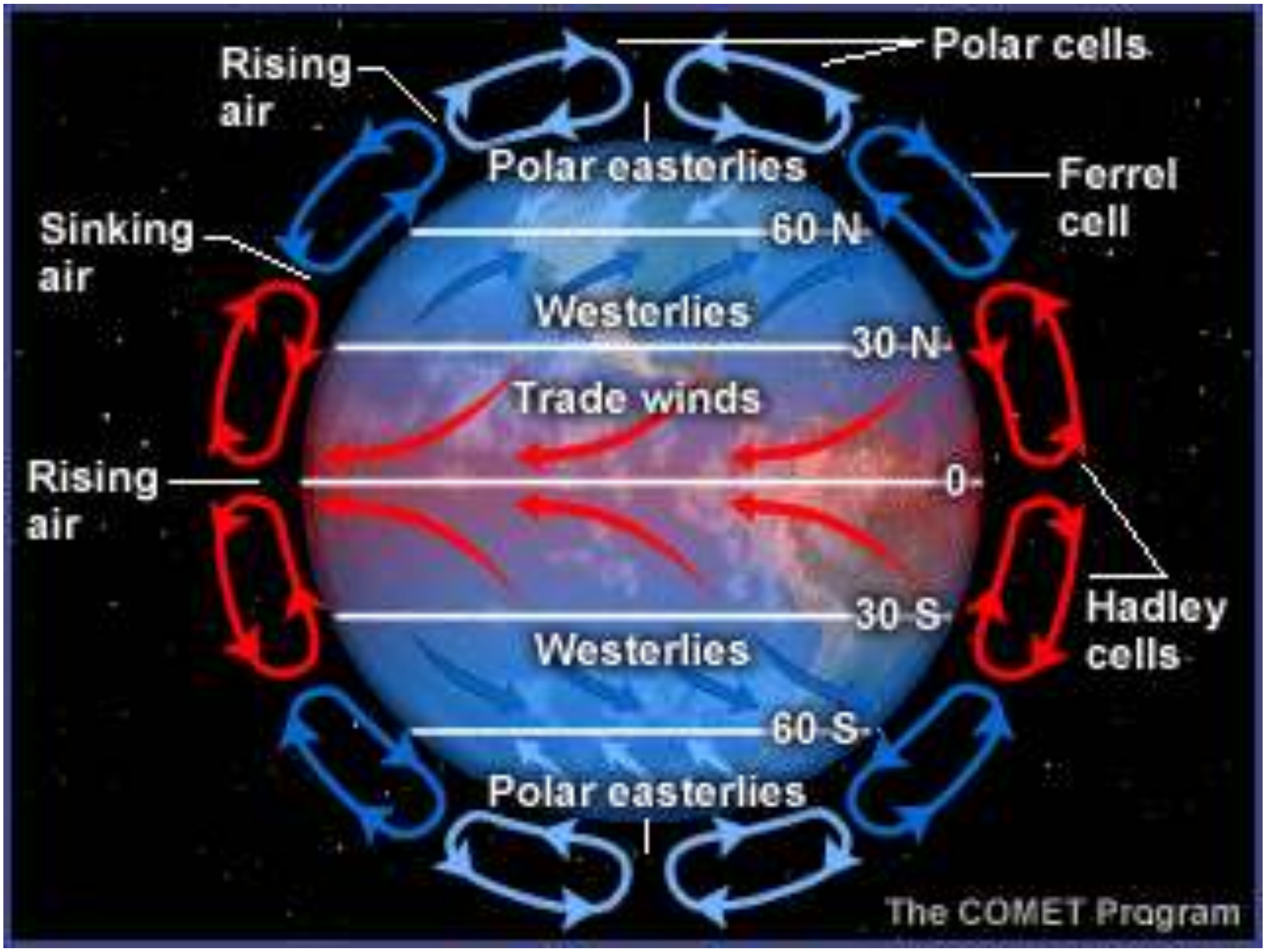
CURRENTS:

Currents are moving water. Major currents are driven by wind and tides and differences in density. As a result currents can be on the surface or under water

So how does the wind operate? Hot air at the equator rises and starts to move north in the N. hemisphere and south in the southern hemisphere. At about 30 degrees from the equator, the air has cooled enough and become dense enough to sink down to the ground. Since the cool air is denser than the warm air toward the equator, the pressure gradient moves the air south.

Currents also operate as heat transport.

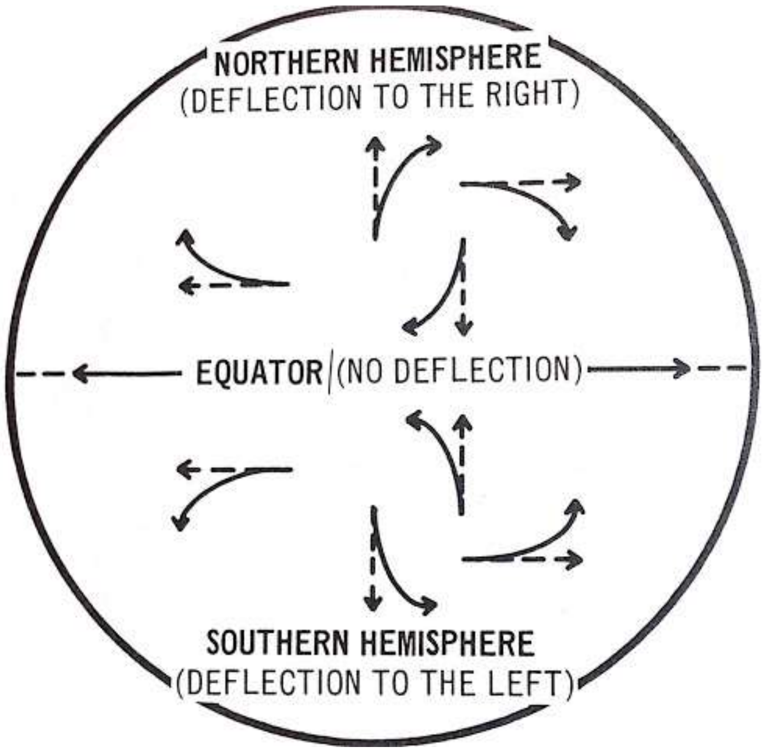
So how does the wind operate? Hot air at the equator rises and starts to move north in the N. hemisphere and south in the southern hemisphere. At about 30 degrees from the equator, the air has cooled enough and become dense enough to sink down to the ground. Since the cool air is denser than the warm air toward the equator, the pressure gradient moves the air south.



At the poles, the cold air over the poles sinks and moves south towards the warmer air. As it moves south it heats and rises at about 60 degrees from the equator. The air between the Hadley Cell and the Polar cell is moved like a gear between the two.

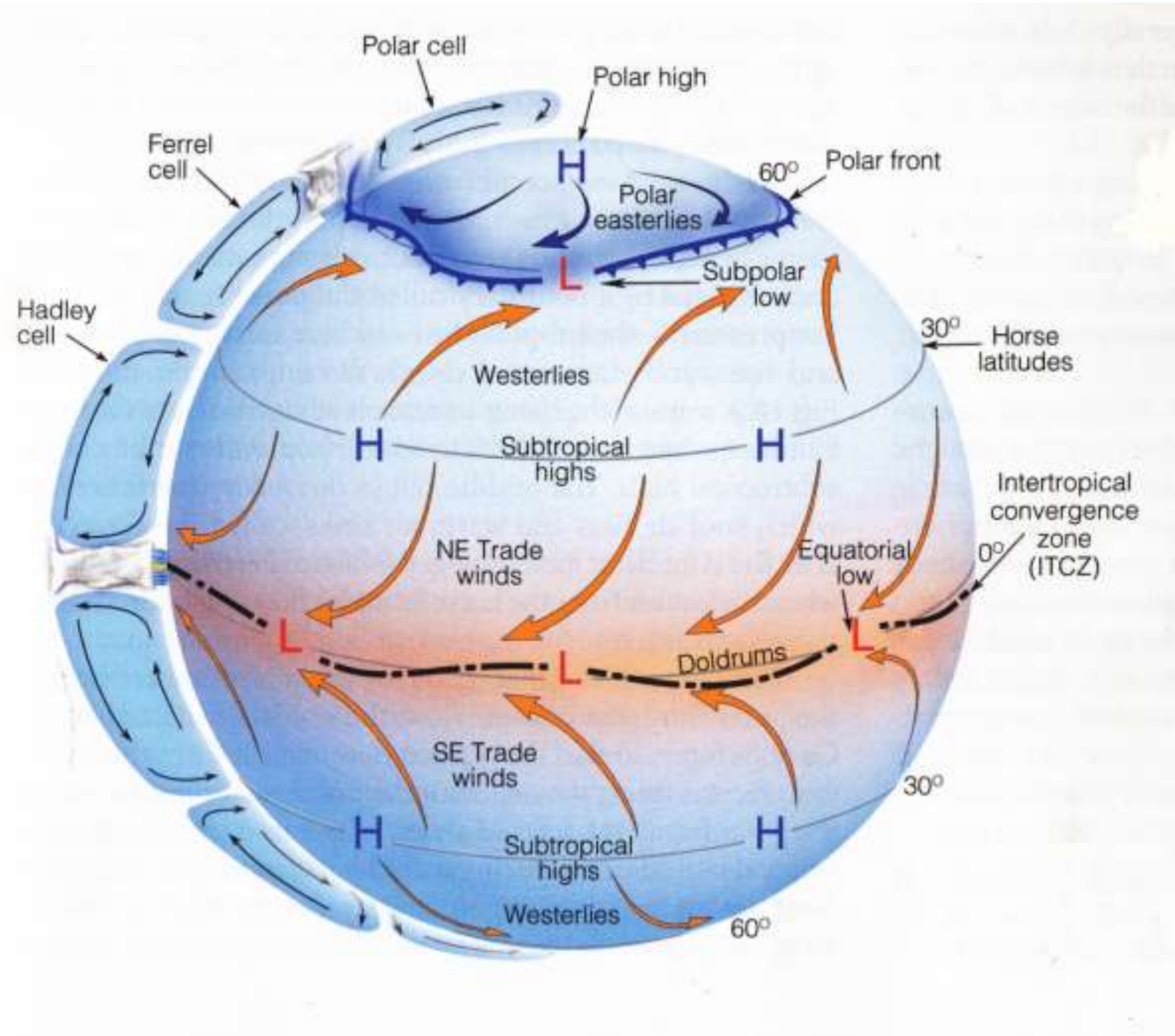
As the air on the surface of the earth moves north and south, the Coriolis Effect takes over and the winds in both directions veer off to the right.

Diagram 2



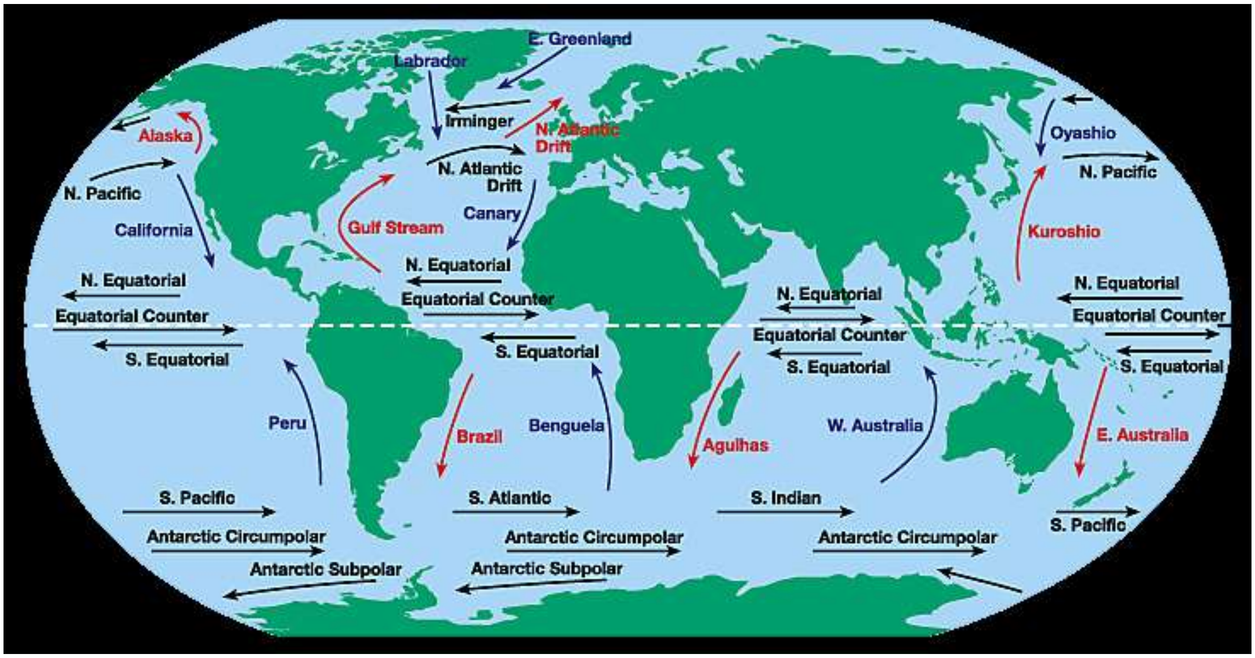
coriolis

This gives the general global wind patterns.

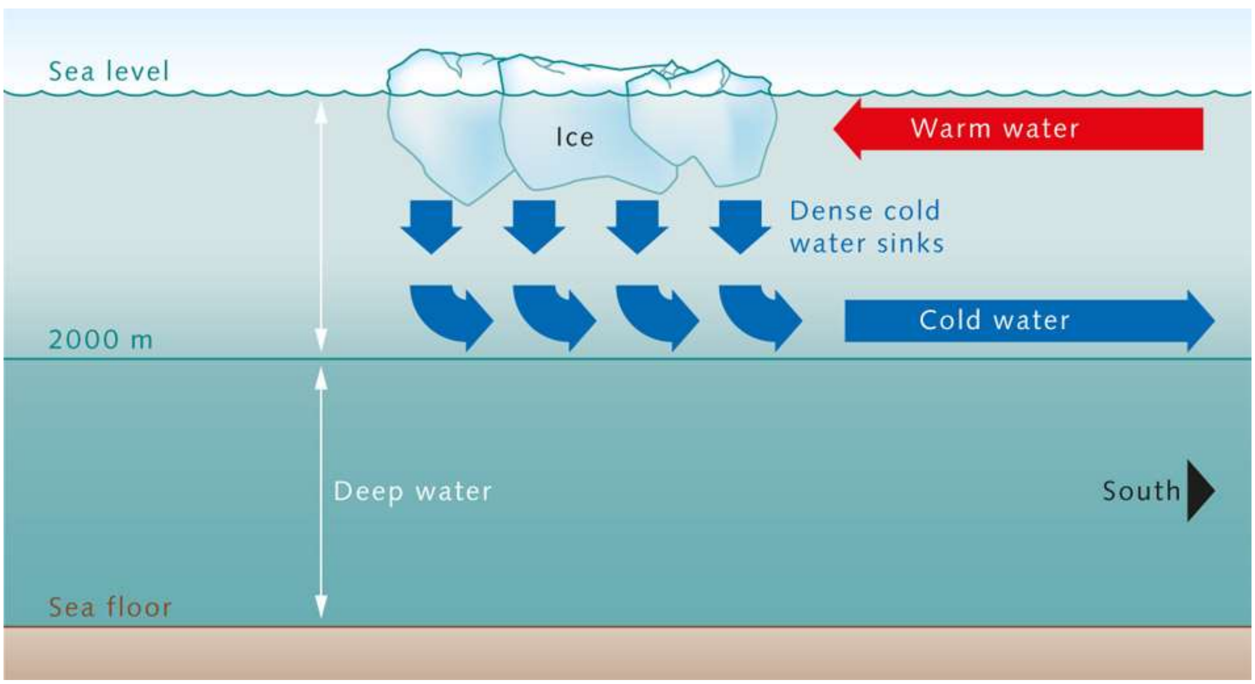


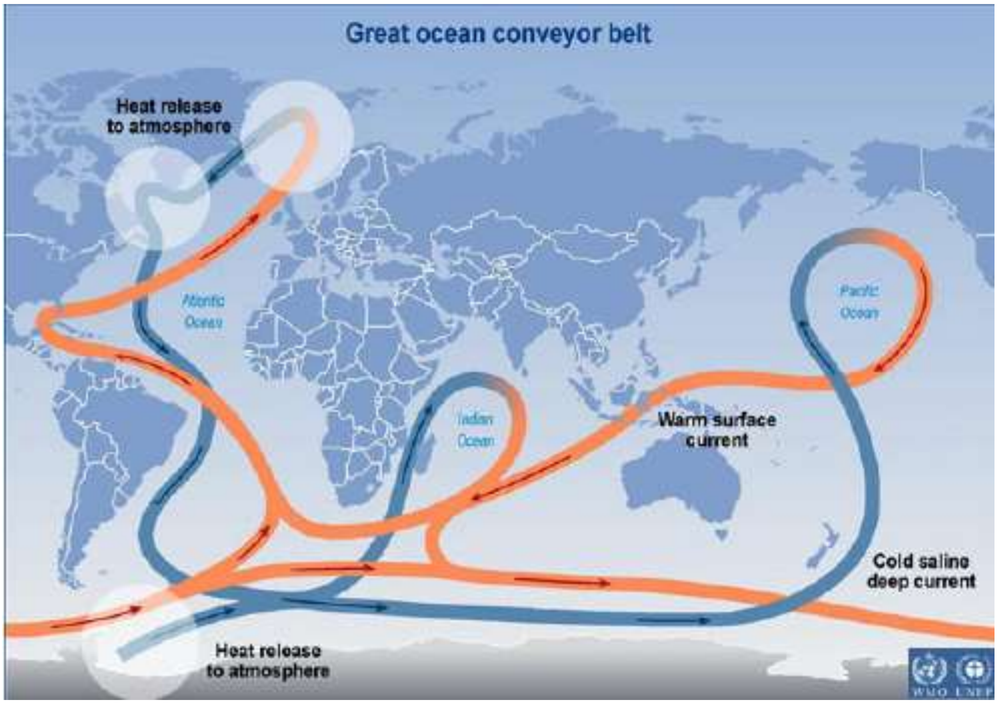
Hadley cells

As a result, ocean currents follow the pattern of the winds



Gulf Stream (surface) and Polar conveyer belt transport (under water) You should note at this point that there are currents that run on the surface of the ocean and those that run deep in the ocean. These have great importance in weather

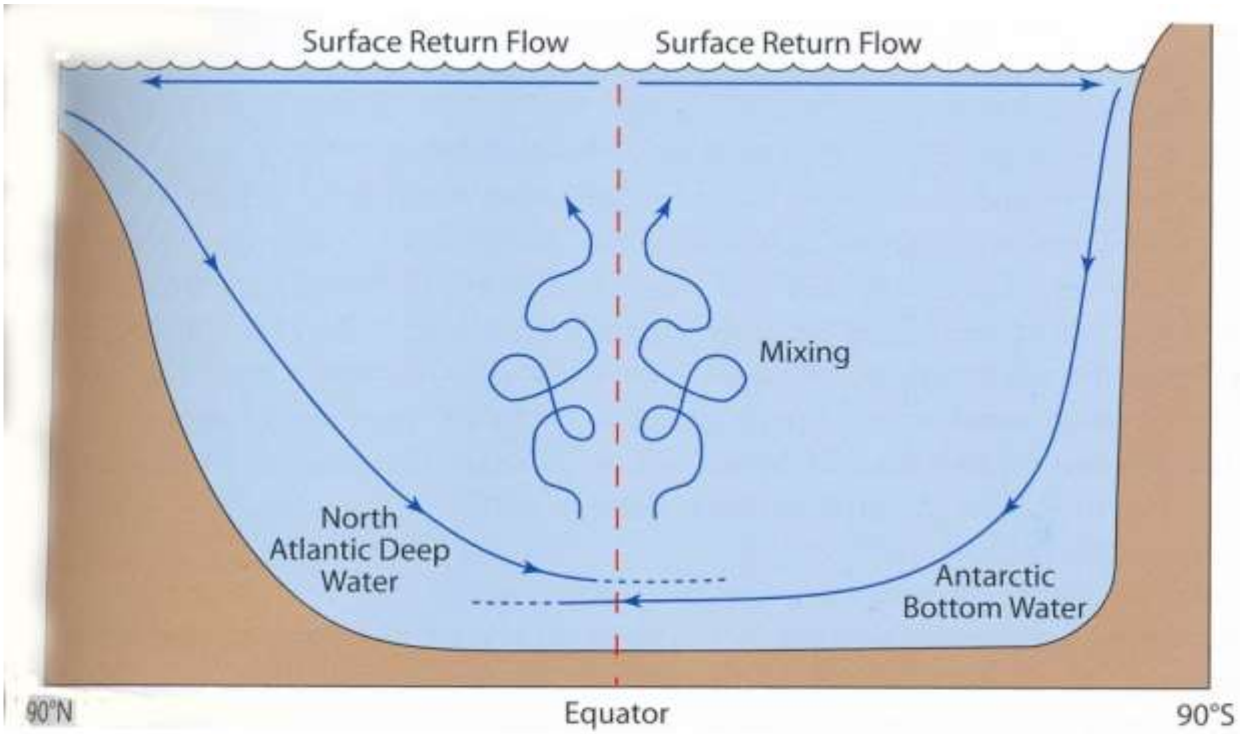




conveyor belt

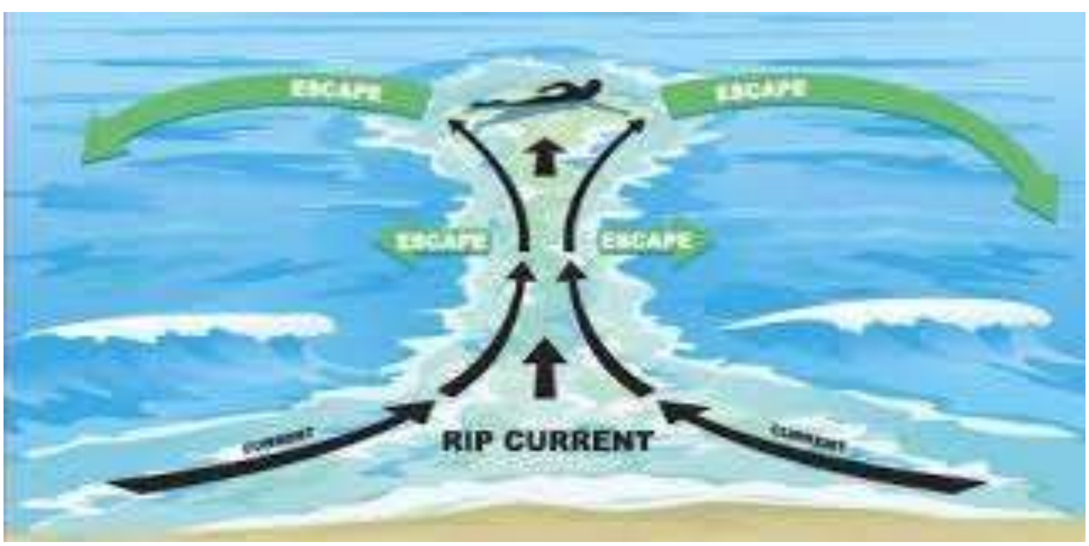
In the polar regions, the water starts to freeze and sheds salts and also becomes denser and sinks. The cold water moves along the bottom of the ocean where it ultimately meets more cold water coming from the Antarctic. Some of this is pushed upwards and mixes with the warmer water above. At the surface, this water is pushed in a northerly direction in the north and a southerly direction in the south. The north moving waters, affected by Coriolis move to the right and bring warm tropical waters across toward Europe in the Gulf Stream.

This accounts for relatively warmer climates in Europe at the same latitudes where it is colder in the US and Canada.



Polar currents

RIP CURRENTS (are not tides) Danger to swimmers who do not understand them



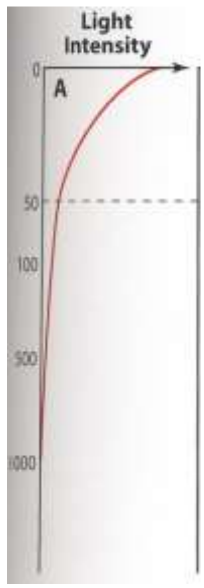
PROBLEMS OF A TWO LAYERED OCEAN

While we have looked at how the ocean is divided into zones going out from the shore- littoral or intertidal, neritic (over the continental shelf) and pelagic (deep ocean) as well as in depth – epipelagic (Euphotic), mesopelagic (Dysphotic) Bathypelagic (aphotic) and Hadalpelagic, we have not discussed many of the changes which occur that are important in understanding how the ocean works.

WHY THIS IS IMPORTANT

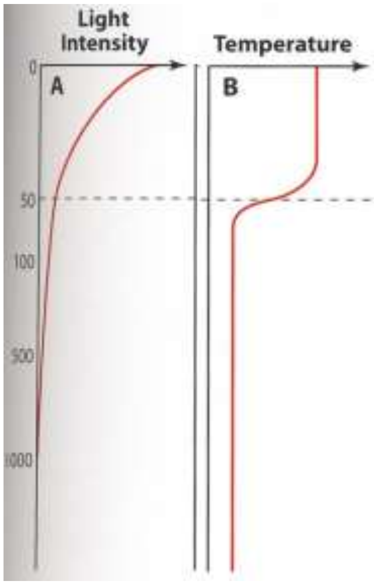
For all life on earth, the point of origin will be the organisms that are able to create their own food from either the sunlight or some chemical source. Most of this takes place through PHOTOSYNTHESIS in which water and carbon dioxide in the presence of sunlight produce sugar which ultimately turn this into energy. However nutrients are needed to move the results of the photosynthesis around the organism. There are nutrients. How this happens in the ocean needs to be understood so that it is possible to see where problems develop and how some of them are solved.

We identified the layers of light because of the ability of autotrophs that need sunlight to photosynthesize. Words like euphotic and dysphotic are based on questions of photosynthesis. Obviously the actual depth at which light fades away is a function of turbidity – how much sediment is mixed in the water. The more sediment, the less the depth to which the light can penetrate. Light clearly penetrated air much more easily that it penetrates water.



From the diagram, it is clear that light (in general) will start to fall off immediately and at about a depth pf 50 meters it is close to gone. By 1000 meters it is gone altogether.

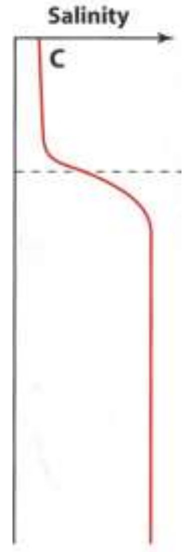
The temperature of the ocean also falls off, but in a slightly different pattern.



The temperature in the ocean from the surface to about 50 meters remains pretty constant and then suddenly becomes colder. Any place where there is this kind of "sudden" change is called a "cline". So where the temperature drops off suddenly, it is called a "thermocline".

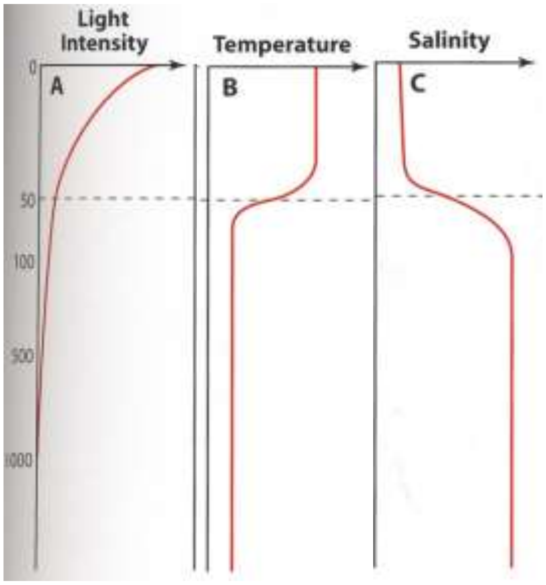
The water near the top of the ocean is heated by the sunlight and there is sufficient water movement from waves and such to keep temperatures up to 50 meters fairly constant, but at the 50 meter mark, things change and the water becomes colder. The polar current, also traveling toward the ocean bottom helps in this as well.

Salinity, or salt content is another variable to be considered.



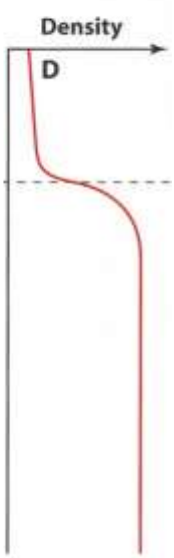
This graph shows the changes in salinity for high latitudes. In low latitudes, it reverses. Most of the processes that have an impact on salinity occur on or near the surface and have little impact on the deep levels of the ocean. In higher latitudes, melting icebergs for example, put fresh water into the ocean at the surface keeping the salinity lower. Precipitation, run off from the land, melting sea ice, sea ice forming, evaporation, all contribute to the lessening of salt in the higher latitudes and the decreasing salinity in the lower latitudes.

This “cline” is called the “halocline”.

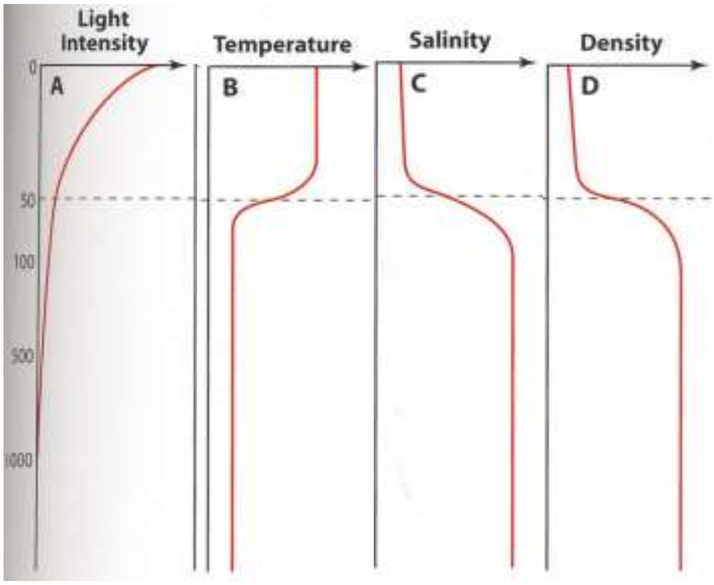


The temperature and a salinity taken together are known as thermohalocline!

Density is next and as one might expect, the deeper one does the more dense the water becomes.



The change matches quite nicely with the thermocline – colder water becomes denser.



The next two measurements, nutrients and oxygen are especially important if we are considering life forms, since both are necessary for primary producers.

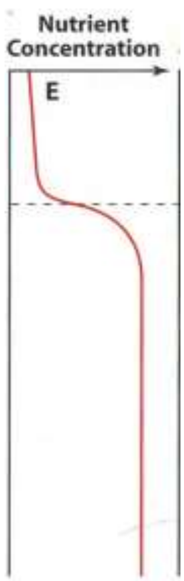
Nutrients may seem an odd inclusion here, because we tend to think that primary producers perform photosynthesis and as a result make all the food they need, but this is not the case. In addition to the sugar produced by photosynthesis, organisms also need mineral nutrients which are defined here as "any small inorganic molecule needed for growth of phytoplankton that is not itself a reactant in photosynthesis". Since water and carbon dioxide are involved in photosynthesis, they are excluded from the definition whereas iron, nitrogen, phosphorous and silicon are not excluded.

Sea water contains (a) Ammonia in the form of ammonium ion HN^{4+} a source of nitrogen; (b) Nitrate NO_3 - also a source of nitrogen; (c) Phosphate PO_4^{3-} (a source of phosphorous) (d) Silicic acid $(Si(OH)_4$. Iron is also found in the ocean.

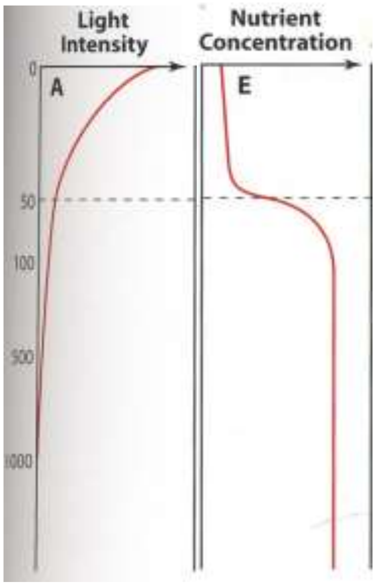
The Idea of a limiting factor

Because all nutrients are NOT available in limitless or equal quantities, those that are scarce limit the amount of activity they are needed for. Suppose for example that you want to make cakes. Each cake requires 2¼ cups of flour, 1½ cups of sugar, 3 teaspoons of baking powder, 1 teaspoon of salt, ½ cup soft shortening, 1-cup milk, 1½ teaspoons flavoring and 2 eggs. You have available 100 pounds of flour, 50 pounds of sugar, 10 pounds of baking powder, 5 pounds salt, 5 pounds of soft shortening, 5 gallons of milk, 1 gallon of flavoring and 4 eggs. How many cakes can you make? Answer 2. Since there are only 4 eggs and you need 2 per cake, the eggs becoming the limiting factor.

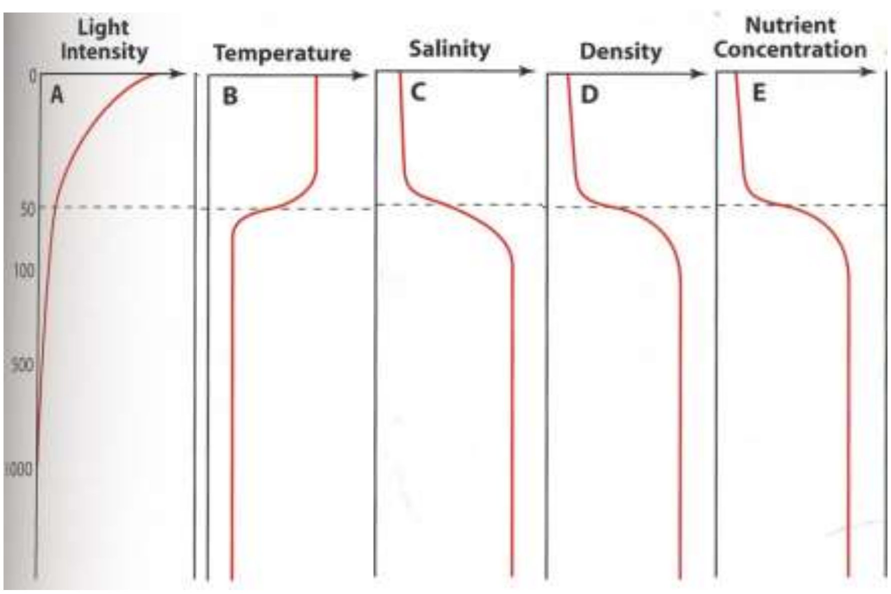
The problems here are with nitrogen which is the "limiting factor" – the one that is least available. The problem is that nitrogen by itself is in great quantities but few organisms can use it in this form. It needs to be "fixed" – that is to be made into a form that is usable. This happens as a result of CYNOBACTERIA – a form of bacteria that is able to "fix" nitrogen so it can be used. It does this by making ammonia. What is important here is the recognition that the production of fixed nitrogen is on the ocean floor.



While some nitrogen fixing does go on, on coral reefs closer to the surface, about 85% happens in deep water.

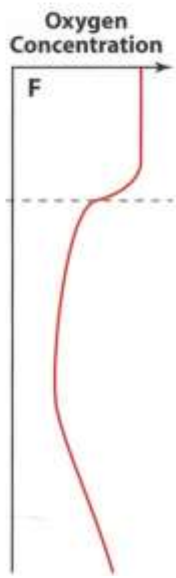


So you can see where you have light, you have little nutrients. Where you have nutrients, you have little light!



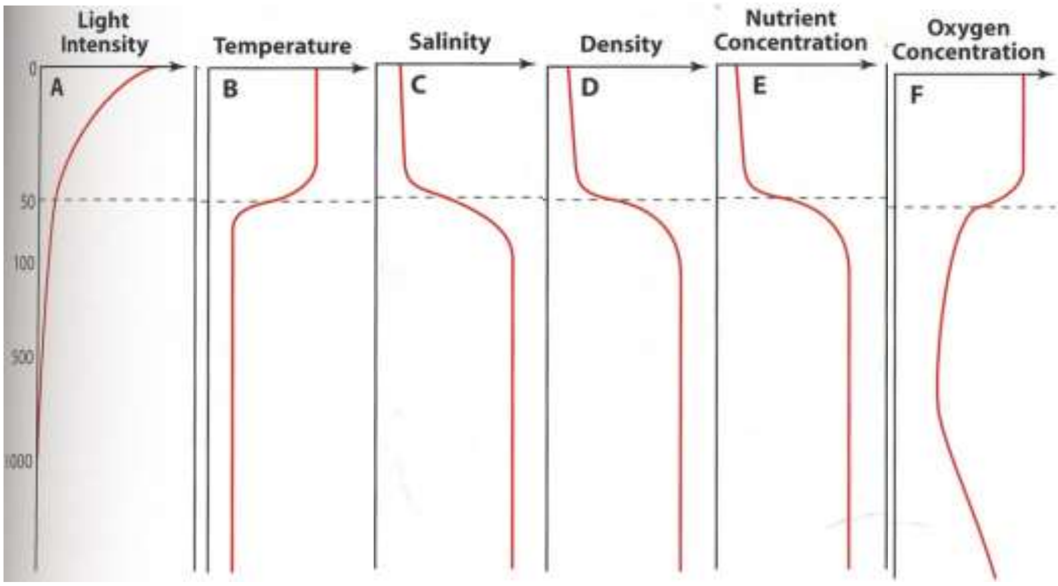
Because the upper levels are low in nutrients, photosynthetic forms have trouble growing here.

The lower level, which has the nutrients doesn't have the light needed for photosynthesis so there seems to be a real problem here. Photosynthesis requires carbon dioxide, but respiration requires oxygen. Photosynthetic organisms usually produce enough oxygen for respiration. Heterotrophs require oxygen which they do not produce. Hence it is only with the appearance of photosynthetic organisms that much life as we know it is possible. There was a time in the history of the earth where life forms did not use oxygen and there was little to no free oxygen in the world. When organisms began to produce oxygen it was lethal to many organisms and is believed in part responsible for a major extinction event. In effect, oxygen was a lethal pollutant. It is still in large quantities dangerous to animals and can be fatal. It is something divers have to worry about because in commercial diving, the amount of oxygen is changed upward from 21% (mixed gasses)



So what happens with the oxygen levels start out fairly constant, then drop off and then rebound!

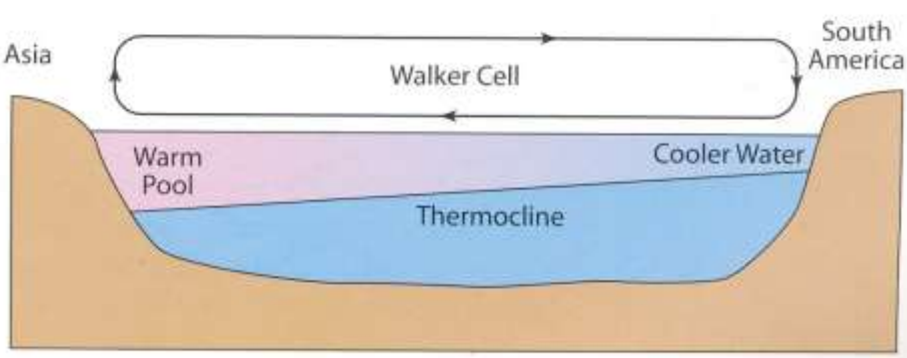
The problem here is that many of the small organisms cannot swim but are plankton. They are also negatively buoyant as adults and tend to sink slowly. As they sink, the move into the dysphotic zone and can no longer produce food and die. (Some reproduce near the surface and the young start the cycle all over again). As they (and other organisms die) they begin to decay and the bacteria that do that respire and use up the oxygen in the water. So the oxygen levels fall off. Finally we reach a level where all that can decay has basically done so. Below this level is the thermocline circulation – the cold water (aerated) moving along the bottom of the ocean. It brings more oxygen with it, raising the level of oxygen.



So the graphs all show, how there are serious changes, starting at about 50 meters and continuing down about another 50. These changes are referred to as the "thermocline" and refers to the changes in all these forms not just temperature.

Remember though, that the actual depth of the thermocline changes both seasonally and in different areas.

So how is it the oceans work at all in terms of life forms? The answer is part "upwelling". Upwelling occurs when minerals are brought up from the bottom, usually caused by a "tilt" in the thermocline.



The Walker cell of zonal winds.

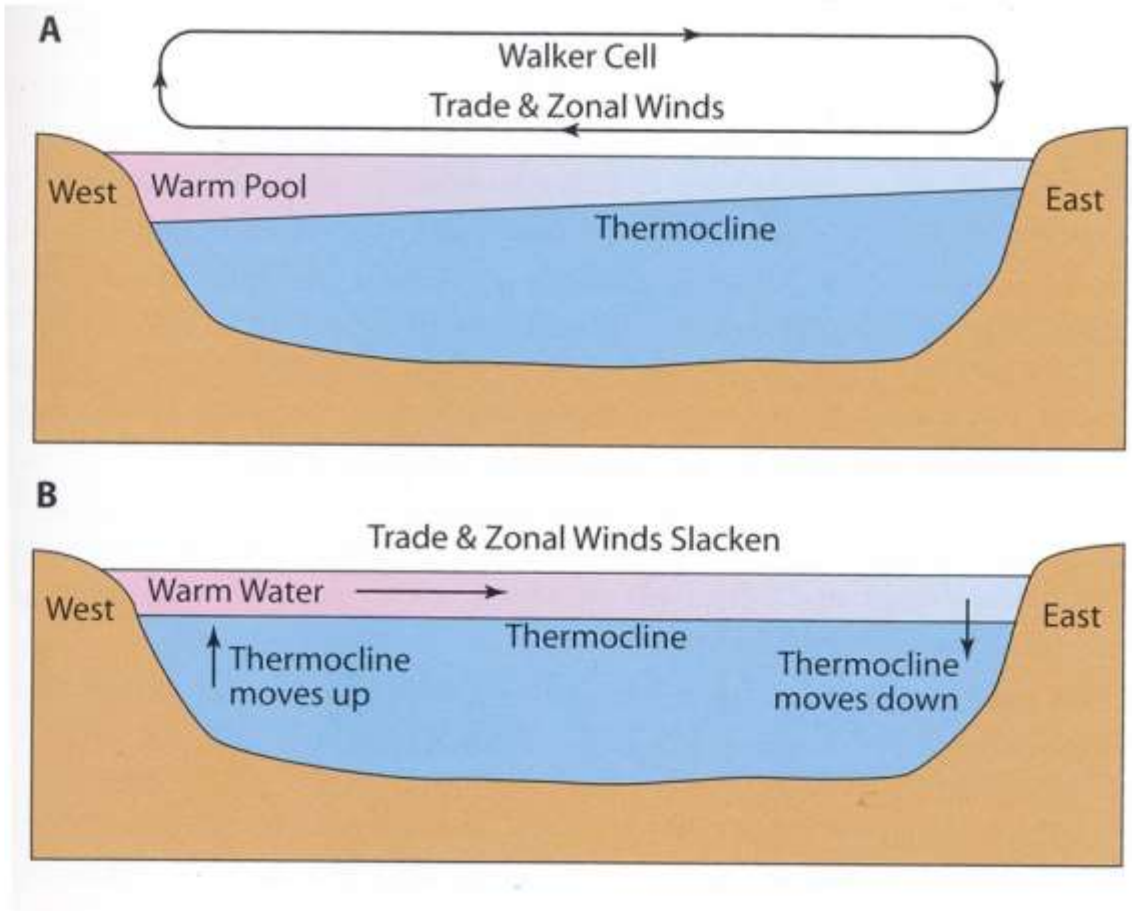
This diagram shows a “tilt” in the thermocline caused by two pressures of air and the Walker Cell (the cell in which the winds move from east to west here) – one low pressure in Asia and one corresponding high pressure in South America. As a result of a pressure differential, air flows from an area of high pressure (over South America) towards one of low pressure (over Asia). This flow of air moves water from the eastern Pacific (SA) towards the western Pacific causing water to begin to “pile up” in the western part. This depresses the thermocline so there is a “tilt” in which the thermocline is deeper in the west than the east.

The warm water in the west heats the air and causes it to rise, whereas cooling air descends over SA and cools the water. Ultimately, the temperatures will start to even off and more and more cool water moves west. This will ultimately cause a stoppage in the Walker cell circulation and a reversal of direction.

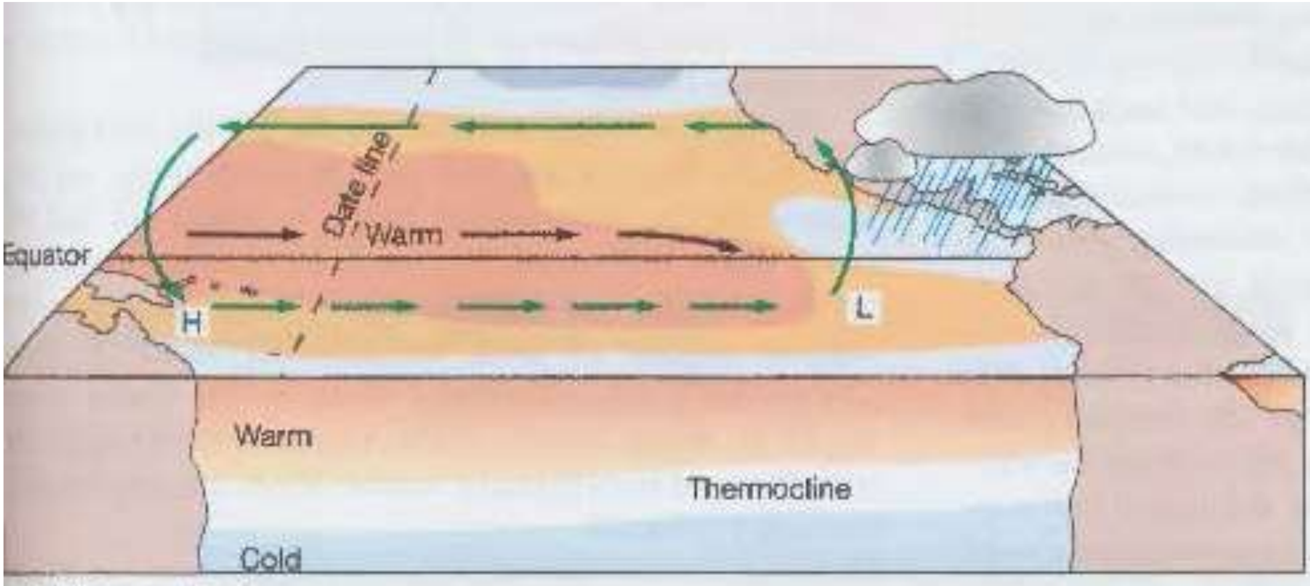
Whether the air or the water is the primary cause is fought about. But the change is not.

When the water moved along the bottom from west to east it finally encounters the shore of SA and must move both up and then north and south (along with the thermocline), which is what it does. The movement up, brings nutrients up from the bottom to the surface and all is well. We now have nutrients and sunlight both at the surface. This movement of nutrients up from the bottom is called “UPWELLING”

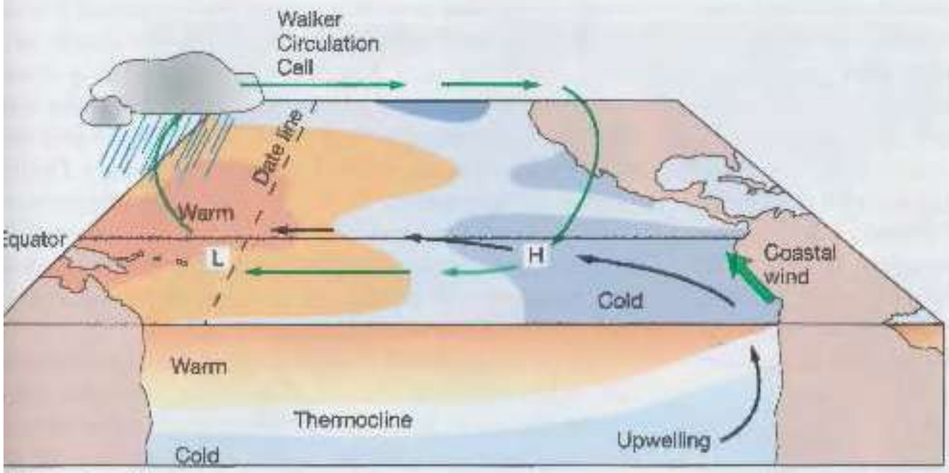
Once the change happens and the winds and water reverse direction, the thermocline that was higher in the east, now begins to descend and the upwelling slows or comes to a halt.



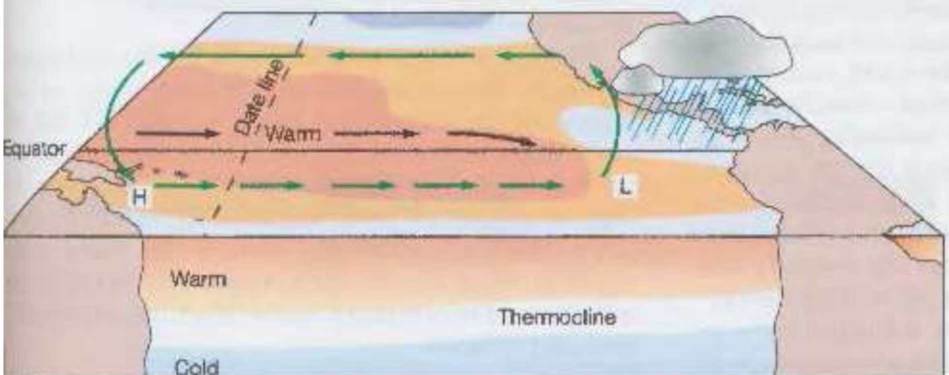
This shift between high and low pressure and rising and falling thermoclines was known to both meteorologists and oceanographers for quite some time. One group referred to it as the "Southern Oscillation" the other as "El Niño". Now that it has been realized this is the same phenomenon it tends to be referred to as "ENSO" (short for "**E**l **N**iño **S**outhern **O**scillation")



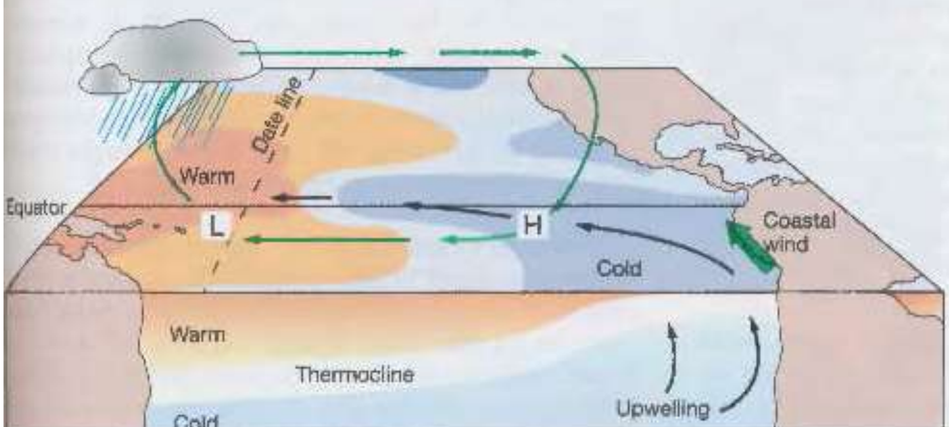
b) El Niño conditions



a) Normal conditions



b) El Niño conditions



(c) La Niña conditions

Similar oscillations happen in the Atlantic as well. The most well known perhaps is the one in the Indian Ocean which causes the Monsoons, although the processes here is a bit different.

The Indian Ocean lies largely in the Southern hemisphere, unlike the Atlantic and Pacific both of which are divided into a Northern and Southern half. This is largely because the currents in the Northern and Southern parts of the ocean have differing currents, thanks to the Coriolis Effect.

In the Indian Ocean, there is a huge land mass sitting in the Northern hemisphere. This heats and cools at a different rate than the waters of the Indian Ocean. In winter, (October to April) cold heavy air sits over the continent and lighter warm moist air rises over the ocean. The pressure gradient brings the winds from Northeast the land onto the ocean. This is sometimes called "the dry monsoon".As summer appears (from May until Sept.) and the land mass begins to warm, the air from the Southwest over the land begins to rise and the air now moves in from the ocean bringing the heavily water laden air which produces tremendous rainfall as it moves over the continent. This is the "wet monsoon" or more frequently just called "the monsoon"

So as we can see, the ocean and the atmosphere operate together to bring very different kinds of weather around the world at different times of the year.

LIFE IN THE OCEAN

The earth forms about 4.5 billion years ago. The geological evolution of the earth. Life appears about 3.8 billion years ago. The history of life on Earth is rather long. Since then life has undergone many changes and different kinds of organism have come and gone. Organisms range from extremely small microscopic animals to huge dinosaurs like the Titanosaurs – the largest animal that we know of. The blue whale is the largest animal in the world today.

CLASSIFICATION SYSTEMS

We need to know about these so that we can understand the basis on which organisms are grouped together Because of this enormous variation, there are literally millions of organisms that need to be named. Worse still, many languages and even dialects call the same kind of organism by different names. As a result, ultimately scientists decided to give animals a "scientific name" which would be constant among scientists of all nations and cultures. These scientific names come in two parts called a "genus" and "species" name, and this is known as the Linnaean system named after its inventor. For example, people are known as Homo sapiens. The genus name is always capitalized, the species name is not. (You should note at this point that there is an "s" at the end of sapiens, which is not a plural maker). The house cat is known as "Felis domestica"; Horseshoe crabs are called "Limulus polyphemus".

Species are normally defined as members of a group that can mate and produce viable offspring – that is to say, the offspring themselves are fertile. This is a good definition although it breaks own with organisms that do not reproduce sexually.

The genus level shows a close relationship between species. One might think of this as a group of animals that historically might have been a single species, but has developed enough variation that interbreeding and producing viable offspring is no longer possible.

Higher and higher levels of classification have been organized and we now often talk about a TAXONOMIC classification system in which there are levels of organization in which lower groups are "nested" into larger ones. Basically, the taxonomic levels are:

Level	Humans	Chimpanzees	Sea cucumber
Kingdom	animalia	animalia	animalia
Phylum	chordata	chordata	echinodermata
Class	mammalia	mammalia	holothuroidea
Order	primate	primate	synallactia
Family	hominid	pongid	stichopodidae
Genus	Homo	Pan	Stichopus
Species	sapiens	paniscus	herrmanni

From this you can see that humans and chimps are closely related, while humans and sea cumbers are related only at the level that they are both animals.

In addition to the levels listed above, there a sub levels (subphylum, subclass, suborder etc.). One sublevel in the chordates is “vertebrata” – animals with backbones. Super levels exist as well (superclass, superorder). In addition, there are infra forms that rank below the sub forms! Each level is defined in specific ways. So for example, animals are often defined by five characteristics:

(1) Multicellular (must have more than one cell)

(2) Motile at some point in their life cycle (move)

(3) Reproduce sexually or asexually

(4) Lack a cell wall

(5) Are heterotrophic (need to eat)

Chordates have a stiffening rod that runs down the dorsal (back) side of the animal; vertebrates have a backbone.

The classification of organisms by taxonomic levels was the most common way scientists used to classify organisms, but another classification system called cladistics is becoming more popular. This form talks about “clades” or groups of organisms making up a common descent group. These are usually based on genetics rather than gross anatomical structure.

As we have said many times, science changes as new data comes in and in this, there have been many regroupings of organisms. Probably the most dramatic have been changes in the higher levels of classification.

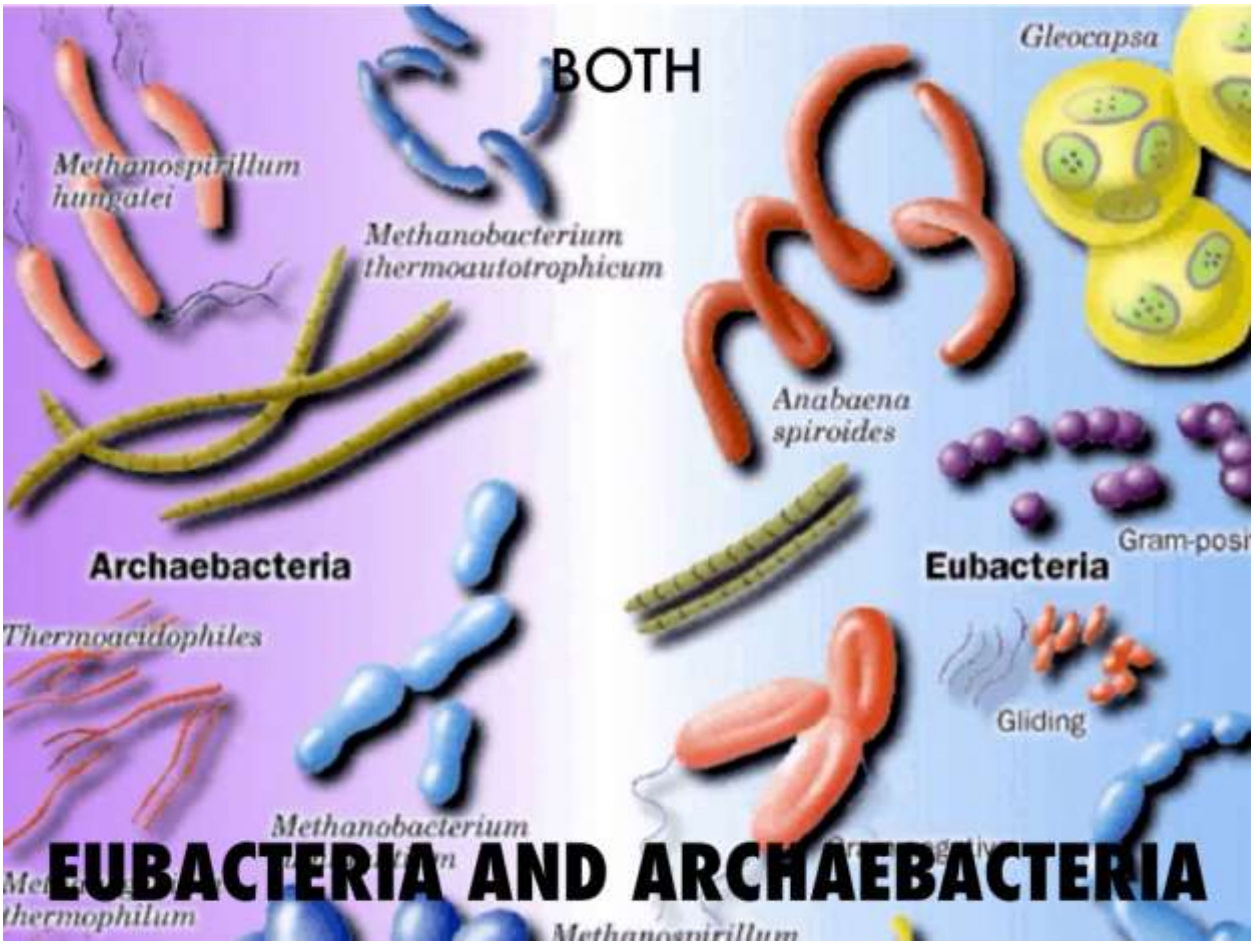
Traditionally organisms were divided into 2 kingdoms called “plants” and “animals”. Many one-celled organisms were difficult to classify as either plants or animals. As a result, a third kingdom was defined called “Protista” which contained all the single celled organisms. Another group of organisms, which seem like plants but do not photosynthesize were separated off and called “Fungi”. These are mushrooms, molds and the like.

More recently, biologist discovered that some of the one-celled organisms did not have a nucleus and did. This led to a division between organisms with a nucleus with a membrane and those without. Organisms without a nuclear membrane were called “Prokaryotes” while those with them were called “Eukaryotes”.

Since plants animals and fungi all have a nuclear membrane, they become part of a “Domain” called Eukaryotes while “bacteria” were seen as ‘Prokaryotes”. Finally, the prokaryotes were found to contain two significantly different groups Archaea and Bacteria. So currently, the thought is that organisms are divided as follows:

PROKARYOTES EUKARYOTES

Archaea Bacteria Protists Fungi Plants Animals



Many biologists feel that the Archaea are more closely related to the Eukaryotes, than the Bacteria are.

An important member of the bacteria are the cyanobacteria (sometimes erroneously called “blue green algae”). They are the only prokaryotes that photosynthesize and produce oxygen. It is thought that they transformed the earth’s atmosphere into an oxidizing one. This radically changed the earth and led to the near extinction of the anaerobic life on earth. In effect, Oxygen, a pollutant given off by the cyanobacteria changed the environment causing a mass extinction but made life possible for the organisms we know today.

They are also “nitrogen fixing” which means they are able to convert nitrogen into a form that is usable by other organisms. Nitrogen is needed by living organisms but is inert. It needs to be made into some form the organisms can use (usually Ammonia)

Why do we need to know this? Since people are alive and are heterotrophs (need to eat) and seafood constitutes part of what we eat, we need to know something about how the system works that makes life possible – especially for humans.

Animals have to eat and hence they need food. We need food for energy. Almost all energy comes from the sun, so there must be some organisms that can convert sunlight into energy. Any organism that can change sunlight into energy for biological use is called an AUTOTROPH. Organisms that cannot do that are called HETERTROPHS. Most autotrophs convert sunlight into biological energy, although some can do it from chemical reactions. These autotrophs perform chemosynthesis as opposed to photosynthesis.

So at the bottom of the food chain (that is the lowest “trophic level”) are autotrophs.

Although chemosynthesis and photosynthesis allow for production of bioenergy, nutrients are also needed. These are chemicals like phosphorous and nitrogen that have to be incorporated into the organism.

What is important to remember here is that these bacteria not only started the oxygenation of the atmosphere, but also a major force in making nitrogen available to living organisms.

So when an autotrophic organism produces food it needs some energy source like sunlight and nutrients. If nitrogen is one of the necessary nutrients then its availability may be a limiting factor. While there is a great deal of nitrogen available in the atmosphere, most organisms cannot make use of it in its atomic or molecular, but need it in some compound lime ammonia. This is one of the major things the cyanobacteria do.

Over the billions of years that life has been on Earth it has changed. When a person is born, they are relatively small, they cannot walk on two legs, they do not talk and so on. Over the course of years, people grow bigger, become bipedal, learn to speak a language and so on. This process is called "development". When a species changes over time, it is called "evolution". One example we have already mentioned is the development of organisms that photosynthesized and gave off oxygen as a by-product. This caused major changes in the nature of the Earth's atmosphere. Many organisms died off because of the oxygen, while others were able to change or adapt to the new circumstances.

Darwin postulated a way in which such change could have happened. He noticed that in any species, there is a certain amount of variation that occurs naturally. For example, there is a good deal of variation in the lengths of people's noses.

If, for some reason, longer noses would help people survive longer and produce more offspring, then more and more members of the population would have longer noses. If somehow, some of the animals spread out into different environments, then in some areas, longer noses might be an advantage and in other areas, shorter noses might be advantageous. Ultimately, the two groups would develop to the point where they could no longer interbreed and produce viable offspring and would have become two different species. This processes is called speciation

As organisms changed (evolved) over time they became more and more varied. As we move up from the species level, there are often arguments among scientists as to just how the classification of any particular animal should be made. Generally there is pretty good agreement at the Genus and species level, but above that things sometimes get a bit hectic. The older taxonomic classification system (Linnaean) tended to work with "gross morphology" – how the animals looked and functioned. The cladistics approach tends to rely more heavily on genetics and descent groups.

For example, in the Linnaean system, reptiles and birds are seen as being the same level (Class) (along with mammals, amphibians and fish). Now the feeling among cladists is to link the birds and reptiles together as a single unit. This is why birds have become "dinosaurs". Unfortunately this has led to the problems of having to talk about "non avian" and "avian" dinosaurs which seems to mirror "reptiles" vs. "bird". You are more and more likely to hear about cladistics classifications currently, along with the older Linnaean system! You will see some of this in the American Museum of Natural History.

Over the billions of years that life has been on Earth it has changed. When a person is born, they are relatively small, they cannot walk on two legs, they do not talk and so on. Over the course of years, people grow bigger, become bipedal, learn to speak a language and so on. This process is called "development". When a species changes over time, it is called "evolution". One example we have already mentioned is the development of organisms that photosynthesized and gave off oxygen as a by-product. This caused major changes in the nature of the Earth's atmosphere. Many organisms died off because of the oxygen, while others were able to change or adapt to the new circumstances.

It is significant that at different periods of time in recent human activity, there are periods where certain ideas tend to dominate. We have all heard the terms like the "renaissance", "the enlightenment", "the reformation" and so on. Each of these deals with a change in the way people looked at things in general. The Renaissance was a periods from the 14th to 17th Century in Europe. Its actual time varies from place to place and it bridges the Middle Ages (5th to 15th Centuries) to the Age of the Enlightenment (18th Century).

The Renaissance rediscovers the classic periods of Greece and Rome and a kind of "humanism" which impacts art, science, politics, literature and so on.

The Enlightenment or Age of Reason stressed reason as the "source for authority". There was an emphasis on scientific reasoning and a questioning of religious orthodoxy which to some degree opposed it. *Sapere aude* "dare to know" was a phrase to catch that spirit of the times. The term "Zeitgeist" is often used to express the idea of "the spirit of the times" whatever times they may be. There were many organizations formed for the dissemination and discussion of ideas – academies, Masonic lodges, and so on. Science develops dramatically in this period and the enlightenment emphasized free speech and thought over religion and traditional authority. The Enlightenment continues to have an impact into the 19th Century (and beyond) . The scientific involvements of people like Darwin and part of this later phase.

By Darwin's time, the idea of change over time (evolution) had been growing Lyell had postulated geological evolution, Darwin and Wallace would do the same for biology and social scientists would also look at social evolution.

All of this caused a certain amount of turmoil as old ideas were overthrown and new ones appeared. Some strongly religious people want to show that evolution was not real and planned a voyage around the world to show this. They hired a young naturalist to go along named Charles Darwin.

Darwin left on a ship called "The Beagle" captained by a man named Fitzroy. The trip took more than 4 years. On the way, Darwin made many observations of natural phenomenon (including the formation of atolls discussed earlier) but also noted the large number of animals that were remarkably similar but were none the less in separate species. He wanted to understand how this might have happened.

Darwin postulated a way in which such change could have happened. He noticed that in any species, there is a certain amount of variation that occurs naturally in any species. For example, there is a good deal of variation in the lengths of people's noses. Some have long noses, some short, some broad some narrow.

If, for some reason, longer noses would help people survive longer and produce more offspring, then more and more members of the population would have longer noses. If somehow, some of the animals spread out into different environments, then in some areas, longer noses might be an advantage and in other areas, shorter noses might be advantageous. Ultimately, the two groups would develop to the point where they could no longer interbreed and produce viable offspring and would have become two different species. This processes is called speciation

Darwin phrased this in four steps:

Natural variation (there is variation in any trait in a population)

Struggle for existence (the environment can only support a limited number of organisms)

Natural selection (Some of these organisms do better in the environment than others, because of the traits they have)

Survival of the fit. (those that fit better, do better)

Darwin had been puzzled by the number of kinds of finch species he found in the Galapagos Islands on his trip around the world. Let us say some finches have beaks that differ from those in other species. Some of these beaks allowed finches with one kind of beak to get to food others could not

Darwin could not explain the natural variation and fell back on another scientist named Lamarck who postulated that organisms passed on ACQUIRED characteristics. Giraffes stretch their necks to reach higher in the trees and the longer necks are passed on to their offspring. This we know now is not true. So the Darwinian Theory has been modified to add genetics as the way in which variation takes place.