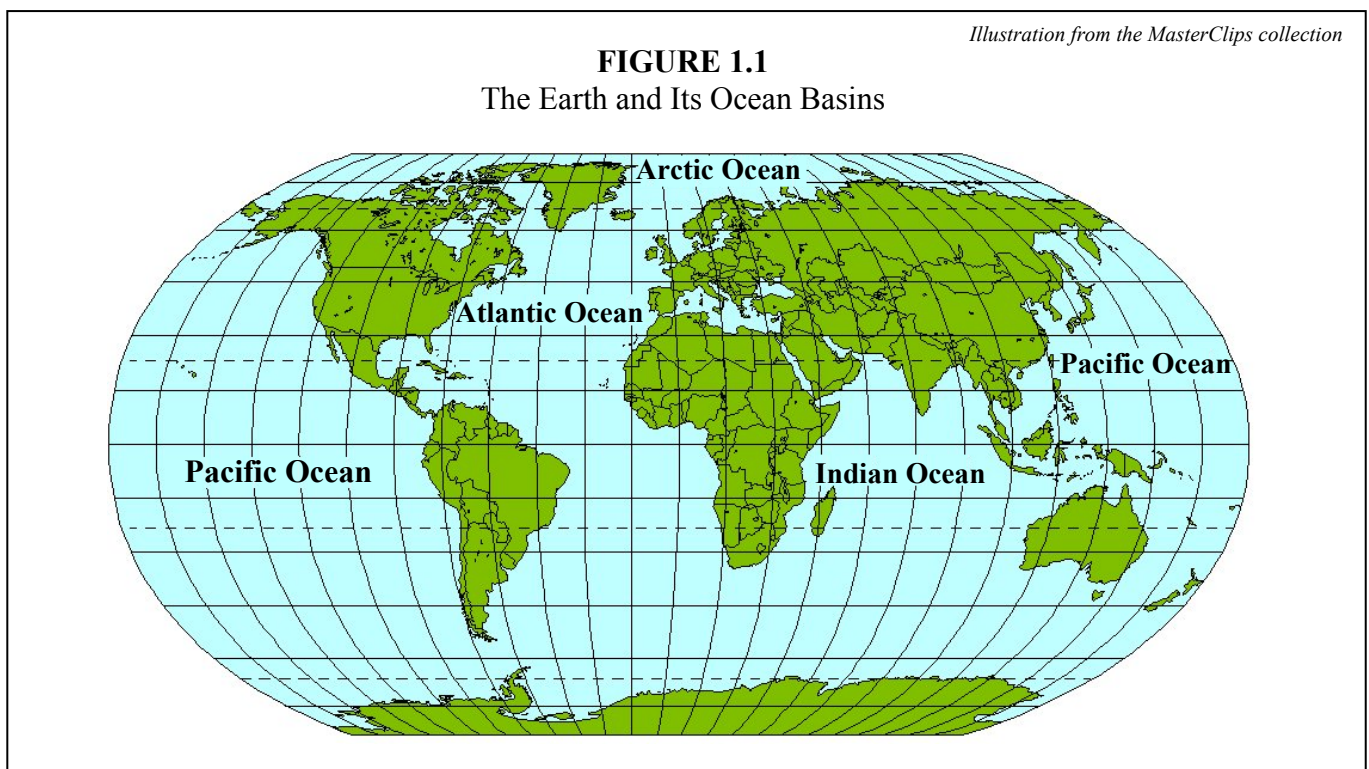
Introduction

This course is going to teach you about marine biology. The science of marine biology represents a specific discipline of biology that, of course, pertains to the sea. You will find that almost all the areas of general biology are covered in the study of marine life. We will learn about the basic chemistry of living things, marine plants and animals, their behavior, and how oceans behave as systems.

The oceans in creation are much more plentiful than you may think. In fact, the combined surfaces of earth's oceans cover 72% of the earth! With nearly three-fourths of our world covered with seawater, it is easy for you to see the great impact marine biology has on all of us and the importance of studying it. In this module, we will discuss the geography of the ocean basins, the properties of seawater, and how the water in the oceans circulates.

The Geography of the Oceans

As I said before, more of the world is covered with oceans than land. This water is not distributed equally over the globe, however. There is more ocean area in the Southern Hemisphere than in the Northern Hemisphere. In fact, almost two-thirds of our planet's land area is located in the Northern Hemisphere, while 80% of the Southern Hemisphere is covered by water! There are four large ocean basins on the earth, as shown in the figure below:



An ocean basin is basically a very large depression, or bowl, on the surface of the earth. The largest and deepest of these is the **Pacific Ocean basin**. It is almost as large as the other three basins

put together. The **Atlantic Ocean basin** is the next largest in size. The **Indian Ocean basin** is a little smaller than the Atlantic, but it is similar in depth. Finally, the **Arctic Ocean basin** is the smallest and shallowest (see Table 1.1). These four deep basins are connected to various shallower seas, many of which are probably familiar to you. The Caribbean, Arabian, and Mediterranean Seas, as well as the Gulf of Mexico, are a few examples of these shallower seas.

TABLE 1.1
Average Depths and Sizes of the Four Major Ocean Basins of the Earth

Ocean	Average Depth (meters)	Approximate Area (sq. km)
Pacific	4,190	166,000,000
Atlantic	3,740	86,500,000
Indian	3,870	73,000,000
Arctic	1,330	9,500,000

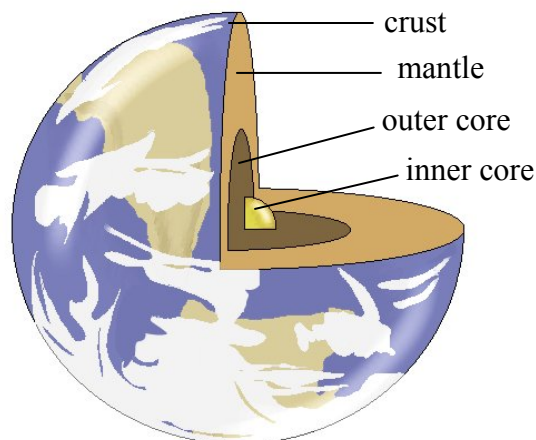
If you look at Figure 1.1, you can see how the Pacific, Atlantic, and Indian oceans are connected by a large pathway of water that surrounds the continent of Antarctica. Scientists sometimes call this the “Southern Ocean.” There also are waterways that connect these oceans to the Arctic Ocean in the north. This makes it possible for seawater and organisms to move from one ocean to another.

The Earth’s Structure

Now that we have discussed the placement of the land and ocean surfaces on the earth, let’s take a look at what is below them. The earth is made up of various layers, as shown in the figure below:

FIGURE 1.2
Section Through the Earth Showing Its Layers

Illustration by Megan Whitaker



Scientists have performed many tests to determine the composition of these layers. Although no one has ever been able to travel through the earth's crust, much less to its center, these tests help reveal the makeup of these layers. At the center of the earth is an inner core that scientists believe is made up of solid iron under intense pressure. The next layer is the outer core, which experiences slightly less pressure, resulting in liquid iron. It is believed that the motions within this outer core produce the earth's magnetic field. The next layer is the mantle, made up of rock that is near its melting point. This slow-flowing material, called **plastic rock**, sometimes behaves like a liquid and sometimes like a solid. The outermost layer of the earth is the crust and is much thinner than the other layers. The crust "floats" on top of the plastic rock of the mantle.

You probably have studied a lot of this in earlier science classes, so I won't be covering this topic much more except to distinguish between two types of crust. Geologists explain that the difference between "ocean" and "continents" is caused by the chemical and physical differences in the rocks, not whether they are covered by water. The part of the earth that is covered with ocean is made up of **oceanic crust**, composed mainly of **basalt** (buh salt'). Basalt is solidified lava that is usually dark in color. The second type of crust is **continental crust**, and it is primarily composed of **granite**, a substance that is chemically different from basalt and has a lighter color. Oceanic crust is denser than continental crust and therefore "floats" a little lower on the mantle than continental crust. It is also much thinner than continental crust. Oceanic crust is about 5 kilometers (3 miles) thick, while continental crust is on average 20 to 50 kilometers (12 to 30 miles) thick.

Oceanic crust – The portion of the earth's crust that primarily contains basalt, is relatively dense, and is about 5 kilometers thick

Continental crust – The portion of the earth's crust that primarily contains granite, is less dense than oceanic crust, and is 20 to 50 kilometers thick

ON YOUR OWN

1.1 What are the four major ocean basins of the world?

1.2 You have a sample of oceanic crust and a sample of continental crust. How could you tell which is which?

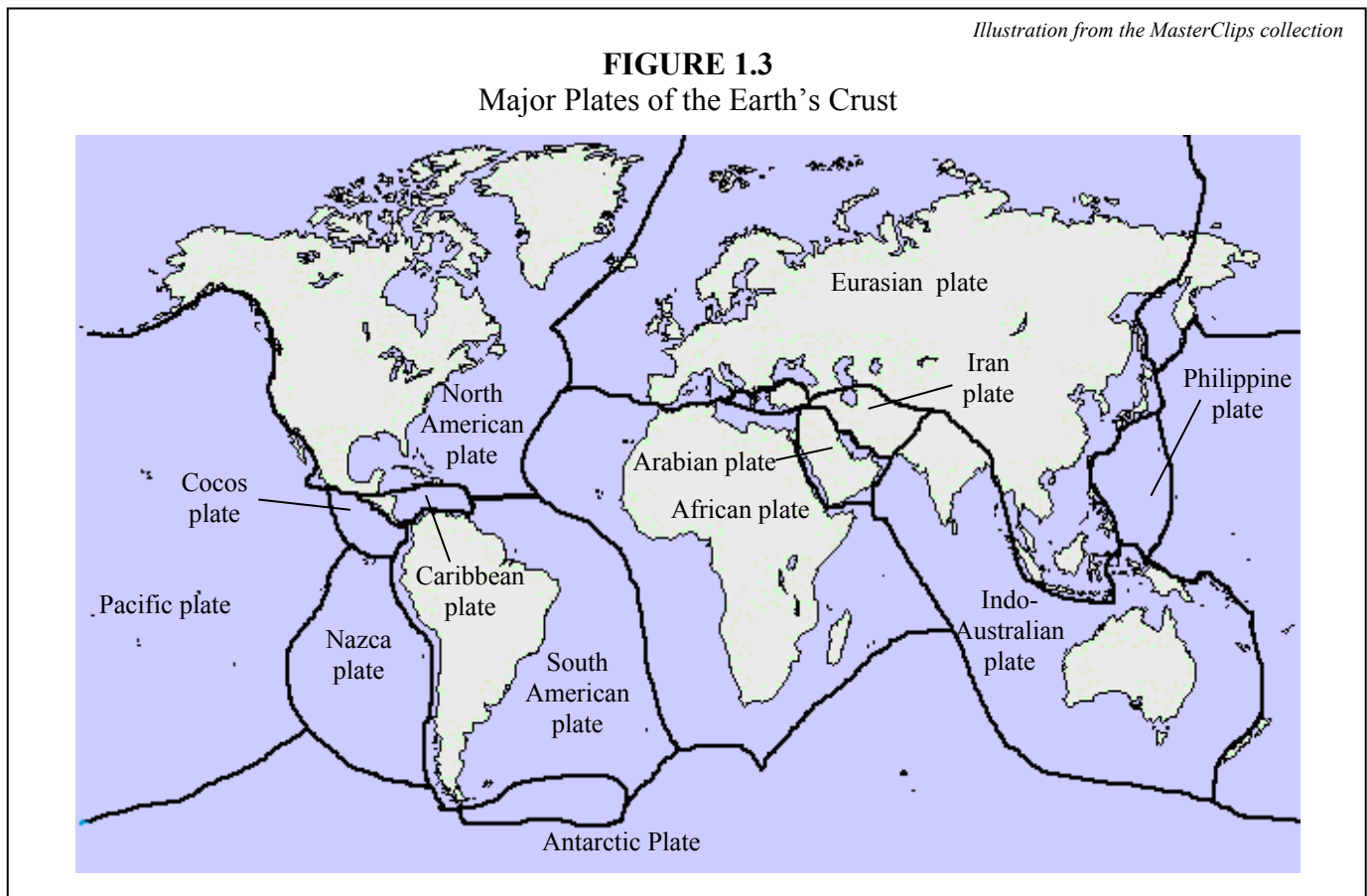
Continental Drift and Plate Tectonics

As early as the 1600s, scientists began looking at the shape of the continents and noticed that they seem to "match up" like puzzle pieces. This led many to suggest that the continents may have been joined at one time in our earth's history. Later, other similarities between continents were discovered. Coal deposits and fossils on opposite coasts of the Atlantic Ocean are so similar that they seem to be parts of a greater whole. In 1912, a German geophysicist named Alfred Wegner came up with a detailed hypothesis of **continental drift** as an explanation of this kind of data. He suggested that all the continents at one time were part of a large supercontinent called **Pangaea** (pan jee' uh). He believed this large land mass began breaking up, and the continents slowly moved away from each other to their present positions today. This idea was not well received in the scientific community of that time because Wegner did not have a believable explanation for the force required to move the land masses. Later, as more evidence was discovered supporting this theory, scientists began to agree that the continents do indeed drift. They named the process that moves them **plate tectonics**.

Plate tectonics – A process involving the movement of large plates on the earth's mantle

Plate tectonics is based on the earth's crust being divided into giant, irregular plates that float on the dense mantle of the earth. Scientists now believe that radioactive decay of elements in the earth's mantle and the resulting heat cause plate movement. They think that as the heat rises through the plastic rock of the mantle, it generates currents that move the plates floating on the plastic rock. To visualize this, imagine a large Styrofoam® rectangle floating in a swimming pool. The Styrofoam would represent Pangaea, and the water would represent the plastic rock of the earth's mantle. Now imagine that you add pressure to the foam until cracks form, yet you hold the many pieces together in their original shape. Once you let go, the pieces, representing plates, will float away from each other due to the movement of the water molecules beneath them. If you heated the water below the Styrofoam, water molecules would move faster, making the pieces float away from each other more quickly. Heat-induced motion of the various compounds in the plastic rock of the mantle could cause the continents to float away from each other in a similar way.

According to the theory of plate tectonics, the continents are resting on various plates of the earth's crust, as shown in the figure below:



At the locations where the plates meet (the dark lines in the figure), there are two types of geological structures: a **mid-ocean ridge** system or a **trench** system. The mid-ocean ridge system is a continuous chain of volcanic underwater mountains. These ridges extend all around the earth and are the largest geological features on the planet!

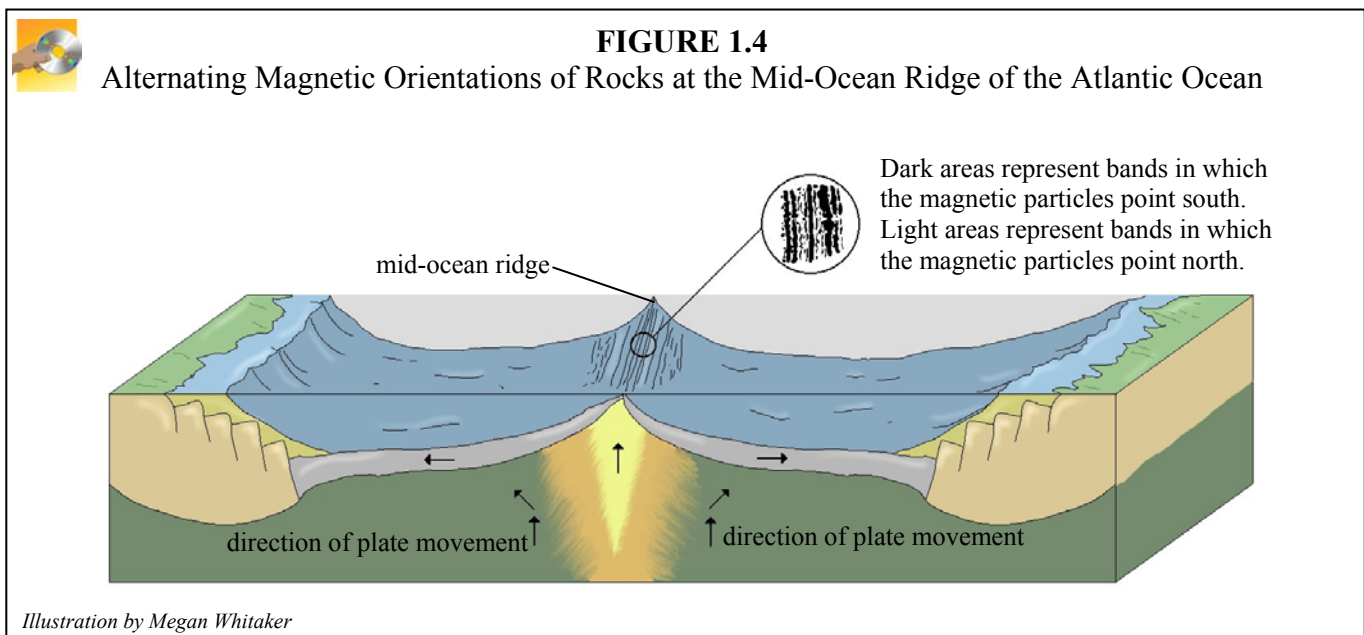
Mid-ocean ridge – A continuous chain of underwater volcanic mountains encompassing the earth

Some mountains of the various mid-ocean ridges rise so high that they actually extend above the ocean's surface and form islands, such as the Azores in the Atlantic Ocean. The ridges seem to snake along the ocean floor, mirroring the positions of the edges of the continents. At other sites where plates meet, there is a system of deep depressions, or trenches. These trenches also seem to follow the shape of the nearby land masses. You will learn how the ridges and trenches form later on.

Now let's talk about some facts and data that scientists began to gather in relation to these ridges and trenches. Scientists discovered that there is a large amount of geologic activity around both ridges and trenches. Earthquakes are common around ridges, and volcanoes are found near trenches. Also, the layer of **sediment**, loose mud or sand that settles to the bottom of the ocean floor, gets thicker as you move away from the ridges.

Additionally, a very interesting phenomenon was discovered around the mid-ocean ridges. Geologists had already discovered that there were times in our earth's history when the magnetism of the earth had reversed. This means that during these reversal periods, a magnetic compass would point to the earth's South Pole, instead of the North Pole (which, of course, is where it points today)! How do scientists know this? Well, in molten rock, there are tiny magnetic particles that move to align themselves toward the earth's magnetic north. As these rocks cool and harden, those magnetic particles are frozen so that they always point to what was magnetic north when the rock cooled. Geologists have discovered many layers of igneous rock (rock that forms when molten rock cools) in which the magnetic particles point south, not north. This means those rock layers must have cooled when the earth's magnetic field was the opposite of what it is today.

As scientists sampled the rocks on the sea floor near the mid-ocean ridges, they began to see a pattern of bands running parallel to the mid-ocean ridge and representing groups of rock that have alternating magnetic orientations! In other words, the magnetic particles in those bands sometimes point north and sometimes point south. These magnetic particles that are pointing in the "wrong direction" are called **magnetic anomalies** (uh nom' uh leez), and they suggest that the bands of igneous rock on the ocean floor were formed from molten rock at different times in the earth's history.



Think about what this means. If the bands of igneous rock near the mid-ocean ridge were formed during different times in the earth's history, the sections of the earth's crust near the mid-ocean ridge seem to be *moving away from each other*. A crack in the crust results from this separation; we call it a **rift** between the plates.

As the plates move away from each other, there is less pressure on the mantle below the rift. The release of pressure allows the mantle material to melt enough to become liquid and rise up through the rift. Once it reaches the surface, however, it cools and becomes new oceanic crust. As it moves upward, it also lifts up the crust around the rift, forming the mid-ocean ridge. This process is called **seafloor spreading** and explains many of the discoveries found around the ocean ridges.

Seafloor spreading – The process that creates new sea floor as plates move away from each other at the mid-ocean ridges

You probably would expect, then, that the crust at the ridges is newer than the crust farther away from the ridges. As a result, the crust near the ridges has had less time to accumulate sedimentary material. That explains why the sediments of the ocean floor are thicker as you travel farther away from the ocean ridges.

Now let's put all of this information together to understand what scientists believe about the ocean floor. Seafloor spreading and plate tectonics are closely related to one another and indicate that the earth's crust is divided into giant irregular plates that float on the denser mantle material below. Each plate is bounded by oceanic trench and ridge systems. Some plates are made of both oceanic and continental crusts. New oceanic crust material is formed at the mid-ocean ridges, and as it moves away from the ridges, it carries the bottom sediments and continental land masses with it. Now this rate of movement is extremely slow; today the plates move at a rate of between 2 and 18 centimeters per year. That's about as fast as the rate at which your fingernails grow!

ON YOUR OWN

1.3 If a scientist discovered fossils of an extinct reptile on the west coast of southern Africa, and he knew that more examples of the same extinct fossil were found on the east coast of South America, would this discovery prove that the supercontinent Pangaea was indeed a reality?

1.4 If you were on a scientific expedition in the deep Atlantic Ocean, took a sample of the sea floor, and found that it had a very thick layer of sediment, would you presume that this area was close to or far from a mid-ocean ridge?

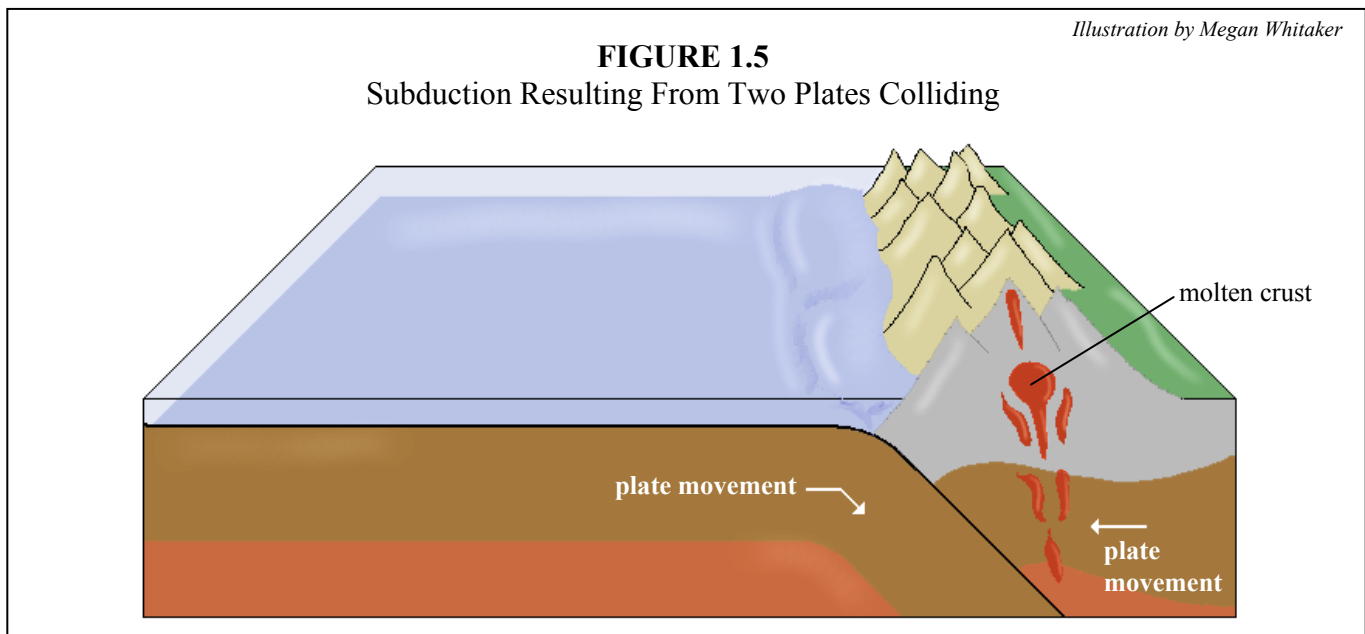
I want to stop here and discuss this phenomenon for a moment. The Atlantic Ocean is up to 1,000 miles wide and is believed to be a completely new ocean that formed when Pangaea broke apart. If it always grew at its present rate, it would have taken millions of years to get to the size it is today. However, there is no strong evidence to suggest that the rate of the ocean's growth has been constant. In fact, many parameters of our earth have not been constant over time, including the earth's magnetic field. Thus, there is no reason to believe that the plates have always moved slowly. During a catastrophic event, the plates might have moved apart from each other very quickly. In fact, there is a very detailed mathematical model of **catastrophic plate tectonics** that predicts very rapid plate movements during the worldwide Flood that occurred in Noah's day.

There is actually some evidence for such rapid plate movement. You see, it appears that many of the magnetic reversals of the earth may have occurred quickly, in a matter of days. Scientists have found evidence of a thin lava flow where the outside cooled first (displaying one particular magnetic orientation) and the inside cooled days later with evidence of a magnetic reversal! If magnetic reversals happened quickly, then the bands of magnetic particles near the mid-ocean ridge must have formed quickly as well, or the magnetic reversals would not have been “captured” in the rocks. This, then, is evidence that the sea floor might have spread very quickly in the past.

Plate Interactions

At this point in our discussion, let me pose a question: If new oceanic crust is forming at the rift, why isn't the surface of the earth increasing in size? Well, it turns out that the earth does not increase in size because when new ocean floor is formed, it is paired with the destruction of plates in another part of the world. This is where the trenches I talked about earlier come into play. A trench is formed when two plates are moving towards each other, and one of the plates dips below the other, sliding back down into the mantle. This process is called **subduction**.

Subduction – The downward movement of one plate into the earth's mantle when two plates collide



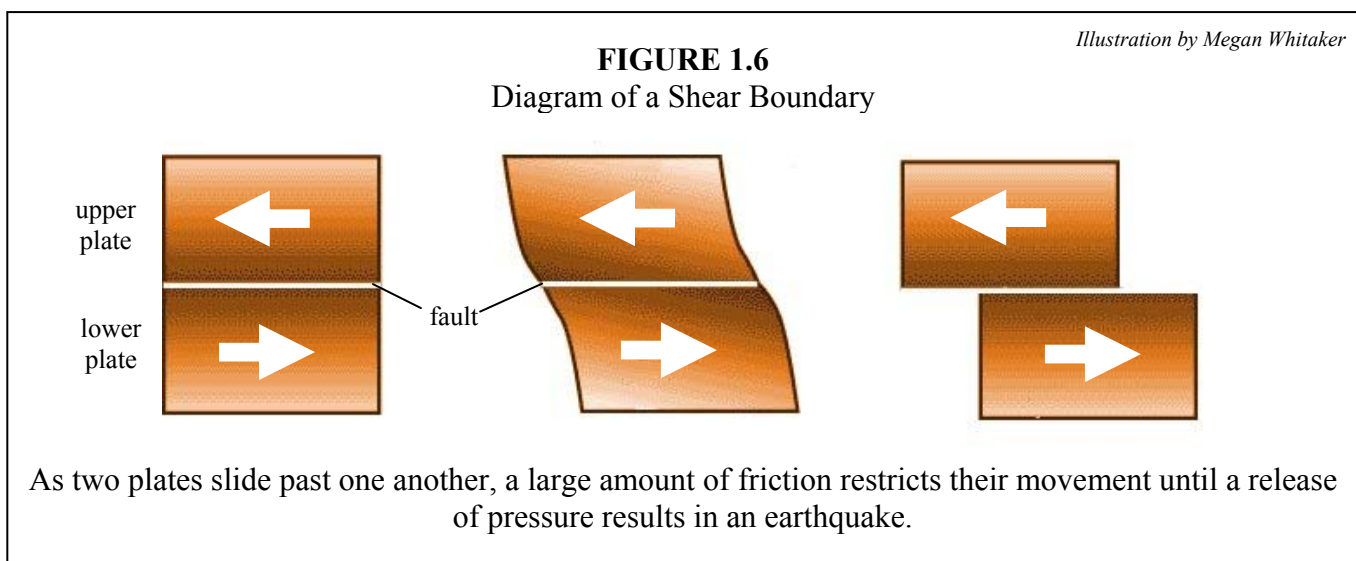
Once the plate enters the mantle, the extreme heat and pressure begin to break it up. The plate material eventually melts, and some rises back up to form volcanoes.

The interaction of plates at a trench depends on the types of plates that are colliding. For example, if an oceanic plate collides with a continental plate, the oceanic plate will sink into the mantle. Remember, it is heavier because it is made of denser oceanic crust. At these trenches, you will find continental volcanoes that form vast mountain ranges, such as the Andes Mountains in South America. In this particular instance, the oceanic Nazca plate in the southeast Pacific collides with and sinks below the continental South American plate.

In some places, two *oceanic* plates will collide, and one will dip below the other to form a trench. This again will result in volcanoes and sometimes form volcanic islands. A good example of this phenomenon is where the oceanic portion of the North American plate collides with the oceanic Pacific plate, creating the Aleutian Islands in the northern Pacific Ocean.

Lastly, two *continental* plates can collide. Since they are essentially the same density, neither will move under the other. Instead, in place of a trench, the two land masses will push against each other with great enough force to cause the rocks to bend and buckle, building up on top of each other. This folding of rock can form large mountain ranges, such as the Himalayas. The Himalayas were believed to be formed when the plate of India collided with Asia.

In addition to mid-ocean ridges, trenches, and mountain ranges, another type of plate boundary can occur when two plates slide past each other. In this boundary, no new plate material is formed and none is destroyed. This type of boundary is called a **shear boundary** and results in a fault.

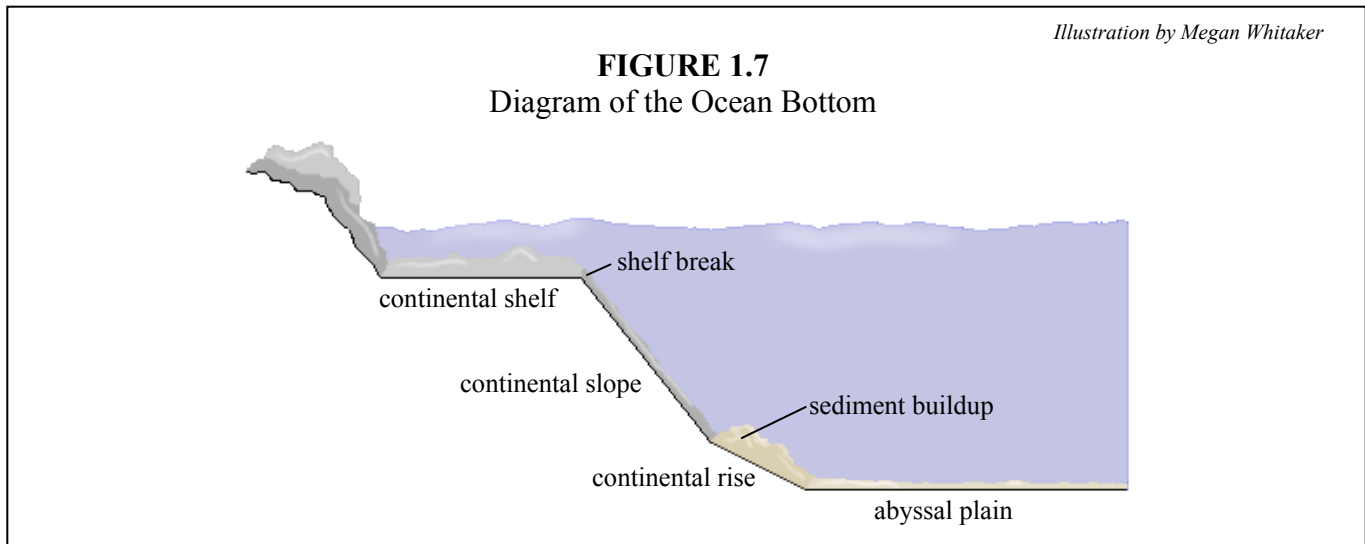


The parallel movement of the plates along the fault is not smooth because there is a great deal of friction between them. The plates become stuck against one another and build up pressure as they try to move. When they finally do move, they slide all at once, resulting in an earthquake. The San Andreas Fault in California is an example of a shear boundary and, as you probably know, is responsible for the many earthquakes that occur there. As you can see, this model of seafloor spreading and plate tectonics explains many observations made by geologists.

Features of the Ocean Bottom

The ocean floor can be divided into four main regions, as shown in Figure 1.7. Beginning at the shoreline of the continents and extending seaward is the **continental shelf**. It is actually a structural part of the continental landmass and would not be under the ocean if sea levels were to drop by as little as 5%.

Continental shelf – The gently sloped, shallow section of the edge of a continent, extending from the shore to the point where the slope gets steeper



Continental shelves make up about 8% of the ocean's surface area but contain the richest part of the ocean where most of its life is found. This is due to the fact that more light reaches the sea floor at the continental shelf, resulting in more producers, such as plants and algae. More producers mean a greater opportunity for animal life, as animals are consumers and therefore need to eat producers. The shelves are relatively smooth, sloping gently outward toward the sea. The outer edge of the shelf, where the bottom begins to become steeper, is called the **shelf break**. This occurs at depths of 120 to 200 meters and marks the beginning of the second region, the **continental slope**.

Continental slope – The steeper section of a continental edge, extending seaward from the continental shelf

This slope is the boundary between the continental masses and the true ocean basins, and it extends downward to the deep sea floor.

Deep at the base of the continental slope is a buildup of sediments resulting in the third region, the **continental rise**, which continues down to the sea floor.

Continental rise – The gently sloping area at the base of the continental slope

Because of its location at the foot of the more steeply graded continental slope, the continental rise collects debris and sediment.

The last region of the sea floor lies at a depth of 3,000 to 5,000 meters (10,000 to 16,500 feet) and is almost flat. This flat seafloor area is called the **abyssal** (uh bis' uhl) **plain**, and it gently slopes toward the mid-ocean ridges. You may think the abyssal plain is the deepest part of the ocean, but remember the trench systems we discussed? In the trench areas, the ocean is actually at its deepest, reaching depths of up to 11,020 meters (6.8 miles) in the Mariana Trench of the Pacific, the deepest known place in all the oceans.

ON YOUR OWN

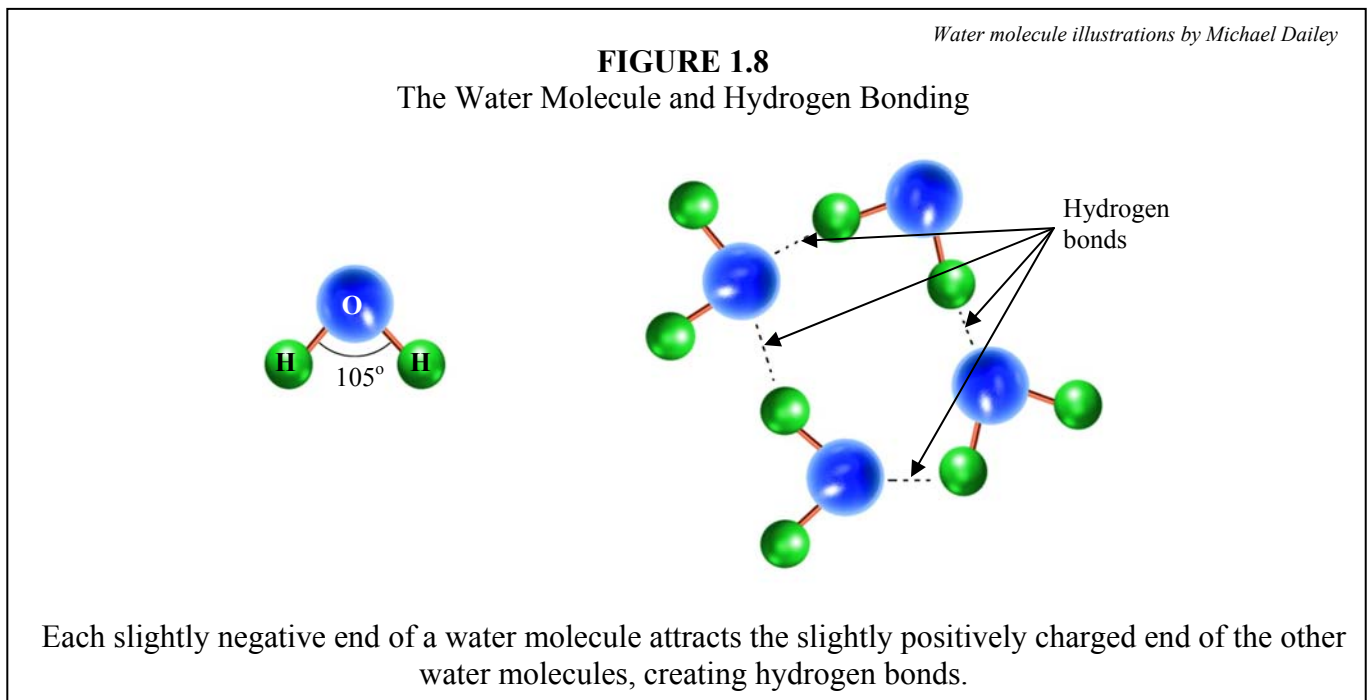
1.5 If an oceanic plate is colliding with a continental plate, what will most likely happen?

1.6 You are given a sample of sediment from the ocean. The container says it is a small sample of a large amount of sediment buildup. From which region of the ocean floor did the sample most likely come?

Properties of Water

I have gone into great detail about the “containers” of ocean water. Now it is time to discuss the nature of what those containers hold. In order to understand the sea life in this ocean water, you must have an understanding of the nature of water. Water makes up 80% to 90% of the volume of most marine organisms and provides buoyancy and body support for many of them. It also is the medium for most chemical reactions needed to sustain life.

As you learned in previous science courses, all matter is made up of tiny particles called atoms. When two or more atoms are chemically combined into a larger particle, the result is a molecule. A water molecule is made up of one relatively large oxygen atom and two smaller hydrogen atoms. The three atoms of a water molecule form an angle, with the oxygen atom at its vertex.



The bonds between the hydrogen atoms and the oxygen atom of a water molecule are formed by the sharing of two negatively charged electrons. The oxygen atom has a stronger “pull” on these electrons, causing the oxygen end of the molecule to have a slight negative charge. This leaves the hydrogen ends of the molecule with a slight positive charge. Each end on one water molecule attracts the oppositely charged end of other water molecules. The resulting attraction between water

molecules forms a weak bond, called a **hydrogen bond**. These bonds are not as strong as bonds within a molecule, but they make water different from most substances on earth.

Hydrogen bonding creates a flexible “skin” at the surface of water. This is called **surface tension**, and it helps hold water molecules close to one another at the surface of a body of water. It is so strong that items such as needles and razor blades can float on the surface of water if they are placed there in a careful manner. Even insects like the water strider can walk on water because of its surface tension. Without hydrogen bonding between molecules, water would be in a gaseous state at normal temperature and pressure, boiling at -80°C and freezing at -100°C . This would make the existence of life on earth impossible!

I want to discuss another amazing property of water. It exists on earth in all three of the possible phases of matter: solid (ice or snow), liquid (what you normally call water), and gas (water vapor). This is very rare. The molecules in liquid water are moving constantly, and some are being held in small groups due to hydrogen bonding. These groups continually form and break apart. The molecules will move faster if the temperature of the water is higher. If a water molecule moves quickly enough, it may break free of all the hydrogen bonds and go from liquid phase to gaseous phase. This process is called evaporation, and you have experienced it whenever you take a hot shower and see the resulting “fogginess” in the air from the water vapor. As the temperature rises, so does the rate of evaporation, resulting in more and more molecules escaping the hydrogen bonds. In water vapor, the molecules are not held together by hydrogen bonds and are much farther apart than in the liquid phase.

As liquid water cools, the molecules move more slowly and pack closer together, taking up less space. This decrease in volume results in the water becoming denser. As a result, cold seawater will sink below warmer seawater. Fresh water also gets denser as it gets colder, but only down to a temperature of about 4°C (39°F). Below 4°C , fresh water actually gets *less* dense as it cools (which is why solid ice cubes will float in liquid water). Why does this happen? It is because of the hydrogen bonding. In the liquid phase, water molecules are free to get very close to one another to take full advantage of the hydrogen bonds. As the water begins to freeze, the molecules actually move apart from one another in order to fit into the arrangement they must have in the solid phase. Since the molecules are farther apart from one another in the solid phase, solid water is less dense than liquid water.

EXPERIMENT 1.1

The Expansion of Solid Water

Supplies:

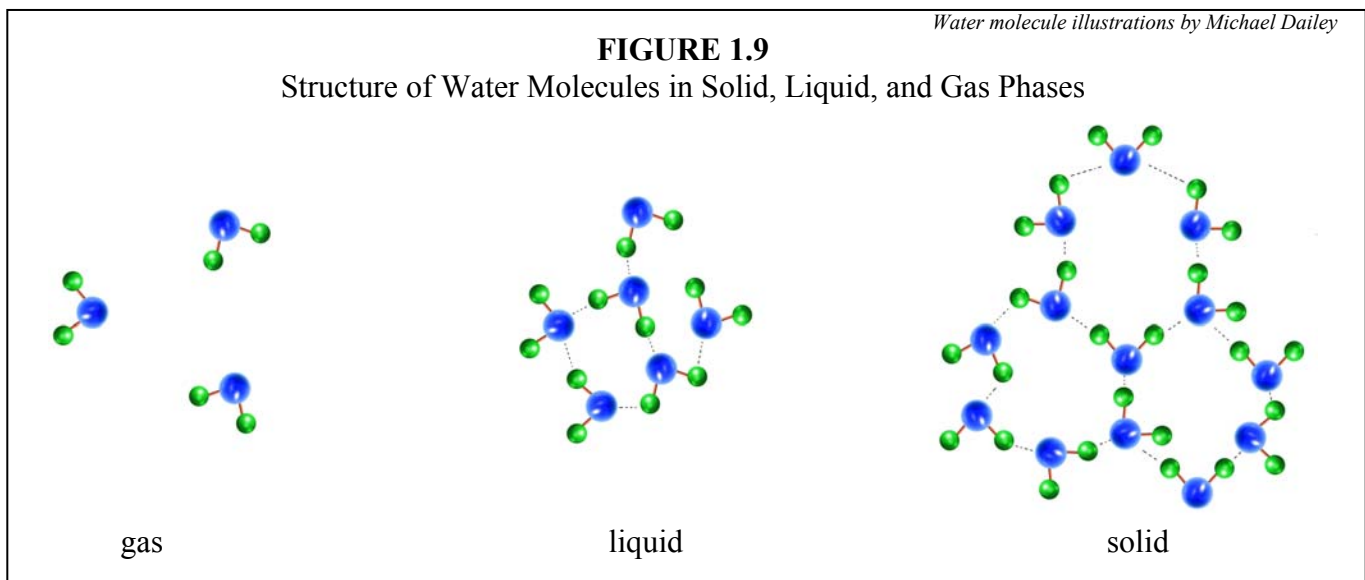
- A tall, clear or translucent *plastic* drinking cup or a 20-oz. empty water bottle
- Water
- A piece of masking tape

Introduction – When water is in its liquid phase, the molecules are in constant motion, some being held in small groups due to hydrogen bonding. When water freezes, the molecules slow down and pull apart from one another. You will observe the result of this movement in this experiment.

Procedure:

1. Fill the cup or bottle $\frac{1}{4}$ of the way with water.
2. Mark the water level by placing a piece of masking tape on the container so that the top side of the tape lines up with the level of the water.
3. Place the container in the freezer on a flat surface. If you are using a bottle, *do not* put a lid on top.
4. Allow the container to stay in the freezer overnight.
5. Note the level of the ice as compared to the position of the masking tape.
6. Allow the water to thaw in a sink and clean up.

What happened in the experiment? The volume of material in the container should have increased, resulting in a higher surface level. The more open, lattice-like pattern of the water molecules in the ice keeps the molecules farther apart than when they were in their liquid phase.



The molecules in your container took up more volume and therefore became less dense as the water froze. It is very unusual for the solid phase of a substance to be less dense than the liquid phase, but it has important implications for aquatic organisms. Because ice floats, it acts as an insulating blanket that helps keep the liquid water below from cooling down too quickly. As a result, lakes and parts of the ocean are kept from freezing into a solid mass, allowing life to exist below the surface of the ice.

Water has another amazing property that results from its hydrogen bonds: It has a large **specific heat**.

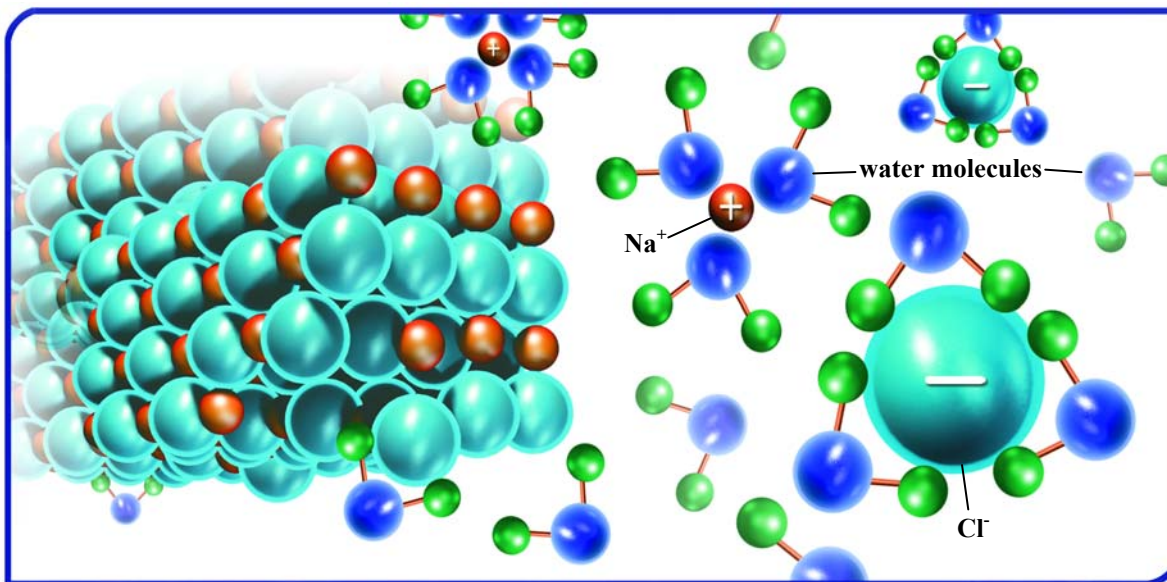
Specific heat – The amount of energy required to raise the temperature of one gram of a substance by $1.00\text{ }^{\circ}\text{C}$

It takes a lot more energy to increase the temperature of water by 1°C than most other substances. Because of this, a large amount of heat must be removed from a sample of water in order to cool it down. In the same way, a large amount of heat must be added to water in order to warm it up. Fortunately for aquatic organisms, this means the temperature of water does not change very quickly, resulting in a more constant environment.

There is one more general property about water I would like to discuss: Water can dissolve more substances than most other liquids. A substance that can dissolve other substances is called a **solvent**, and water is sometimes called the “universal solvent.” It is able to dissolve a lot of substances because of its small size and because of the slight electrical charges on the atoms of its molecules. Water is especially good at dissolving a class of molecules called **salts**, which are made of particles that have opposite electrical charges. These electrically charged particles are called **ions**, and they are either negatively or positively charged. Table salt (sodium chloride) is an example of an ionic molecule, consisting of a positively charged sodium ion (Na^+) and a negatively charged chloride ion (Cl^-). Remember, water molecules have a slight positive side (the hydrogen atoms) and a slight negative side (the oxygen atom). Ions have a stronger charge than the slight charges of water molecules, so when a salt crystal is placed in water, the strong electric charges on the ions attract the water molecules, causing a layer of water molecules to surround each ion. This weakens the attractions that hold the salt crystal together, and it causes the salt crystal to dissolve.

FIGURE 1.10*3-D illustration by Michael Dailey*

The Dissolving of a Salt Crystal by Water

**ON YOUR OWN**

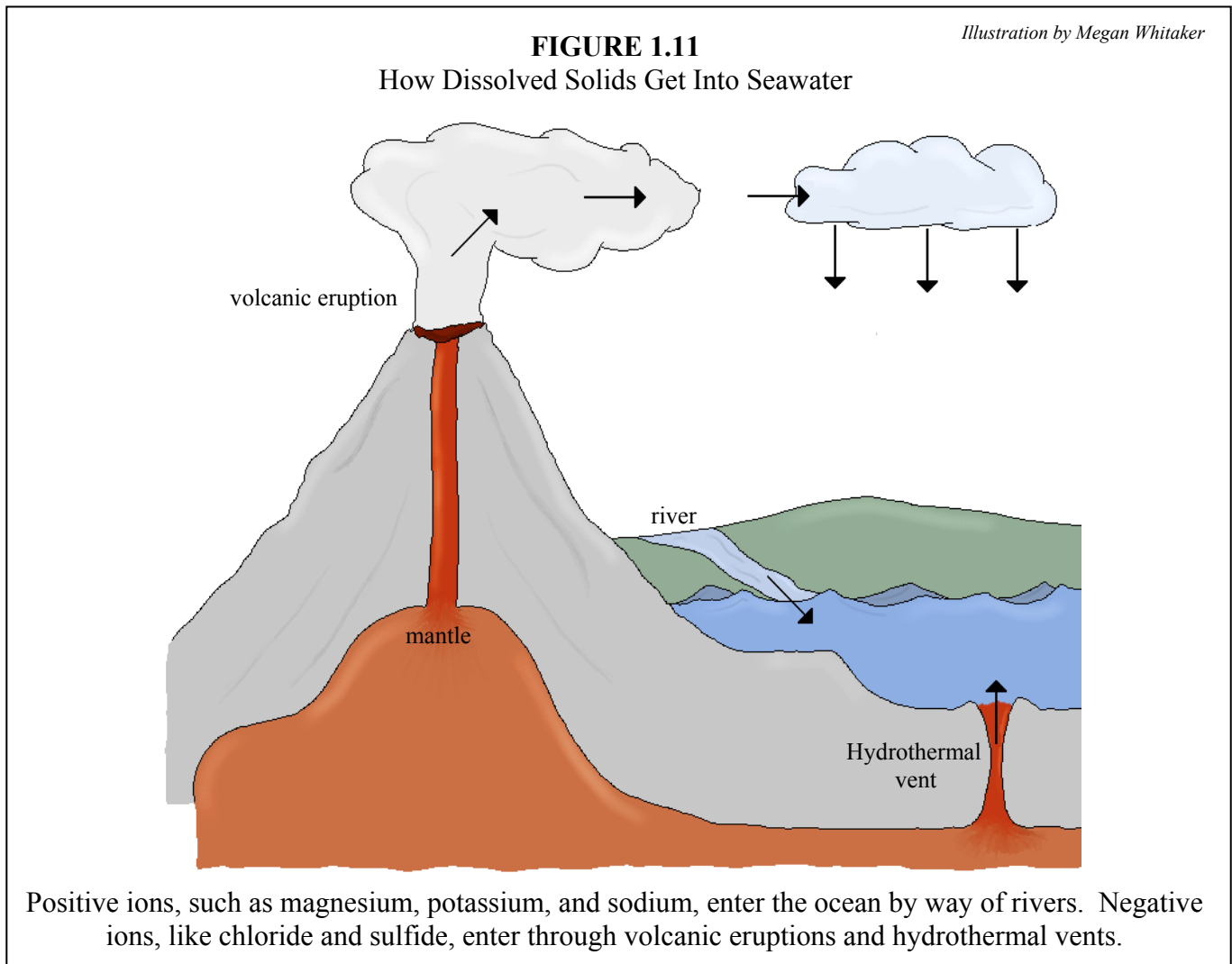
1.7 What gives water many of its unusual properties?

1.8 Benzene is a chemical that is liquid at room temperature. If frozen benzene is placed in liquid benzene, will it float or sink?

Seawater

Now that we have covered a lot of background material, we can finally discuss seawater. Seawater consists of pure water with materials dissolved in it. The solids dissolved in seawater come from two main sources. Some solids come from the weathering of rocks on land and are carried to the ocean by rivers. Others come from the mantle areas of the earth and are released into the ocean

through deep openings called hydrothermal vents. We will go into more detail about these areas of the ocean later in this course. Materials from the mantle can also reach the ocean by volcanic eruptions. This puts materials into the atmosphere that then enter the ocean by way of rain or snow.



If you have ever taken a swim in the ocean, your taste buds probably told you that salts make up the majority of dissolved substances in seawater. Sodium and chloride account for about 85% of the solids in the ocean. If we took a sample of seawater and allowed all of the water to evaporate, the material left behind would be the salts that had been dissolved in it. To see this phenomenon, perform the following experiment. Note that this experiment requires a few days.

EXPERIMENT 1.2

Removing the Salt From Salt Water

Supplies:

- A liquid measuring cup
- Water
- A small saucepan

- Stove
- A tablespoon
- Salt
- Metal stirring spoon
- A small bowl

Introduction – In order to determine the salinity of the salt water in the ocean, one first must be able to remove and measure the quantity of salt that is in solution. This experiment shows you one way this is done. **NOTE:** If you live near the coast and have access to ocean water, you can place 2 tablespoons of ocean water in the bowl and skip to step 8.

Procedure:

1. Measure 1 cup of water into the measuring cup, and pour it into the saucepan.
2. Place the saucepan on the stove and heat over medium heat. Do not let it boil.
3. Add two tablespoons of salt to the water while it is heating.
4. Stir the water until the salt dissolves and the water becomes clear again. It is okay if there is a little bit of undissolved salt left.
5. Turn off the stove and remove the saucepan.
6. Place 2 tablespoons of the salt-water mixture into a bowl, being careful not to transfer any undissolved salts. The water should appear clear.
7. Clean up everything except the bowl that has 2 tablespoons of salt water in it.
8. Allow the bowl of salt water to sit out for a few days until all the water is gone. (This process will occur more quickly in a warm, sunny window.)
9. Observe what is in the bowl.

In this experiment, you created salt water, took a measured sample, and allowed all the water to evaporate out of it. What was left behind? You should have found crystals of salt in the bowl. You see, water can only evaporate in its pure form. It does not bring dissolved solids into the air with it. As a result, a scientist could take a sample of seawater and perform an experiment like the one you just did. He could then measure the amount of salts in grams, and that would determine the seawater's **salinity**.

Salinity – The total amount of salt dissolved in a solvent

Salinity is typically expressed as the number of grams of salt left behind when 1,000 grams of seawater is evaporated. The units we would use would be **parts per thousand**, or ‰. For example, if we evaporated 1,000 grams of seawater and were left with 32 grams of salt, we would say that the salinity of the seawater was 32 parts per thousand, or 32 ‰. You may not be familiar with the “‰” symbol, but it is similar to the percent symbol (%). While “%” means a part of one hundred, the “‰” symbol refers to a part of one thousand, thus giving scientists the ability to measure amounts in smaller increments.

The organisms that live in the ocean are strongly affected by salinity. Even the smallest change in salinity can affect or even kill some of them. However, with the exception of areas that experience regular changes, such as at the mouths of rivers, the salinity of the oceans in creation stays relatively constant. As you study more about life on our earth, you will be amazed to see that in practically every habitat, no matter how harsh, some types of organisms are able to survive and even thrive there. This

is the case at river mouths. These areas, where fresh water is constantly flowing into salt water, contain many creatures that have specially designed mechanisms to cope with drastic salinity changes.

Organisms are affected not only by the total amount of salt in seawater but also the kind of salt. The more common ions found in seawater are shown in Table 1.2 and are grouped according to their abundance. The first seven ions make up over 98% of the total salt concentration in seawater. And, no matter what the salinity is in the ocean, the *relative concentrations* of these ions remain remarkably constant. In other words, no matter where you take a sample of seawater in the world, chloride ions will make up the same percentage of whatever salt is present. This very interesting fact means that although marine organisms are exposed to possible salinity change due to evaporation, rain, or other mechanisms, they don't have to deal with changes in the *ratios* of various ions. It is therefore easier for them to control their internal salt and water balance.

TABLE 1.2
Ions Found in Seawater with 35‰ Salinity

	Ion	Concentration ‰
Major Ions	Chloride	19.3
	Sodium	10.6
	Sulfate	2.6
	Magnesium	1.3
	Calcium	0.4
	Potassium	0.3
	Bicarbonate	0.1
Minor Ions*	Bromide	0.067
	Borate	0.027
	Strontium	0.013
	Fluoride	0.001

*Other elements are found in trace amounts

I want to point out something else that is quite amazing. There is a remarkable and vital similarity between the chemical composition of seawater and the composition of the body fluids of marine organisms. In other words, the body fluids of most sea creatures are very much like seawater. Well, according to the hypothesis of evolution, the seawater in the oceans of the world has changed substantially over time. As a result, an evolutionist would have to assume that animals adjusted their body fluids to match their environment as the oceans of the world evolved. This is a very difficult “model” to explain, since it requires random mutations in a very complex DNA structure to produce *any* desired result in an organism's bodily makeup. A much more reasonable explanation is that organisms were designed to fit their environments by an intelligent Designer.

Think about it: If the evolutionist view were true, there should be many areas of the ocean where no organism could exist, because it would take time for an organism's DNA to alter itself to fit the existing living conditions. In addition, there would be organisms living in environments for which they were not yet *perfectly* suited, because they were in “evolutionary transition,” trying to “catch up” with the changing ocean. We do not see either of these conditions, however. The world's oceans are teeming with life in every major sector, and the organisms are perfectly suited for their particular habitats. In the end, this gives us strong evidence that life in the oceans and the oceans themselves have not changed radically over time. They have all been designed by an almighty Creator.

Salinity, Temperature, and Density

We have already discussed how temperature affects the density of seawater. Cold seawater is denser than warm seawater and will sink below it to a lower depth. Well, it turns out that salinity influences the density of seawater, too. Perform the following experiment to observe this:

EXPERIMENT 1.3

The Effects of Salinity and Temperature on the Density of Water

Supplies:

- A measuring cup for liquids
- Six clear drinking glasses
- Water
- Small saucepan
- Stove
- Measuring tablespoon
- Salt
- Stirring spoon
- Two colors of food coloring (yellow and blue work the best)
- Chilled water from the refrigerator
- Turkey baster

Introduction – Many parameters can affect the density of water. You will be performing a three-part experiment to observe how salinity and temperature affect water density. **NOTE:** If you live near the coast and have access to ocean water, you can use one cup of ocean water instead of making salt water in steps 1-3.

Procedure:

1. Measure one cup of tap water and place it in the saucepan on the stove.
2. Heat the water on medium heat and add 2 tablespoons of salt.
3. Stir until the salt is dissolved, then remove the saucepan from the heat to cool. Turn off the burner.
4. While the salt water is cooling, perform the next part of the experiment by filling two of the glasses with tap water until they are one-third full.
5. Add two drops of blue food coloring to one glass and mix.
6. Add two drops of yellow food coloring to the other glass and mix.
7. Draw some of the blue water into the turkey baster, placing your finger over the tip so none will escape.
8. **Very carefully**, place the tip of the baster into the very bottom of the glass with the yellow water. **Slowly** squeeze the bulb of the baster so that the blue water is injected into the glass. You do not have to squeeze all the water out – just enough to observe where the blue water goes. Make a note of what happens. Rinse the baster with tap water.
9. For the second part of the experiment, fill a third glass with chilled water until it is one-third full.
10. Add two drops of blue food coloring and stir.
11. Fill the fourth glass one-third of the way with very hot water from the tap, being careful not to get burned. Add two drops of yellow food coloring to this glass and stir.
12. Now, using the turkey baster, draw some of the cold (blue) water and carefully place the tip of the baster into the very bottom of the glass with the hot yellow water.

13. **Very slowly**, squeeze the bulb of the baster so that the cold blue water comes out into the glass. Again, you do not have to squeeze all of it out – just enough to note where the blue water goes. Make a note of what happens. Rinse the baster with tap water.
14. Finally, once the salt water has come to room temperature, fill the fifth glass one-third full of the salt water and add two drops of blue food coloring to it. Stir.
15. Fill the sixth glass one-third full of tap water. Add two drops of yellow food coloring and stir.
16. Using the turkey baster, draw up some of the salt water (blue) and carefully place the tip of the baster into the very bottom of the glass with the yellow tap water.
17. **Very slowly**, squeeze the bulb of the baster so that the salty blue water comes out into the glass. Make a note of what happens.
18. Clean up everything and put it away.

What happened in the experiment? In the first two glasses, the water had the same temperature and salinity. This is called the **control** of the experiment. It is important to see what happens to two samples of water with the same densities when they are moved around from one glass to another through the turkey baster. You should have seen the blue water coming up from the bottom and mixing with the yellow water. In the next part of the experiment, the cold, blue water should have mostly remained on the bottom of the glass with the warm, yellow water on top. Because of their temperature differences, the two colors of water remained separated, with the denser (cold) water on the bottom. This illustrates that colder temperatures make water denser. In the last part of the experiment, the blue salt water also should have remained mostly separated from the tap water. Just like the cold water, it was denser and stayed on the bottom of the glass.

As water gets saltier, then, its density increases. Therefore, the saltier and/or colder the water, the denser it is. Salinity and temperature, therefore, affect the density of water. In the ocean, we find that temperature has a greater influence on seawater density than does salinity because it has a greater range. Ocean temperatures can range from -2°C to 30°C , but open-ocean salinities vary by only a few parts per thousand.

I would like to add an aside here that has to do with the salinity of the oceans and the age of the earth. There are many processes in creation that bring salts into and out of the ocean. However, the rate at which salts enter the ocean is much higher than the rate at which salts are leaving the ocean. This means that the ocean is constantly increasing in salinity. In fact, scientists have been studying this for several hundred years, and they know how quickly the salinity of the ocean has been increasing. With this information, they can calculate how long it took for the sea to become salty. Well, it turns out that it probably did not take very long. Calculations indicate that at *most*, it has taken 62 million years for the oceans to reach their current salinity, and that is using very generous assumptions including that the oceans *started out as fresh water seas*. If we take into account that the oceans were most likely created with some saltiness in order for the organisms that inhabit them to survive, the time required for the oceans to reach their present salinity is probably much shorter. The oceans themselves, then, are strong evidence that the earth is quite young, despite what some scientists would have you believe.

Seawater also contains dissolved gases in addition to its dissolved solids. However, unlike solids, gases dissolve better in cold water than they do in warm water. Nitrogen, carbon dioxide, and oxygen are the most abundant of these gases. They are found in the earth's atmosphere and dissolve into seawater at its surface. Nitrogen gas is not involved in the basic life processes of most organisms, but carbon dioxide and oxygen play an active role. As you may remember from studying biology, carbon dioxide is used by producers such as plants and marine microorganisms for photosynthesis,

making oxygen as a byproduct. Many organisms utilize oxygen for respiration and produce carbon dioxide as a byproduct. Marine life, therefore, depends upon dissolved gases in the ocean.

Now let's discuss how these parameters change in regard to ocean depths. There are some general statements that can be made about the vertical distribution of ocean temperature, salinity, and density. The densest seawater is found on the bottom of the ocean, but the physical processes that cause water to become more dense (such as evaporation and cooling) occur on the ocean surface. So, dense water on the ocean bottom must have once been at the surface and then sunk to its present location. This is the process that drives the circulation of water into the deep ocean basins.

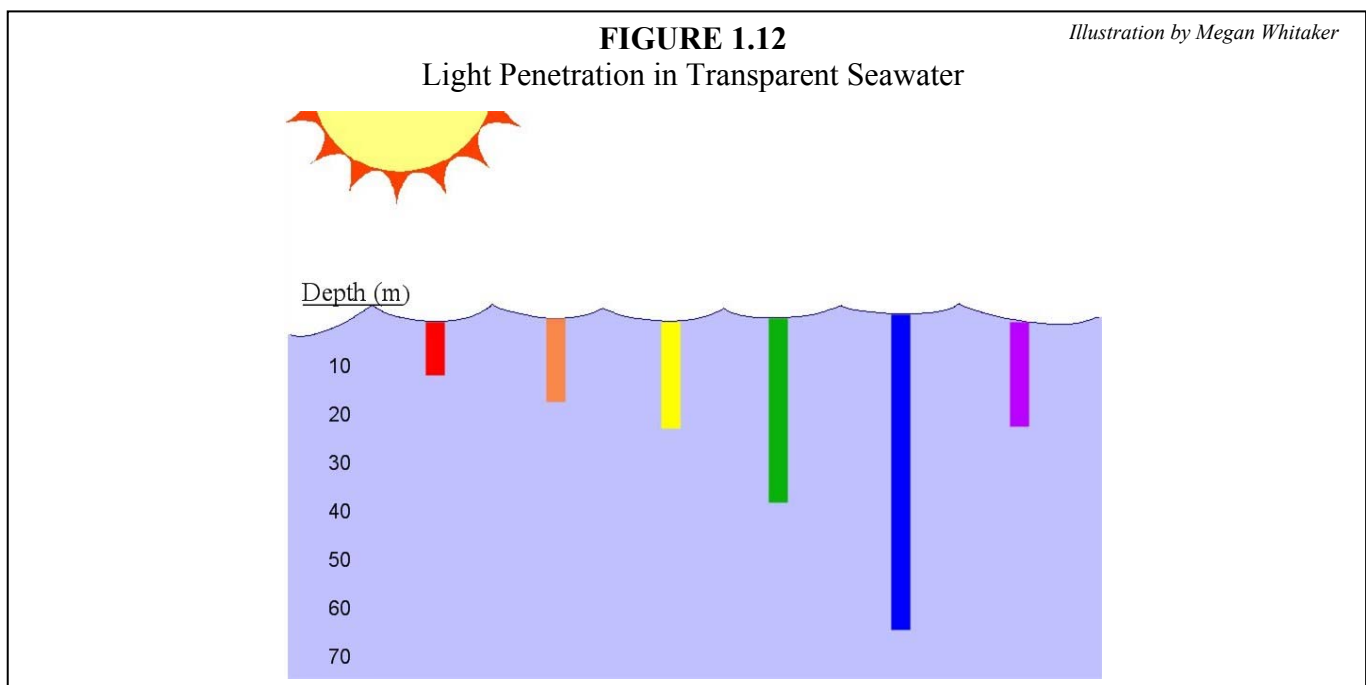
Most of the oceans in creation are made up of two major layers. On top, there is a thinner, well-mixed layer. This layer extends down to a point at which a rapid decrease in temperature occurs. Scientists call this feature a **thermocline**. Below this point is a layer of heavier, cold and dense water that remains very stable. The thermocline inhibits the mixing and exchange of nutrients and gases between the two layers. In some cases it even prevents organisms from moving from one layer to the other.

ON YOUR OWN

1.9 If you were given a fish in a fish tank and were told to keep the salinity of the water very high and the temperature of the water very low in order to keep this fish healthy, what part of the ocean do you think was the natural habitat of this fish?

Light in the Sea

Now we get into one of the great questions of marine science: Why is the ocean blue? There is actually a very simple answer to this question. Visible sunlight is made up of different wavelengths of light that are perceived by our eyes as various colors. Different wavelengths (colors) of light penetrate transparent seawater to different depths.



The ocean is most transparent to blue light, so the greater the depth, the fewer the colors that can penetrate, and the bluer the ocean appears. Also, the blue sky reflects off the surface of the ocean, enhancing its blue appearance. It's that simple!

All producers need light in order to make food for themselves, and the penetration of light into the ocean is vital for marine life. The amount of light that can enter the water depends upon the water's transparency. The more material suspended in the water, the more difficult it is for light to penetrate, and the fewer producers that can survive there.

ON YOUR OWN

1.10 The Red Sea is given its name due to an abundance of red bacteria that gives the water a reddish color. If the red bacteria were not able to live in the Red Sea, what color would the Red Sea appear to be and why?

Pressure

There's one final aspect I want to talk about before we leave the topic of seawater. Organisms living in the ocean constantly experience pressure from the weight of the water above them. On land, pressure from the earth's atmosphere is 14.7 pounds per square inch, or 1 atmosphere. Pressure in the ocean increases dramatically with depth, because water is much heavier than air. For every 10 meters (33 feet) of depth, another atmosphere of pressure is added. And, as the pressure increases, gases are compressed, affecting marine life. Because of this drastic pressure change, most marine organisms can tolerate only small changes in depth, limiting the range in which they are able to live. Most of the marine organisms with which you are familiar can survive at only 1 to 3 atmospheres of pressure, which means they can live in only the first 100 feet of water. At the same time, however, there are some organisms which have been designed to withstand the constant high pressure of the deep sea. The life cycles and habits of these creatures are relatively unknown because, in order to study them, we must bring them to the surface, or at least to depths in which *we* can function. At the surface, their bodies cannot withstand the relatively small pressure, and they cannot survive.

FIGURE 1.13

Photo of a Megamouth Shark

Photo copyright © Tom Haight



The megamouth shark lives in the deep waters of the ocean. Because they rarely come to the surface waters, little is known about them. We think that they live at depths between 150 and 1,000 meters. The inside of the shark's mouth is silvery, and its teeth are small and hook-like. Like the whale shark and the basking shark, the megamouth shark is a filter-feeder, eating small shrimp and a variety of plankton. Adult megamouth sharks reach a length of about 5 meters.

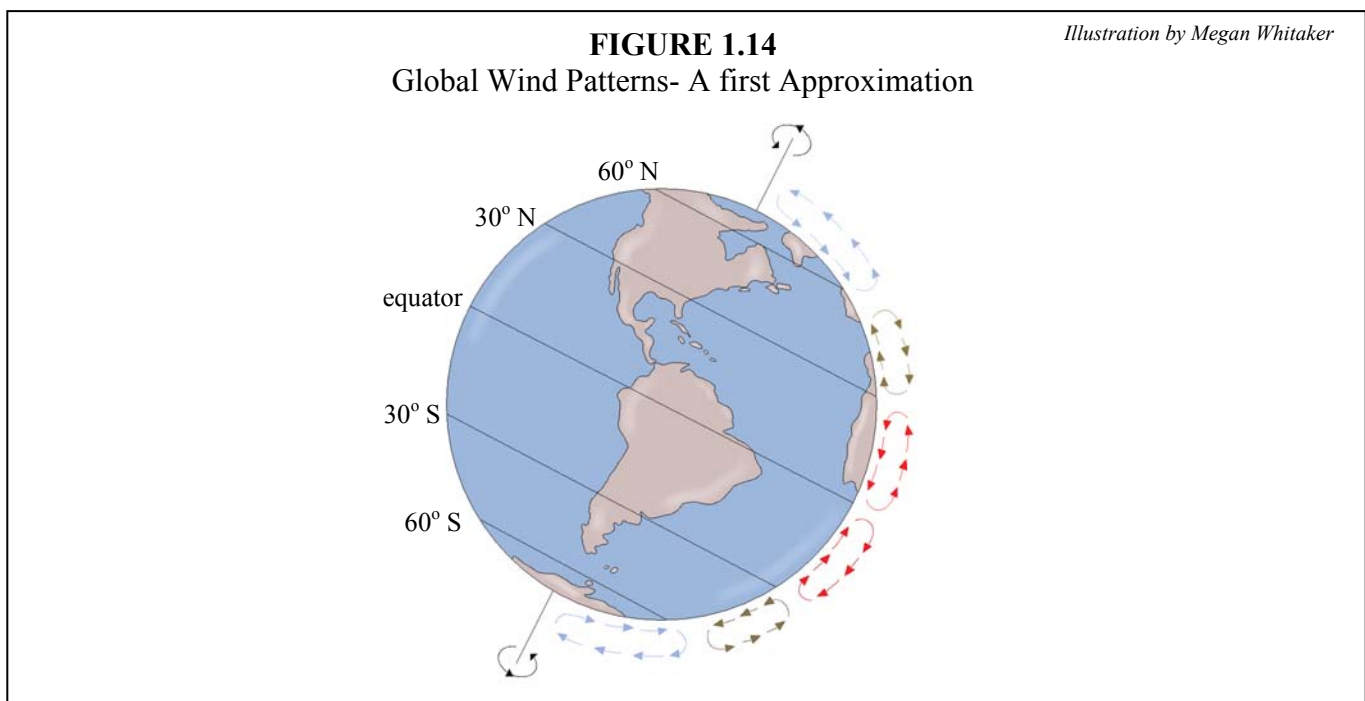
The Motion of the Ocean

The ocean is always in motion. In your mind, when you think of the ocean, you probably think of waves. This constant moving and churning helps keep the temperature and salinity of the world's oceans at a constant level. Heat from the sun drives these circulation processes, benefiting all marine life forms. These processes include currents, waves, and vertical water movements. The tides are also a part of the motion of the ocean, but they are not caused by heat from the sun. You will learn about them in a moment.

The strongest motion in the ocean is at its surface and is made up of surface currents and waves. Ocean surface currents are in regions where winds regularly blow over the ocean in a reasonably constant direction and velocity, pushing the water along. Surface currents, then, are large, horizontal movements of water molecules being pushed by the winds above them.

The winds in our atmosphere result from temperature differences caused by heat from the sun. The heat is its strongest at the equator and, of course, much weaker at the North and South poles. To understand wind patterns, consider cold air near the surface of the earth at the North Pole. The air will move from the North Pole toward the equator, to even out the temperature differences. As it makes its way there, however, it encounters warmer climate. This warms up the air, causing it to rise. When the air makes it to the 60° N latitude, it becomes so warm that it rises into the upper atmosphere and begins *moving back toward the Pole!* In the end, this sets up a loop of winds that travel continuously from the Pole to a latitude of about 60° N and back again. This loop of winds is shown as the blue loop in Figure below. A similar loop of winds extends from the South Pole.

If we now turn our attention to the equator, we will see the exact opposite effect. As the warm air rises, it starts traveling toward the poles. At a latitude of about 30° N, however, it cools down enough to sink and begin traveling back toward the equator. Thus, from the equator, there is also a loop of winds that travel to a latitude of about 30° N and then turn around and come back again. That is represented by the red loops of wind in the figure. In the middle of these two loops of wind there is a third loop (the brown loop) that occurs as a reaction to these two loops. The result of all this mess is shown below:



This is not the end of the story, however. The winds don't move straight as shown in Figure 1.14. They actually *curve*. To understand this curving of winds, perform the following experiment:

EXPERIMENT 1.4 The Coriolis Effect

Supplies:

- One sheet of cardstock
- Scissors
- A tack or push pin
- One foot of string
- A pencil
- A cork bulletin board or sheet of corrugated cardboard
- A marker
- A helper

Introduction – Winds do not move in straight lines on the earth. This experiment will illustrate why this happens.

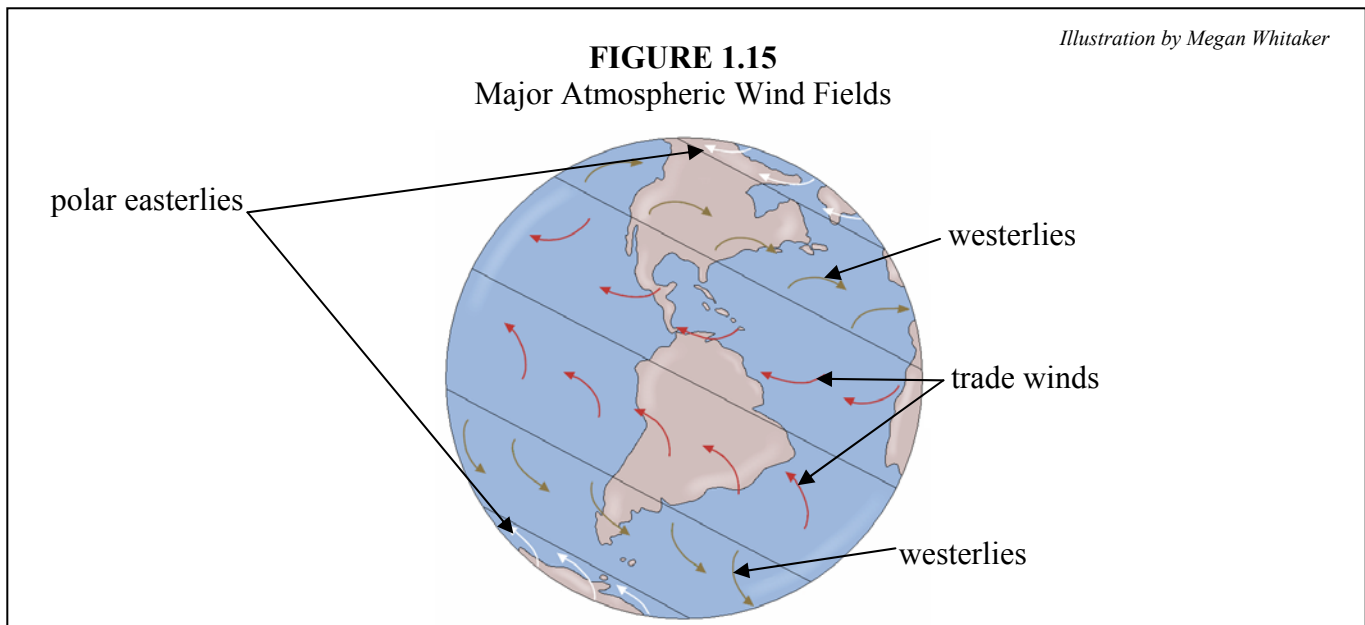
Procedure:

1. Cut a circle about 6 to 7 inches in diameter out of card stock. To do this, tie a loop on one end of the string and push the tack through it into the center of the card stock and into the bulletin board.
2. Tie the pencil to the other end of the string and pull it taut.
3. Draw a circle on the card stock by moving the pencil along in a circular motion while continuing to keep the string taut.
4. Remove the card stock from the bulletin board and cut the circle out with the scissors.
5. Replace the circle back onto the bulletin board, affixing it through the center with the tack, but not so tightly that it cannot revolve.
6. Draw an arrow along the outside edge of the circle that points in a clockwise direction.
7. Next, have your helper stand on your right-hand side and place his finger at the 9 o'clock position on the circle. Meanwhile, place the marking pen at the center of the circle.
8. At the same time, have your helper begin to slowly spin the circle in a clockwise direction while you slowly try to draw a straight line downward.
9. Remove the circle and note whether the line you drew moved straight down, clockwise (with the rotation), or counter-clockwise (opposite of the rotation).

What happened in the experiment? When you tried to draw a straight line toward the lower edge, it should have curved. Notice the *direction* in which it curved. It moved *away from* the direction of the rotation of the wheel. That's what happens on the earth. The winds moving toward the equator curve in a direction opposite of the rotation of the earth. Scientists call this phenomenon the **Coriolis** (cor ee oh' lis) **effect**, named after the French physicist Gaspard de Coriolis.

Coriolis effect – The way in which the rotation of the earth bends the path of winds and resulting sea currents

Consider the winds nearest the equator. They are pictured by the red loops in Figure 1.14. We are going to concentrate on the winds that blow near the surface of the earth, because those are the winds that blow on the ocean. Thus, just look at the bottom of each loop in Figure 1.14. In the red loops, the winds blowing near the surface of the earth are moving toward the equator. Because of the Coriolis effect, these winds bend west (opposite the rotation of the earth) and approach the equator at an angle of about 45° . These winds are called the **trade winds** (shown in Figure 1.15 below) and are the most consistent winds on earth. Farther away from the equator, we find the brown loops of winds shown in Figure 1.14. The winds near the surface of the earth on these loops are bent opposite the trade winds, because they are traveling away from the equator instead of toward it. Thus, the Coriolis effect causes them to bend in the opposite way. These winds are called the **westerlies** (shown in Figure 1.15). They are more variable than the trade winds due to many land interruptions. Scientists call these winds “westerlies” because they move in the opposite direction of the trade winds and come from the west. The northernmost and southernmost winds are called the **polar easterlies** and are the most variable winds of all. They curve in the same direction as the trade winds, since they once again move toward the equator near the surface of the earth.



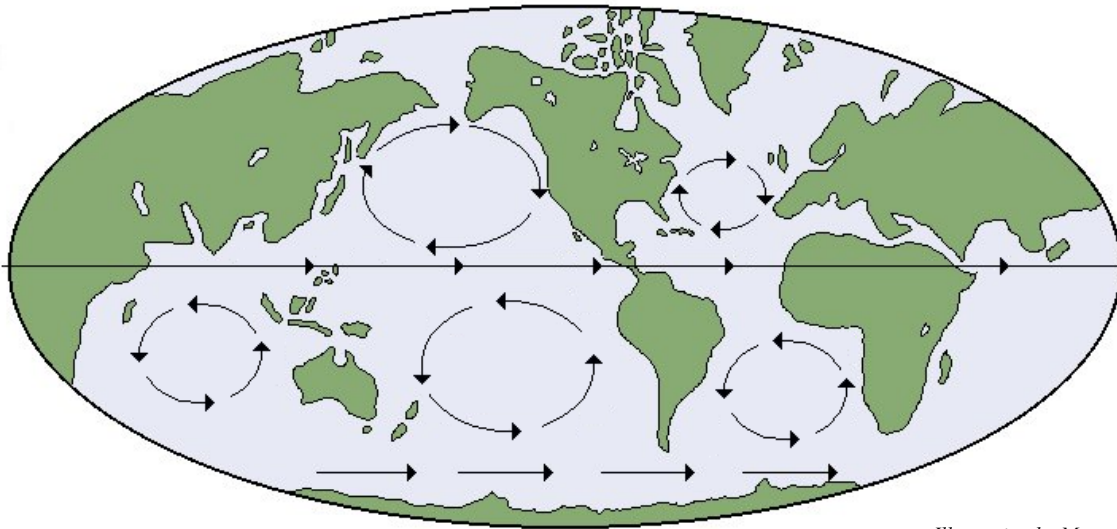
Now all these major wind fields in the atmosphere push against the ocean surface and create currents. In fact, you could say that all the major currents of the open ocean are driven by the wind. As the wind pushes against the ocean surface, it causes the water to move. When the wind moves the water, it actually forces the surface currents to move at a 45° angle from the wind direction. The equatorial trade winds being bent from the Coriolis effect, for example, cause the currents below them to move parallel to the equator. As water gets “pushed around” all over the world, large surface currents result in a circular pattern. Scientists call these currents **gyres** (jires), and they are outlined in Figure 1.16 on the next page.

Gyres – Large, mostly circular systems of surface currents driven by the wind

The warm-water currents on the western side of the gyres of the world carry a lot of solar heat from the equator to higher latitudes. And the opposite is true, too; cold currents flow along the eastern sides of the oceans, bringing colder water to the equatorial areas. This movement helps to regulate the temperatures of our planet, keeping the cold and hot temperatures from becoming extreme.

FIGURE 1.16

Map of the Earth Showing Major Surface Currents and Gyres of the Ocean Basins

*Illustration by Megan Whitaker*

The temperature of the sea surfaces of the world is also a result of this circulation. Along the Pacific coast of the United States and the western coast of South America, the colder water temperatures are a result of a gyre. Look at the loops of current on the west coasts of North and South America. On the west coast of North America, the current loop carries water from near the Arctic (cooler water) southward. On the west coast of South America, the loop of current carries water from near the Antarctic (cooler water) northward. As a result, the ocean water is cooler on the west coasts of North and South America. Because of this, cold-water organisms can survive closer to the equator on these coasts than in other parts of the world. Conversely, warm-water organisms can survive farther from the equator on the eastern coast of Asia, because the gyres bring warm water from near the equator to parts of the ocean far from the equator.

ON YOUR OWN

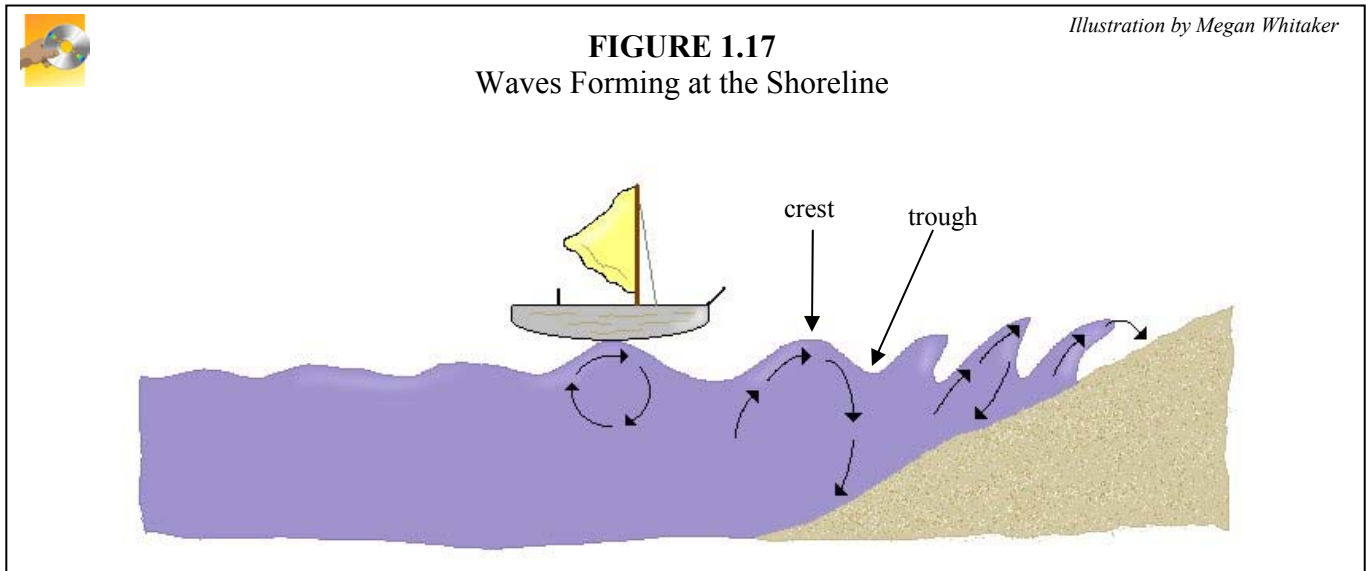
1.11 During a terrible storm on the west coast of South America, a boat loses a box of its cargo of rubber ducks. One of the ducks is found in Japan months later. How did it get there?

1.12 Suppose you were looking for coral reefs (which love warm water) in the Atlantic Ocean relatively far from the equator. Would you tend to find them on the eastern coast of North America or the western coast of Europe?

Waves

Now let's talk about the most familiar of ocean movements: waves. You are probably well acquainted with the motion of waves, as they can be observed in a bowl of water or a bathtub. What you may not realize, however, is that each individual water molecule does not actually move along with the wave crest as it travels. The water molecules actually move in a circle. In Figure 1.17, a toy boat resting on the water's surface will move mostly up, around, down, and back up again as a series of

waves pass by. Now remember, I'm not talking about currents, in which water is getting pushed along, I am just talking about waves.



Perform the following experiment to observe this for yourself:

EXPERIMENT 1.5

The Motion of Waves

Supplies:

- A tub
- Water
- A cork or small toy boat
- A 12-inch length of 2-by-4 wood

Introduction – Surface waves actually move the molecules of water in a circular motion. You will observe this as you do this experiment.

Procedure:

1. Fill the tub with water until the water is about 3 inches deep.
2. Place the cork or boat in the very center of the tub.
3. Place the length of wood about halfway down into the water at the end of the tub near the spigot so that its longest side is in the water perpendicular to the length of the tub.
4. Gently but steadily move the plank about 10 times up and down. Move it about $\frac{1}{2}$ to 1 inch in each direction, and keep it at the end of the tub. Do not let it splash! This should create a series of parallel waves moving down the length of the tub toward the cork. Observe the cork's position in the tub while you do this.
5. Allow the water to become still again. Reposition the cork, and repeat the experiment a few more times.

In the experiment, the cork should have only bobbed up and down as the crests of waves came by. That's because waves carry *energy* across the sea surface. They do not actually transport water. As a result, the cork moved up and down with the individual water molecules, and the energy continued past.

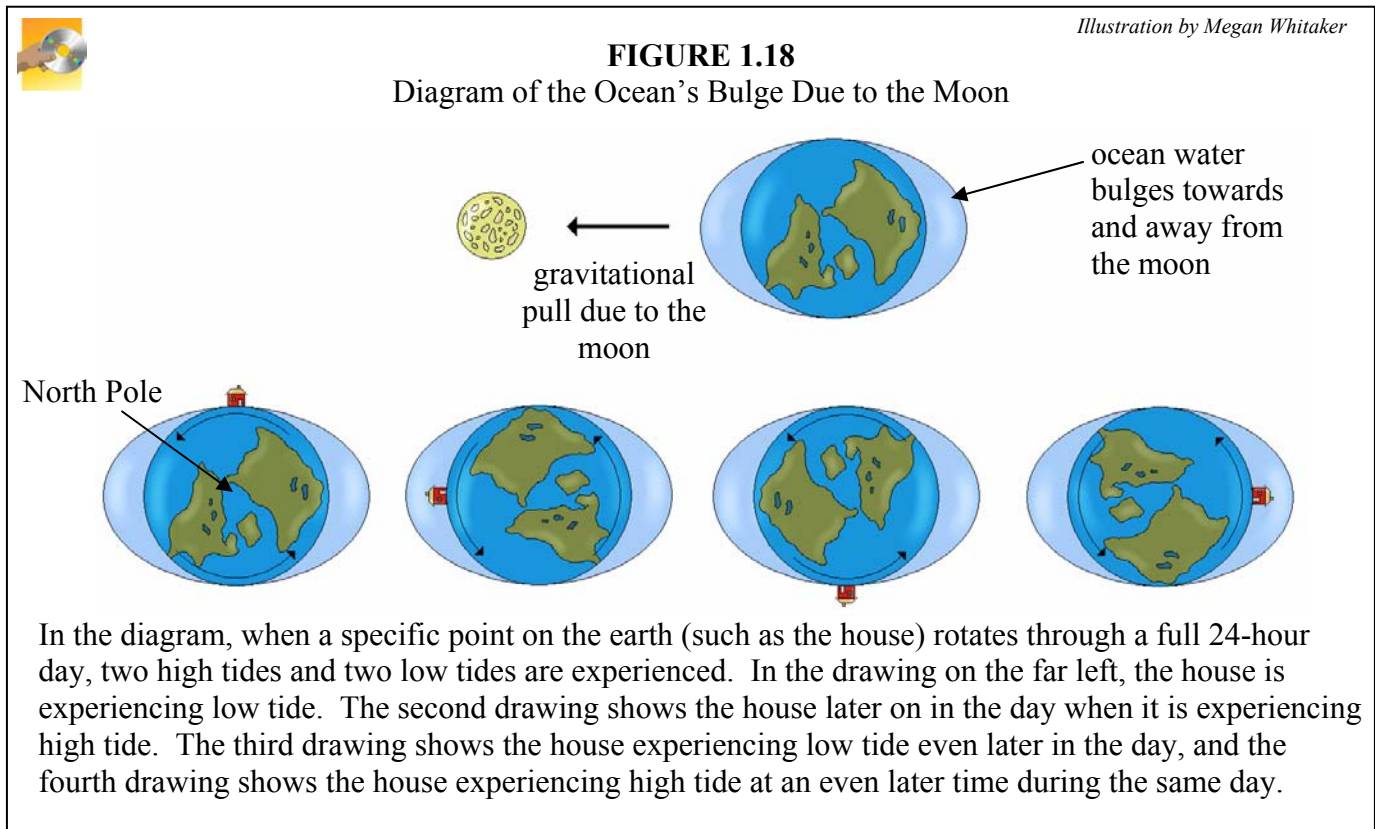
Waves entering shallow water behave differently than open-ocean waves. Look again at the diagram in Figure 1.17. As the water becomes more shallow, the sandy surface interrupts the circular motion of the waves, slowing down the underside as it drags across the bottom. This causes the faster water above to pile up behind the top of the wave. Eventually, the wave becomes so high and steep that the wave top falls forward and breaks against the shore.

Tides

Another aspect of ocean water movement is the tides. Tides greatly impact sea life near the shore. They are so regular that some animals actually have reproductive cycles that coincide with them.

Let's first talk about what causes tides. In 1687, Sir Isaac Newton explained ocean tides as the result of gravitational attractions of the moon and sun on oceans of the earth. Because gravitational force is strongly affected by distance, the moon, due to its closeness to the earth, exerts about double the tide-generating force as the more massive but more distant sun. Newton's explanation is still considered the best general description of what causes tides. The gravitational pull of the moon causes the oceans to bulge toward it. At the same time, the earth is also being pulled toward the moon and away from the water on its opposite side. This distorts the water levels to form an oval shape. If the earth were completely covered with water, it would look something like what is shown in Figure 1.18.

Illustration by Megan Whitaker



As is shown Figure 1.18, the earth is spinning on its own axis. As a result, any given point on the earth will move from a bulge area to a non-bulge area and back again. When a point on the earth is in the bulge area, high tide occurs. When a point is in the non-bulge area, low tide occurs. Because it takes one day to complete a rotation, most locations on the earth will experience two high tides and two low tides in one day.

The sun can affect these tidal bulges as well, but its gravitational effect is not as strong. Even though the sun is much more massive than the moon, it is much farther away from the earth. Thus, its gravitational pull on the earth is smaller than that of the moon, but it does still pull on the oceans. When the sun and moon are aligned with each other, their pulls are added together. This results in a higher high tide and lower low tide. The name for this phenomenon is **spring tide**, even though spring tides can occur about every two weeks – not just in the spring. When the sun and moon are at right angles to each other, they partially cancel each other's gravitational pull. The result is called a **neap tide**, which is a tide with lower high tides and higher low tides.

Spring tide – A time of largest tidal range due to the gravitational pull of the aligned sun and moon (during full moon and new moon)

Neap tide – A time of smallest tidal range due to the moon and sun being located at right angles to each other (during quarter moons)

ON YOUR OWN

1.13 If the moon were farther from the earth, what change would you expect in high tide and low tide?

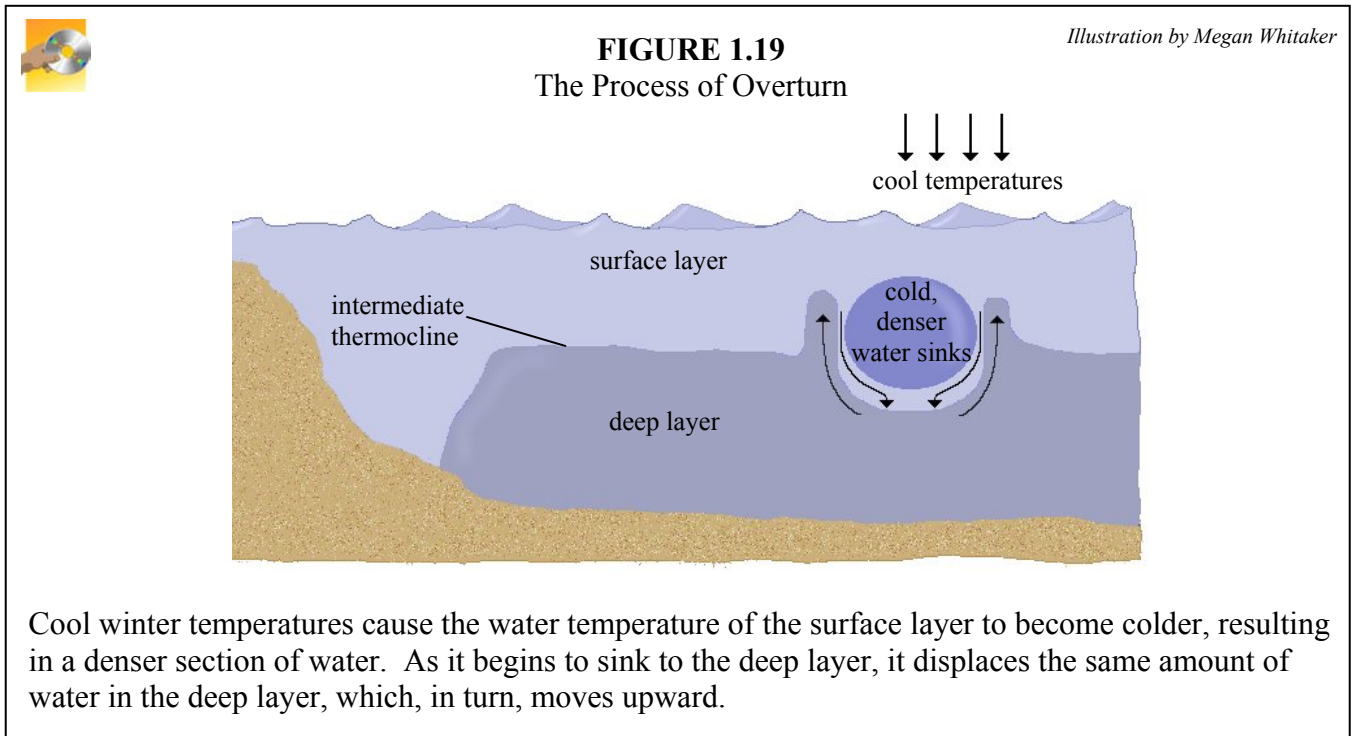
1.14 A man living at the beach looks out his window and sees a full moon. What type of high tides can he expect in the next few days?

Vertical Motion

I want to talk about one more way that ocean water can move. It has to do with vertical movement and the density of seawater. As I mentioned before, the ocean has two main layers separated by a thermocline. The thermocline can actually be considered a third layer between the upper and lower ones. The **surface layer** is about 100 to 200 meters (330 to 660 feet) thick. It is subjected to wind, waves, and currents, so it is usually well mixed. The **thermocline** is a layer from about 200 to 1,500 meters (660 to 5,000 feet). It is a transitional zone between the warmer layer on top and colder layer below. It is found in the open ocean, away from the continental-shelf areas (which are part of the surface layer). Below 1,500 meters is the **deep layer**, which is uniformly cold and much thicker than the other two layers.

A group of water layers like this is called a **water column**, and as you would expect, the densest water in the water column is at the bottom, while the least dense water is at the top. Deep water is mostly cold and dense, and surface water is warm and less dense. Usually, these layers will stay where they are and will not mix unless a storm or strong wind stirs them up. A water column such as this is highly stable due to the differing densities of its layers. When the layers' densities are not very different from one another, however, it is much easier for them to mix. Scientists call this situation a **low-stability water column**. In a low-stability water column, the surface water can

become denser by excess evaporation or a cooling due to seasonal temperatures. The surface water sinks, displacing the less dense water below in a process called **overturn**.



Overturn benefits the ocean because sinking surface water brings dissolved oxygen to the deep sea. In addition, the rising water replacing the upper water brings nutrient-rich material to the surface for use by the organisms living there.

ON YOUR OWN

1.15 Would you expect to see greater overturn in the winter or summer months?

Summing Up

In this first module, I have covered many aspects of the physical features of the ocean. You have learned about the geography and placement of the world's oceans, features of the ocean bottom, properties of seawater, and how seawater moves around the world. This information will help as you study marine organisms, because you now understand many of the conditions under which they must survive.

ANSWERS TO THE “ON YOUR OWN” PROBLEMS

- 1.1 The four major ocean basins of the world are the Pacific Ocean basin, the Atlantic Ocean basin, the Indian Ocean basin, and the Arctic Ocean basin.
- 1.2 Since the crusts are composed of different chemicals, you could chemically test for basalt or granite. The granite-containing sample is from continental crust, while the basalt-containing sample is from oceanic crust. Alternatively, since oceanic crust is denser than continental crust, you could measure their densities. The denser sample is from oceanic crust.
- 1.3 No, but this find would be evidence that supports the idea that the land masses of the world were once connected. In order to *prove* it was true, there would have to be documentation from eyewitnesses. Note: Such fossil discoveries have actually been made!
- 1.4 It would most likely be far from a mid-ocean ridge. Sea floor is created at the mid-ocean ridges and is newer than the sea floor farther away from the ridges. The older floor has more time to collect sediment than the newer floor.
- 1.5 The oceanic plate will sink into the mantle, forming a trench and continental volcanoes. Oceanic plate material is denser than continental plate material and therefore will sink below it.
- 1.6 It most likely came from the continental rise. That is where a lot of debris and sediment form.
- 1.7 Hydrogen bonding gives water many unusual properties.
- 1.8 It will sink. Since water is the only readily available chemical that is denser in its liquid phase than its solid phase, it is the only substance in which the solid phase floats on the liquid phase. All other readily available substances are denser in their solid phase, so solid benzene will sink in liquid benzene.
- 1.9 This fish probably lived in a deep ocean environment. Colder water with a high salinity would be denser than average conditions and therefore would be located below the other layers of seawater.
- 1.10 The Red Sea would appear blue due to the ocean being most transparent to blue light and also the reflection of the blue sky.
- 1.11 The duck would have traveled north along the cold current coming upward from the Antarctic waters. It then would have traveled a bit east along the equator, but once it crossed the equator, it would have floated north and west with the warm equatorial current moving up into the northern hemisphere until it reached Japan.
- 1.12 Look at Figure 1.16. The gyre found in the northern hemisphere of the Atlantic Ocean carries water from near the equator to the eastern coast of North America. As a result, the water there is relatively warm. That same gyre, however, brings water from near the Arctic to the western coast of Europe. Thus, you would be more likely to find coral on the eastern coast of North America.
- 1.13 The moon’s gravitational pull has the most influence on the earth’s tides. If the moon were farther away from the earth, its gravitational pull would be smaller. As a result, the tides would not be as extreme. Thus, high tide would be lower and low tide would be higher.

1.14 He can expect to see much higher high tides than average (spring tides). This is because of the spring-tide phenomenon where the gravitational pulls from the moon and the sun work together.

1.15 Greater overturn would occur in the winter months. As the warmer surface water cools due to the winter temperatures, it becomes denser and will therefore sink. In the summer months, the surface layer gets warmer, making it even less dense. As a result, it will not sink into the deeper water.

STUDY GUIDE FOR MODULE #1

1. Define the following terms:

- | | |
|-----------------------|---------------------|
| a. Oceanic crust | i. Continental rise |
| b. Continental crust | j. Specific heat |
| c. Plate tectonics | k. Salinity |
| d. Mid-ocean ridge | l. Coriolis effect |
| e. Seafloor spreading | m. Gyres |
| f. Subduction | n. Spring tide |
| g. Continental shelf | o. Neap tide |
| h. Continental slope | |

2. Name the four large ocean basins of the world in order of increasing size.
3. Geologically speaking, what are the differences between the crust of the “oceans” and the crust of the “continents”?
4. If a specific location in the world is known for experiencing a large amount of earthquakes throughout modern history, what would you propose is occurring in the earth’s crust underneath that area?
5. Given the fact that most of the deep ocean trenches in creation are located in the Pacific Ocean, what is the main type of plate interaction that occurs in that ocean?
6. Ocean crust is constantly being destroyed and reformed. Considering the four large ocean basins in the world, which ocean has the most oceanic crust formation? Which has the most oceanic crust destruction?
7. Although there is a large surface area under the oceans of the earth, in which main region of the ocean bottom do you find most of the marine life?
8. What one major property of water helps it hold its molecules together, keeping it from having severely colder boiling and freezing temperatures?
9. If a marine organism lives in an area where there are drastic changes in the weather resulting in extremely high and low air temperatures, what property of water prevents the organism from “feeling” such changes?
10. What will happen to the water near the ocean surface if a portion of the surface layer experiences excess evaporation? What will happen if that portion experiences a large drop in temperature?
11. Why is the ocean blue?
12. A fisherman was deep-sea fishing and pulled up a large bottom-dwelling grouper he had hooked. He was able to bring the fish up to the surface very quickly, but was surprised to see that the fish appeared extremely bloated (puffed up) and did not survive the stress of coming to the surface. What happened?

13. Why do winds not move in a straight line on the earth?
14. Suppose the earth rotated opposite of the direction it currently rotates. What effect would that have on the directions of the gyres shown in Figure 1.16?
15. Where do water molecules move in a surface wave?
16. During which phase (or phases) of the moon are the tidal ranges the largest and why?
17. Describe the two major layers of the deep ocean and the feature that separates them.