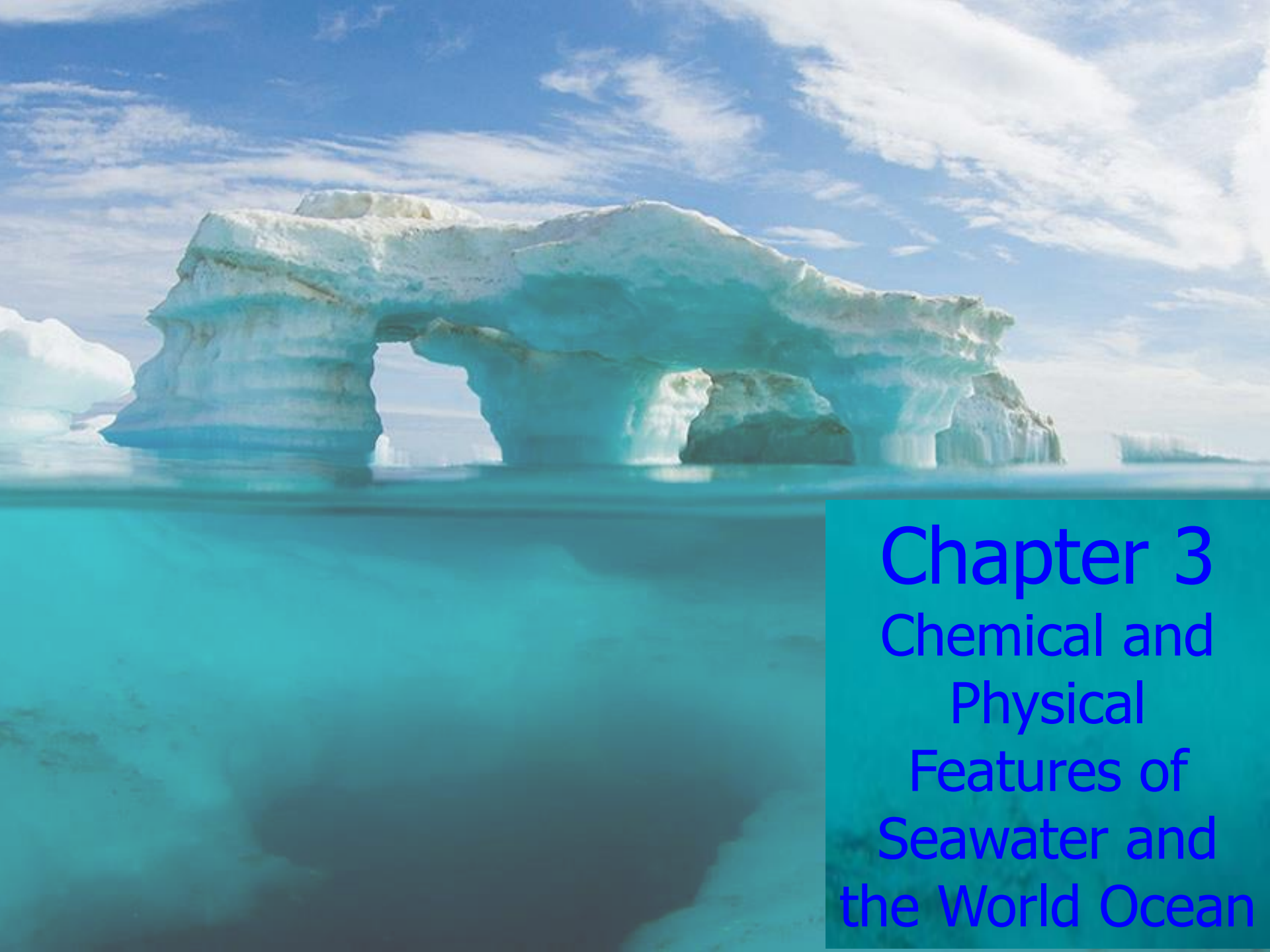
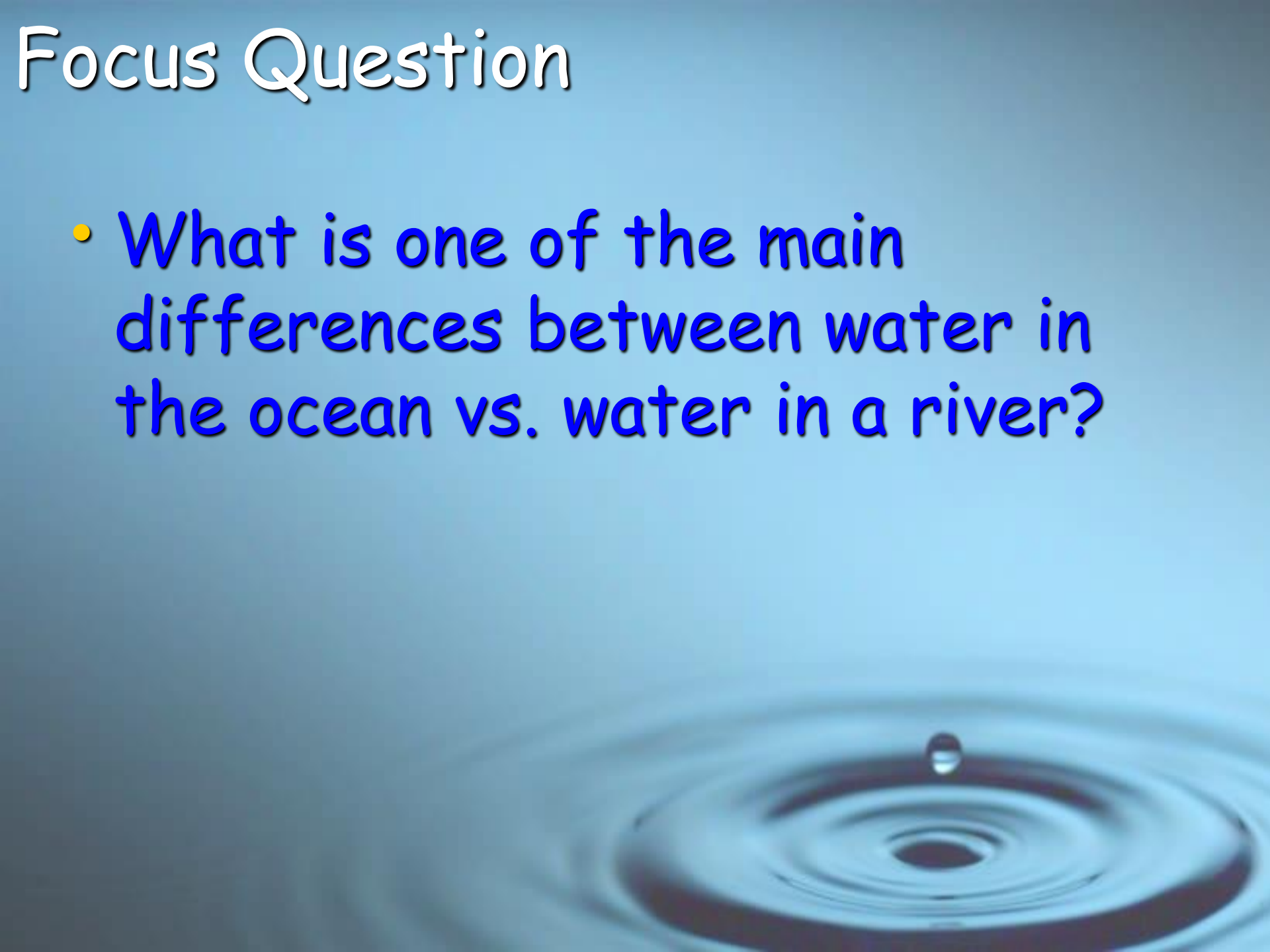


Chapter 3

Chemical and Physical Features of Seawater and the World Ocean

Focus Question

- What is one of the main differences between water in the ocean vs. water in a river?

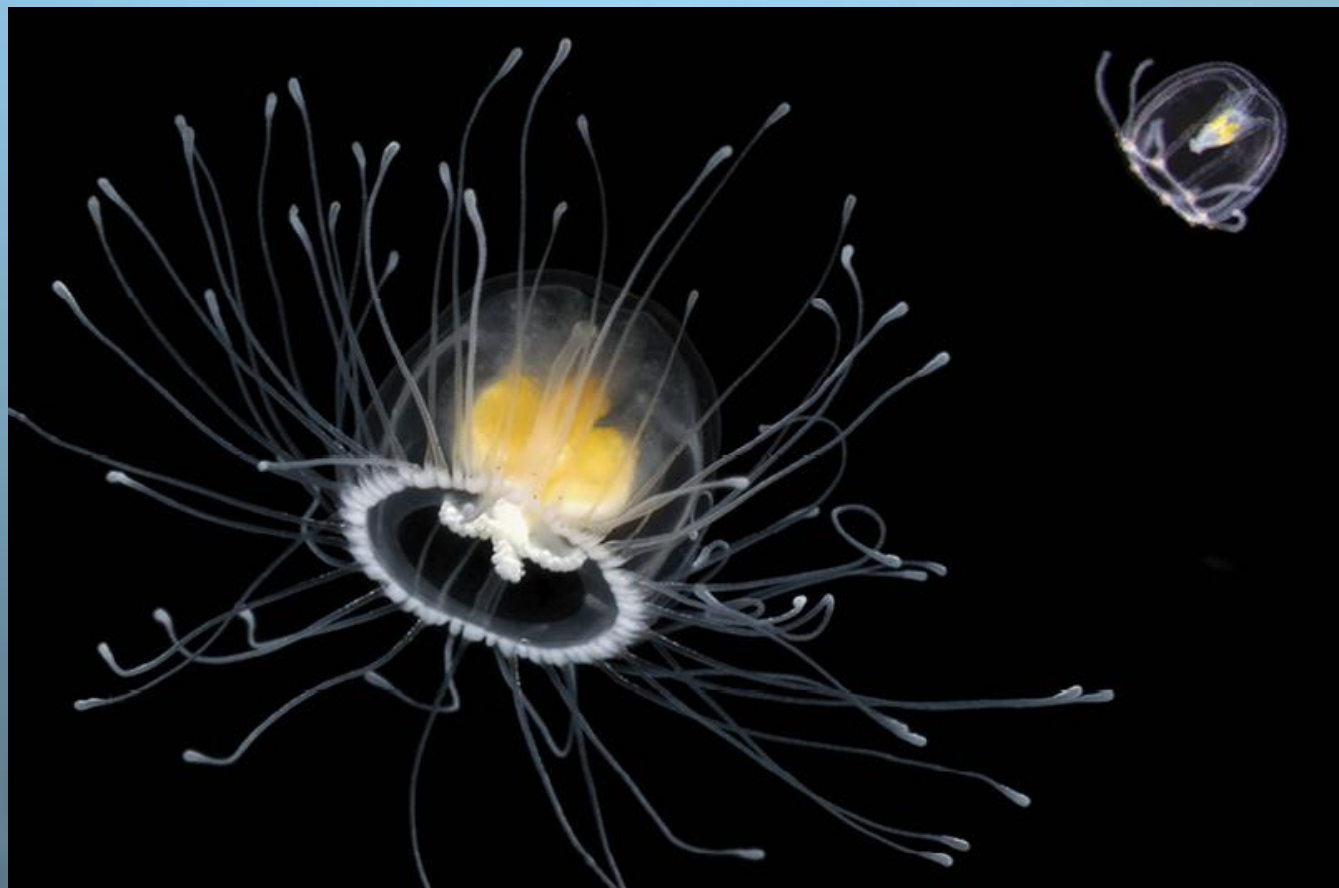


Introduction to the Ocean

- If the Earth were the size of a basketball, the ocean would be a film of water over its surface.
- Its average depth is 2.3 miles.

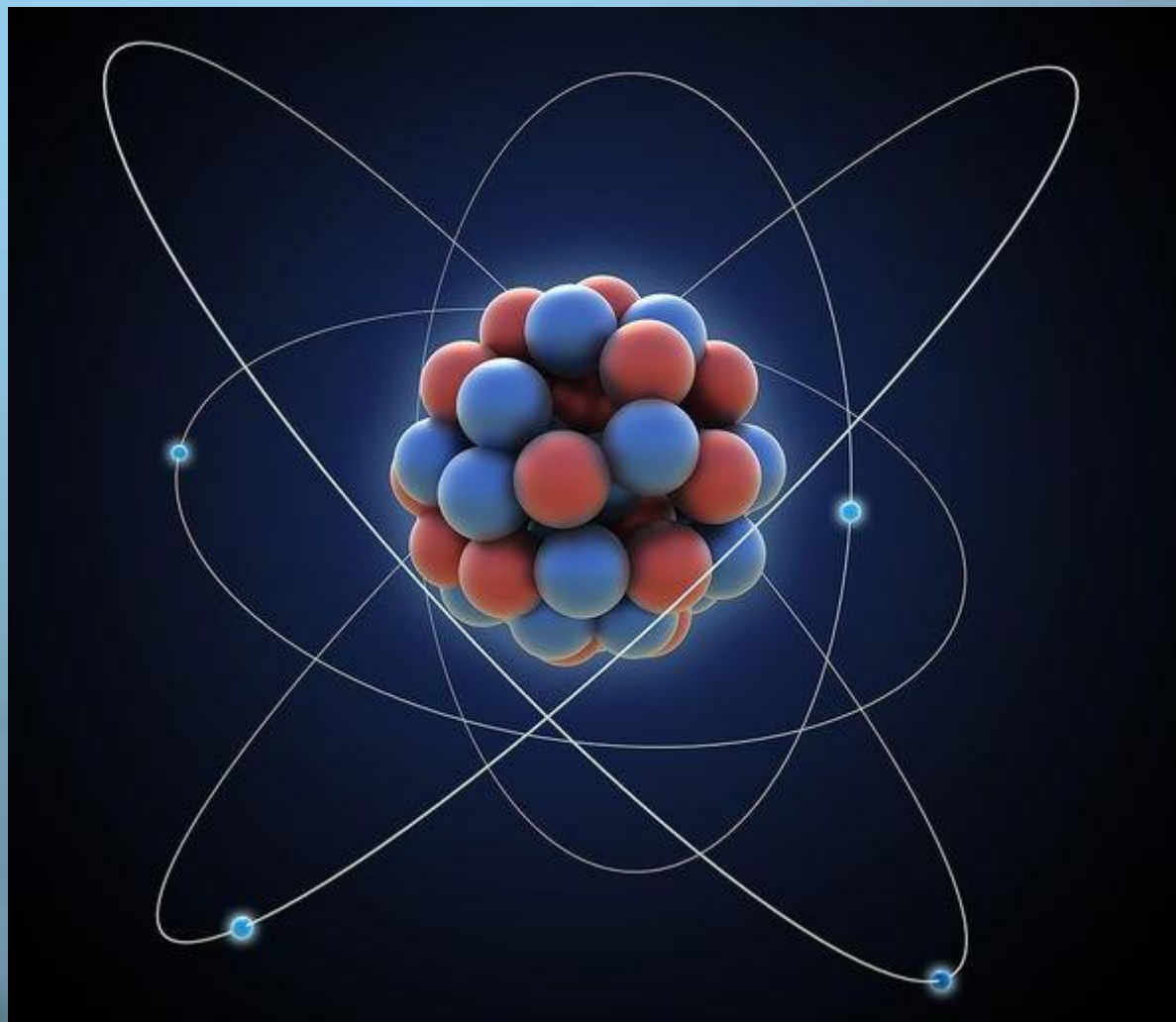
The importance of water

- Water makes up about 80% of most marine life.
- Jellyfish are 95% water!!!!!



What is water?

- All matter is made up of tiny particles called **atoms**.

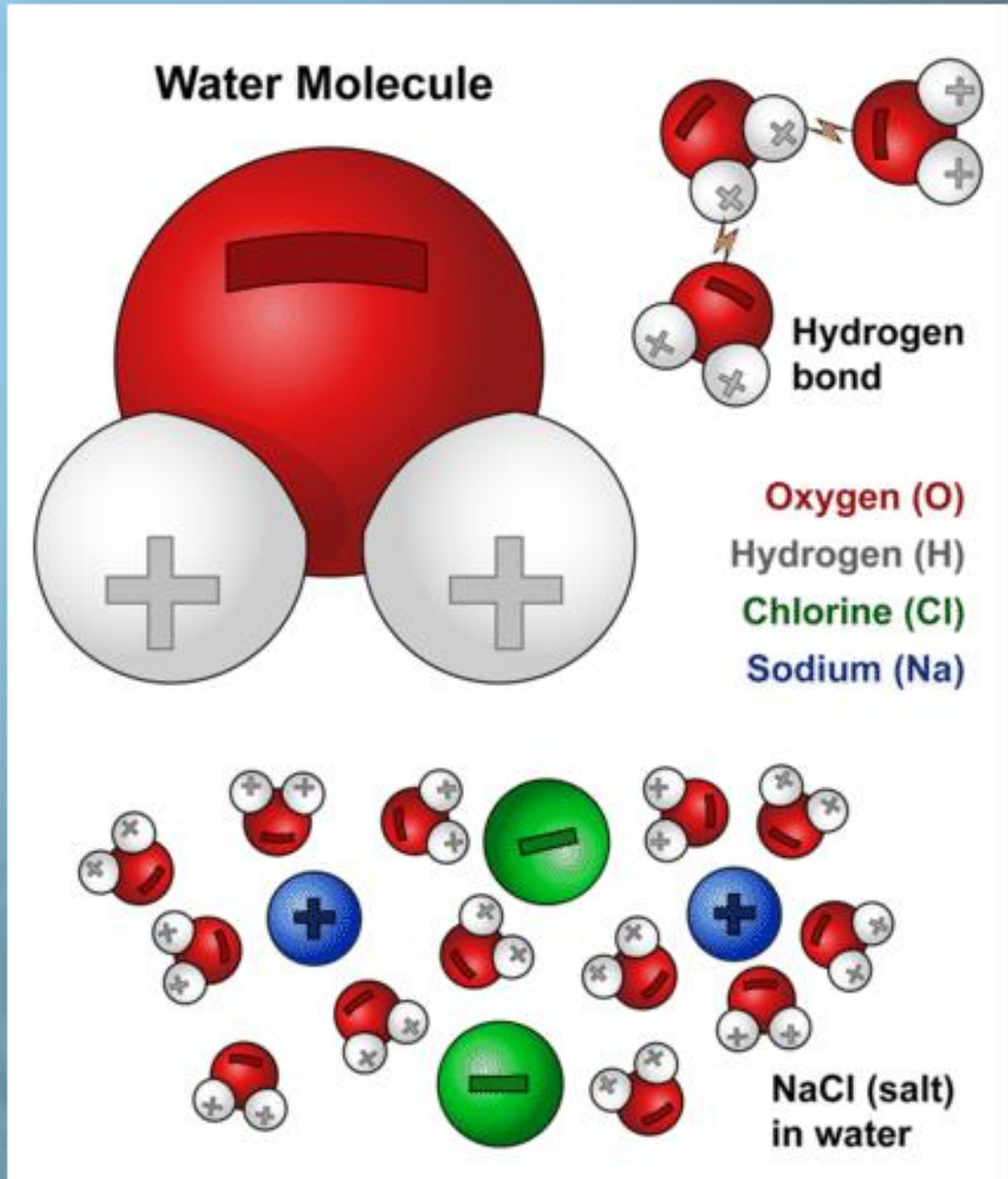


What is water?

- There are 115 substances that are made up of the same kind of atoms. They are called **elements**.

What is water?

- Two or more different atoms can combine into larger particles called **molecules**.

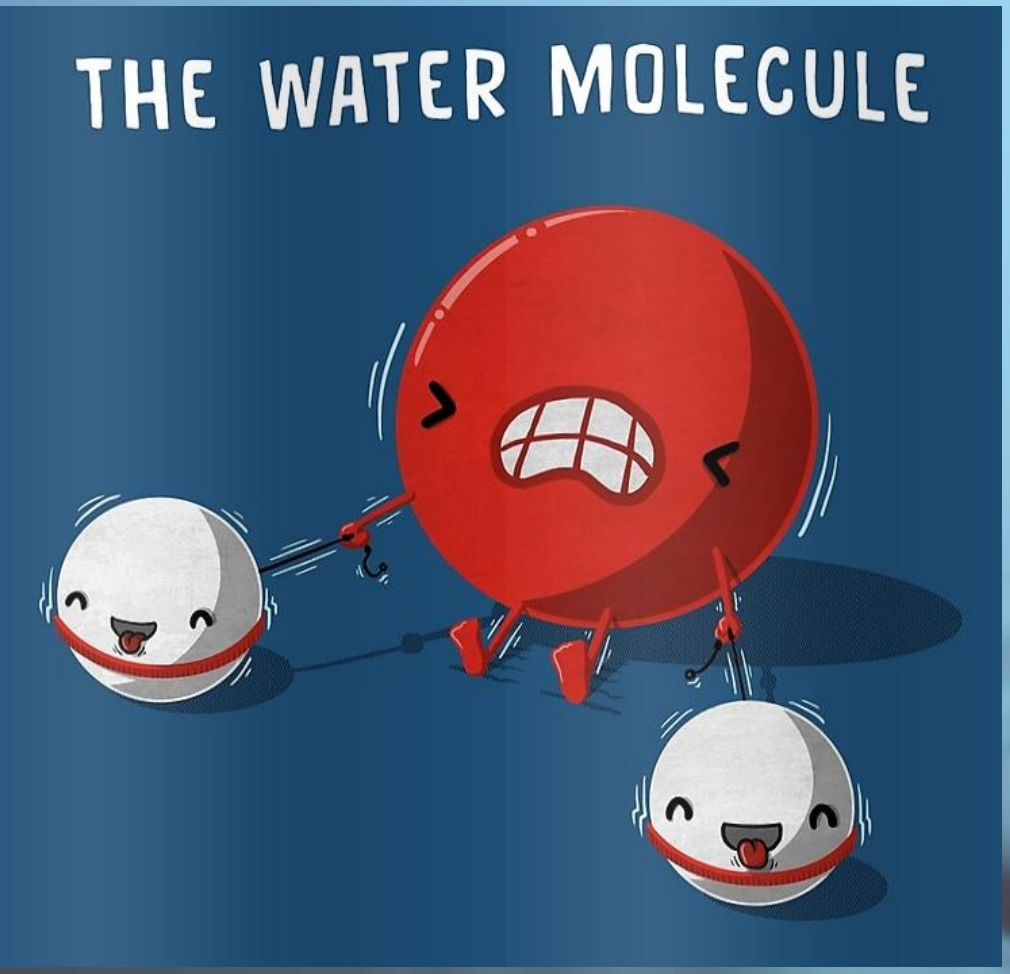


Basic Chemistry 101

- One molecule that everyone on the planet has encountered is H_2O.

- You should recognize this as a chemical description of water

Basic Chemistry 101

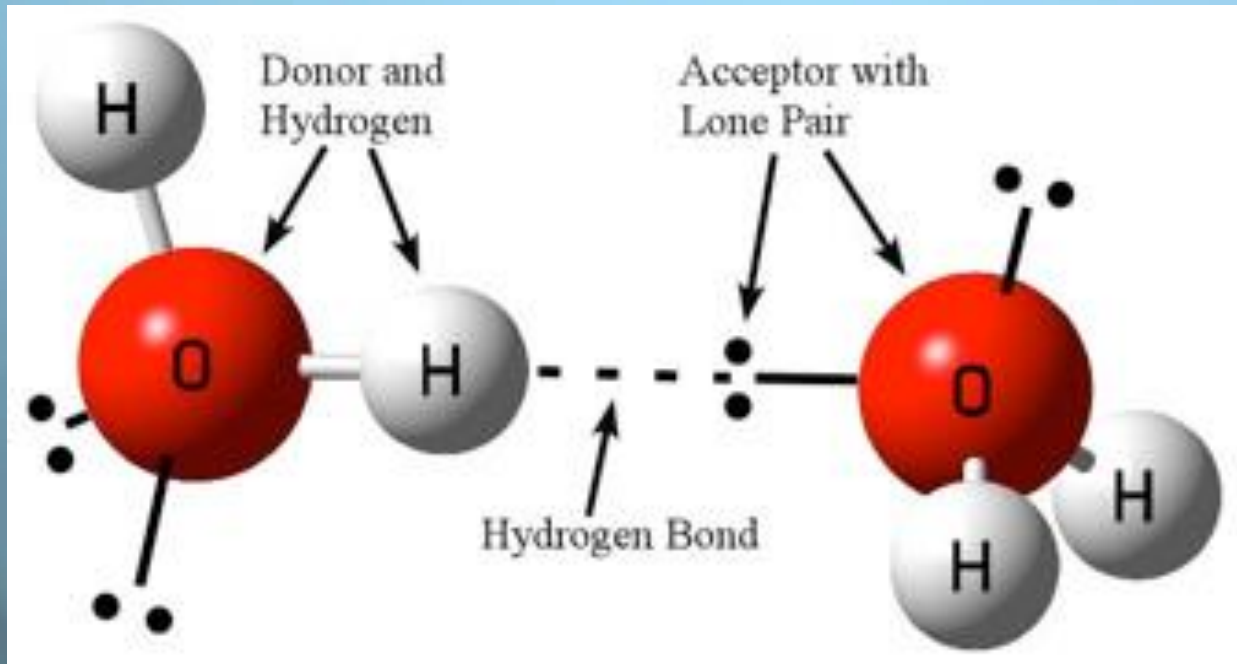


- In the water molecule, there are two atoms of hydrogen and one atom of oxygen bonded chemically together.

Water is a molecule!!!!

- What atoms make up water?

- Water molecules are attracted together by weak bonds called **hydrogen bonds.**



Unique Nature of Water

- First of all, each water molecule has slight positive and negative electrical charges.
- The positive charges are near the hydrogen atoms and the negative charges exist around the oxygen atom.

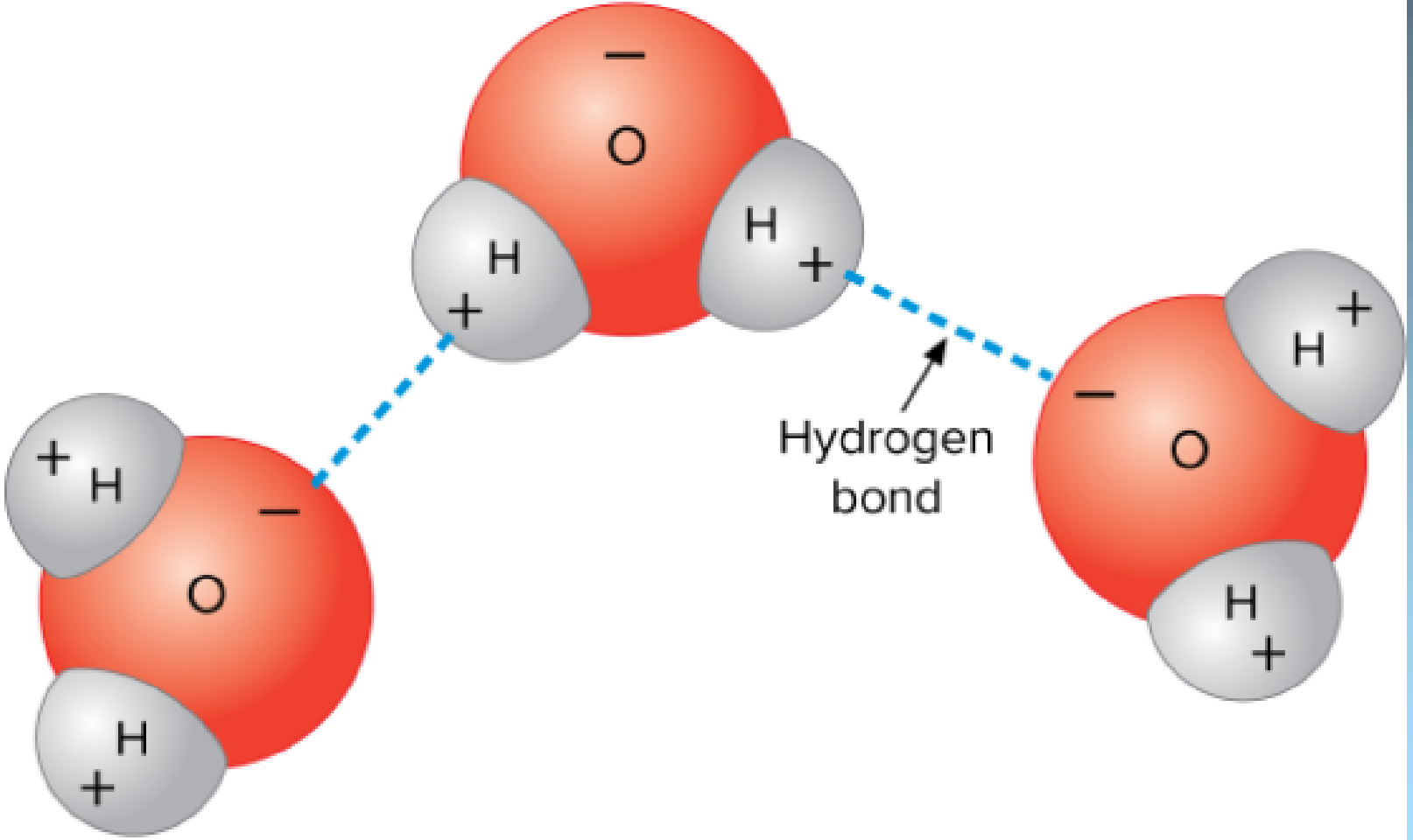


FIGURE 3.1 The different ends of water molecules have opposite electrical charges. The oxygen (O) end has a weak negative charge, while the hydrogen (H) end a slight positive charge. Opposite charges attract each other like the opposite poles of a magnet, so the oxygen end of one molecule is attracted to the hydrogen end of neighboring molecules. These weak attractions between water molecules are known as hydrogen bonds.

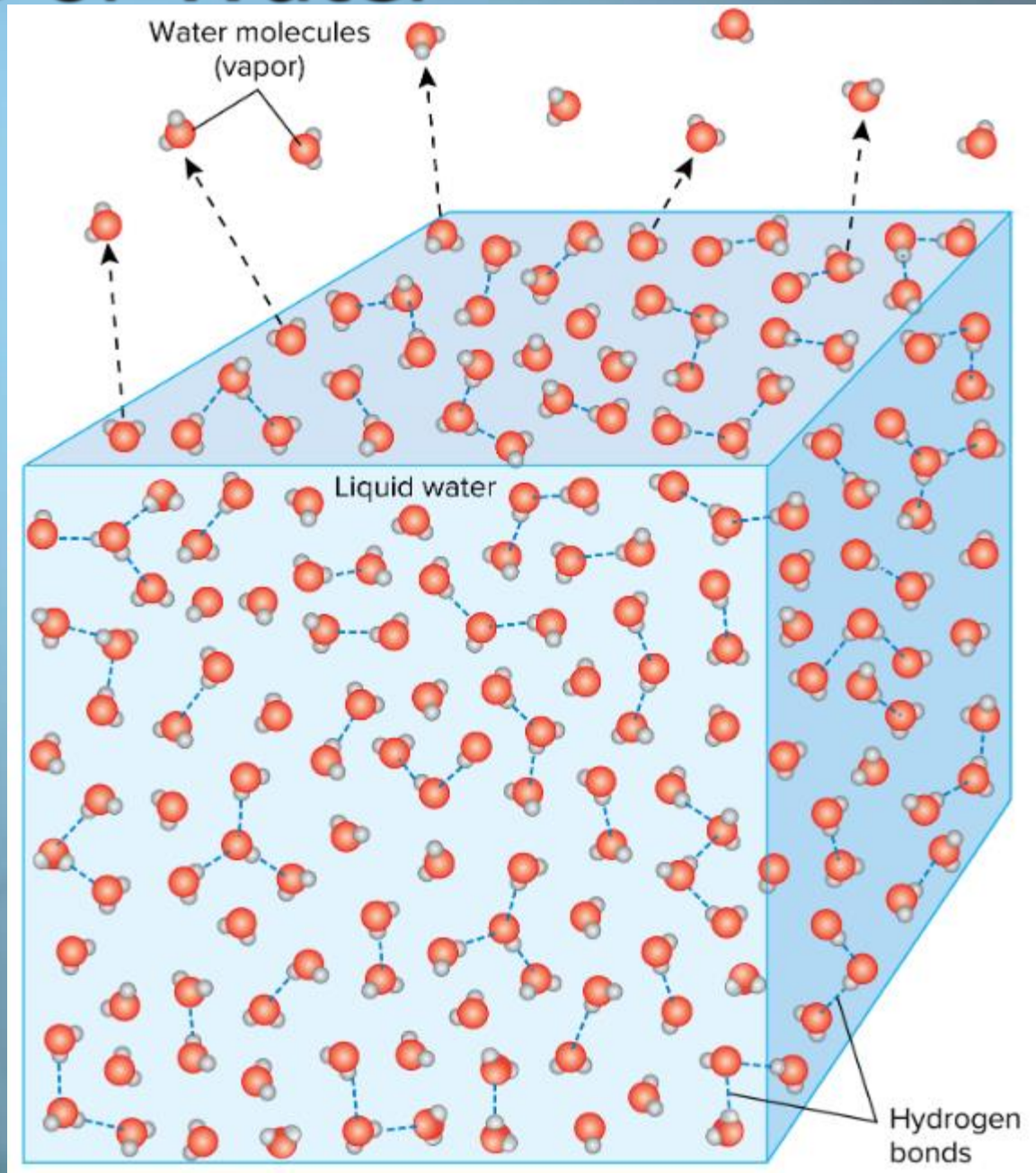
Source: Bill Ober

Unique Nature of Water

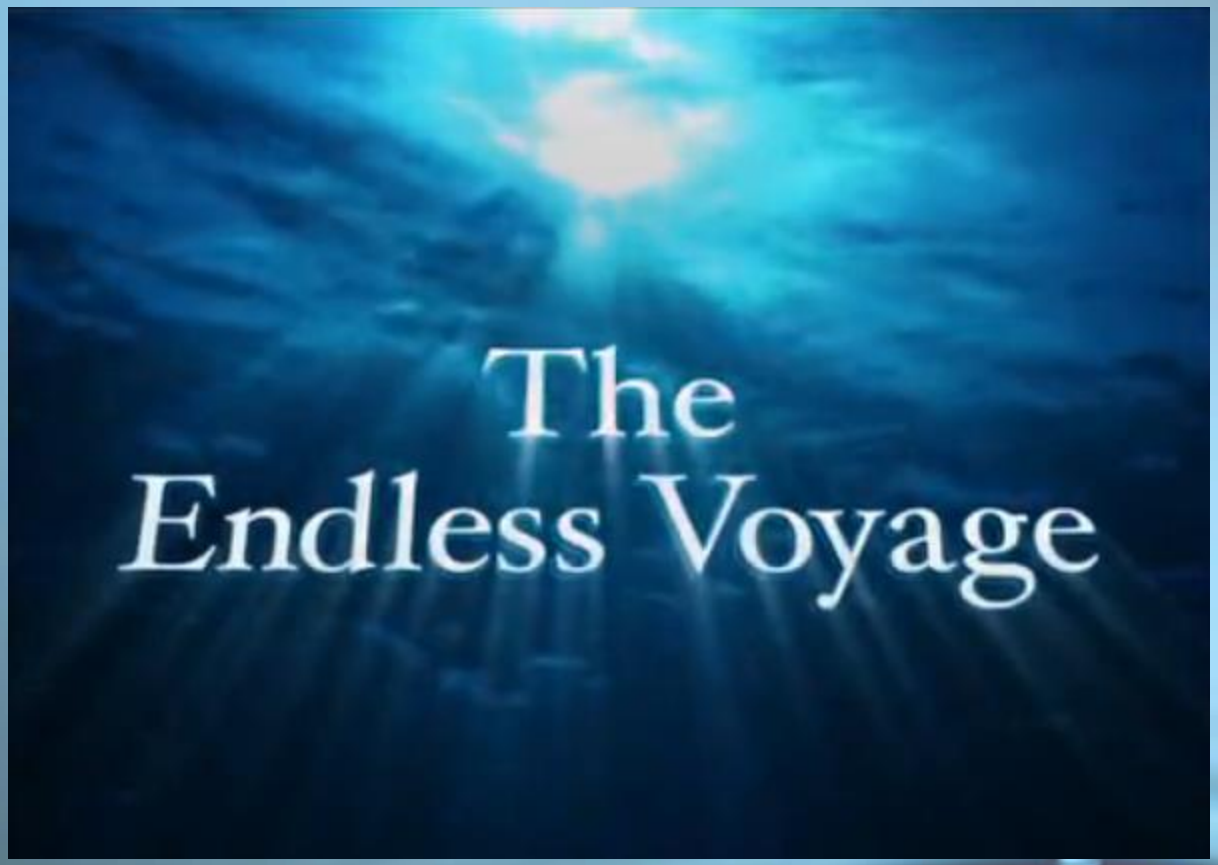
- Due to these slight electrical charges, water molecules are attracted to one another.
- The negative charge of one molecule is attracted to the positive charge of other molecules (remember: opposites attract!)

Unique Nature of Water

- This attraction of one water molecule to another is known as hydrogen bonding.



Unique Nature of Water



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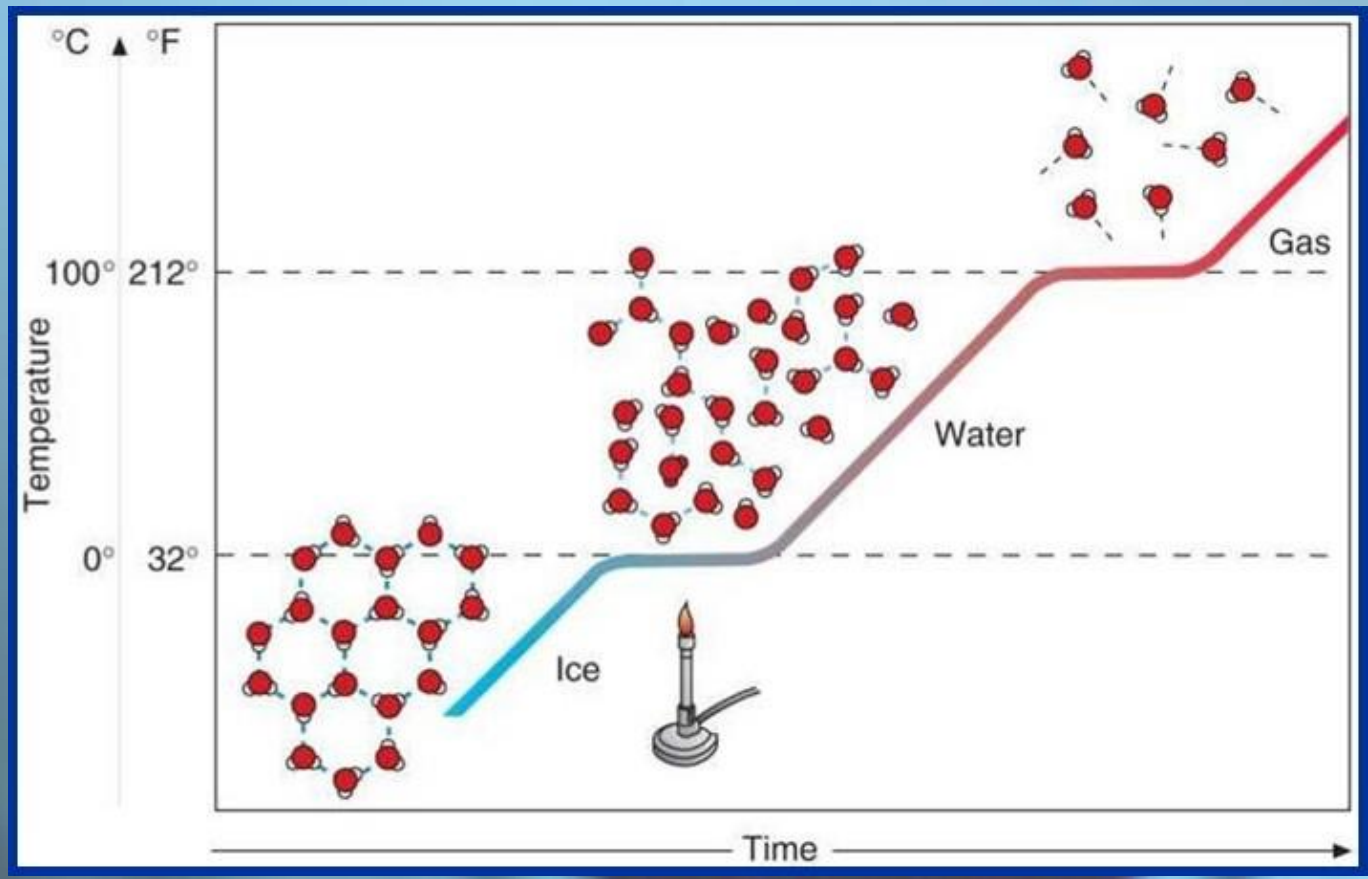
Unique Nature of Water

- Hydrogen bonds help keep water molecules as a cohesive group at most temperatures found on earth.

- This is the reason we have liquid water.

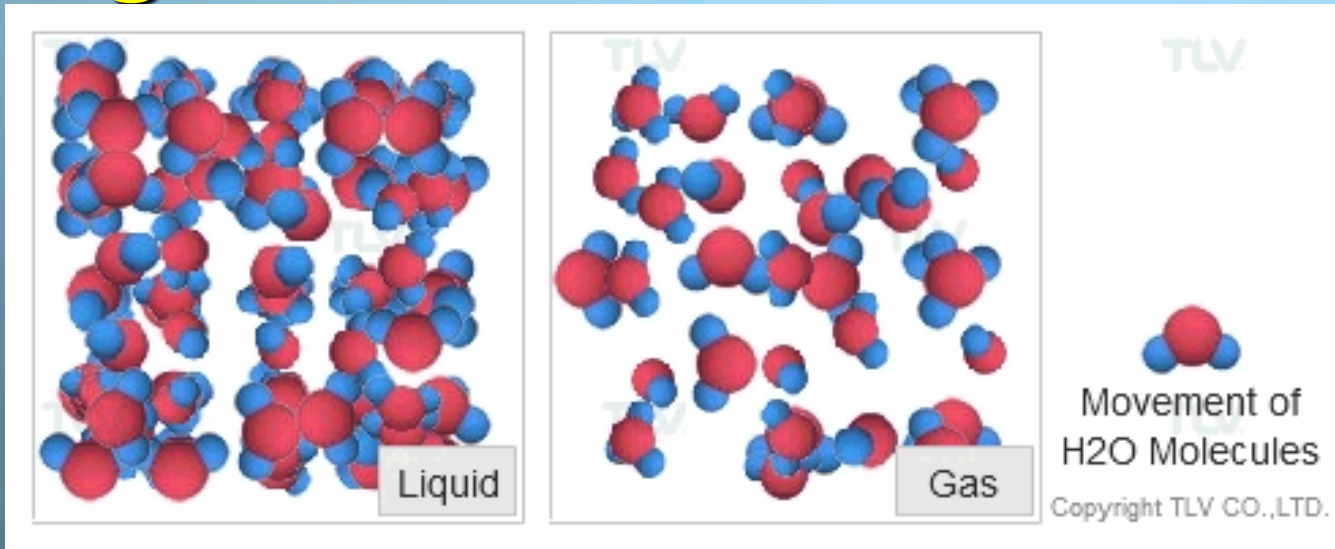
The States of Water

- Water is the only substance that naturally occurs in all three states on Earth.
- Water can be a liquid, solid or a gas.



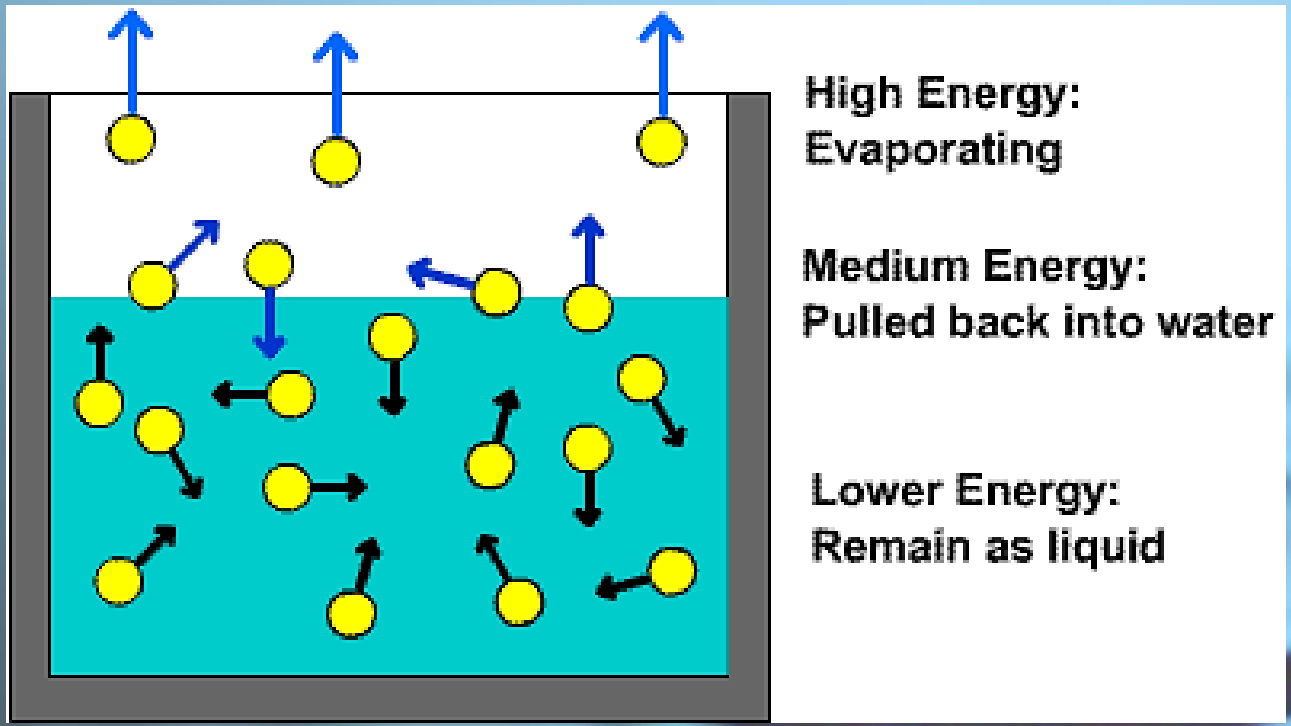
How does temperature impact water?

- As temperature increases, water molecules move faster.
- If the molecules moves fast enough it can break free of all the hydrogen bonds.



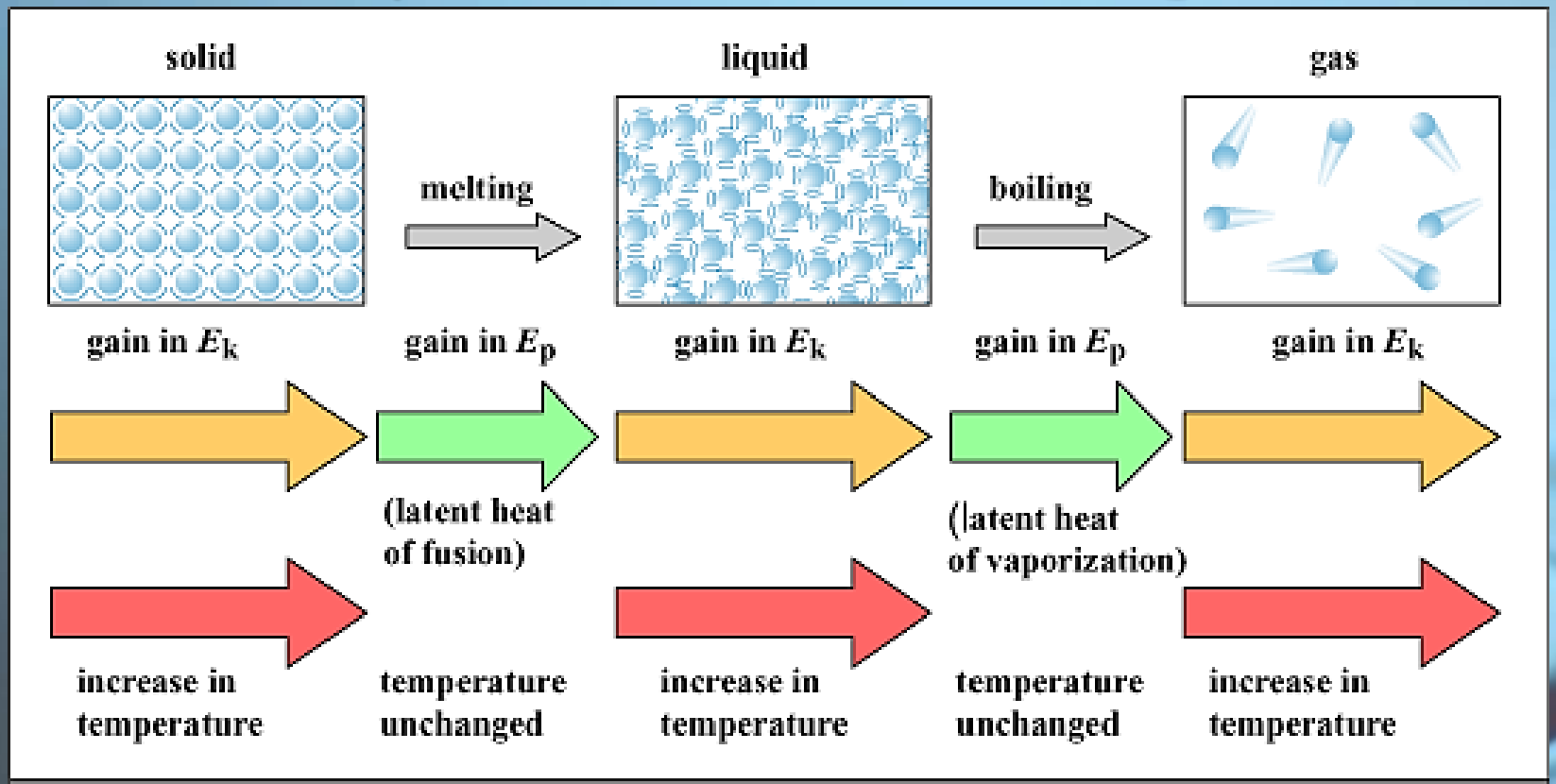
How does temperature impact water?

- If this happens, water goes from the liquid phase to the gaseous phase in a process called **evaporation**.



How does temperature impact water?

- As temperature decreases, sea water molecules move slower and are packed closer together.



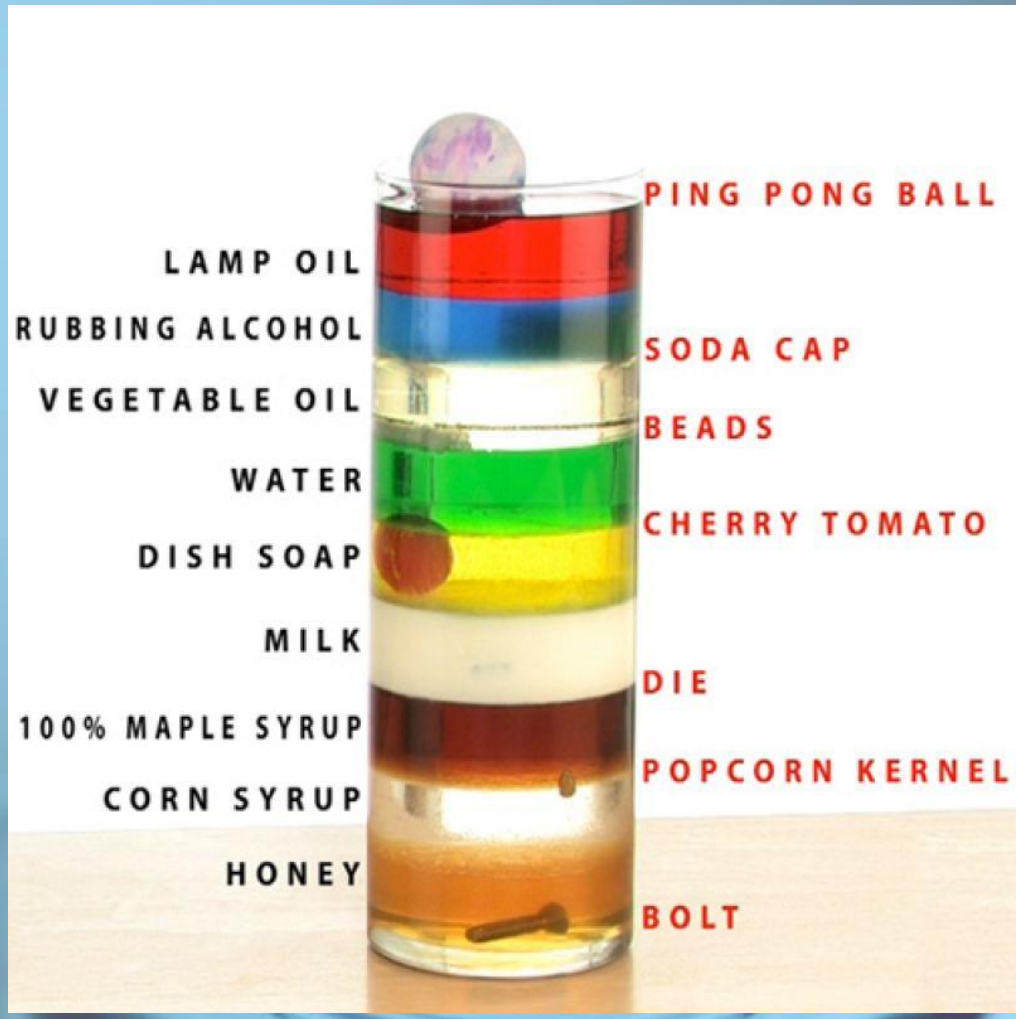
How does temperature impact water?

- What happens to volume? DECREASES.
- Weight does NOT change. So it gets more dense.
- Remember…

❖ $Density = \frac{Weight}{Volume}$

How does temperature impact water?

- Substances with more density are heavier than those with less density when the same volume is present.



How does temperature impact water?

- Think ….
- Imagine that you have two kitchen measuring cups (volume = one cup):
  - You fill one cup with bird feathers.
  - You fill the other cup with lead pellets.
- Which cup weighs more?

How does temperature impact water?

- Of course, the cup of lead pellets weighs more because lead has a greater density than the feathers.

- Now, how does this apply to marine biology?

How does temperature impact water?

- Cold water has more density than warm water
- So …. Cold water weighs more per volume of water.
- Therefore …. Cold water sinks underneath the warmer water.

How does temperature impact water?

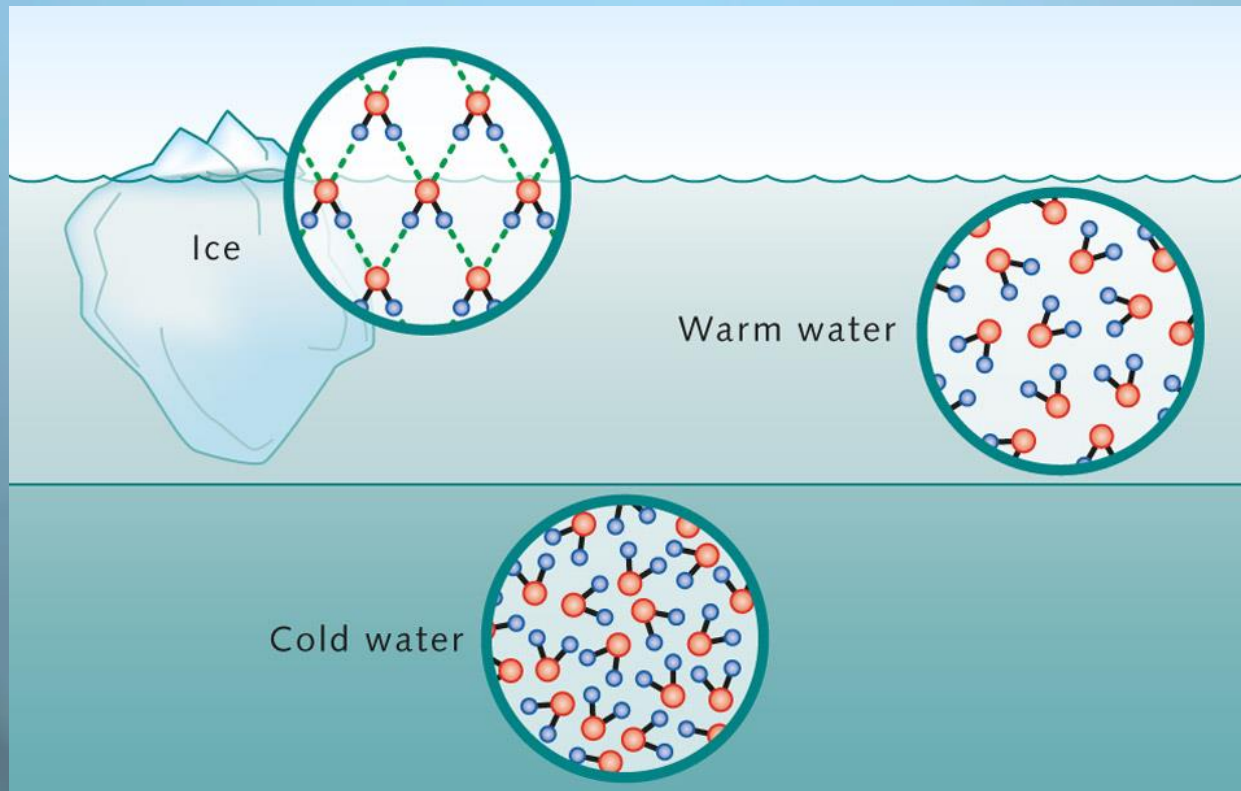
- Think ….
- You might have actually experienced this yourself.

- Ever been in a pool, pond or ocean and noticed that while the water close to the surface was warm, your legs are feeling cooler water?

How does temperature impact water?

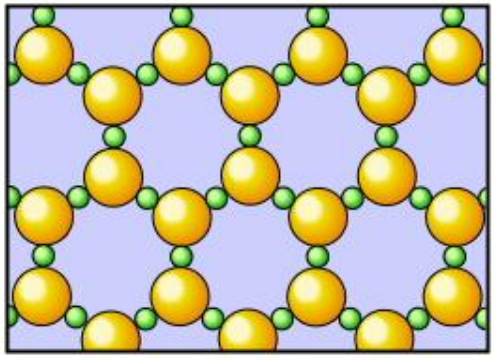
- As temperature decreases, water becomes more dense…..but only to a temperature of 4 °C.

- Below 4 °C, water gets less dense as it cools.

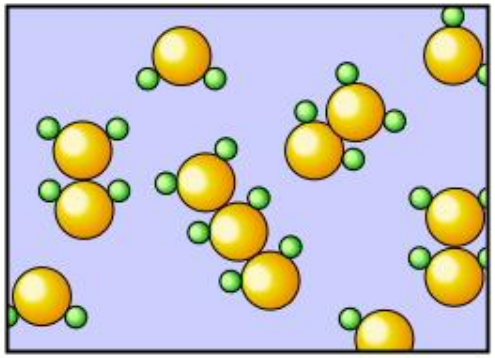


How does temperature impact water?

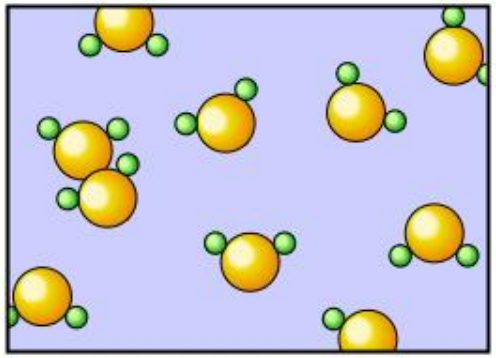
- Eventually, hydrogen bonds hold water in a fix 3-D pattern.
- It is now a solid!!!!!



Ordered Molecular Structure of Frozen Water

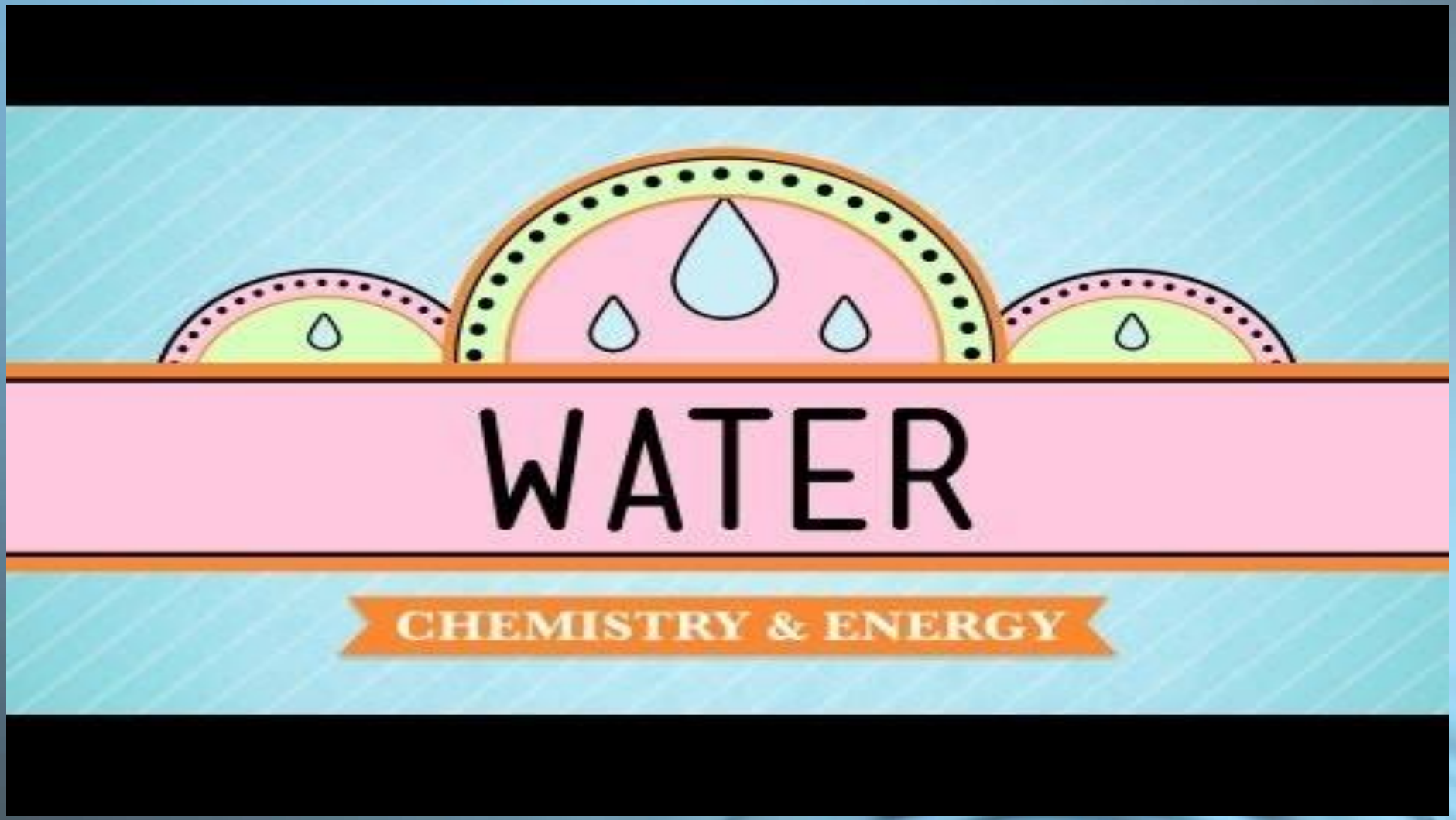


Semi-Ordered Molecular Structure of Liquid Water



Random Molecular Structure of Vaporized Water

Heat and Water



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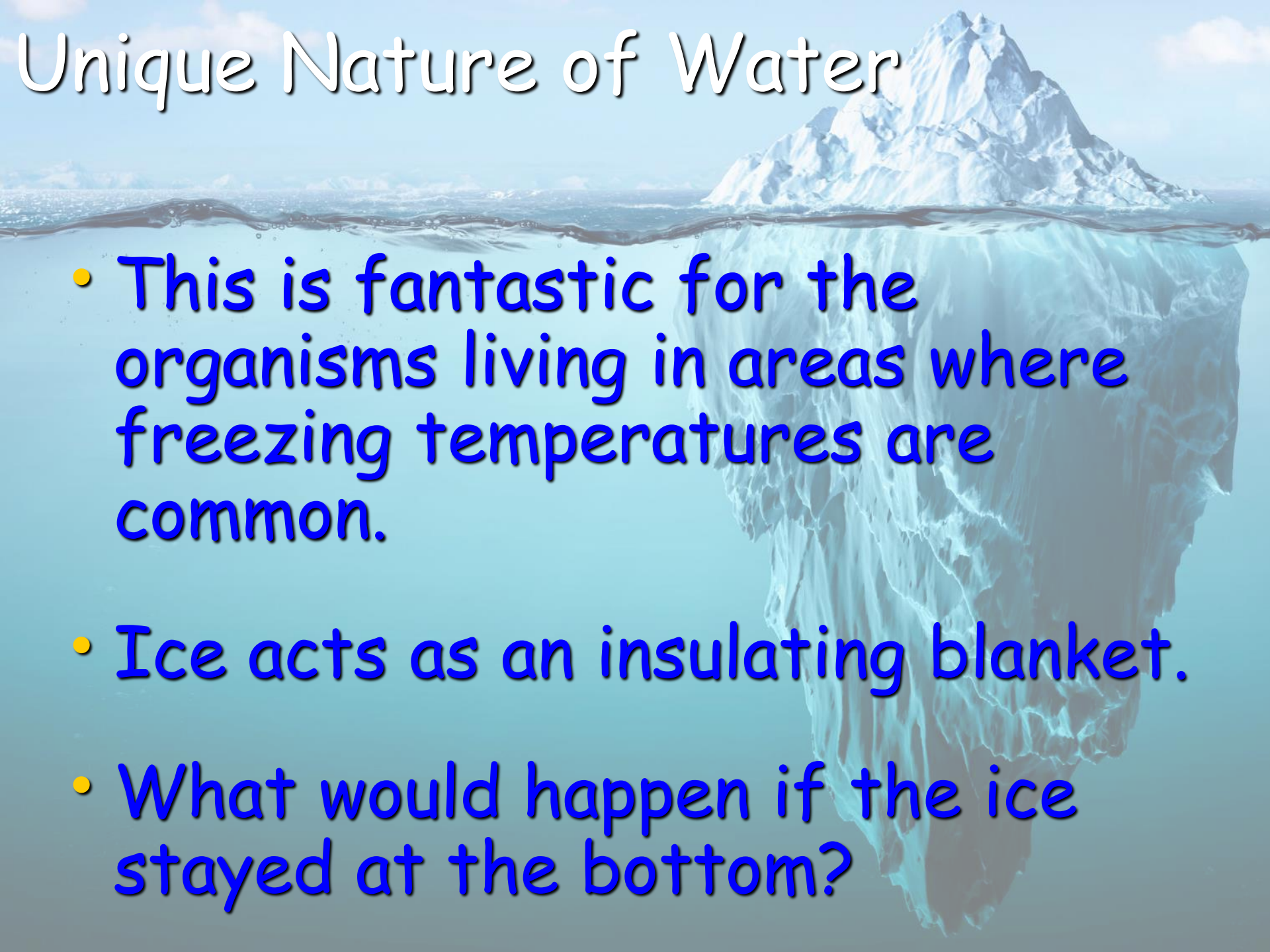
Unique Nature of Water

- Colder water also holds more oxygen (and gases) than the same volume of water.
- Great for all those organisms living at the ocean floor.
- Now, even though colder water is more dense than warmer water, this changes when the water gets cold enough to freeze.

Unique Nature of Water

- Water expands as it freezes!!!!
- Due to all of the air trapped in it.
- Since the same weight of water occupies more volume in ice than liquid water, ice is **less dense** than liquid water.
- So it floats!

Unique Nature of Water



- This is fantastic for the organisms living in areas where freezing temperatures are common.
- Ice acts as an insulating blanket.
- What would happen if the ice stayed at the bottom?

Unique Nature of Water

- If ice did not float, a body of water would freeze from the bottom up and eventually the whole body of water would freeze.

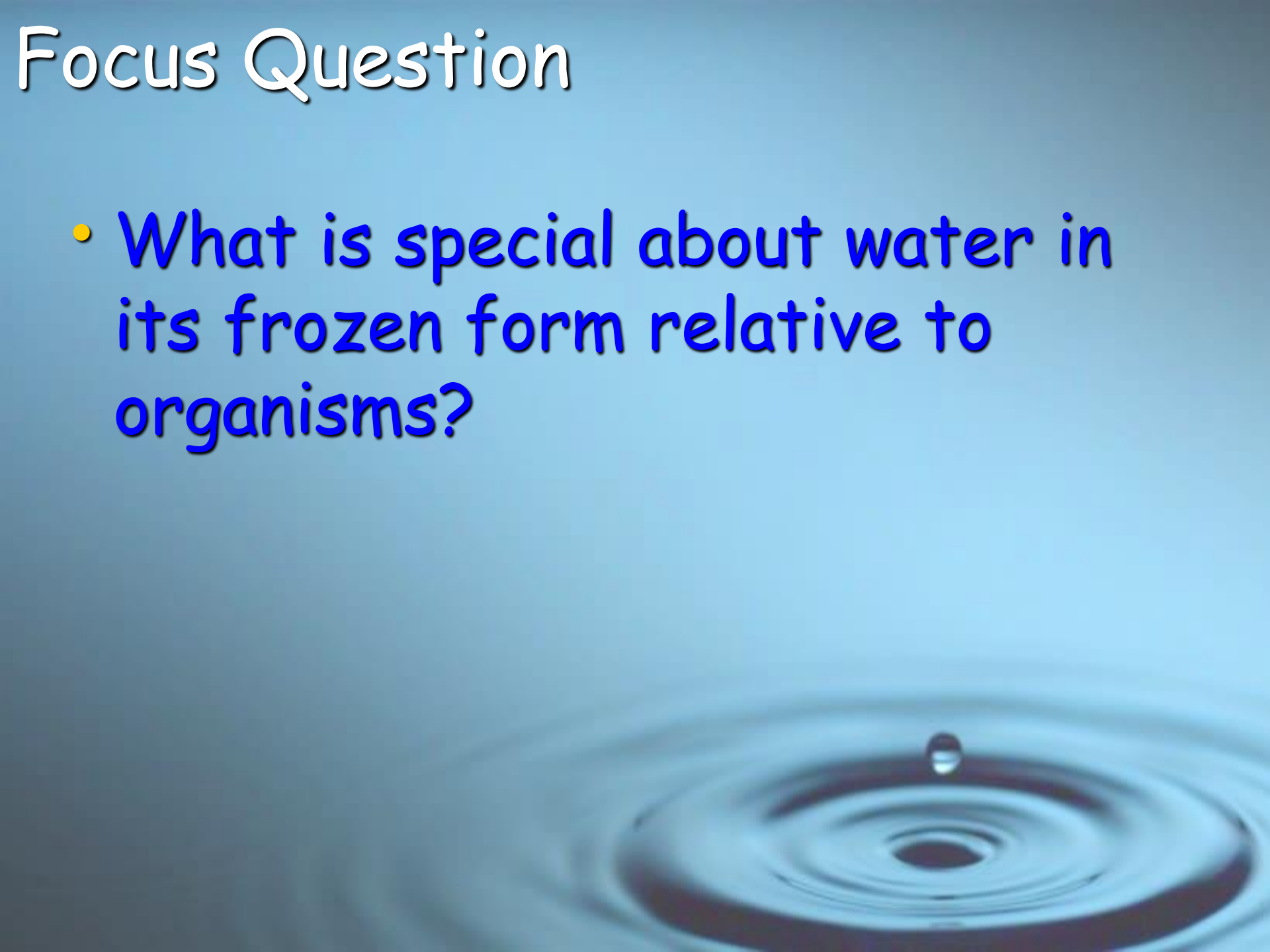
- This would not be great for all the organisms in that water.

Unique Nature of Water

- Since ice floats, the floating ice creates a barrier between the air temperature and the water below the ice, keeping it from freezing.
- Whew, the organisms under the ice are safe! (from freezing anyway!)

Focus Question

- What is special about water in its frozen form relative to organisms?



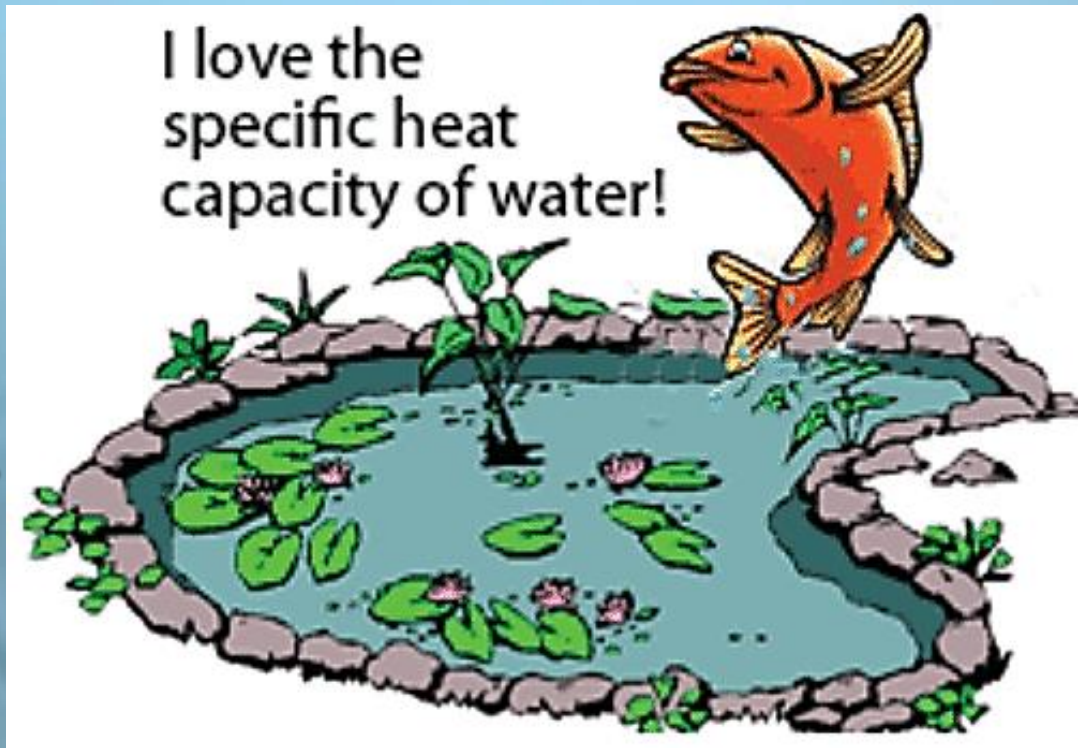
Water

Heat and Water

- It takes a lot of heat to melt ice!
- Water molecules in ice vibrate but do not move form place to place within the crystal.
- Added heat makes the molecules move faster and faster eventually breaking some of the hydrogen bonds – it melts.

Heat and Water

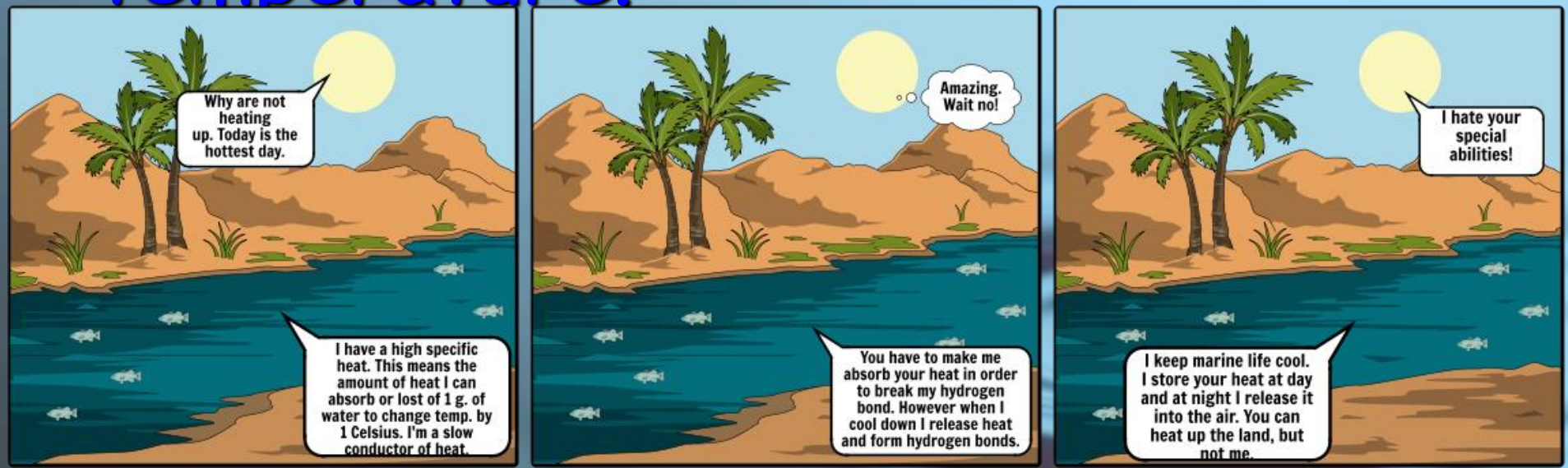
- Water has a high **heat capacity**.
- This means that it takes a lot of heat to raise the temperature.



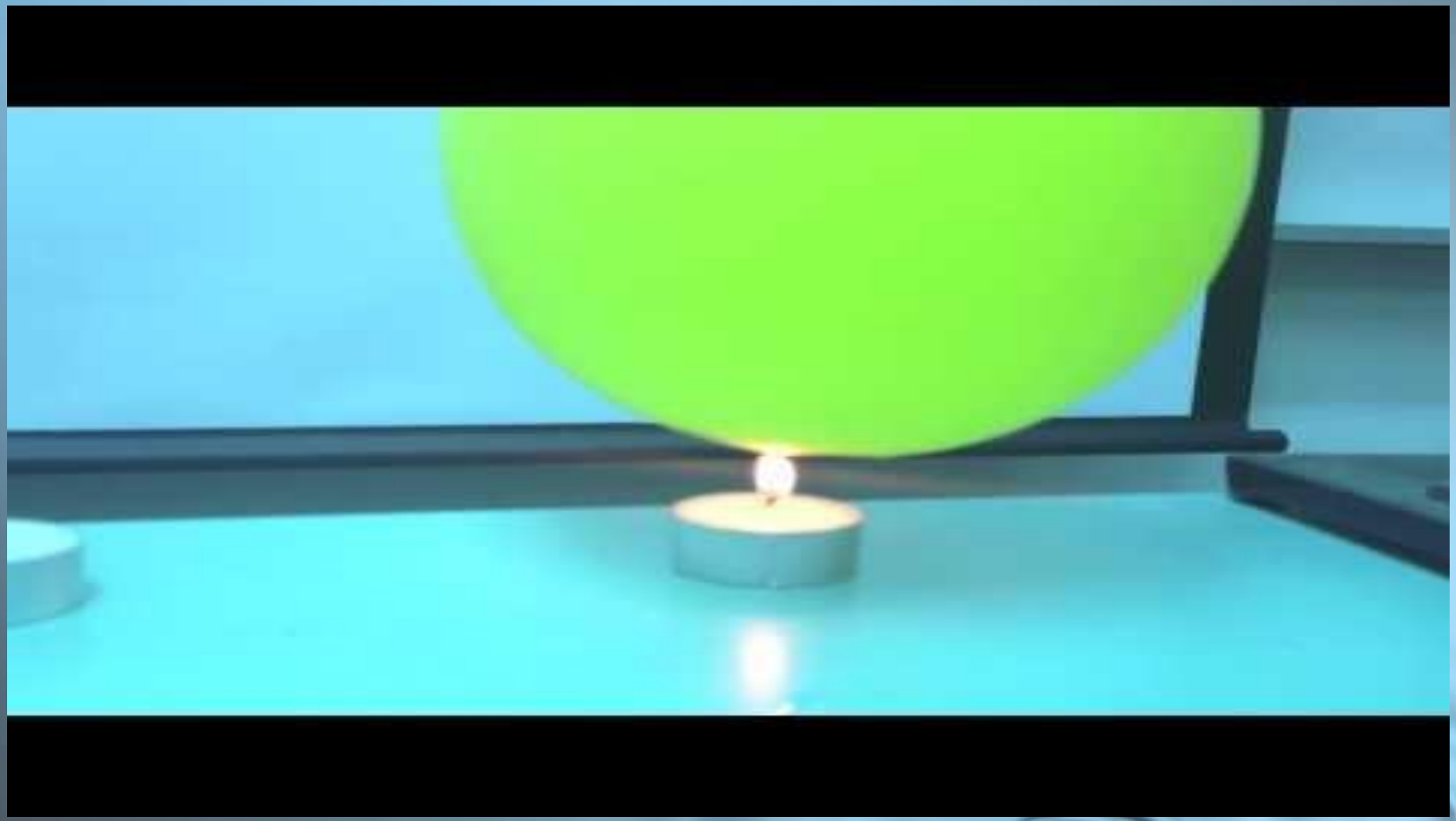
Heat and Water

- This is great for marine life!!! Why?

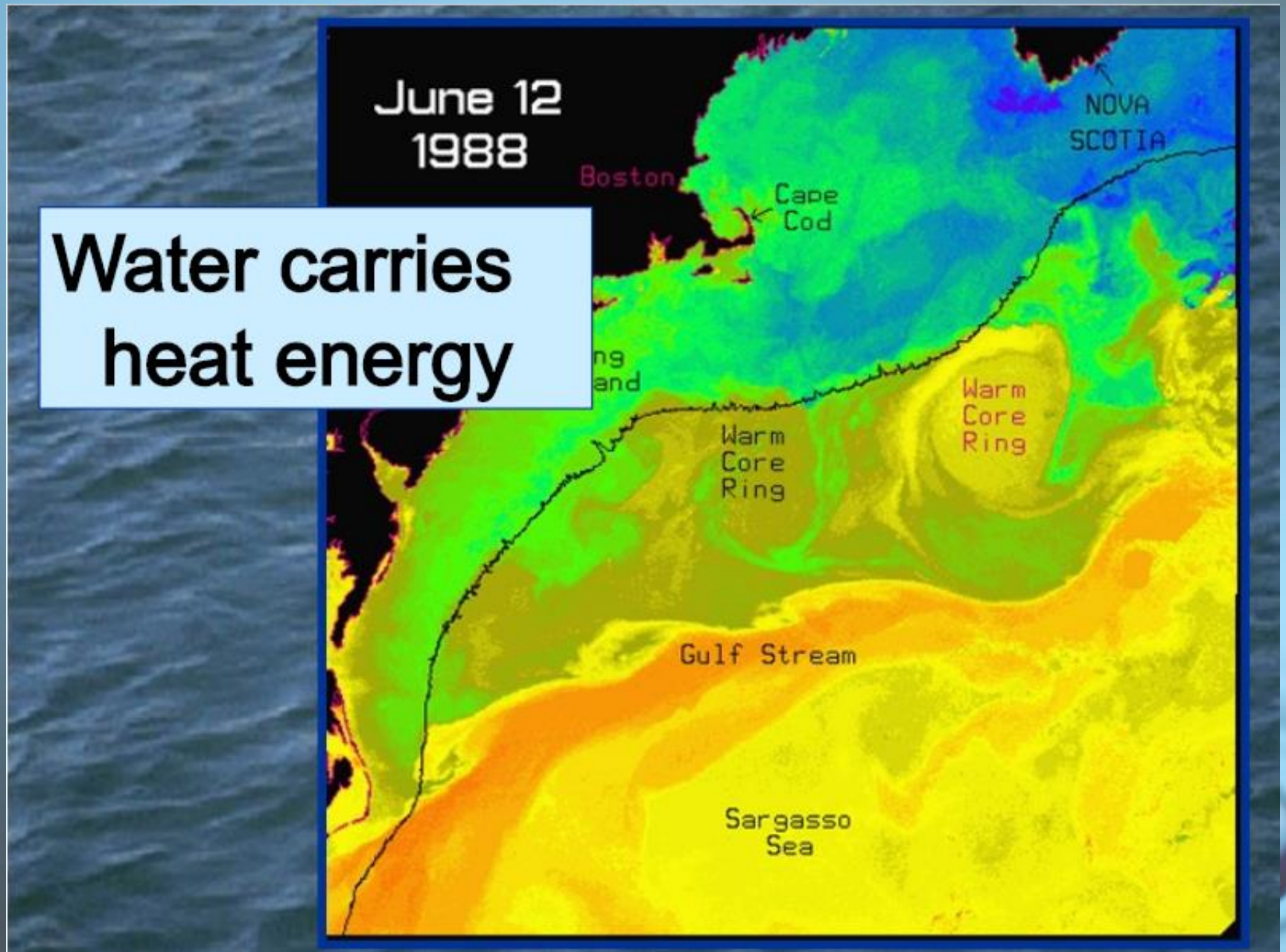
- Most marine organisms are NOT subjected to rapid changes in temperature.



Heat and Water



Heat Energy & Water



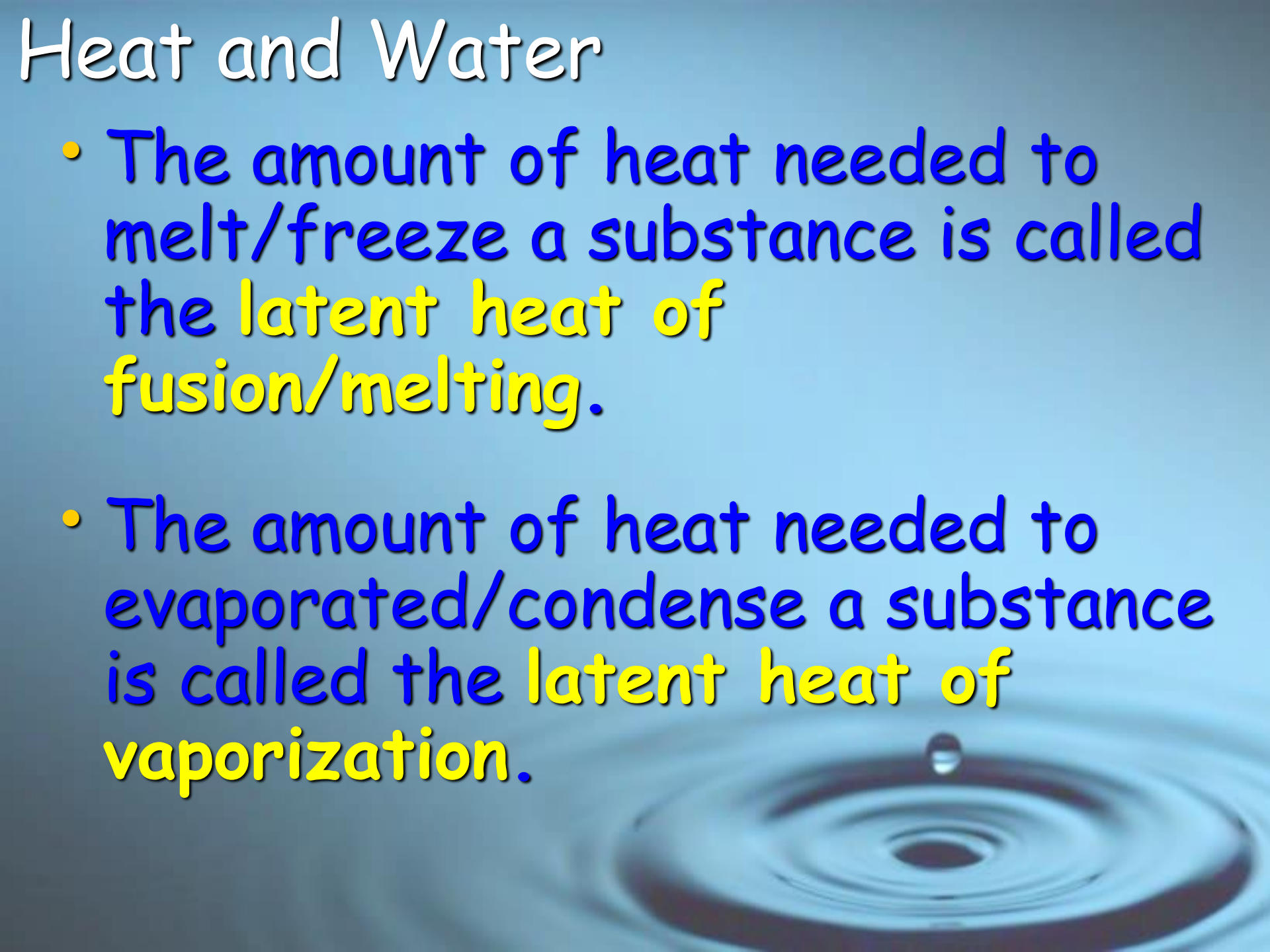
Water carries heat energy

Heat and Water

- Water also absorbs a great deal of heat before its temperature rises.
- This property, know as heat capacity.
- Water has one of the highest heat capacities of any naturally occurring substance.

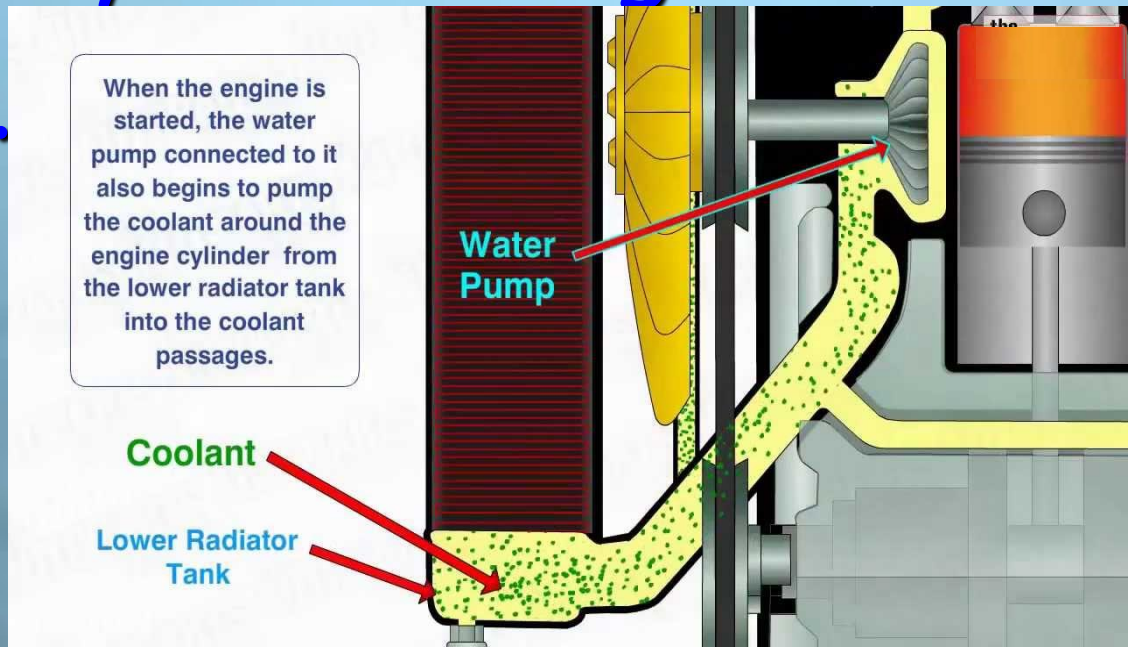
Heat and Water

- The amount of heat needed to melt/freeze a substance is called the **latent heat of fusion/melting.**
- The amount of heat needed to evaporated/condense a substance is called the **latent heat of vaporization.**



Car Connection…

- Did you know that water is used in the cooling system of cars ?
- Water can absorb a lot of heat with out greatly increasing in temperature.

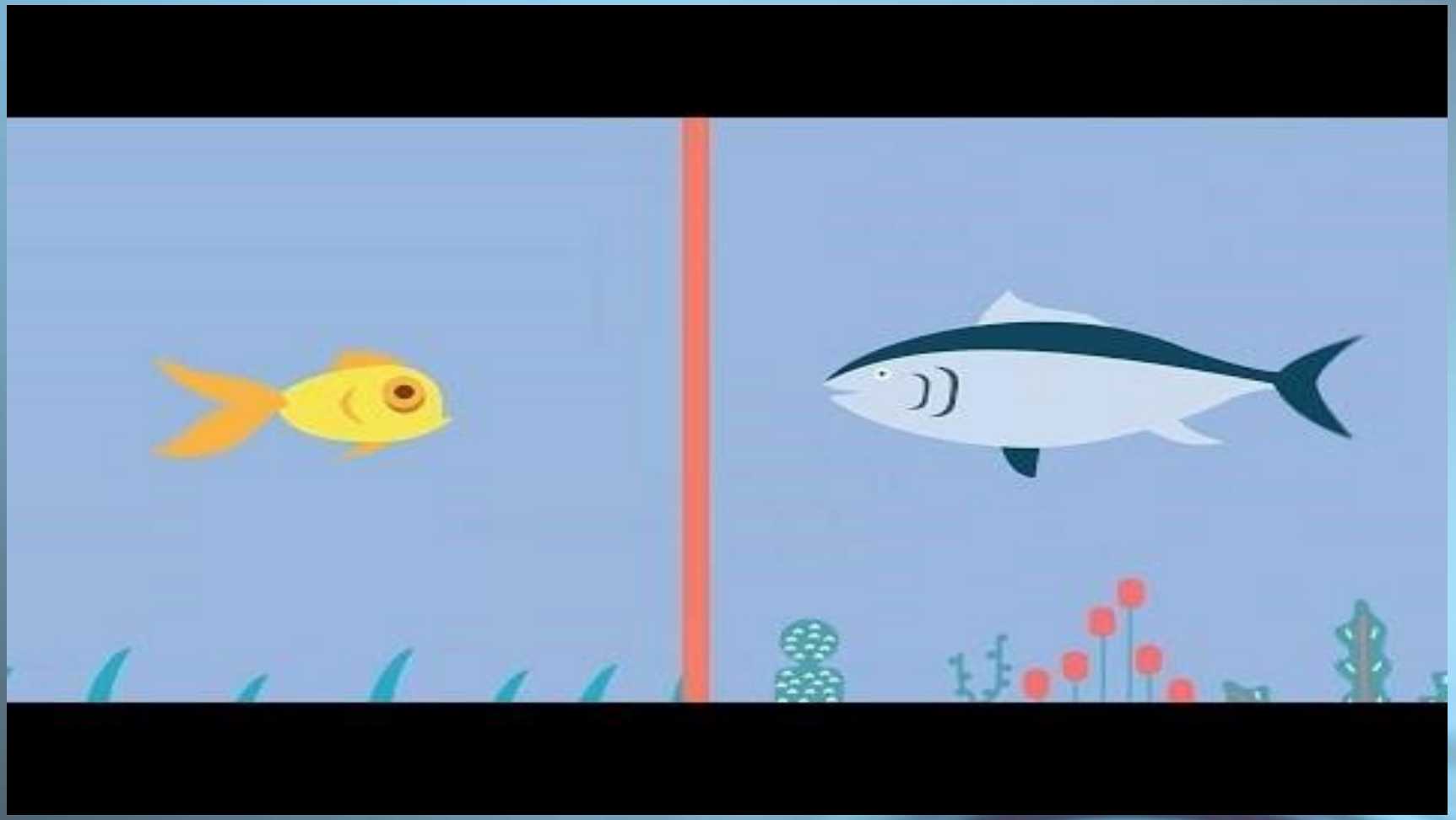


What is Salinity?

- Salinity ~ is a measure of how much salt is in the water.

- Ocean water has a high salinity, fresh water has a low salinity.

Salinity



Seawater sampling

A Niskin Bottle
in action

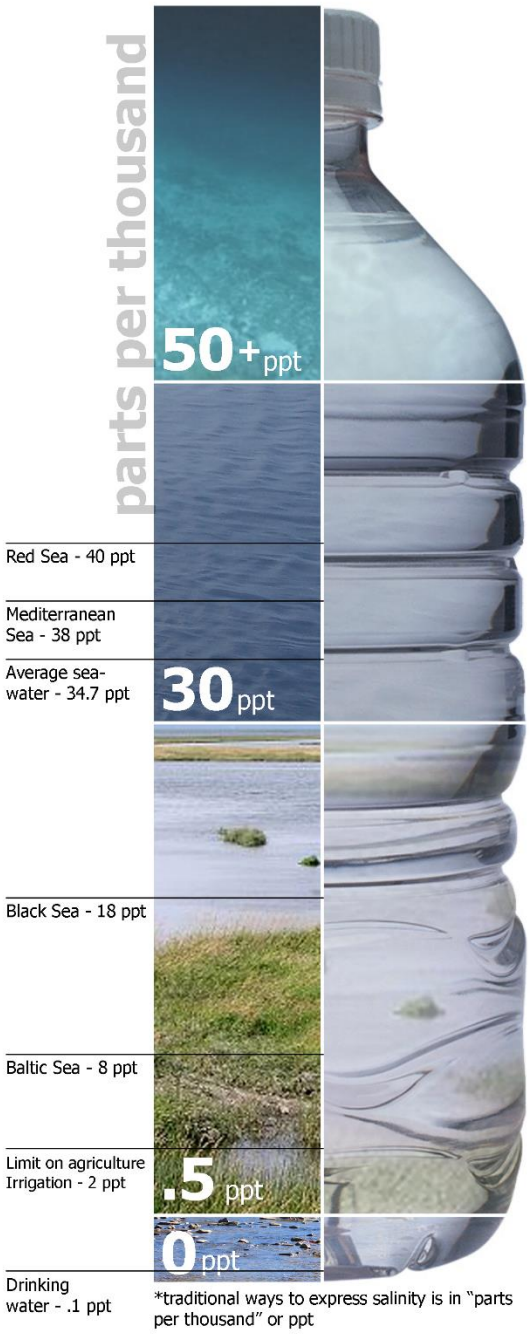
How is salinity expressed?

- Salinity is expressed by the amount of salt found in 1000 grams of water.

- If we have 1 gram of salt and 1000 grams of water, the salinity is 1 part per thousand or 1 ppt.

How is salinity e

- The average ocean salinity is 35 ppt. (Which means 35 pounds of salt per 1000 pounds of water).



Salt Water

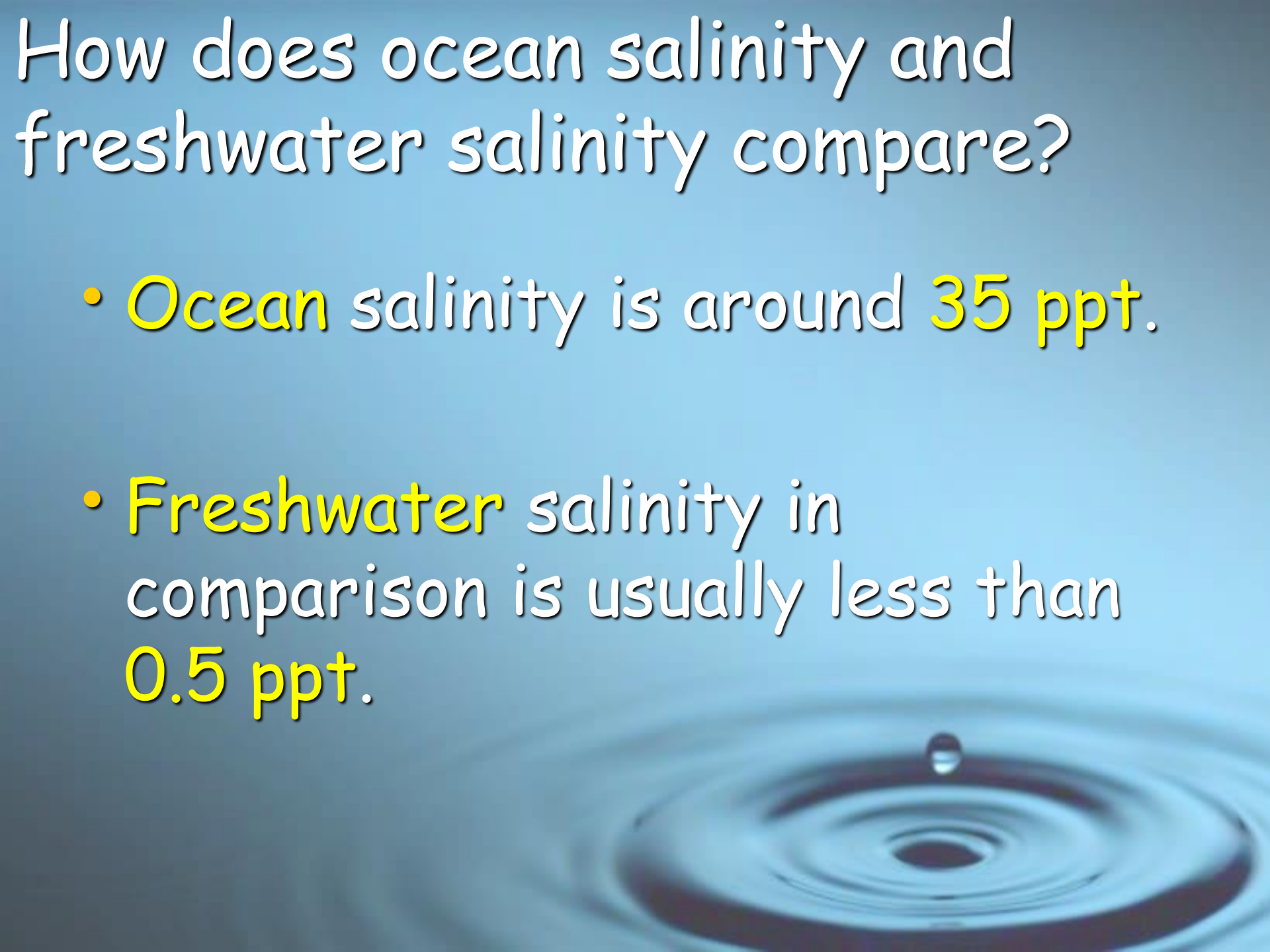
- Salinity is Measured using
  - Hydrometer ~ floats based on density
  - Refractometer ~ Light bends differently in different densities
  - Conductivity ~ more saline = better conductivity
  - Titration ~ Chemical method of measuring amount of Cl^- ions

Who discovered average salinity?

- This average salinity was obtained by **William Dittmar** in 1884 from chemical analysis of 77 sea water samples collected from many parts of the world during the expedition of the H.M.S. **Challenger**.

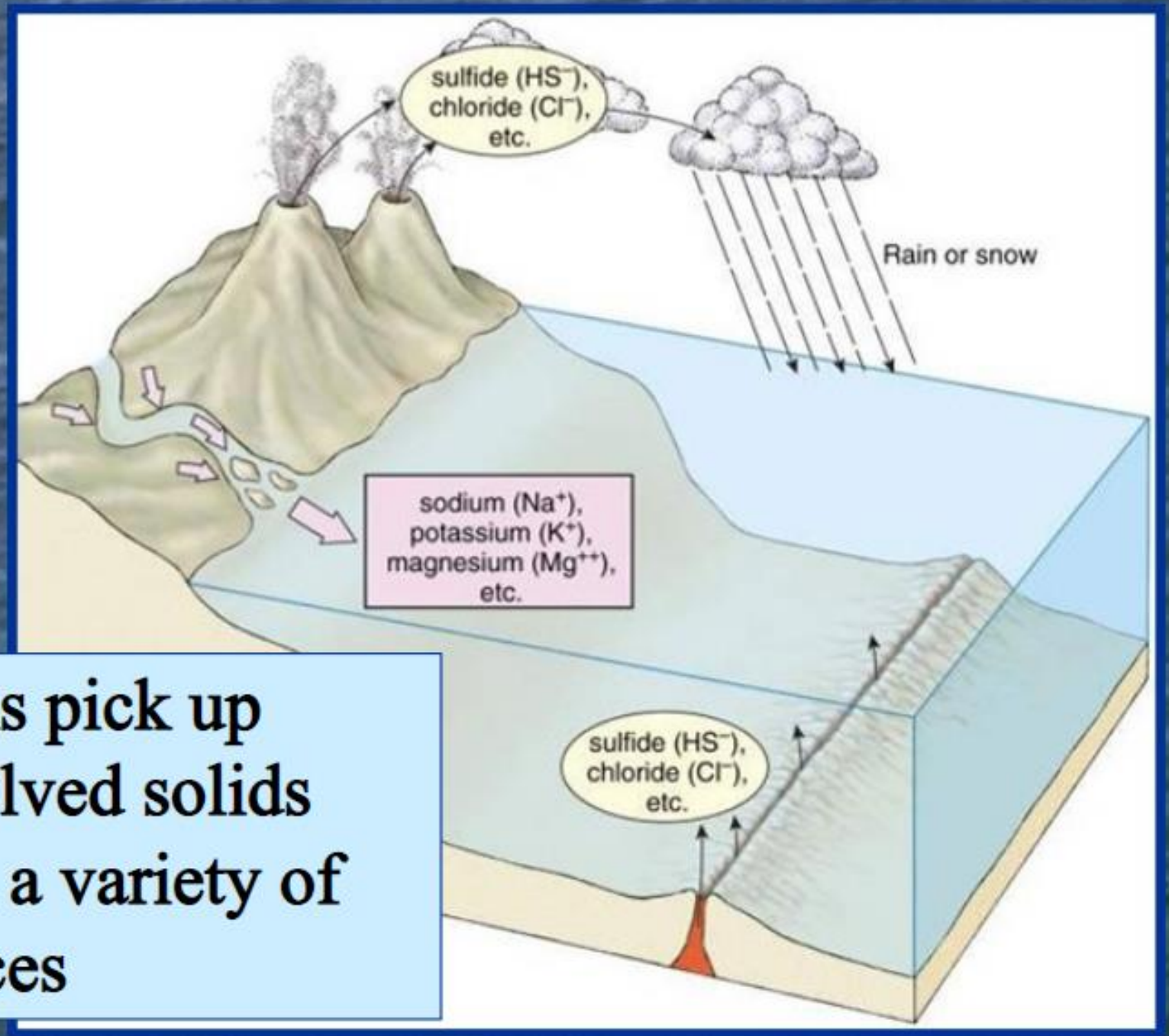
How does ocean salinity and freshwater salinity compare?

- Ocean salinity is around 35 ppt.
- Freshwater salinity in comparison is usually less than 0.5 ppt.



The oceans continue to get saltier due to the following:

1. Erosion of the land
2. Wearing down of mountains
3. Dissolving action of rain and streams
4. Volcanic eruptions
5. Chemical reaction between seawater and hot, newly formed volcanic rocks of spreading zones (i.e. Hydrothermal vents at mid-oceanic ridges).



Oceans pick up dissolved solids from a variety of sources

Do all bodies of water have about the same salinity?

- NO!!!!!
- Different bodies of water have different salinities. Rainfall, evaporation, river runoff and ice formation cause the variations.
- Black sea is diluted by river runoff so its salinity is only 16 ppt.

Not So Salty Sea Water…

- Low salinities occur in polar seas where the salt water is diluted by melting ice.

Low Salinities

Baltic Sea

Atlantic Ocean at mouth of Amazon River

The Saltiest Sea Water

- Salts become concentrated in the sea because the sun's heat vaporizes water from the surface of the sea and leaves the salts behind.
- The saltiest water (40 ppt) occurs in the Red Sea and Persian Gulf, where the rates of evaporation are very high.

Elevated Salinity

Red Sea

The most common salt…

- About 85% of that salt would be sodium chloride (NaCl) which is ordinary table salt.

The Composition of Seawater at 35 ppt Salinity

Table 3.1
The Composition of Seawater of 35‰ Salinity

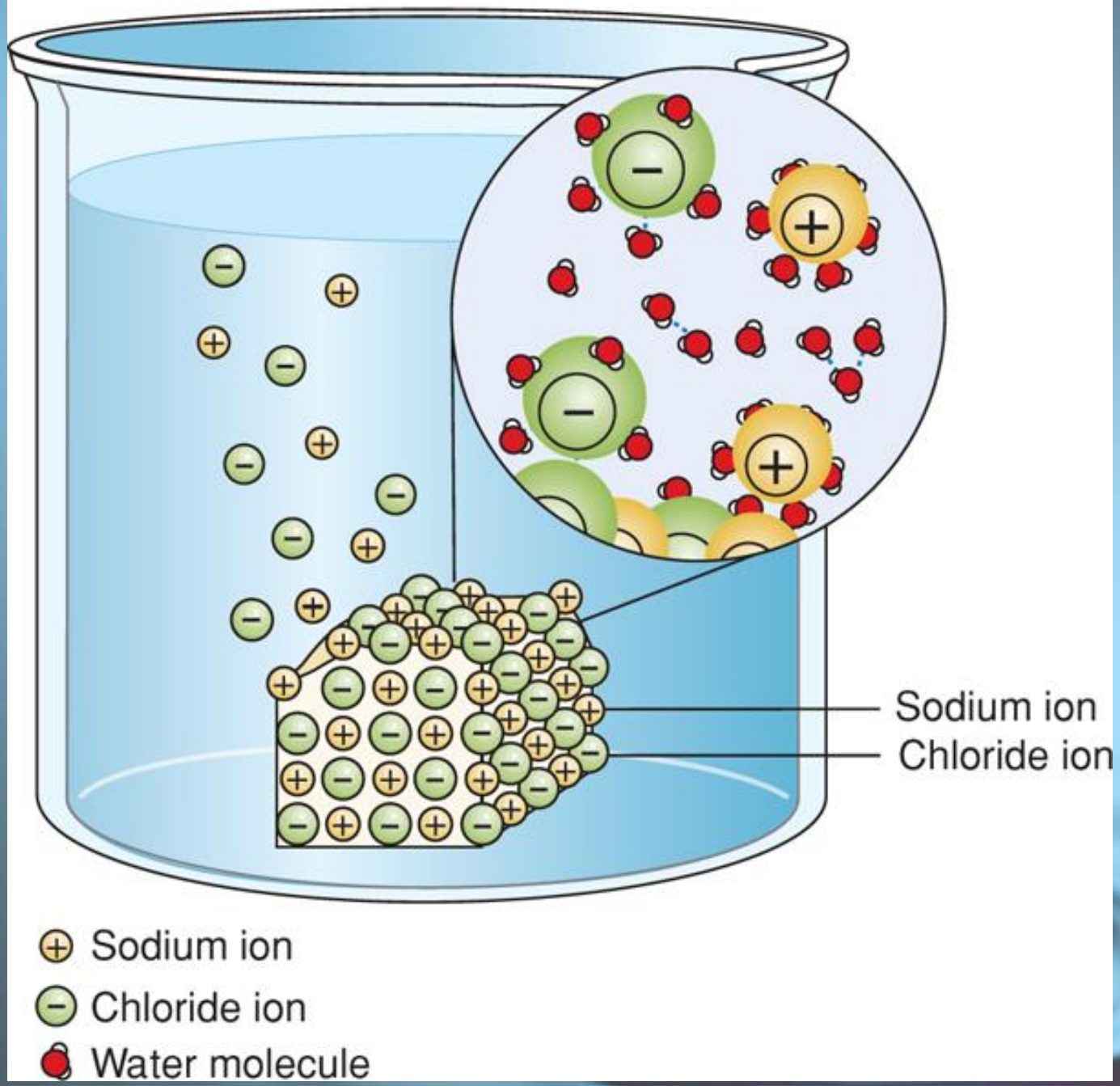
Although the concentration varies slightly from place to place in the ocean, the percentage of total salinity of each ion remains constant.

Ion	Concentration ‰	Percentage of Total Salinity
Chloride (Cl^-)	19.345	55.03
Sodium (Na^+)	10.752	30.59
Sulfate (SO_4^{-2})	2.701	7.68
Magnesium (Mg^{+2})	1.295	3.68
Calcium (Ca^{+2})	0.416	1.18
Potassium (K^+)	0.390	1.11
Bicarbonate (HCO_3^-)	0.145	0.41
Bromide (Br^-)	0.066	0.19
Borate ($H_2BO_3^-$)	0.027	0.08
Strontium (Sr^{+2})	0.013	0.04
Fluoride (F^-)	0.001	0.003
Other dissolved material	<0.001	<0.001

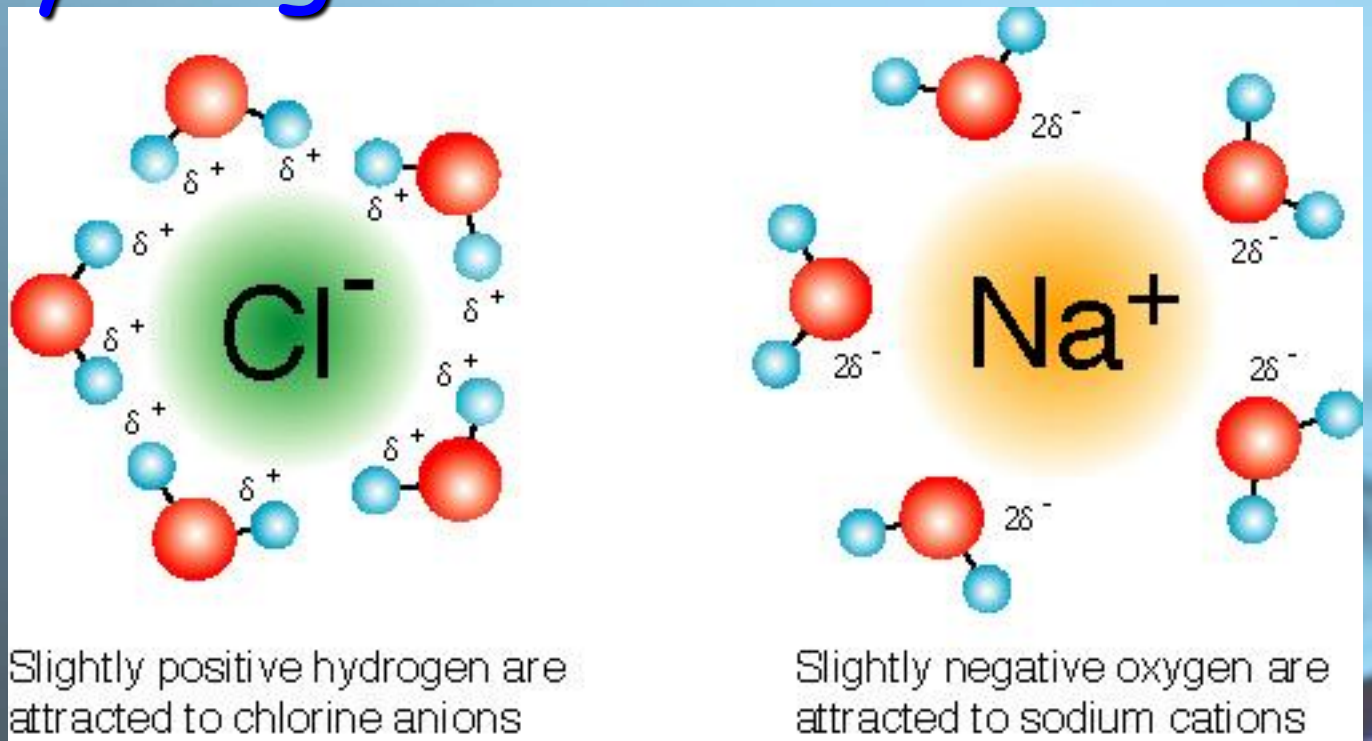
What is a salt?

- Salts are made of ions (charged particles).
  - Example NaCl is made of Na^+ and Cl^-
- What happens when salt is placed in water?

It dissolves!!!!



Water molecules surround and insulate the ions from each other because the + is attracted to the Oxygen and the – is attracted to the Hydrogen of water.



Slightly positive hydrogen are attracted to chlorine anions

Slightly negative oxygen are attracted to sodium cations

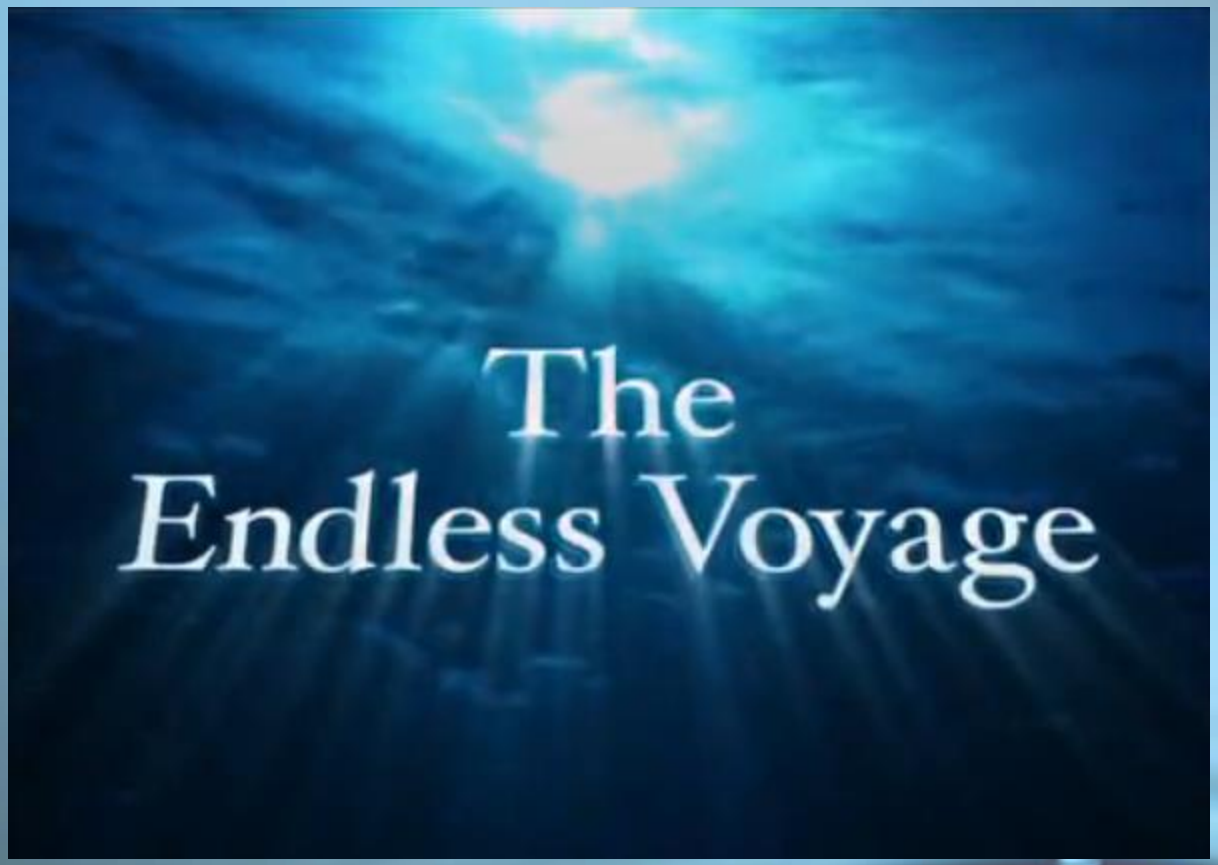
Solute & Solvent

- Solute- the dissolved material
  - Ex. NaCl
- Solvent- What the solute is dissolved in.
  - Ex. Water

Rule of Constant Proportions

- States that relative amounts of various ions in seawater are always the same.
- Why is that important?
- Because organisms don't have to deal with different proportions of salts, just varying total concentrations.

Unique Nature of Water



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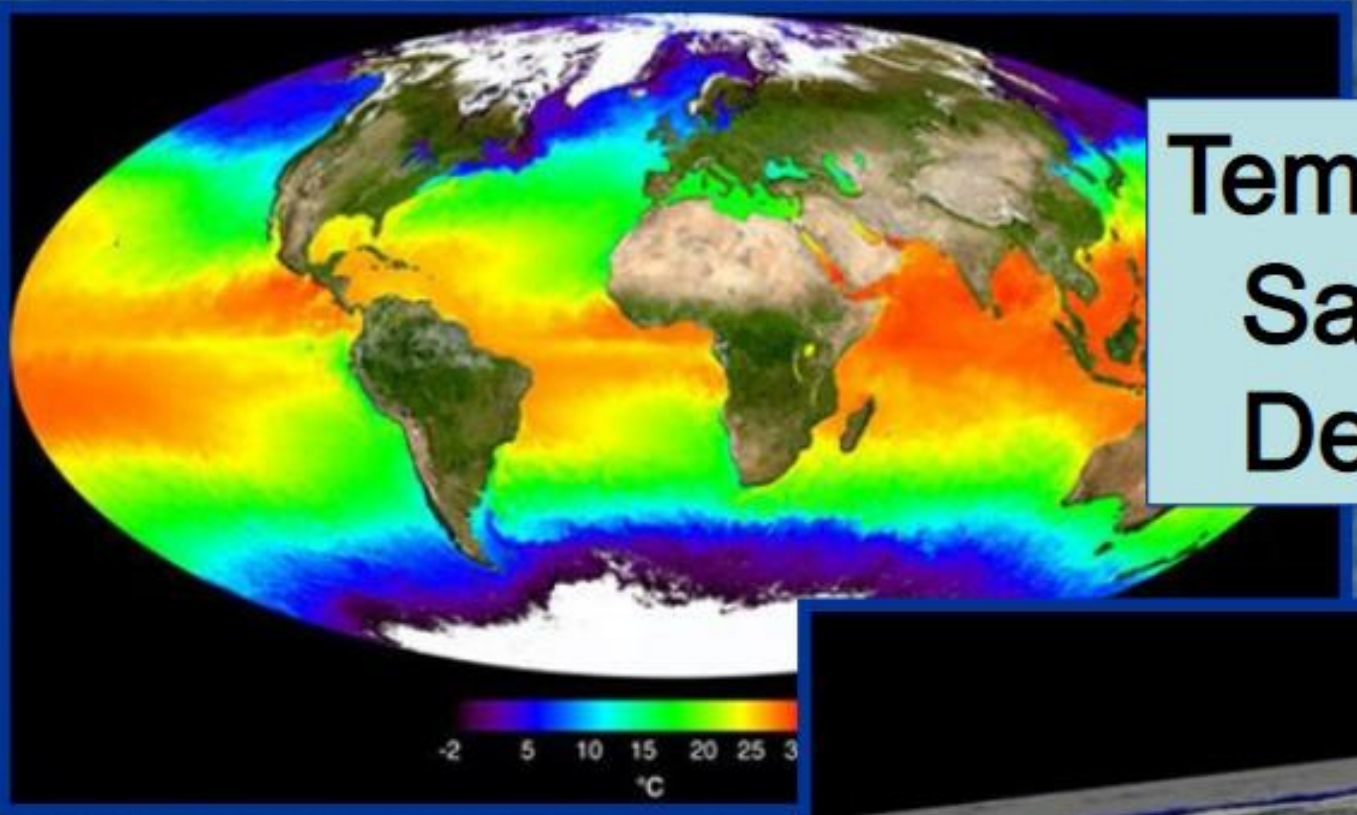
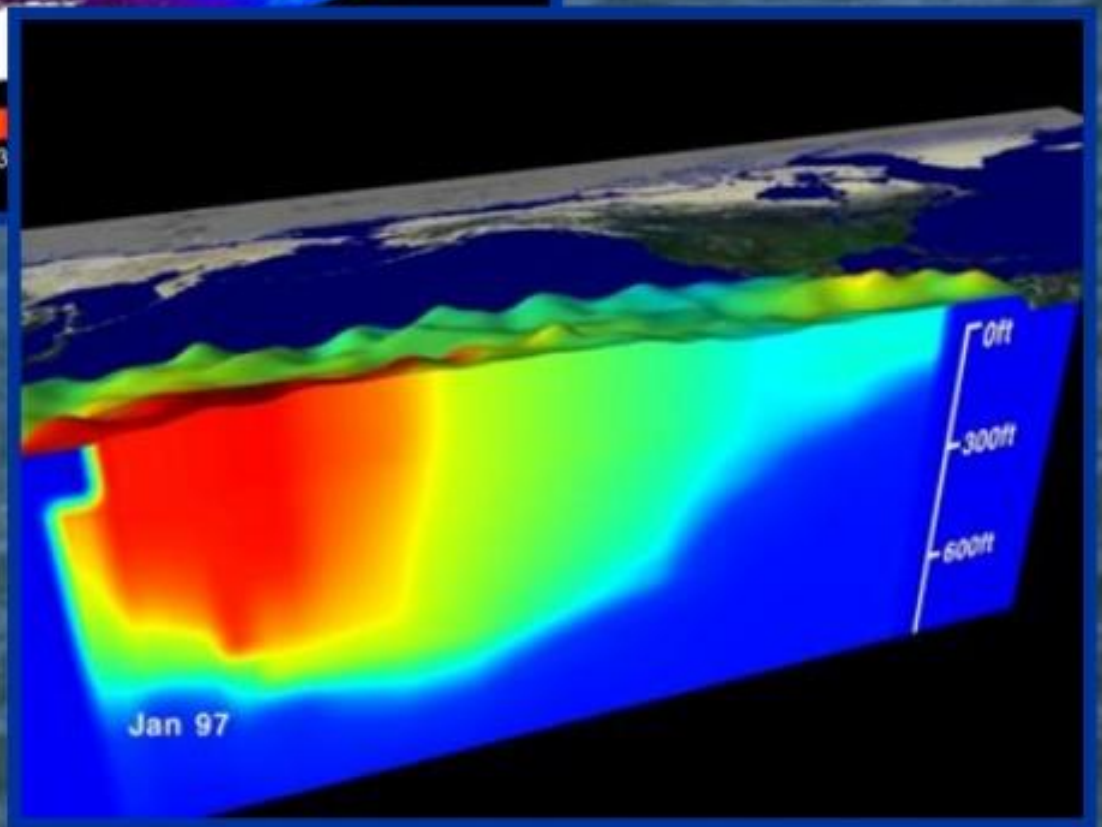
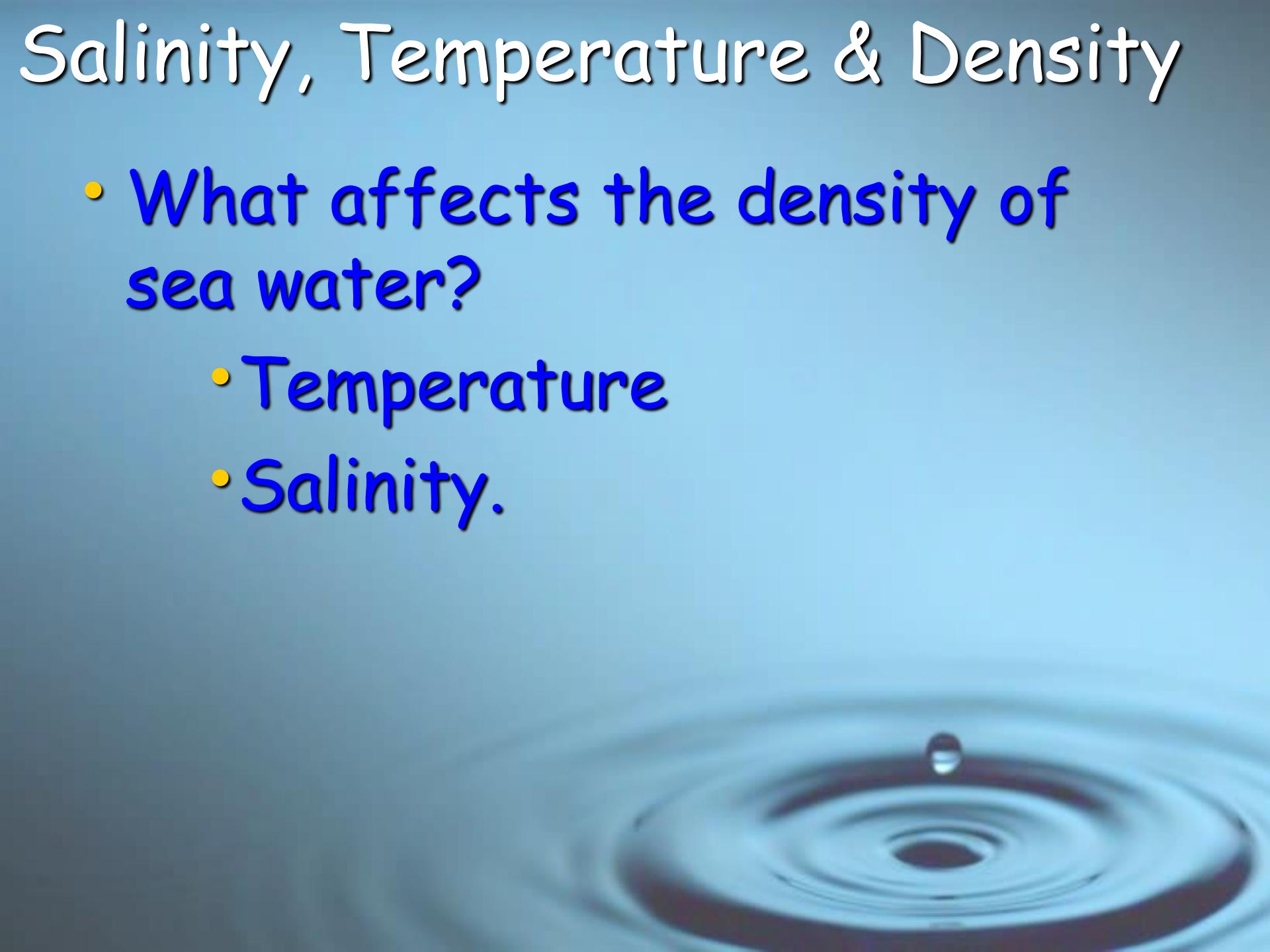
Temperature, Salinity and Density





Salinity, Temperature & Density

- What affects the density of sea water?
  - Temperature
  - Salinity.



String of water bottles

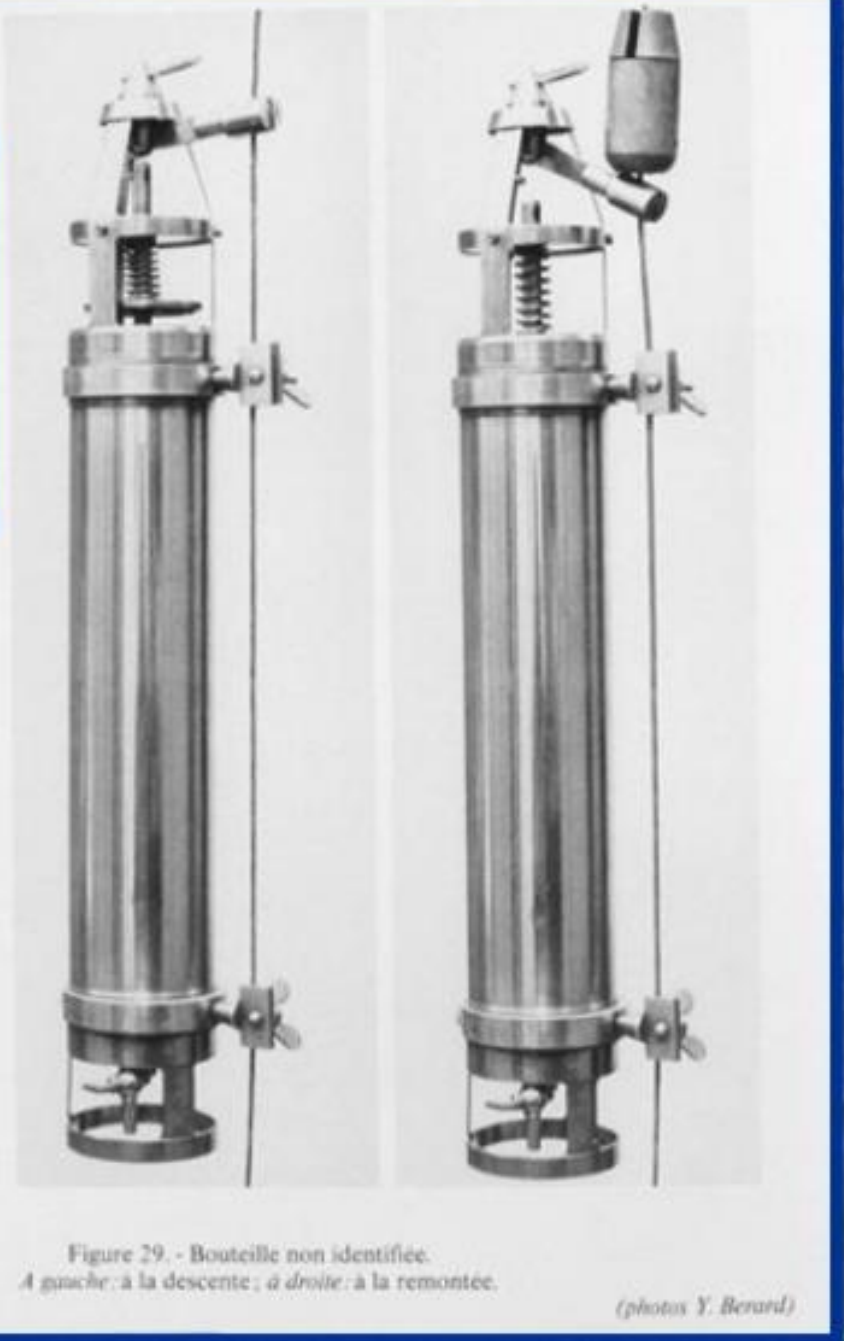
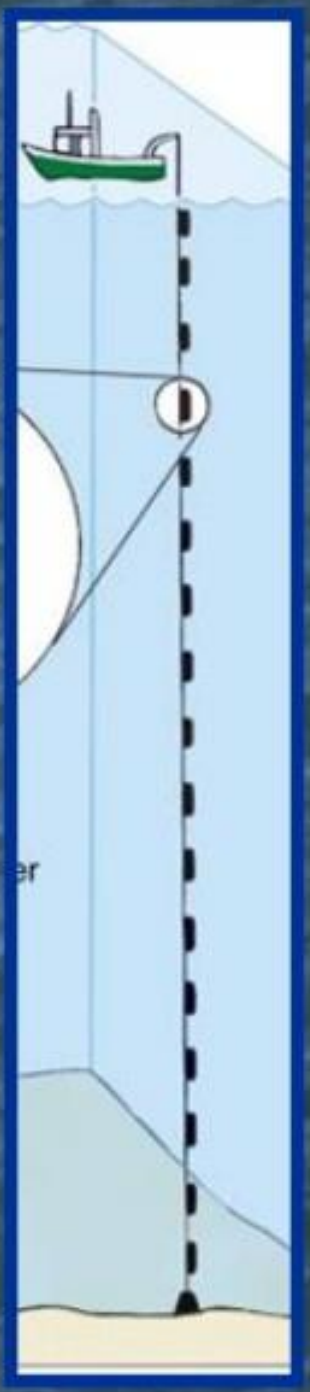


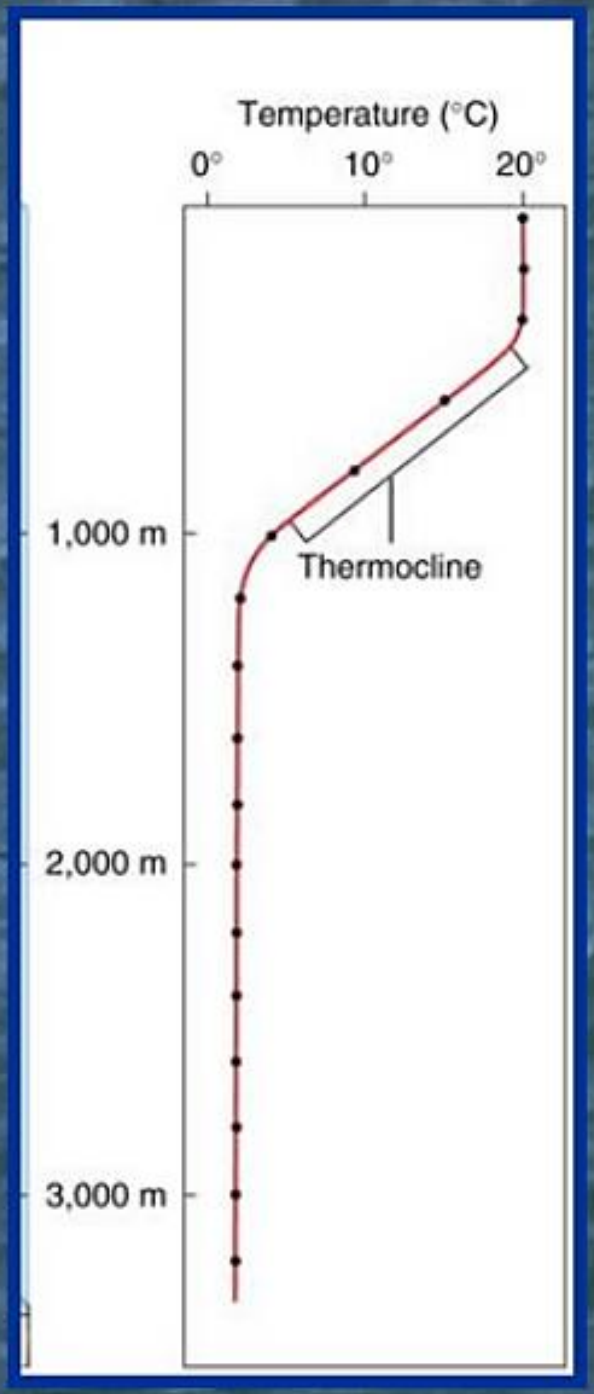
Figure 29. - Bouteille non identifiée.
A gauche : à la descente ; *à droite :* à la remontée.

(photos Y. Berard)



A rosette of sampling bottles and other instruments

Water Column profile for temperature



19th Century Oceanography

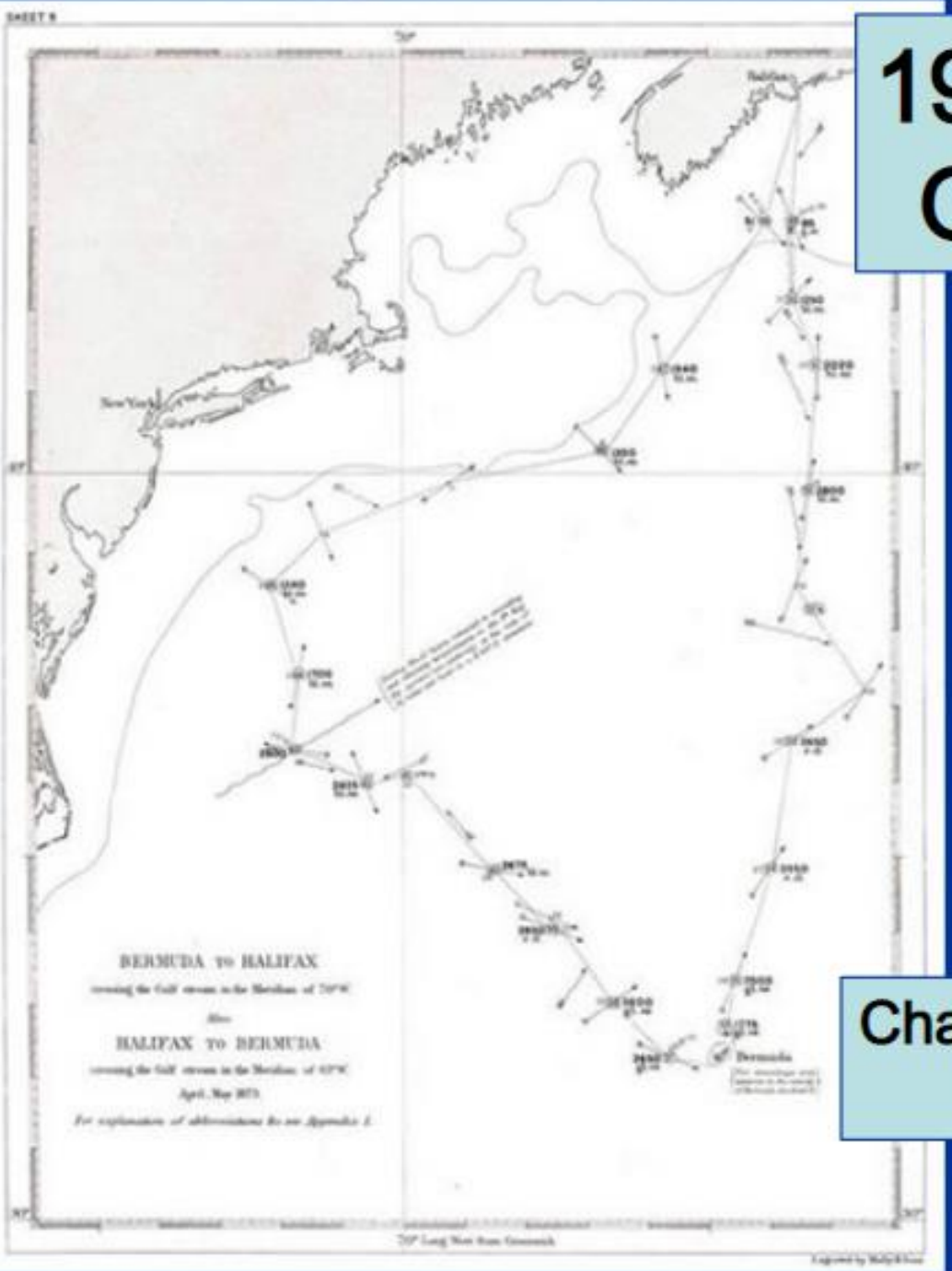
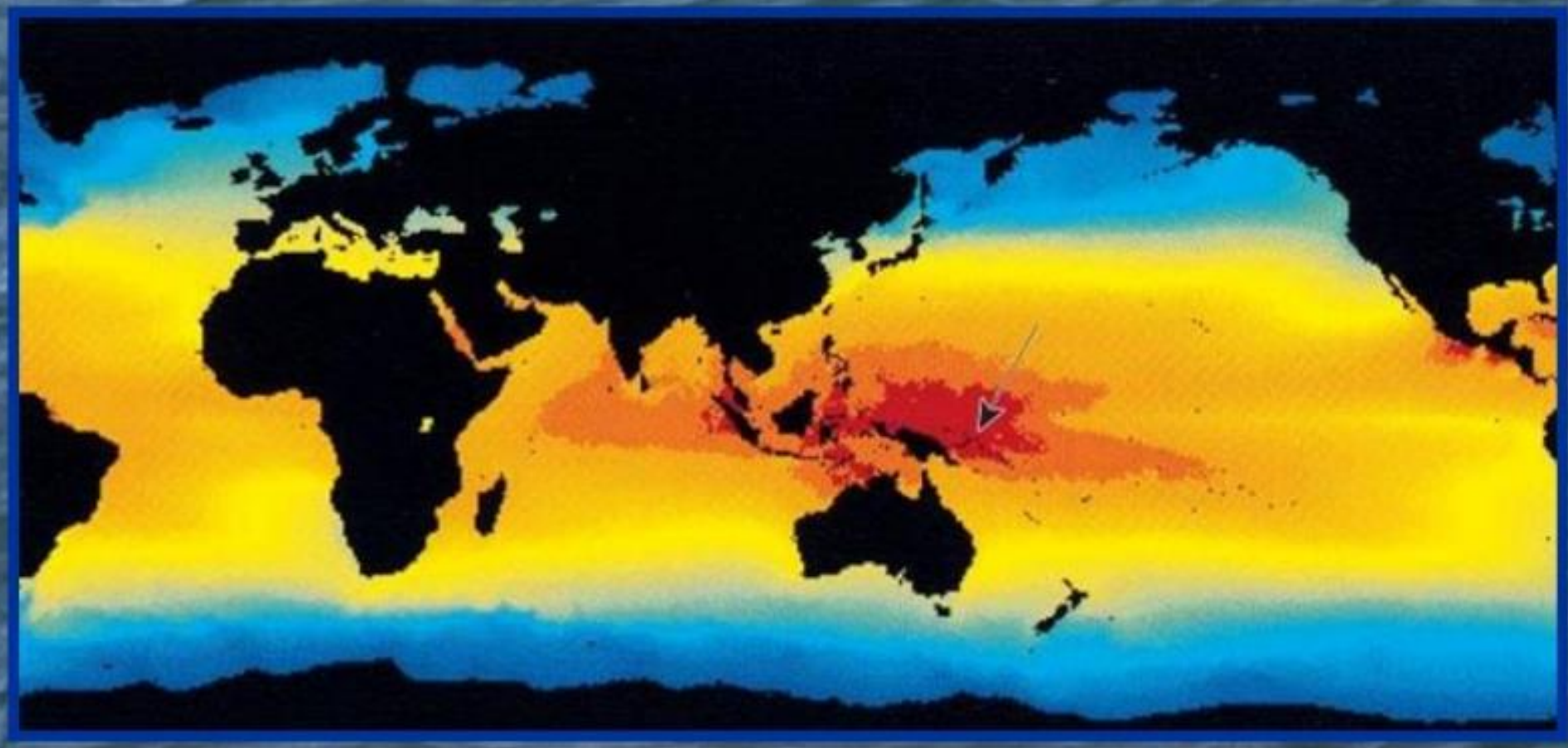


Chart from HMS *Challenger* Expedition

Satellite Imagery



Ocean surface temperatures – easier than taking millions of Niskin samples (assuming you have satellite).

Salinity, Temperature & Density

Salinity, Temperature & Density

- Temperature has a greater effect on ocean water because it is more variable.

- Temperature varies from about -2° to +30° C (28°-86°F)

Seawater and Dissolved Gases

Dissolved Gases

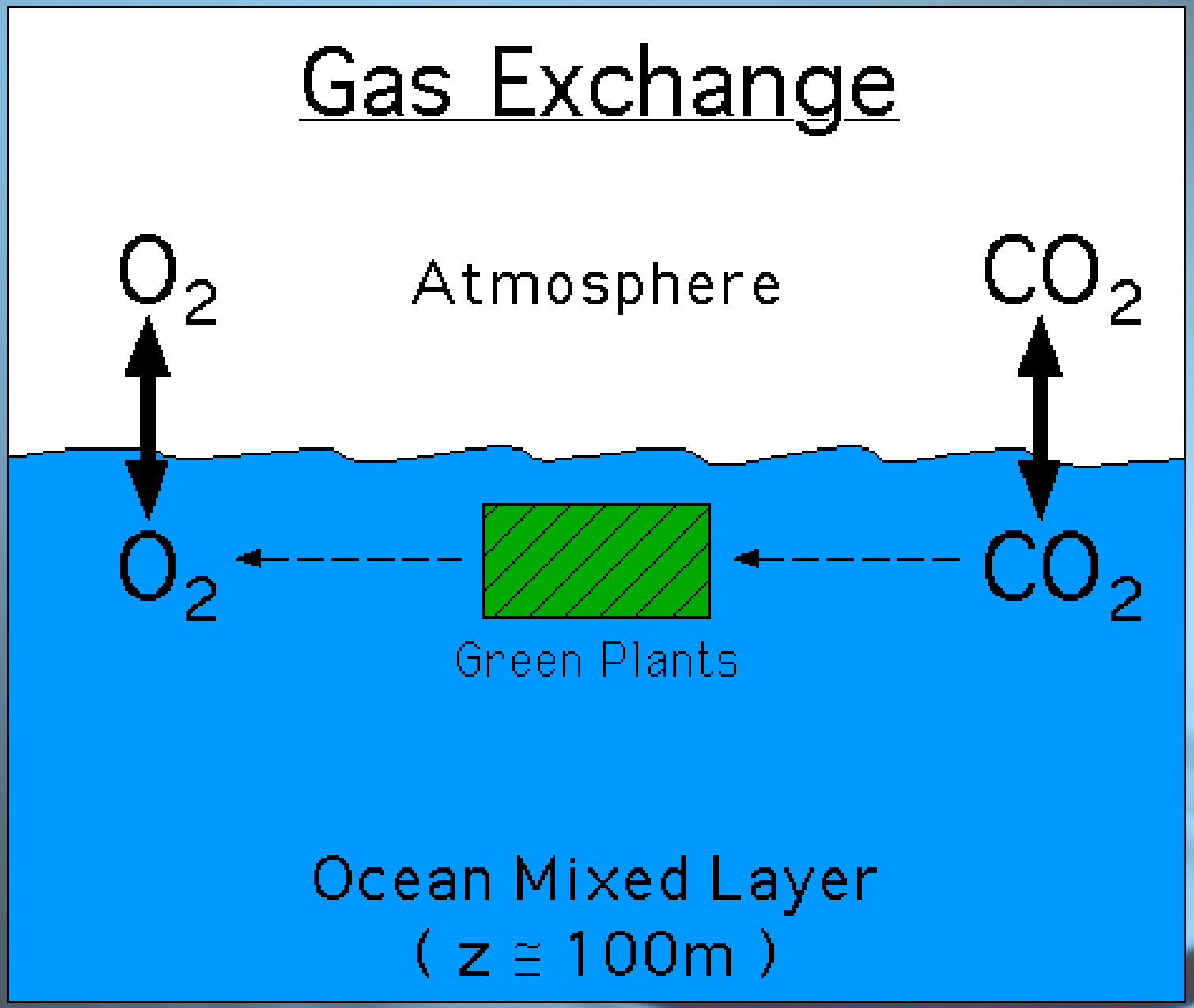
- Gases are also dissolved in seawater.

- The three most important gases in the ocean are:
  - Oxygen
  - Carbon dioxide
  - Nitrogen.

Dissolved Gases

- These gases are found in the atmosphere.
- They are dissolved in seawater at the surface. Sometimes, gases are released from the surface into the atmosphere.
- This is called **gas exchange**.

Dissolved Gases



How does temperature impact the ability for gases to dissolve?

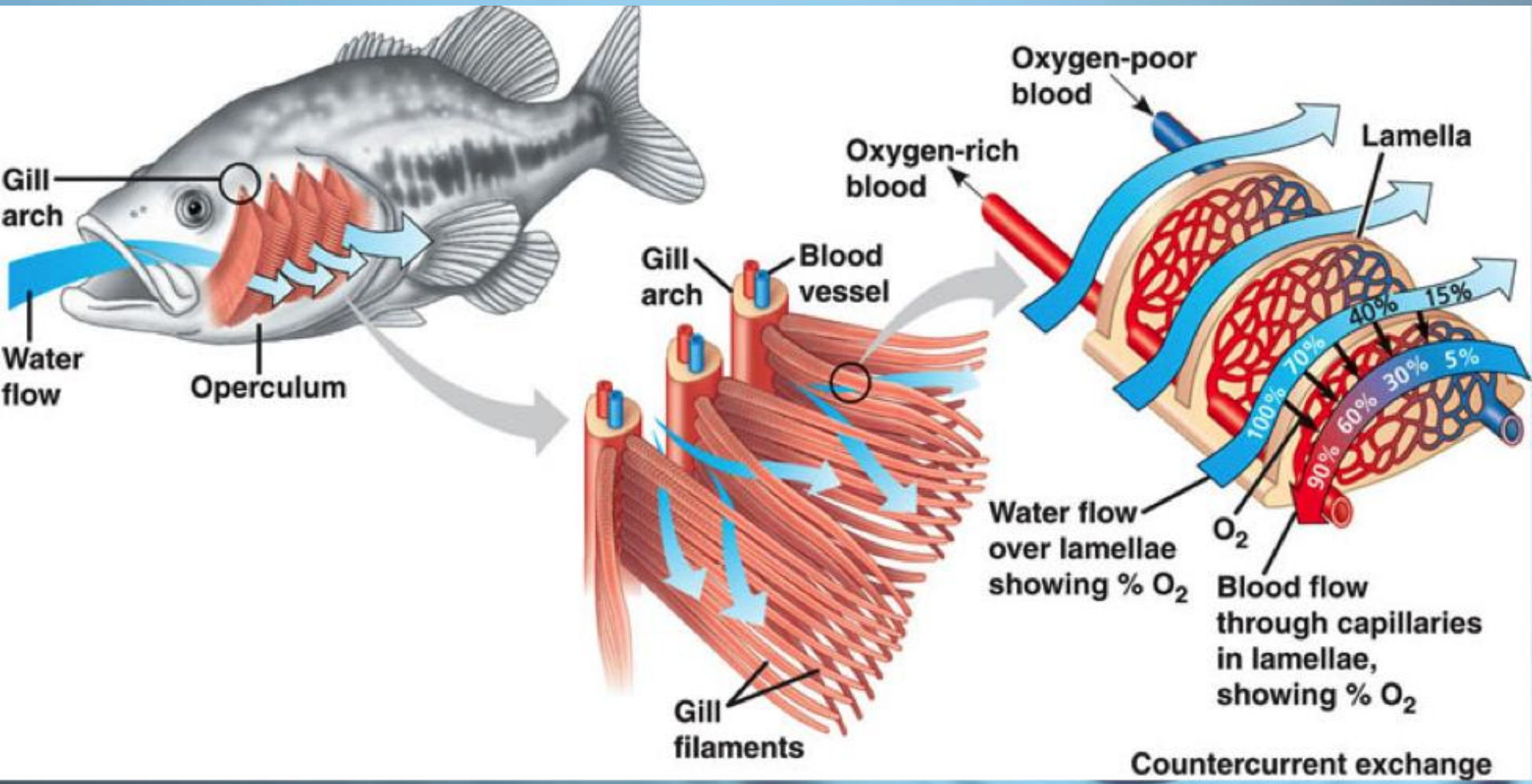
- Gases dissolve better in cold water.

- Whereas, most solids dissolve better at warmer temperatures.

Animals can impact the amount of gases in seawater.

- Like other aerobic organisms, many organisms in the ocean utilize oxygen and expel carbon dioxide.
- Animals use up oxygen in respiration.

Animals can impact the amount of gases in seawater.

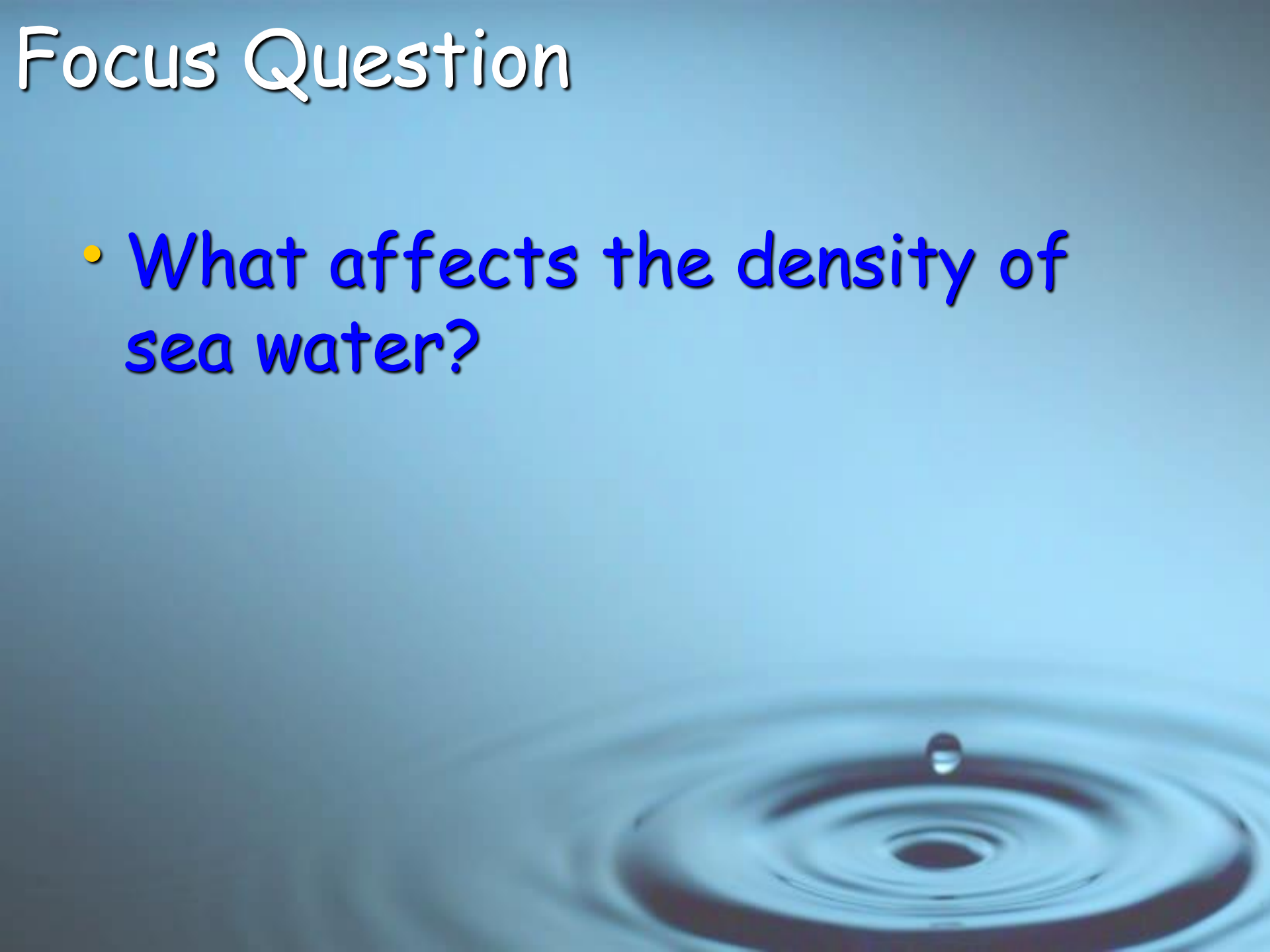


Conditions are not the Same at All Depths

- Conditions at the ocean floor, in the water column and at the surface can vary greatly.
- Oxygen content, temperature, salinity and other factors are often very different from one depth to another.

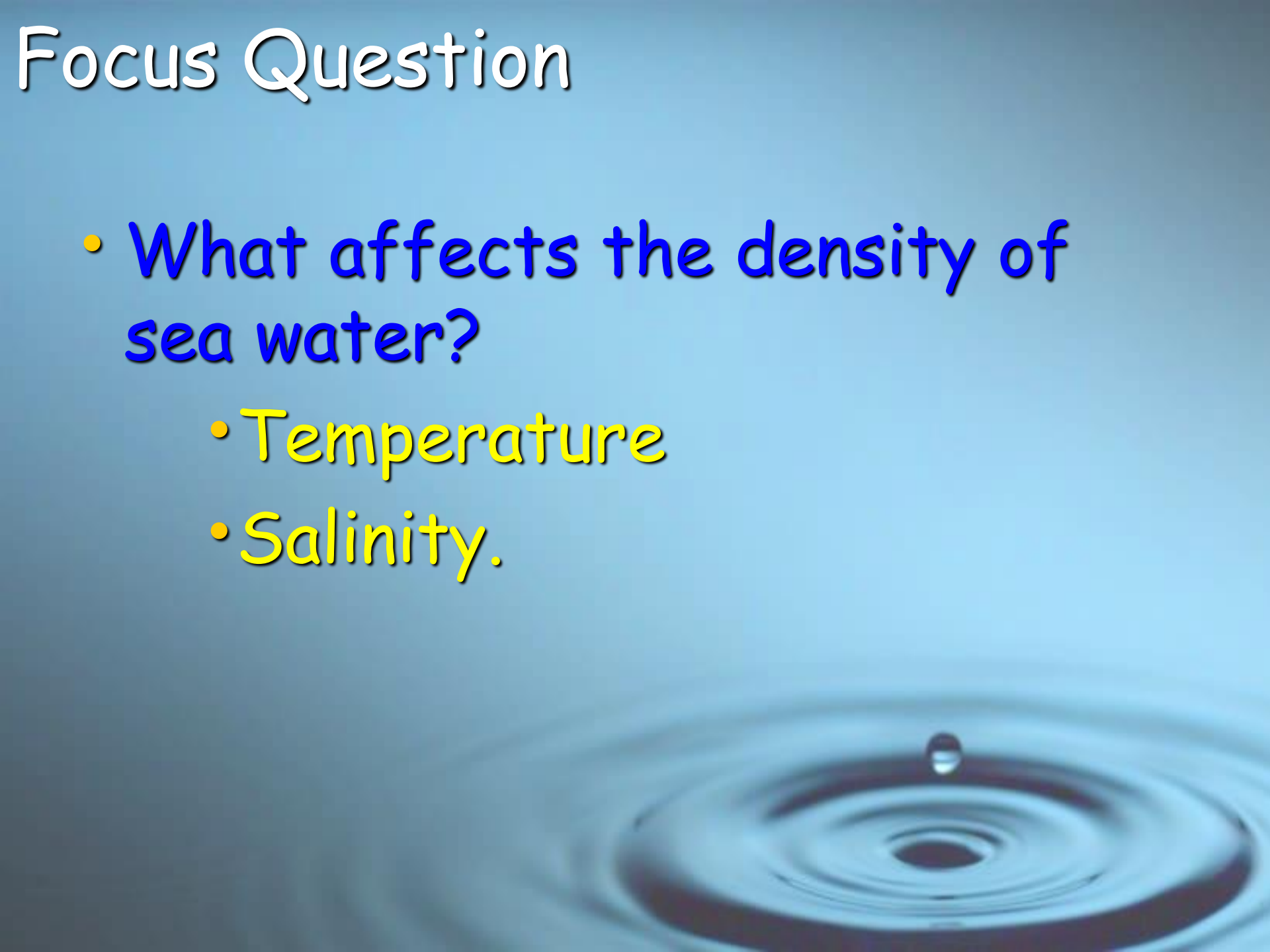
Focus Question

- What affects the density of sea water?



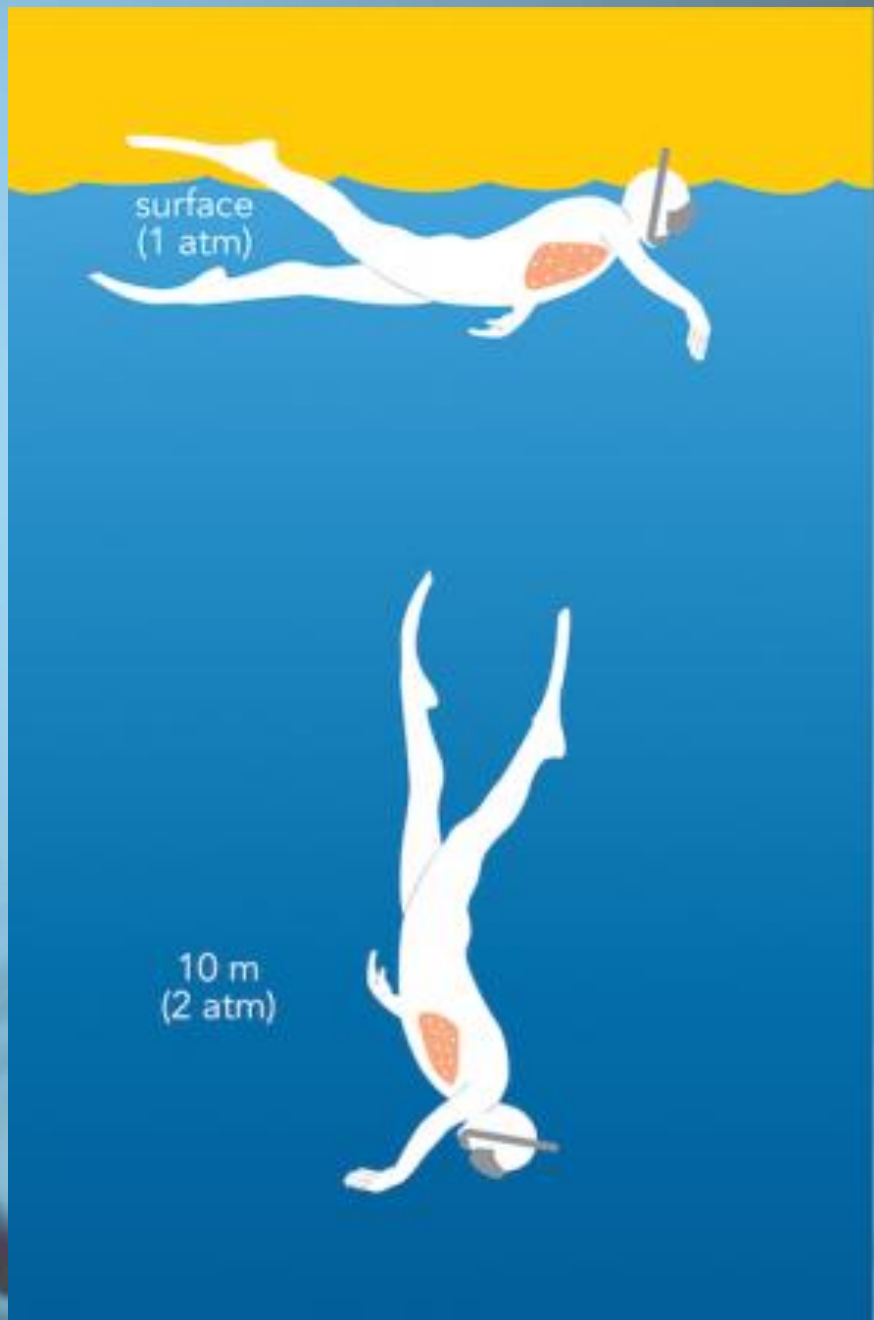
Focus Question

- What affects the density of sea water?
  - Temperature
  - Salinity.



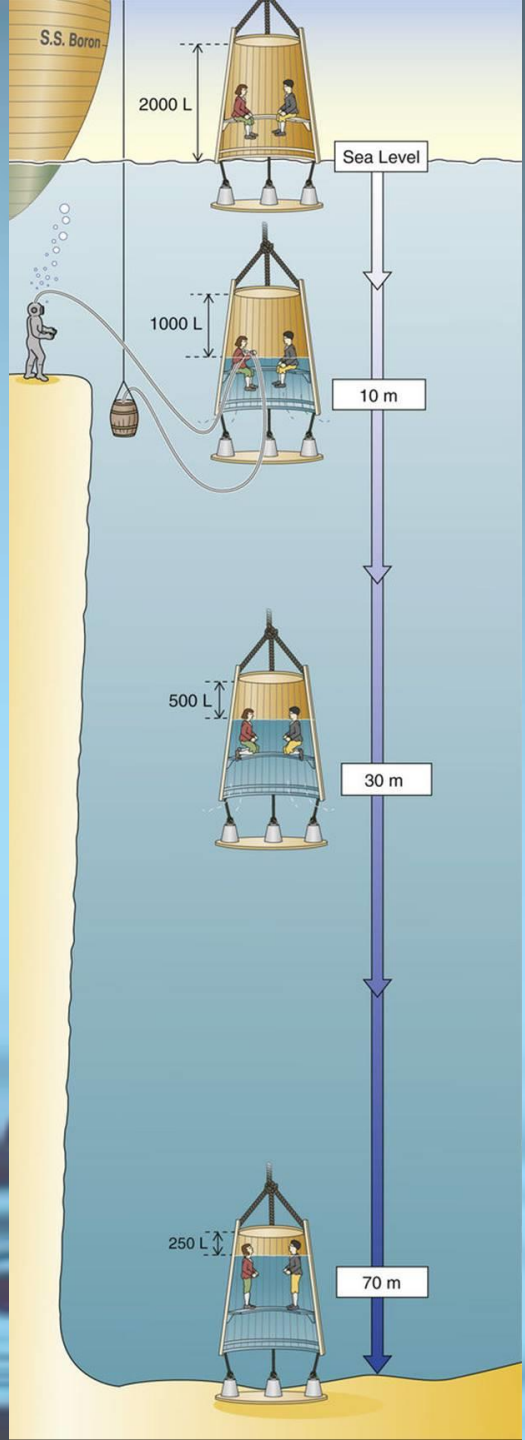
Pressure

- Organisms on land are under 1 atm of pressure at sea level.
- Marine organisms are under the weight of the water above them + atmosphere.



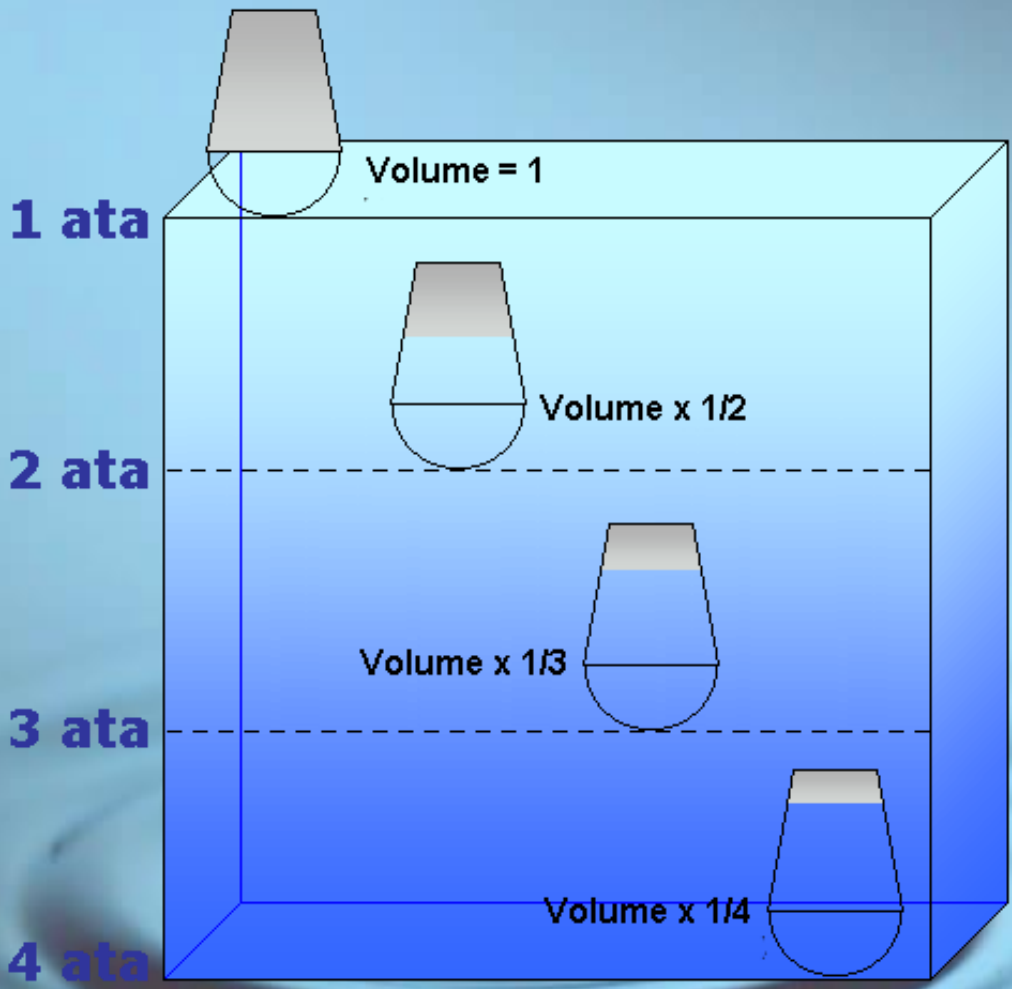
Pressure

- Water is heavier than air.
- Therefore, marine organisms are under MORE pressure.

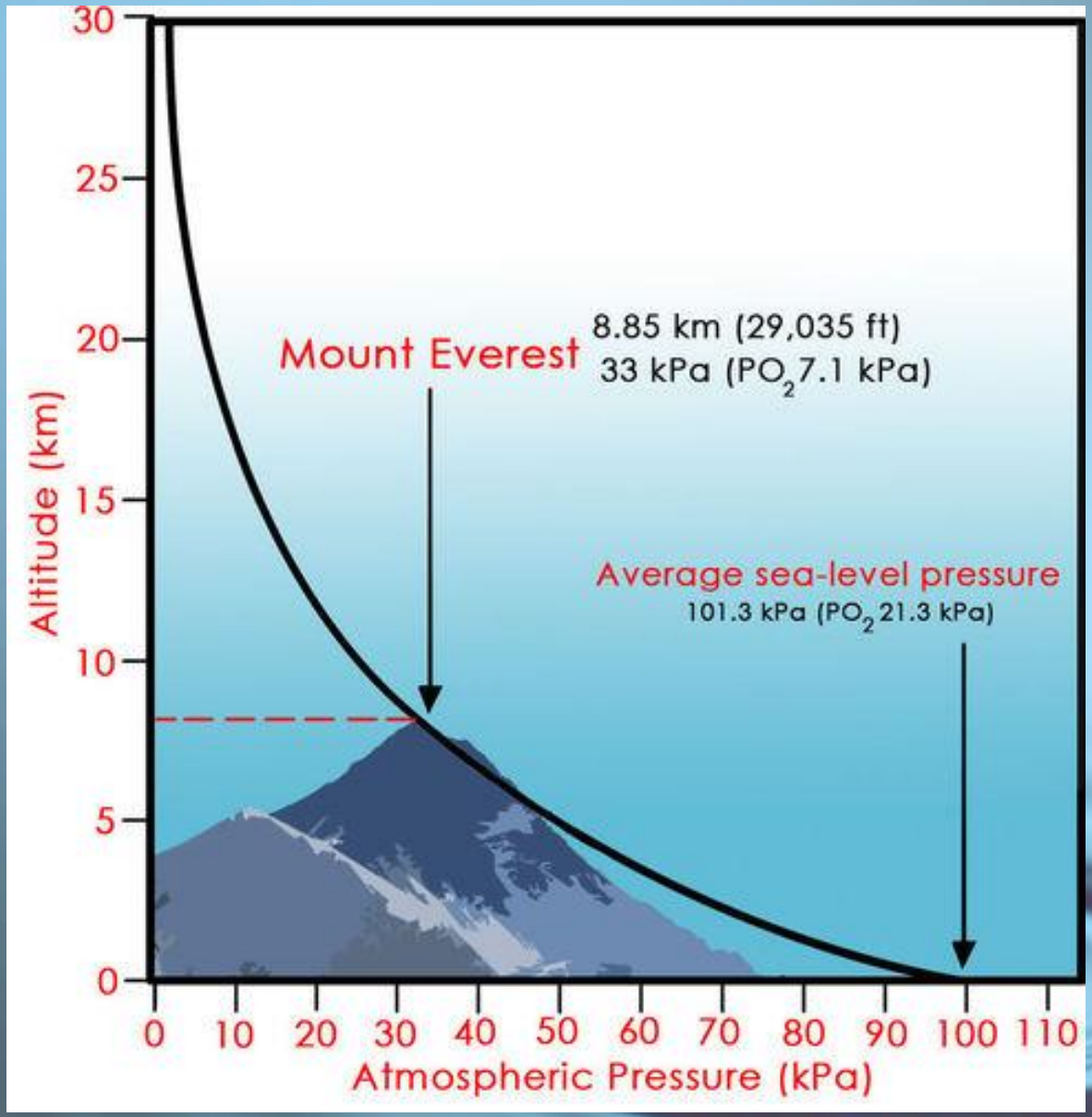


Pressure

- Pressure INCREASES with DEPTH.
- With every 10 m (or 33 feet) of increased depth, another atmosphere of pressure is added.



Conditions are not the Same at All Depths



Water depth	Total pressure atm	bar	psi
0	1	1.0	14.7
10 m (33 ft)	2	2.0	29.4
20 m (66 ft)	3	3.0	44.1
30 m (98 ft)	4	4.1	58.8
40 m (131 ft)	5	5.1	73.5
50 m (164 ft)	6	6.1	88.2
60 m (197 ft)	7	7.1	102.9
70 m (230 ft)	8	8.1	117.6
80 m (262 ft)	9	9.1	132.3

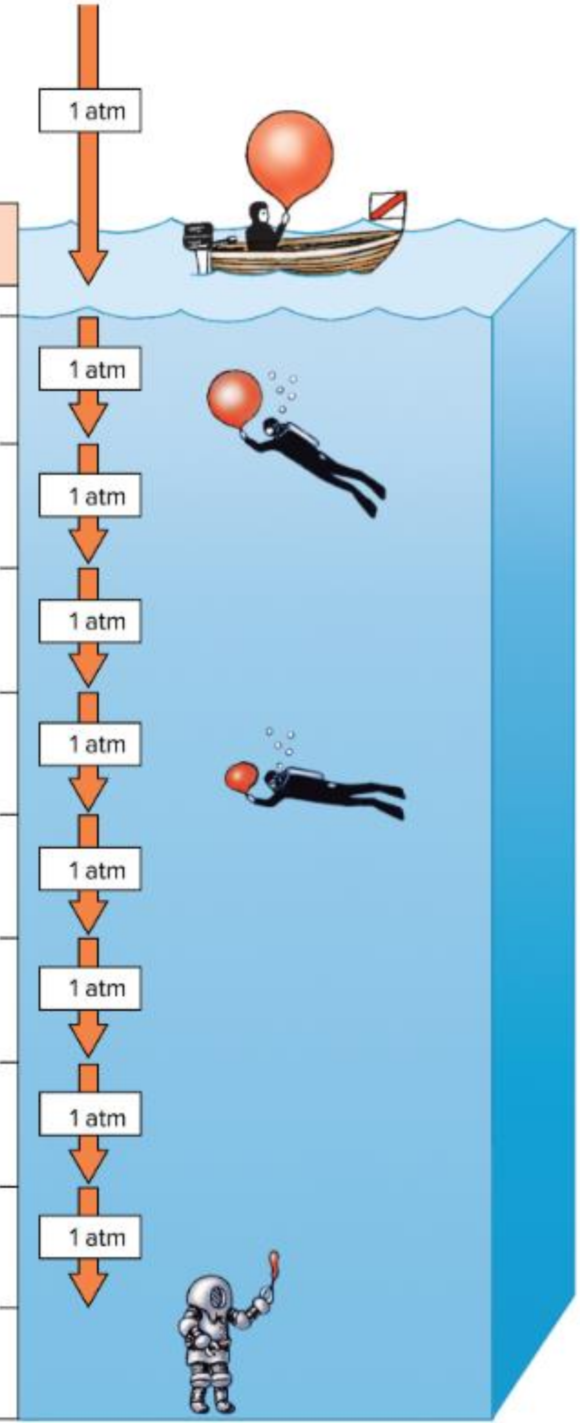


FIGURE 3.14 The pressure at any place depends on the weight pressing down from above. At the sea surface or on land, only the atmosphere is above. Divers and marine organisms, however, are also under the weight of the water column. The deeper the diver goes, the more water presses down from above and the greater the pressure. As the pressure increases, flexible gas-filled structures like the red balloon are compressed. Pressure can be measured in atmospheres (atm), bars, pounds per square inch (psi), or other units.

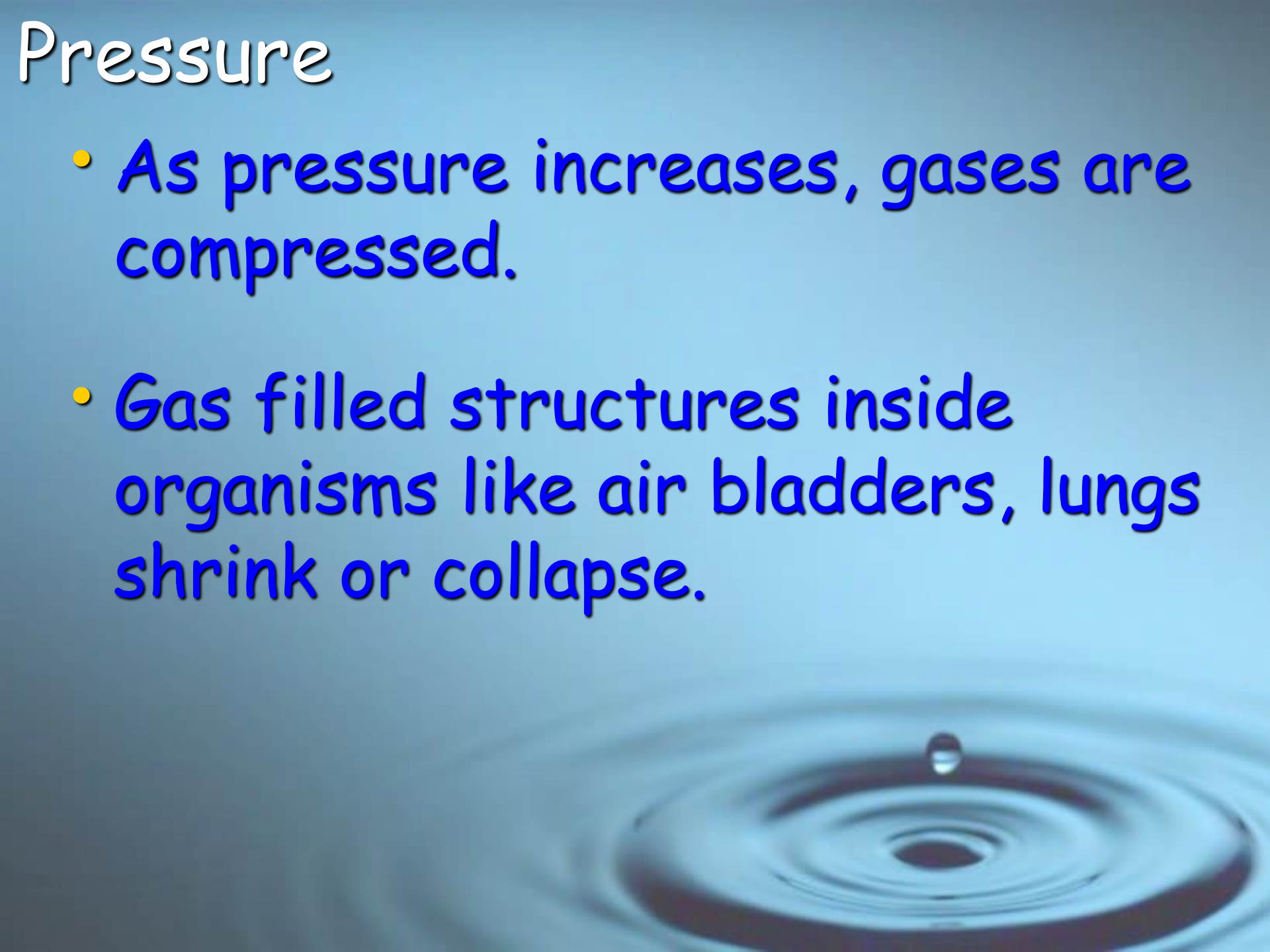
Source: Bill Ober

Conditions are not the Same at All Depths

- Pressure is also greater the deeper the depth.
- Water at the bottom has the weight of the water above it pushing down on it (which means that organisms living there also experience this pressure).

Pressure

- As pressure increases, gases are compressed.
- Gas filled structures inside organisms like air bladders, lungs shrink or collapse.



Pressure

- Limits depth range of many organisms.

Yelloweye Rockfish that has died of barotrauma. Reduced water pressure causes the air in the swim bladder to expand and push out the stomach and eyes. BUT this is a reversal condition whereby the fish can survive through use of a "fish descender". Photo: Hildering.

Transparency

- Water is also relatively transparent (you can see through it).

Transparency

- This means that sunlight shining on the surface can penetrate the surface (great for those photosynthetic organisms living under the sea)
- This level of penetration varies greatly depending on the amount of solutes in the water.

Transparency

- To illustrate that point, imagine the crystal clear waters of the Bahamas (or other tropical locations you may have visited or seen in photos).

Transparency

- Compare this with the less transparent water at the NC coast or the Mississippi River outflow.

Transparency

- The difference is rivers.
- Several rivers in North Carolina &/or Louisiana empty into the Atlantic.
- This means more solutes and less transparency (we sometimes also call this visibility).

Transparency

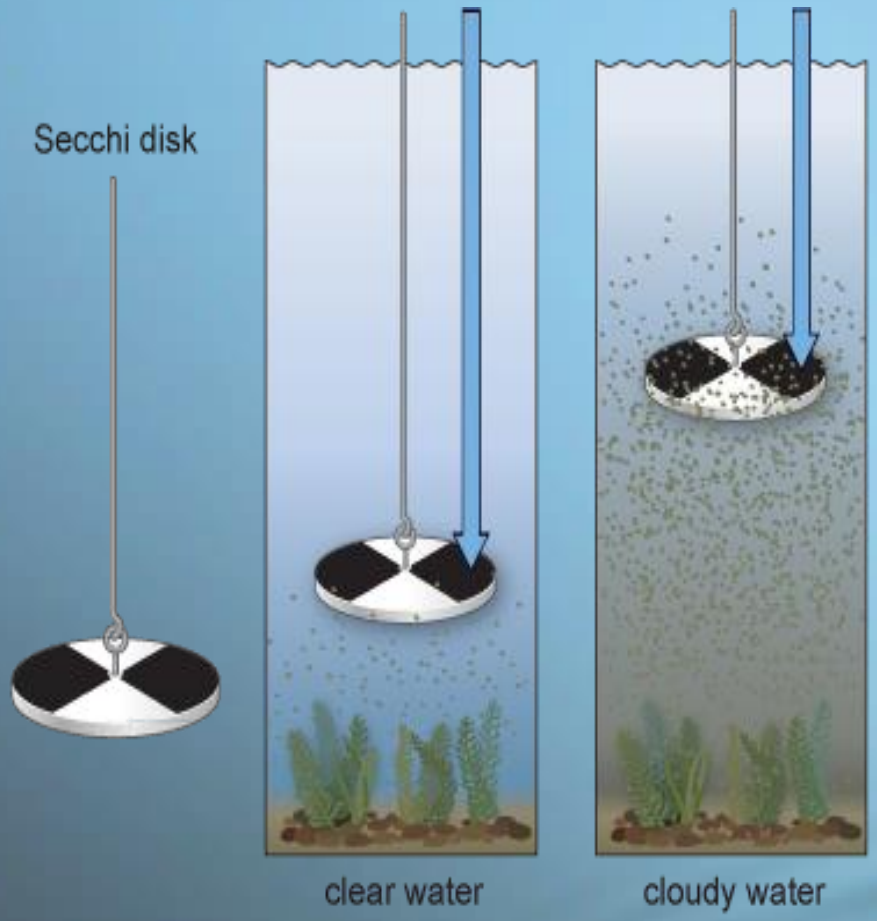
- Sea water is transparent.
- Sunlight can penetrate into the ocean.
- This is very important for plants. Why?

Transparency

- Turbidity is measured with a secchi disk.

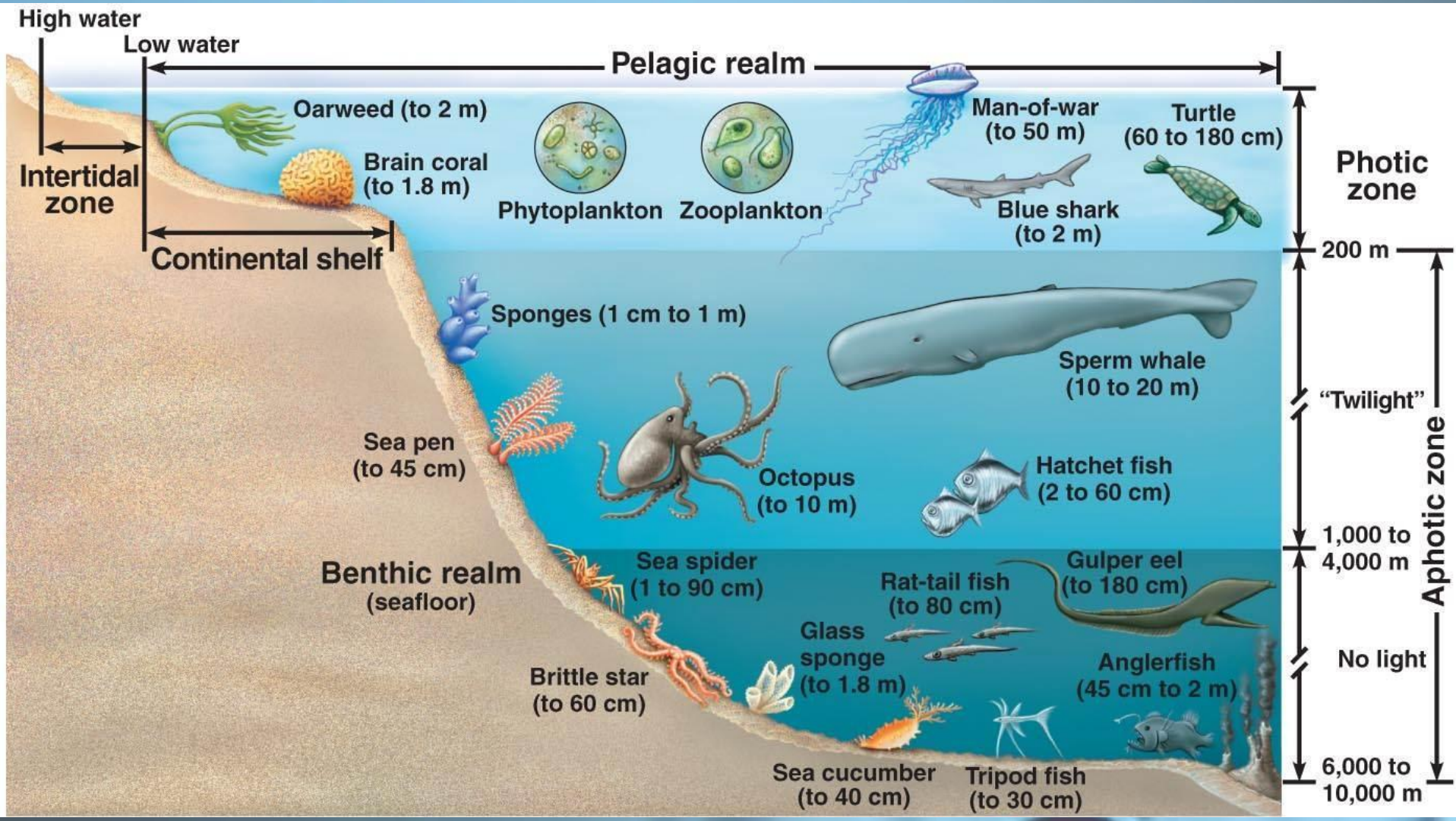
- Water transparency depends on how much and what kind of material is suspended and dissolved in the water.

Transparency



- Ex. Muddy water reduces transparency.
- Ex. Large quantities of plant life reduces transparency.

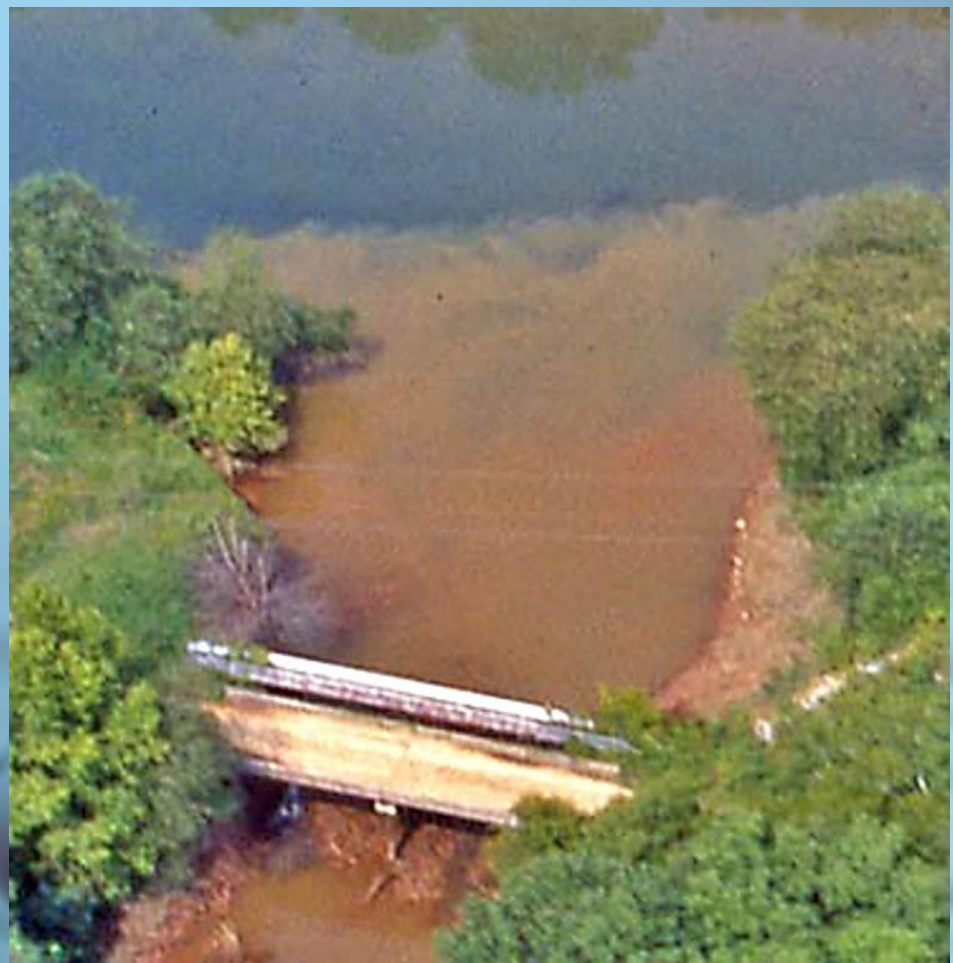
Transparency



Transparency

- Water near the coasts is generally not as clear as that of the open ocean.
- Remember!!!

  Rivers bring runoff.

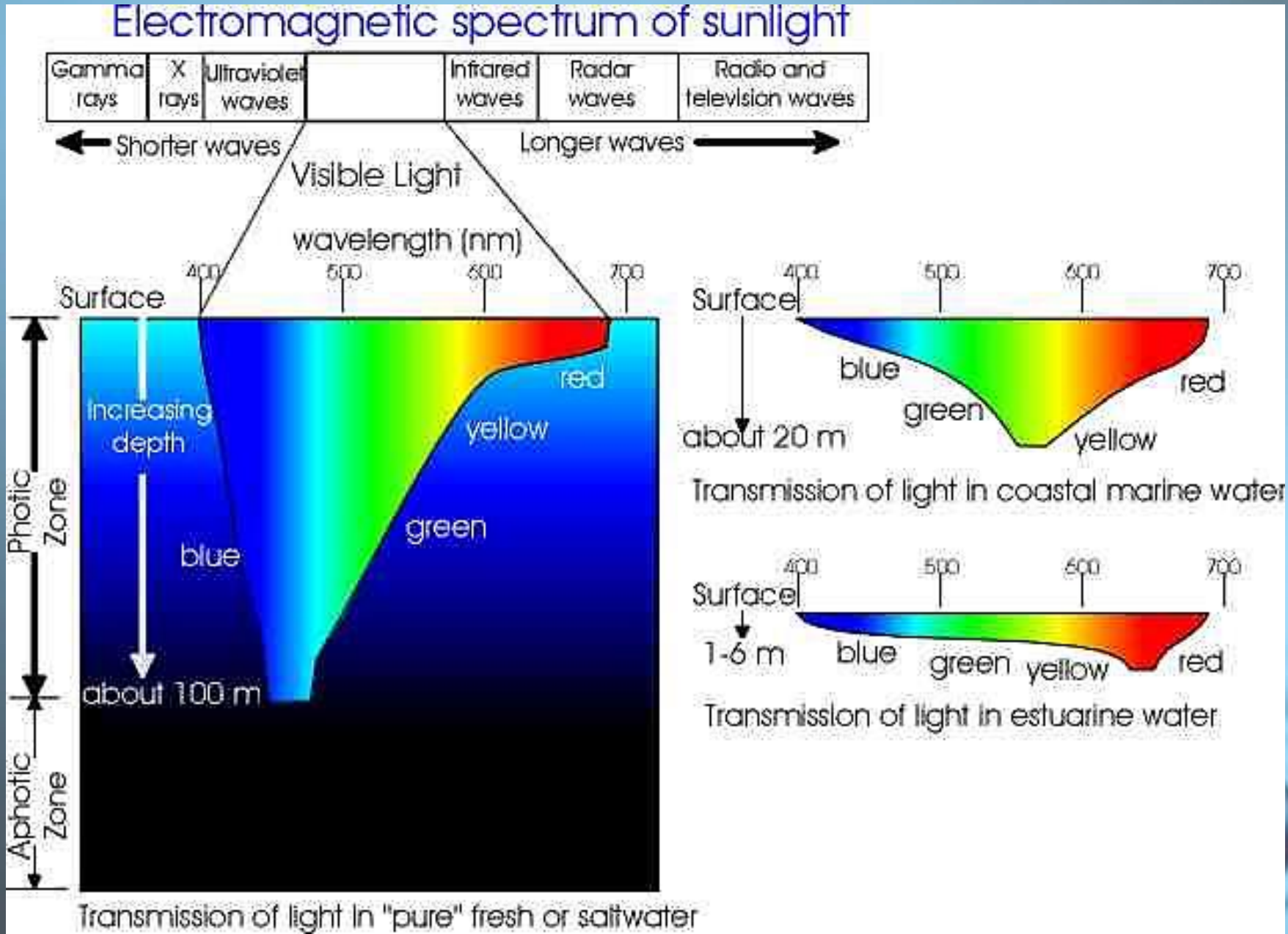


ROY G BIV

- Sunlight contains all the colors of the visible spectrum.

- Not all colors of light penetrate seawater equally.

ROY G BIV


Electromagnetic spectrum of sunlight
Gamma rays
X rays
Ultraviolet waves
Infrared waves
Radar waves
Radio and television waves
Shorter waves
Longer waves
Visible Light
wavelength (nm)
400
500
600
700
Surface
Increasing depth
red
yellow
green
blue
about 100 m
Photic Zone
Aphotic Zone
Transmission of light in "pure" fresh or saltwater
Surface
about 20 m
blue
green
yellow
red
Transmission of light in coastal marine water
Surface
1-6 m
blue
green
yellow
red
Transmission of light in estuarine water

ROY G BIV

- Different colors of light penetrate to different depths in the ocean.
  - Blue light penetrates the deepest.
  - Red light the least.

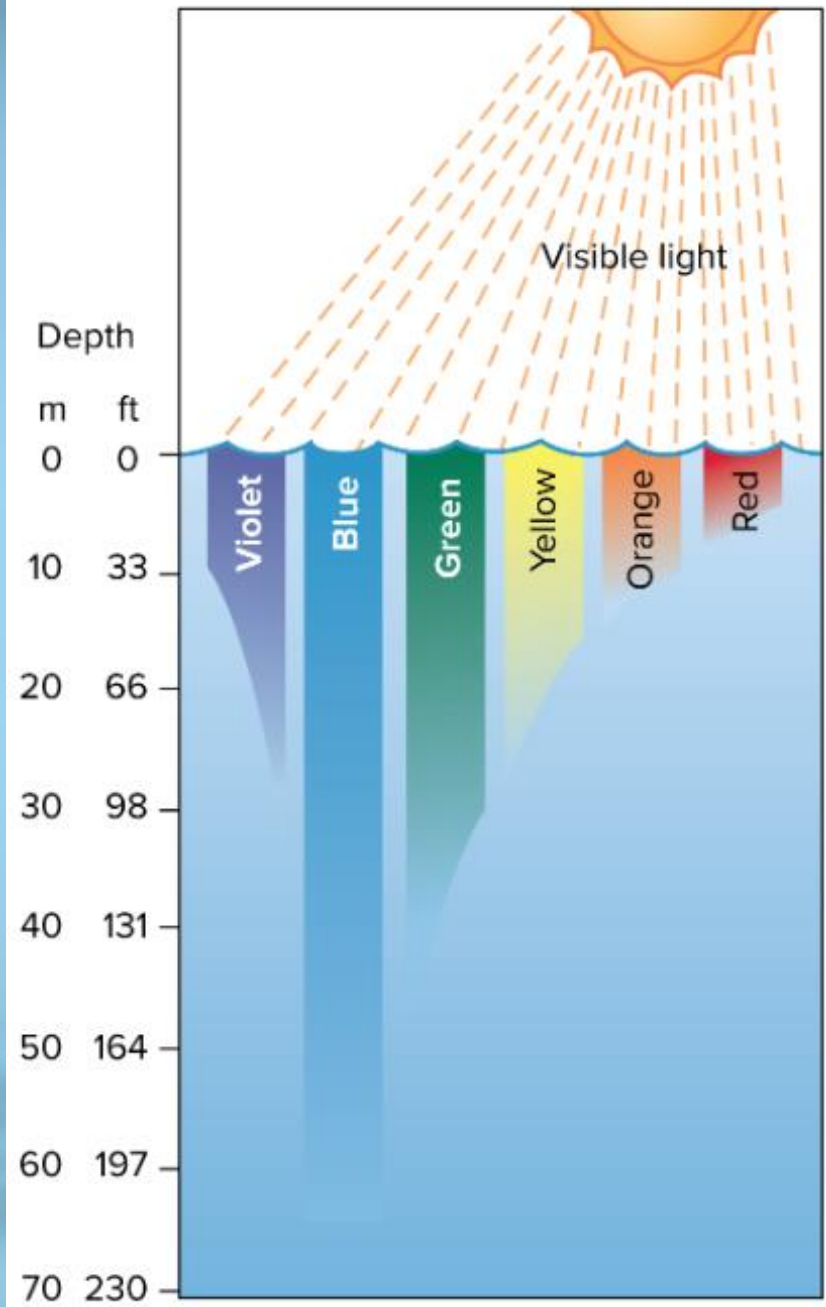


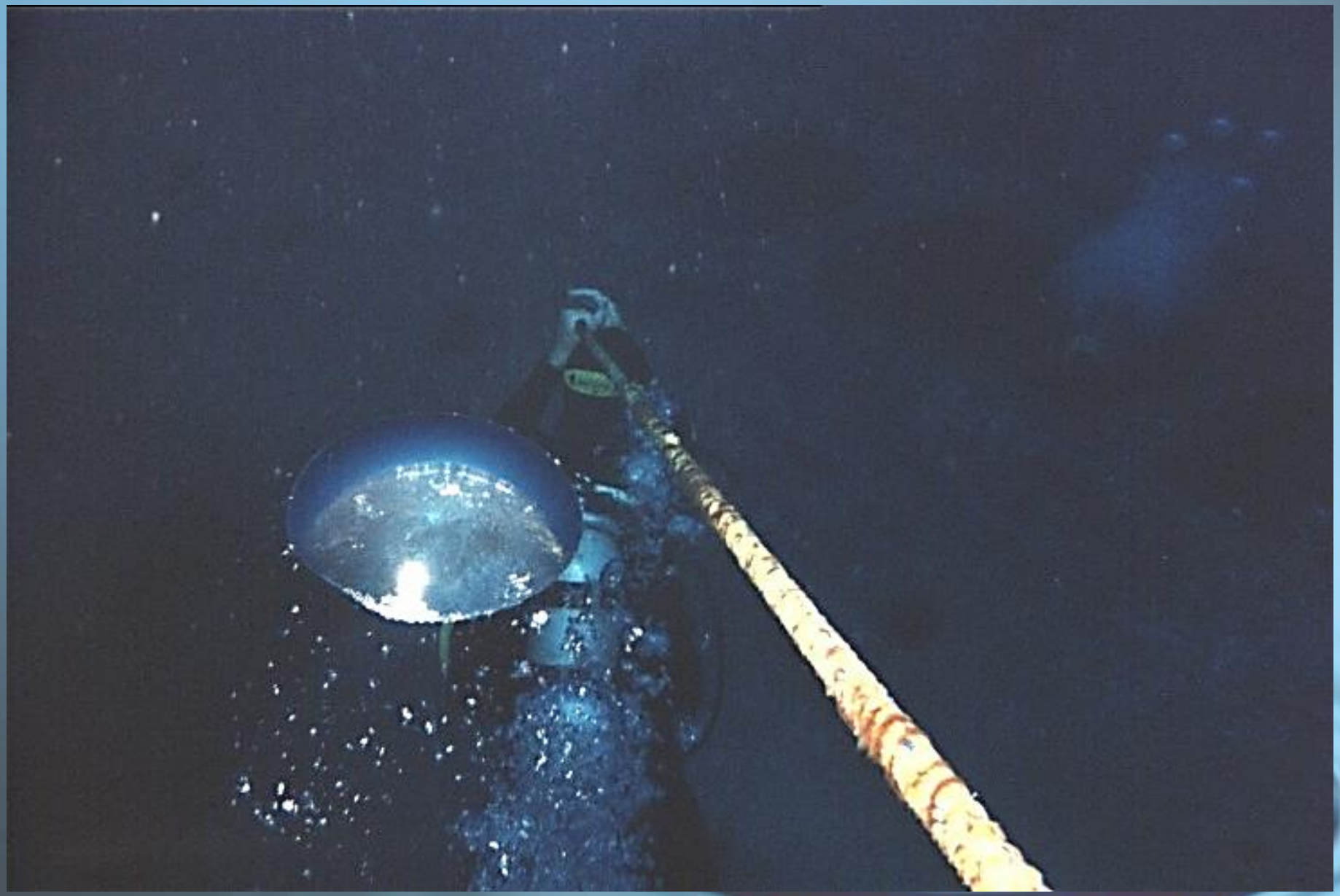
FIGURE 3.11 Different colors of light penetrate to different depths in the ocean. In clear ocean water blue light penetrates the deepest, red light the least. Coastal waters often contain materials that absorb blue light so that green penetrates deepest.

Photic Zone

- The upper regions of the ocean where photosynthesis occurs.

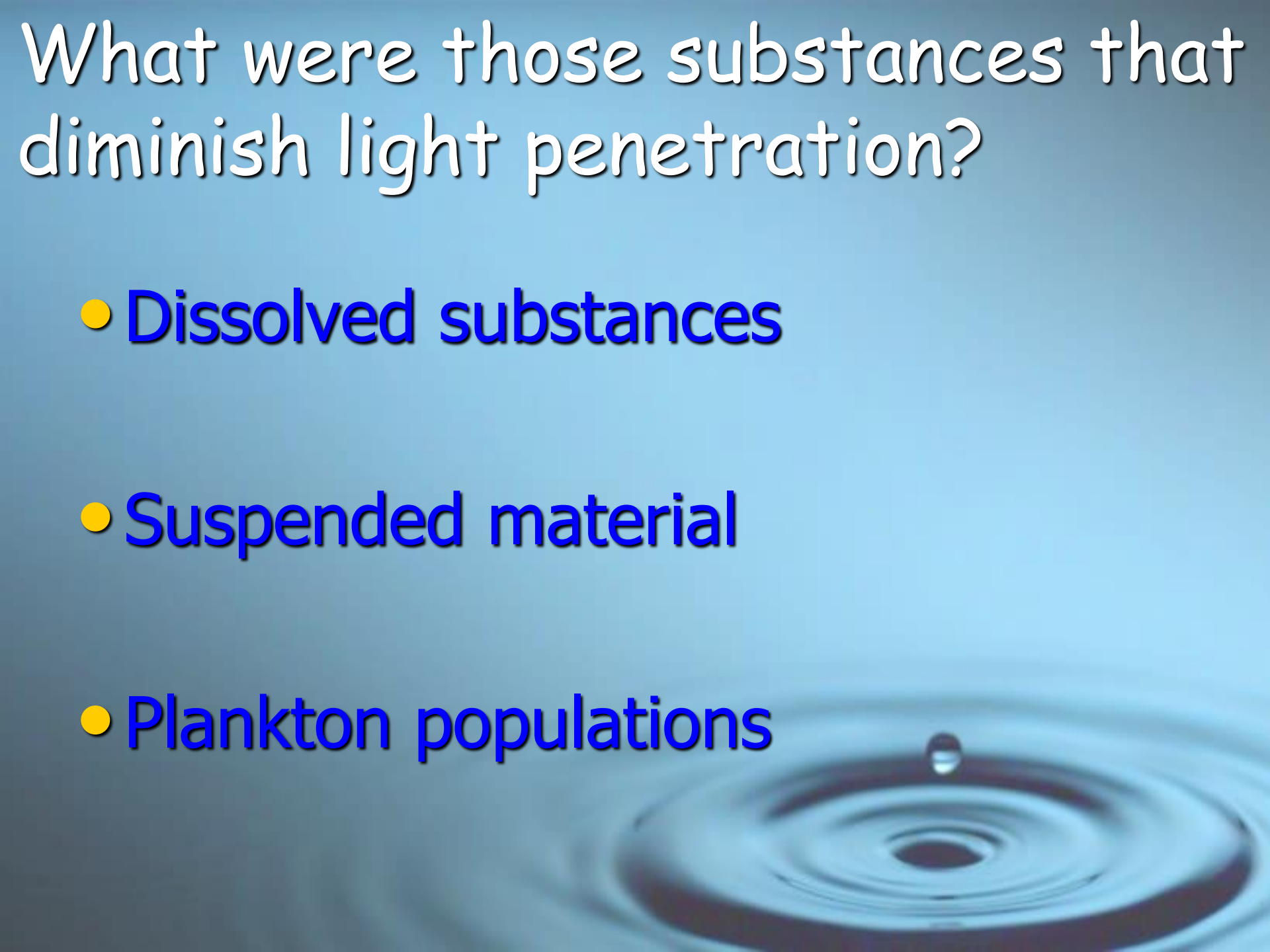
- Depth of photic zone is determined by how rapidly light is absorbed.

Light In Water



What were those substances that diminish light penetration?

- Dissolved substances
- Suspended material
- Plankton populations



Light In Water

Light In Water

Photic versus Aphotic zone

Sunlight Availability

Photic zone:

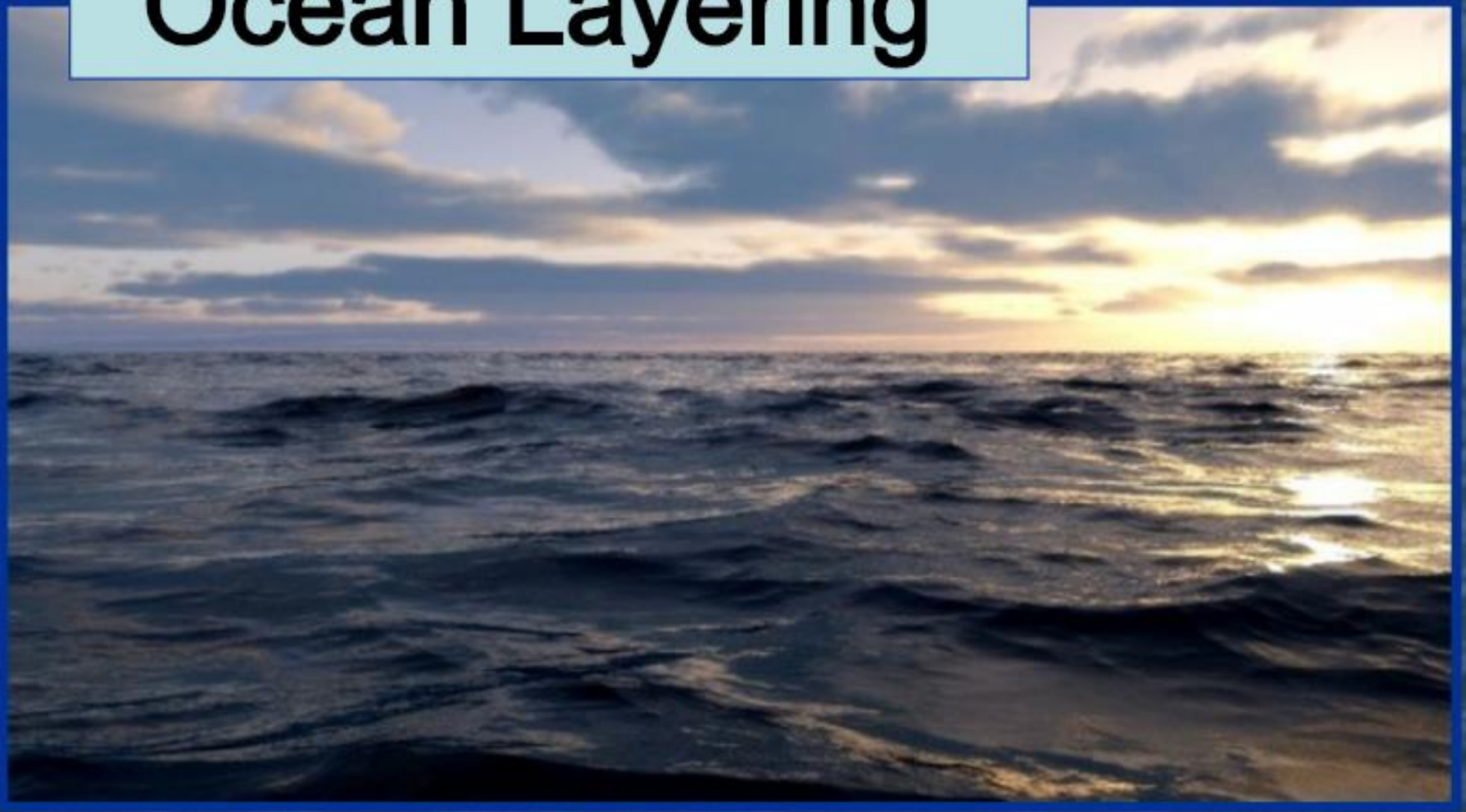
- Euphotic zone- portion of photic zone where photosynthesis occurs
- 0-200 meters
- The sunlit zone

Aphotic zone:

- 200 meters to ocean floor
- Little to no sunlit zone

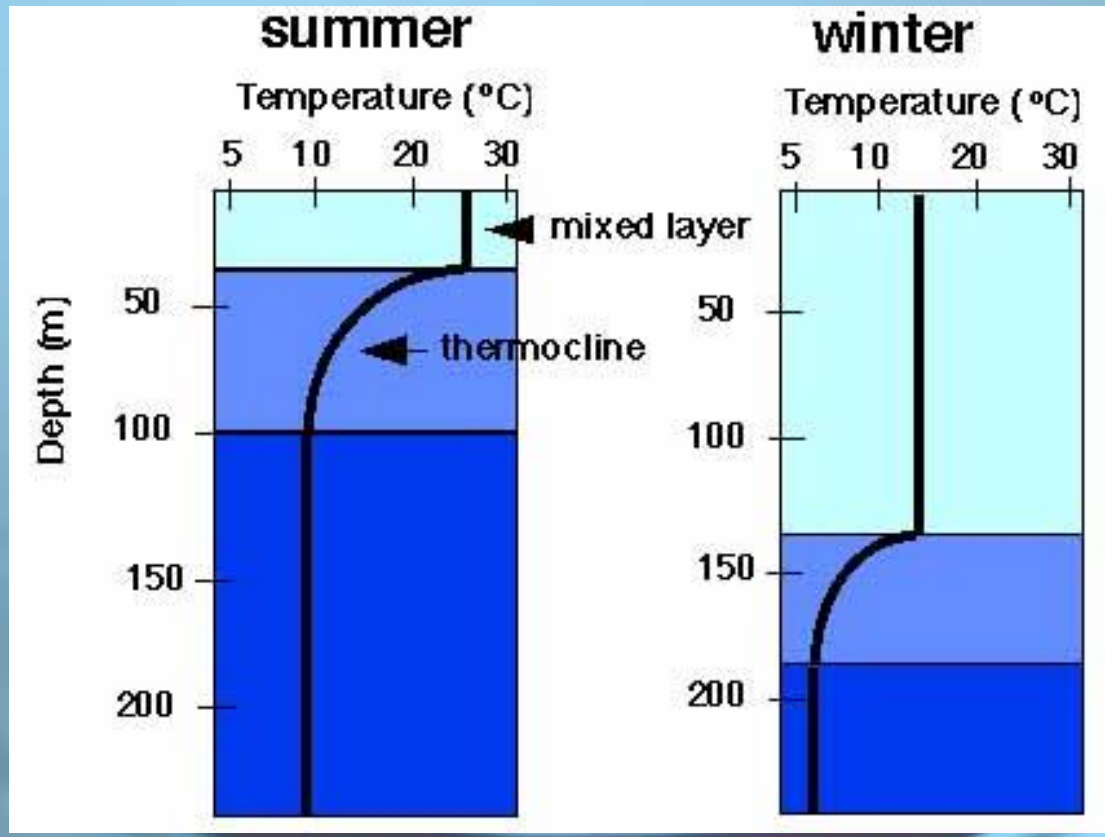
•Critters:

Density and Ocean Layering



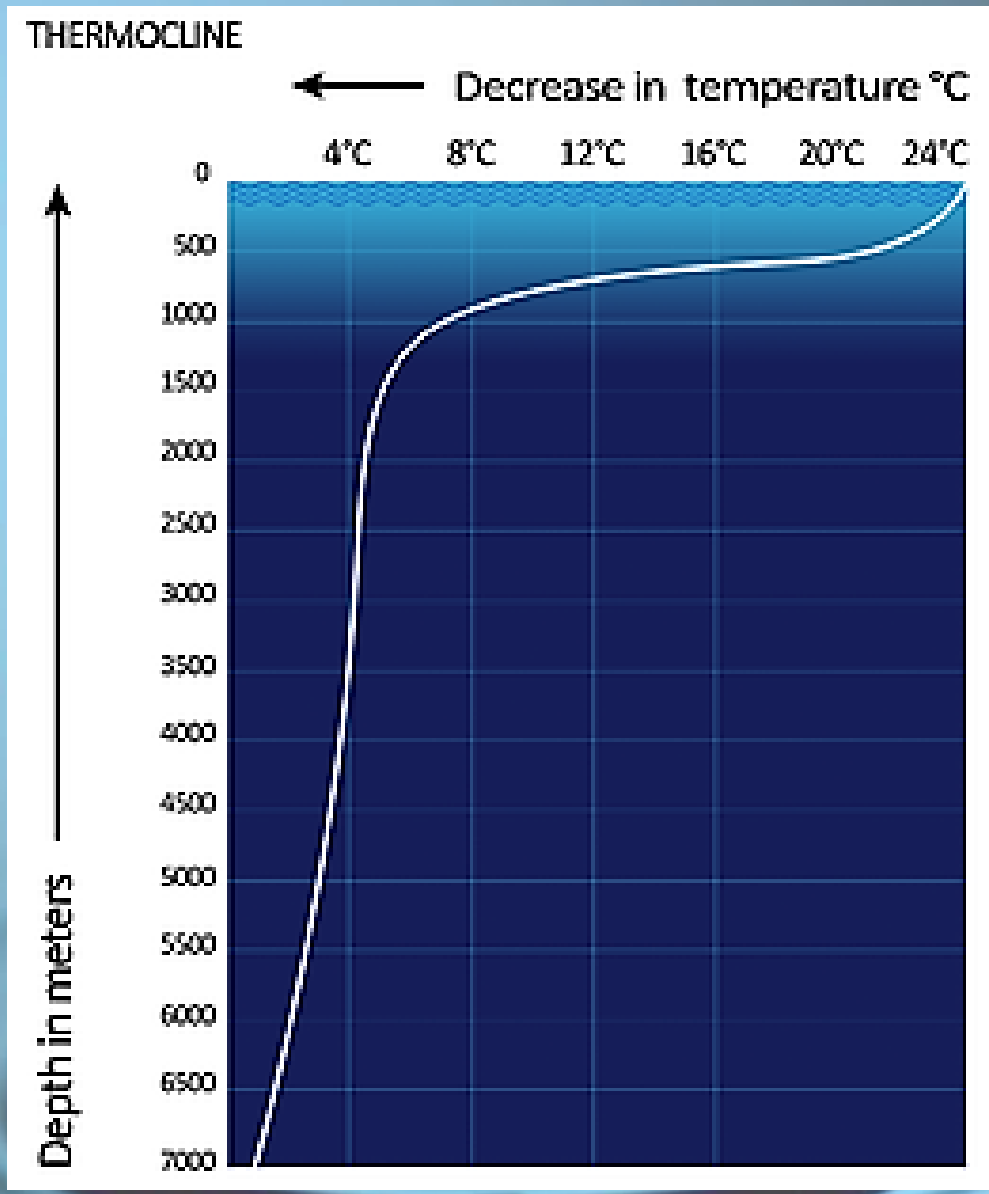
Thermocline

- A subsurface zone of rapid temperature change.
- The layer between the mixed layer at the surface and the deep water layer.



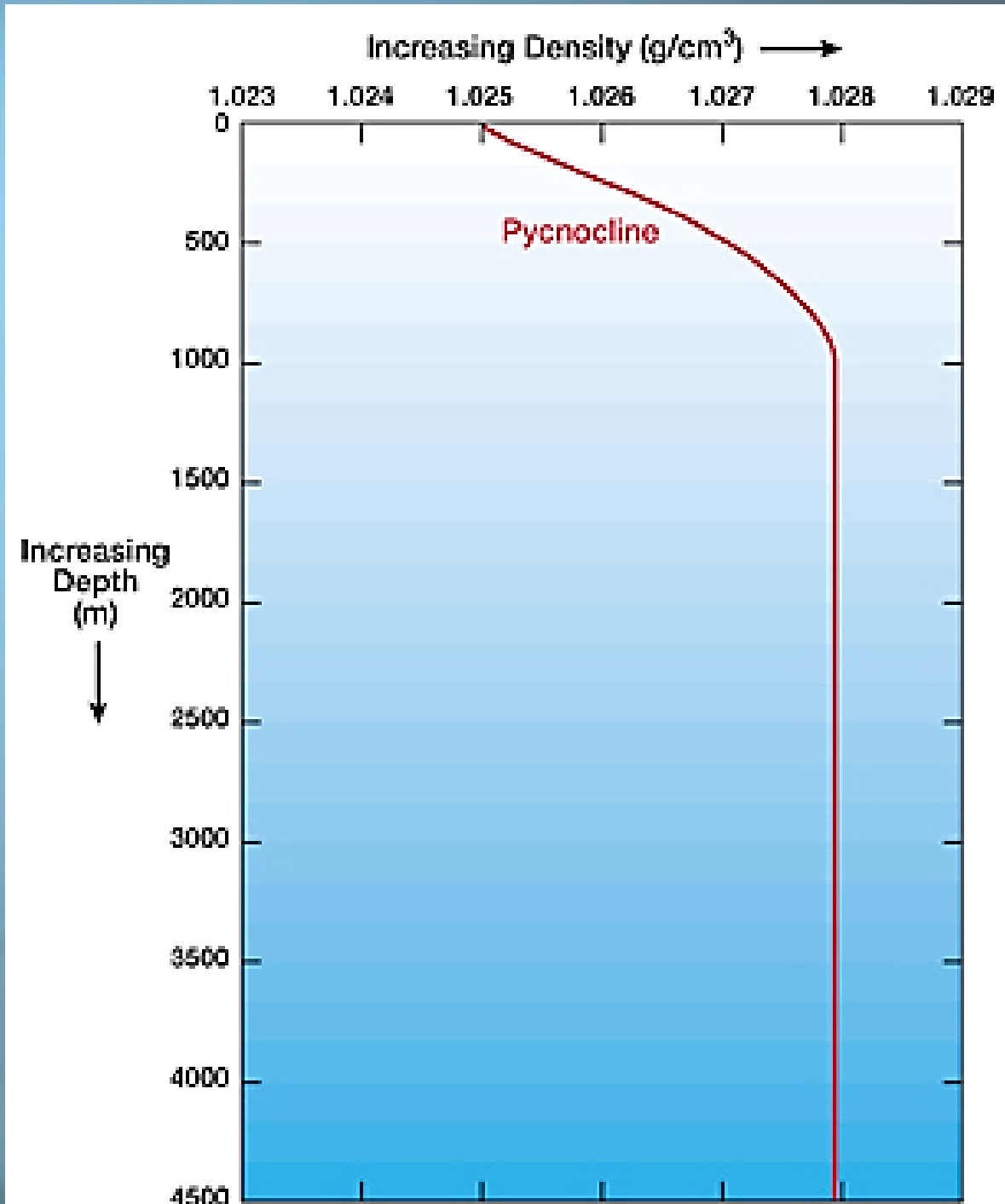
Thermocline

- Temperature changes rapidly from the mixed layer to the deep water layer.
- Prevent vertical mixing of the water.

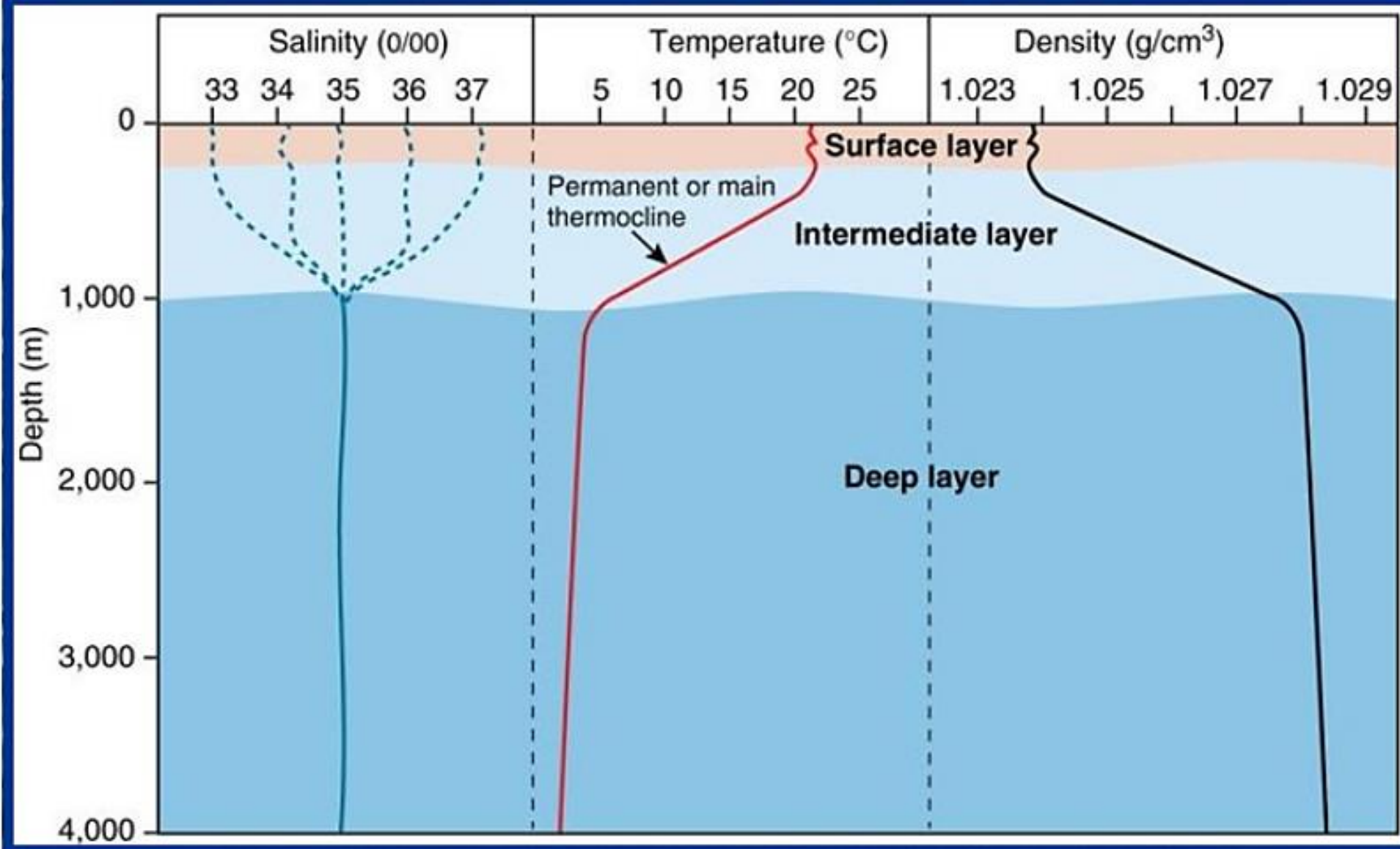


Pycnocline

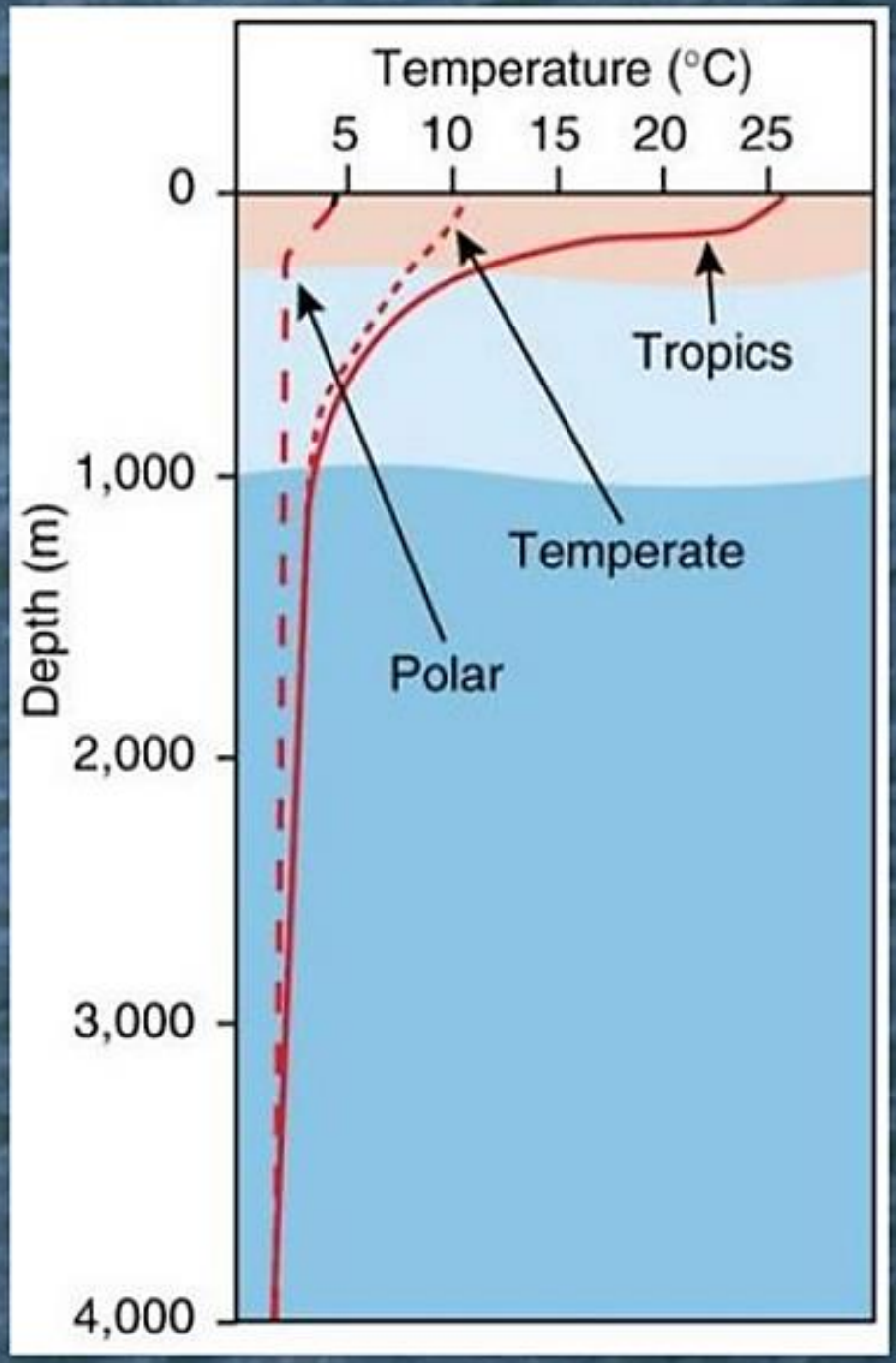
- A LAYER of rapid change in water density with depth.



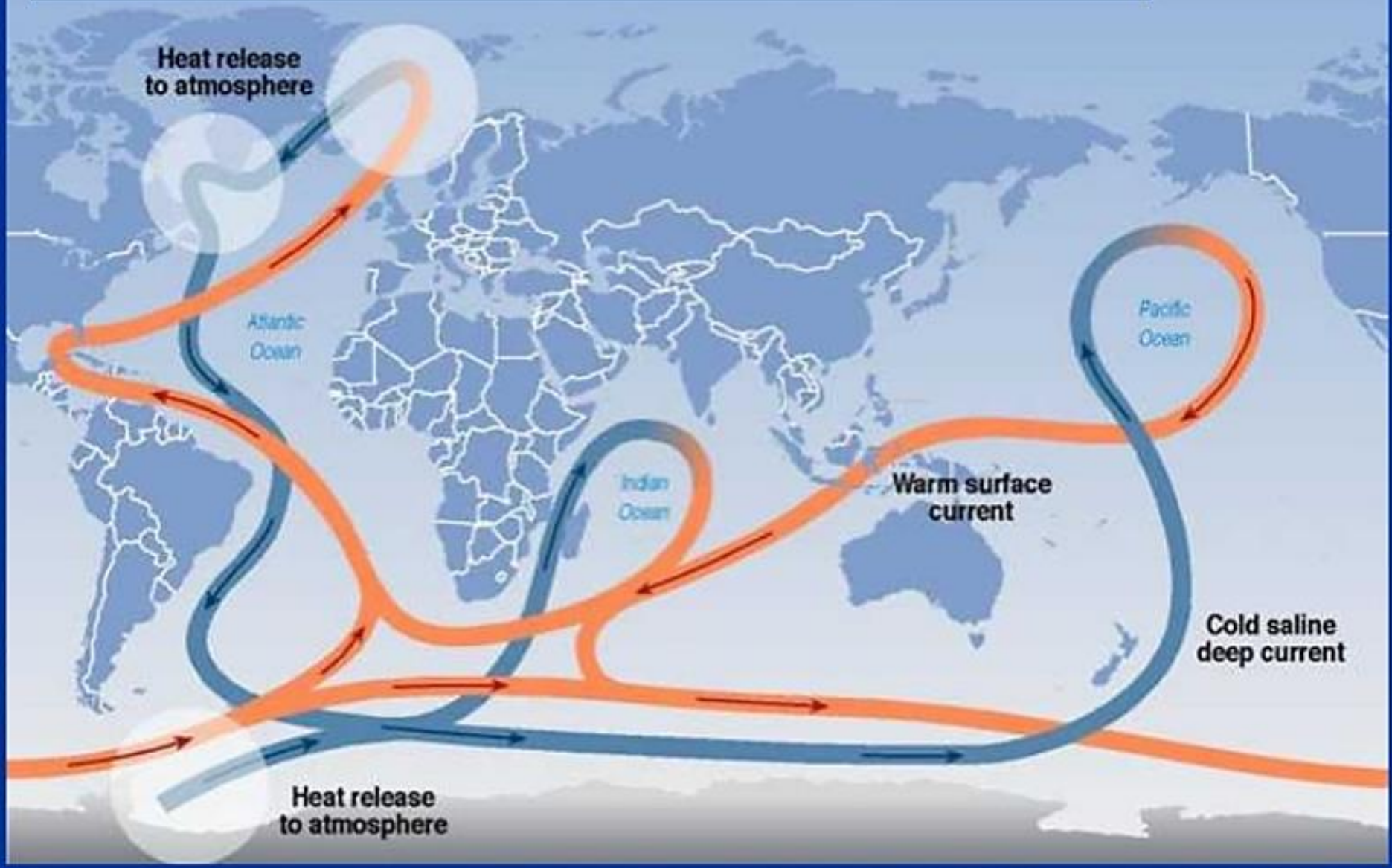
Water Column Profiles



Temperature profiles vary with latitude



Thermohaline Circulation



Ocean Layering

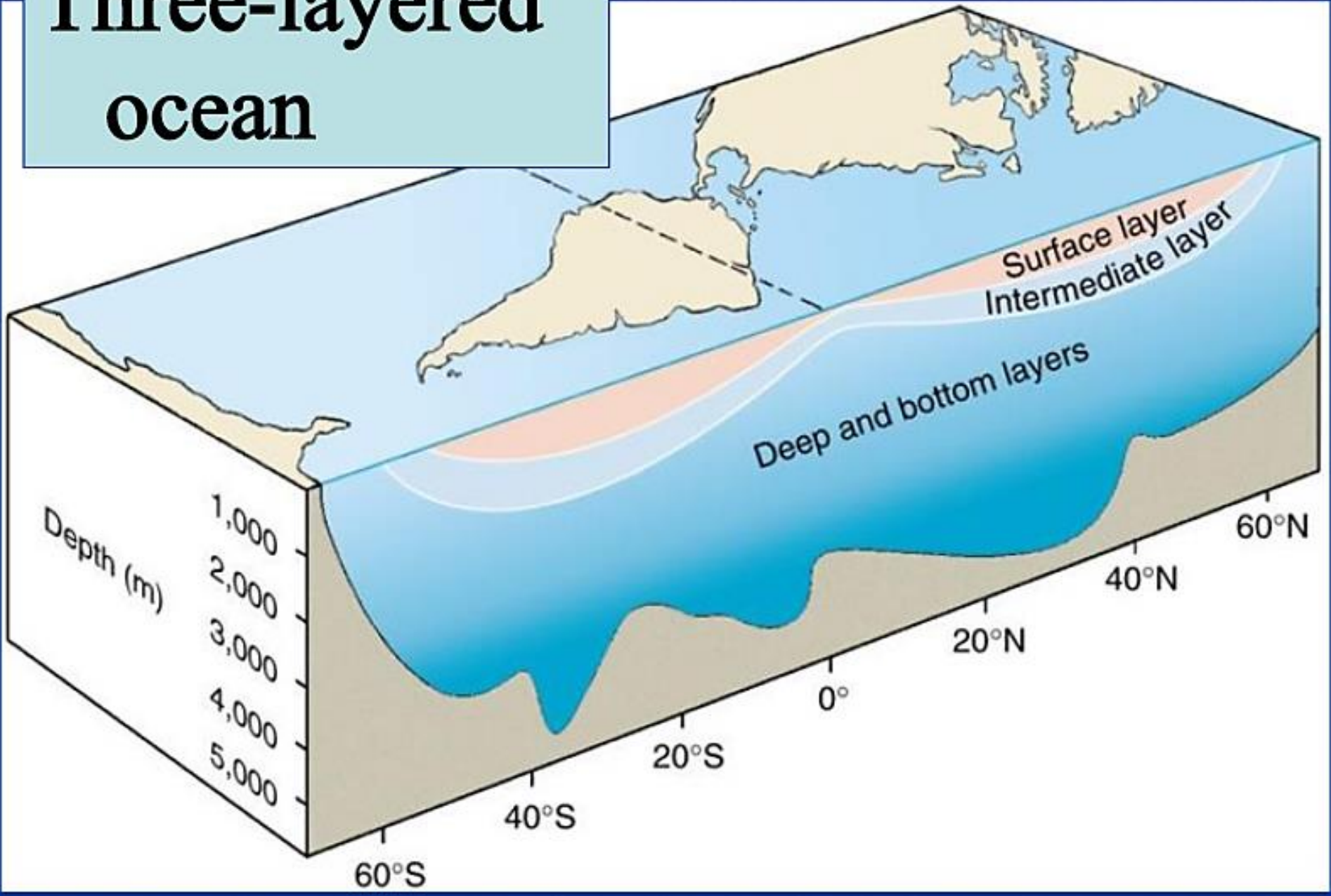
- Despite repeated mixing by winds and currents at the ocean's surface, the ocean is still stratified into three layers:
  - Surface layer – from surface to about 200 meters; this layer stays well mixed most of the year.

Ocean Layering

- Intermediate layer - from 200 - 1500 meters; major temperature change (thermocline) is located here. Less mixing occurs here.

- Bottom layer - below 1500 meters; low mixing and normally uniformly cold.

Three-layered ocean



Major Surface Currents of the Ocean

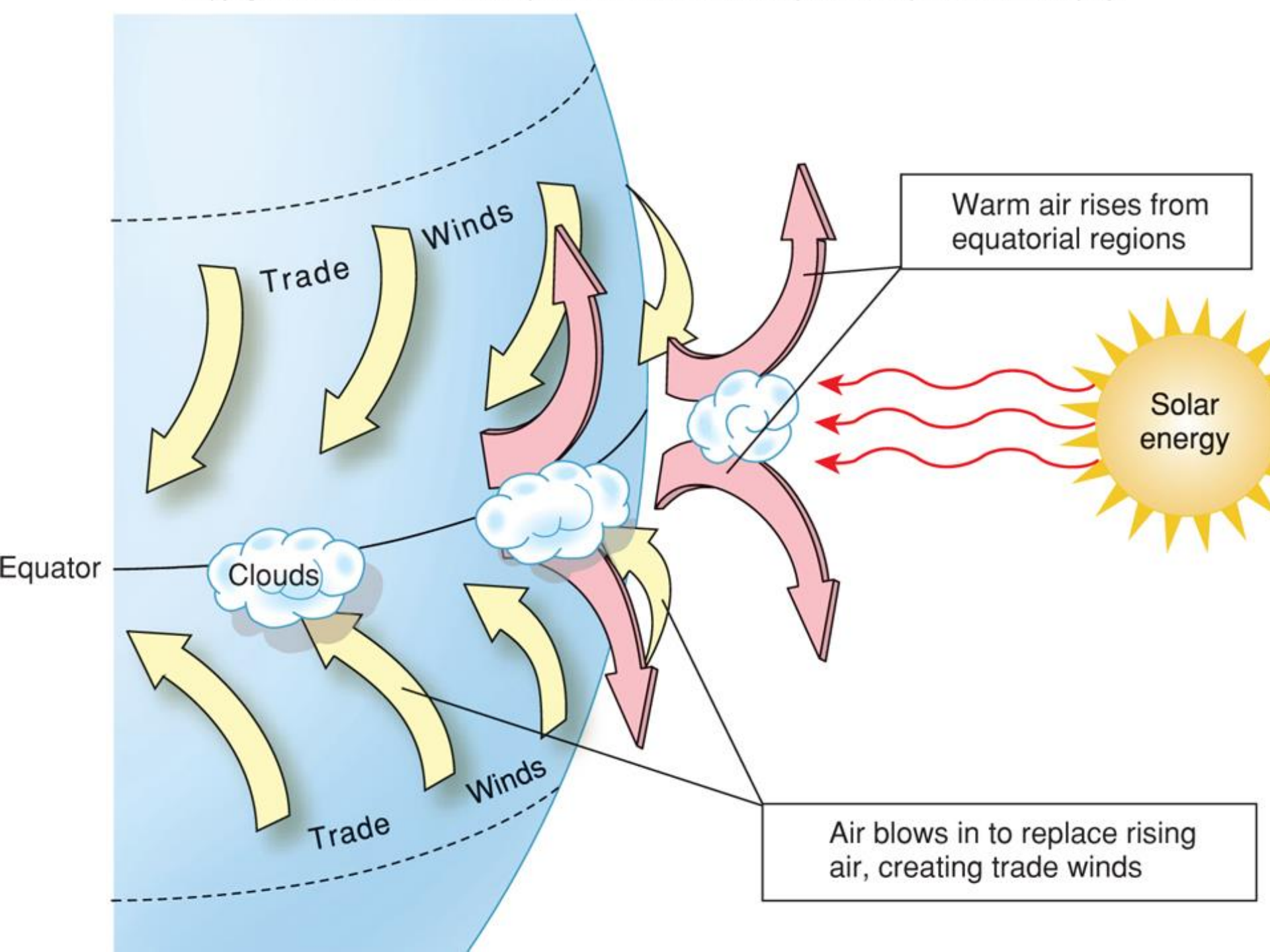
Ocean Circulation

- Circulation within the ocean is significantly driven by wind patterns.

- Winds are ultimately driven by sunlight energy.

Ocean Circulation

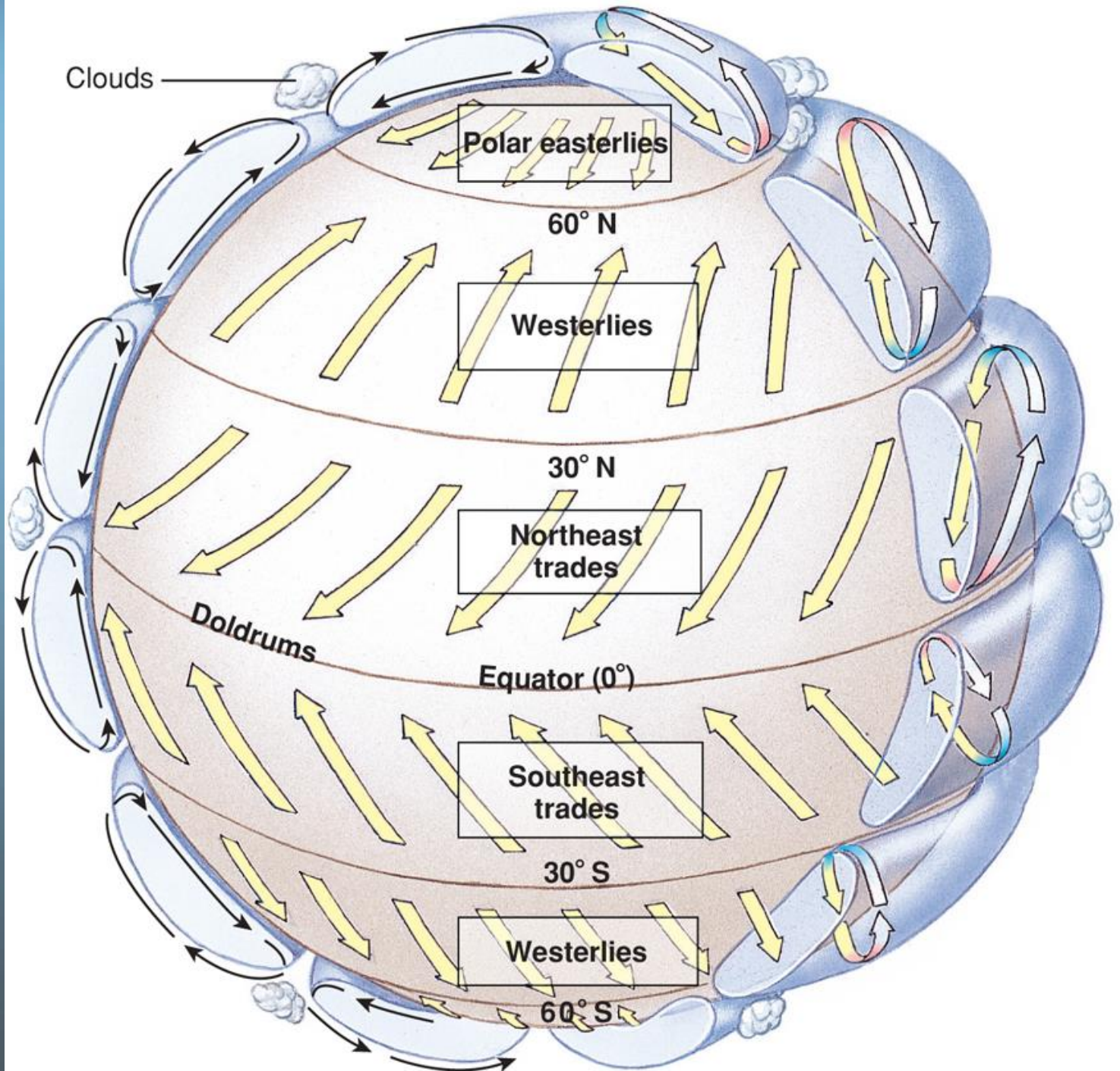
- As sunlight heats air, air rises.
- Cooler air rushes in to take the place of air that has risen.
- This movement is the source of winds.
- Ever notice how the winds at the coast are stronger during the day than at night?


Trade
Winds
Warm air rises from equatorial regions
Solar energy
Equator
Clouds
Trade
Winds
Air blows in to replace rising air, creating trade winds

Ocean Circulation

- Winds created in this manner continuously at the equator are known as the Trade Winds.

- The Westerly's in the mid latitude and the Easterlies at the poles are less consistent than the Trade Winds.



Ocean Circulation

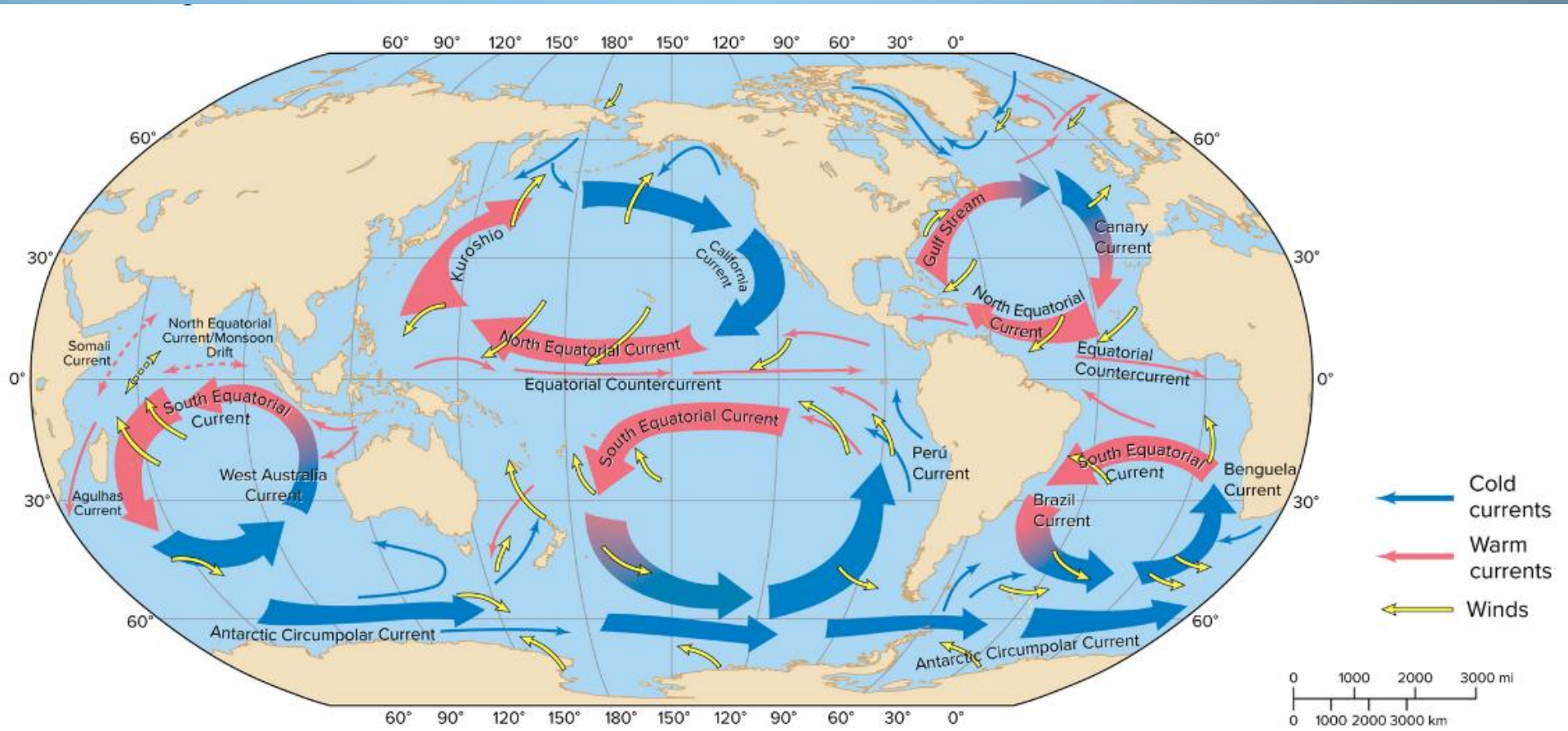


FIGURE 3.20 The major surface currents of the oceans. In the main ocean basins the currents combine to form large circular systems called gyres.

Source: Bill Ober

Ocean Circulation

- Currents are also a product of the wind.
- Current can be in surface layers of deeper water layers.

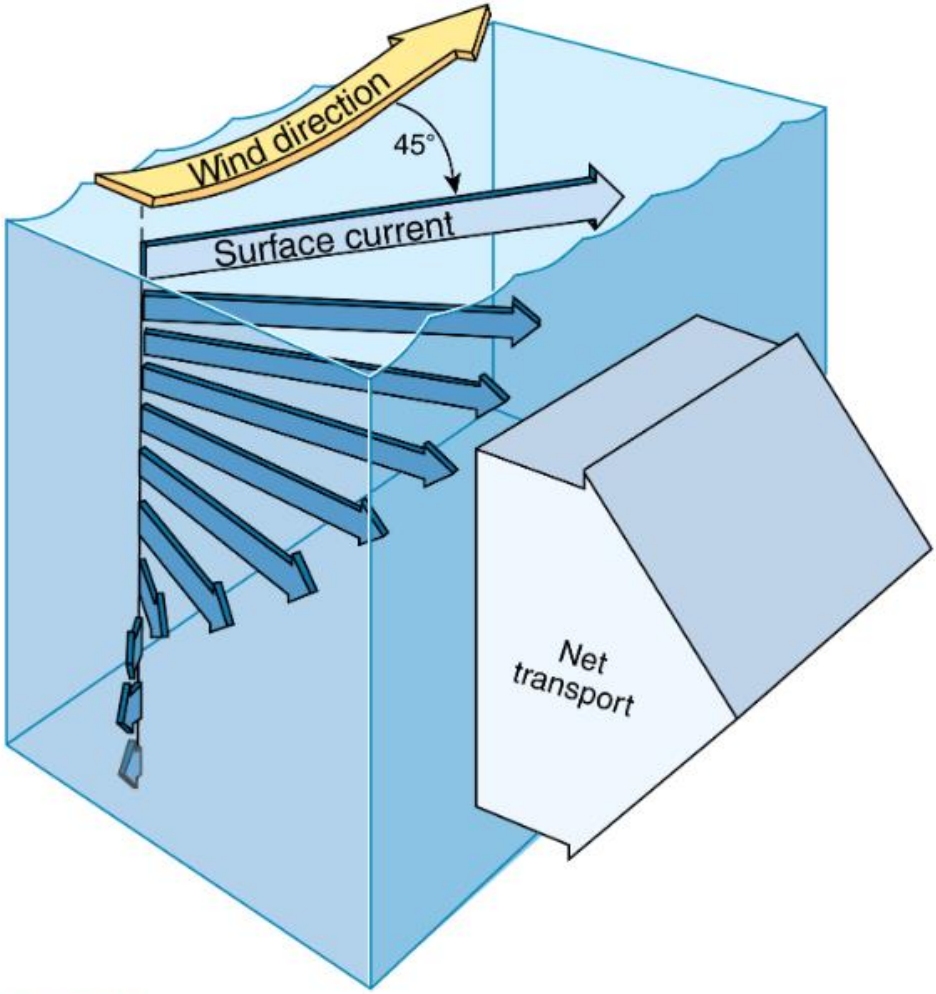
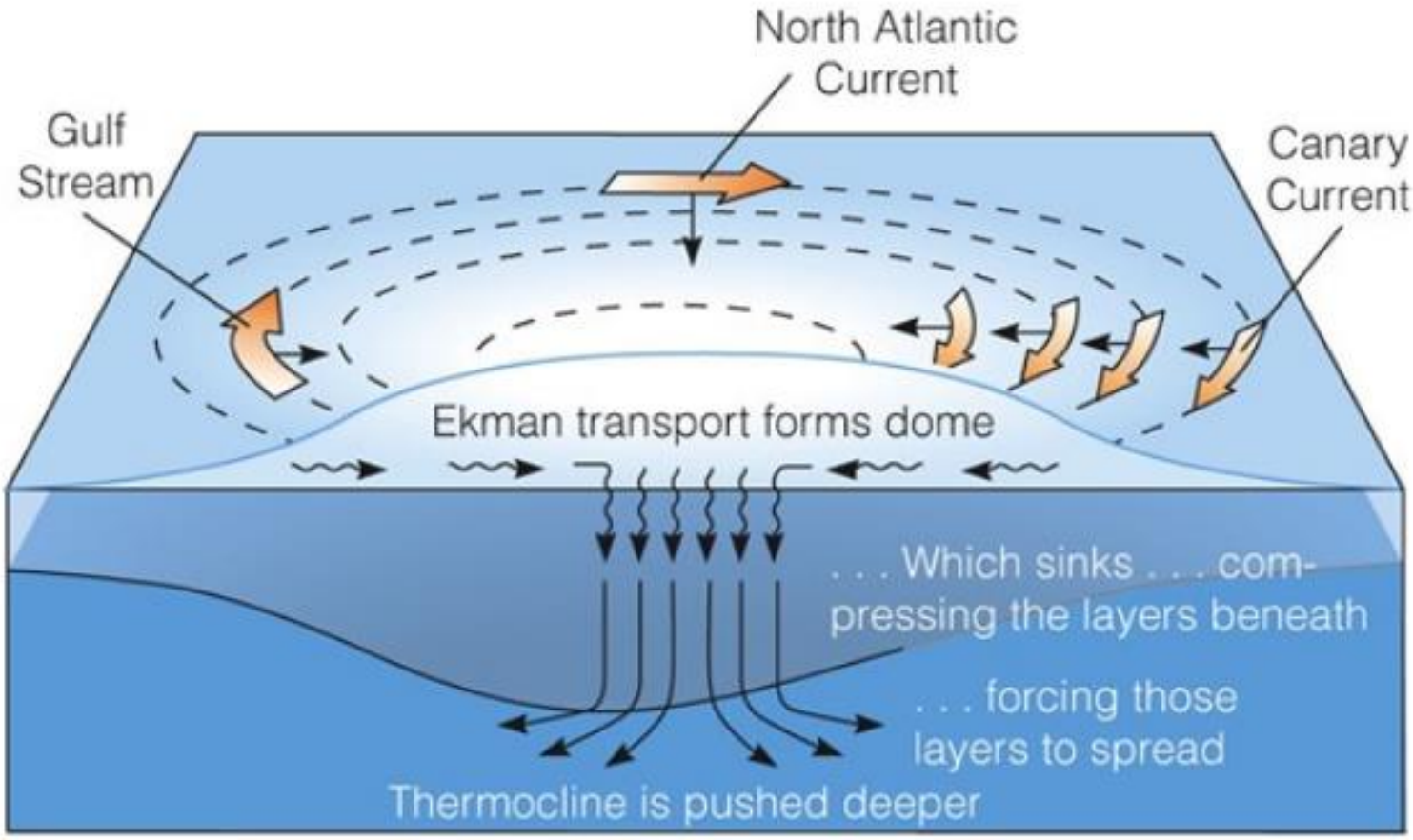


FIGURE 3.19 When a steady wind blows over the sea surface, the uppermost layer moves at 45° from the wind direction. Each deeper layer moves farther to the right in the Northern Hemisphere, shown here, or to the left in the Southern Hemisphere. When the direction of the current at each depth is plotted, the result is a spiral, called the Ekman spiral. The net result of this process is that the affected layer of water, called the Ekman layer, is transported at right angles to the wind direction.

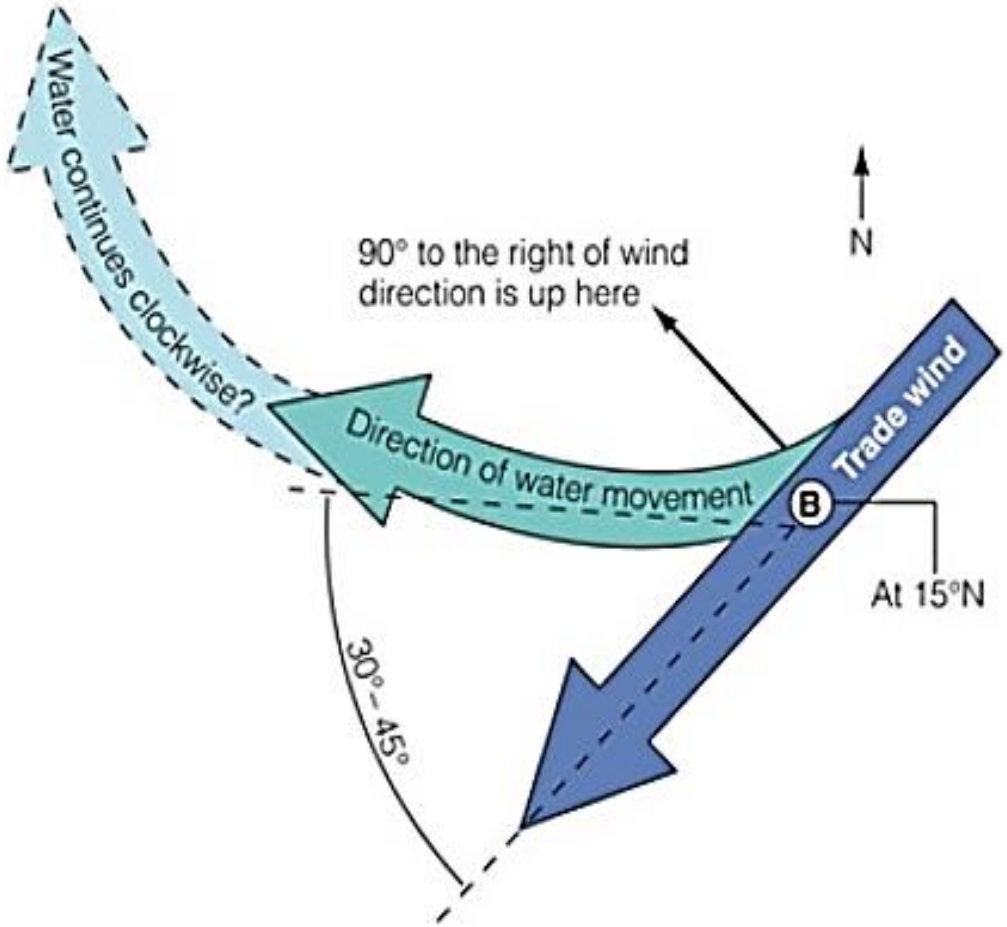
Source: Bill Ober

Ocean Circulation

Ekman Transport



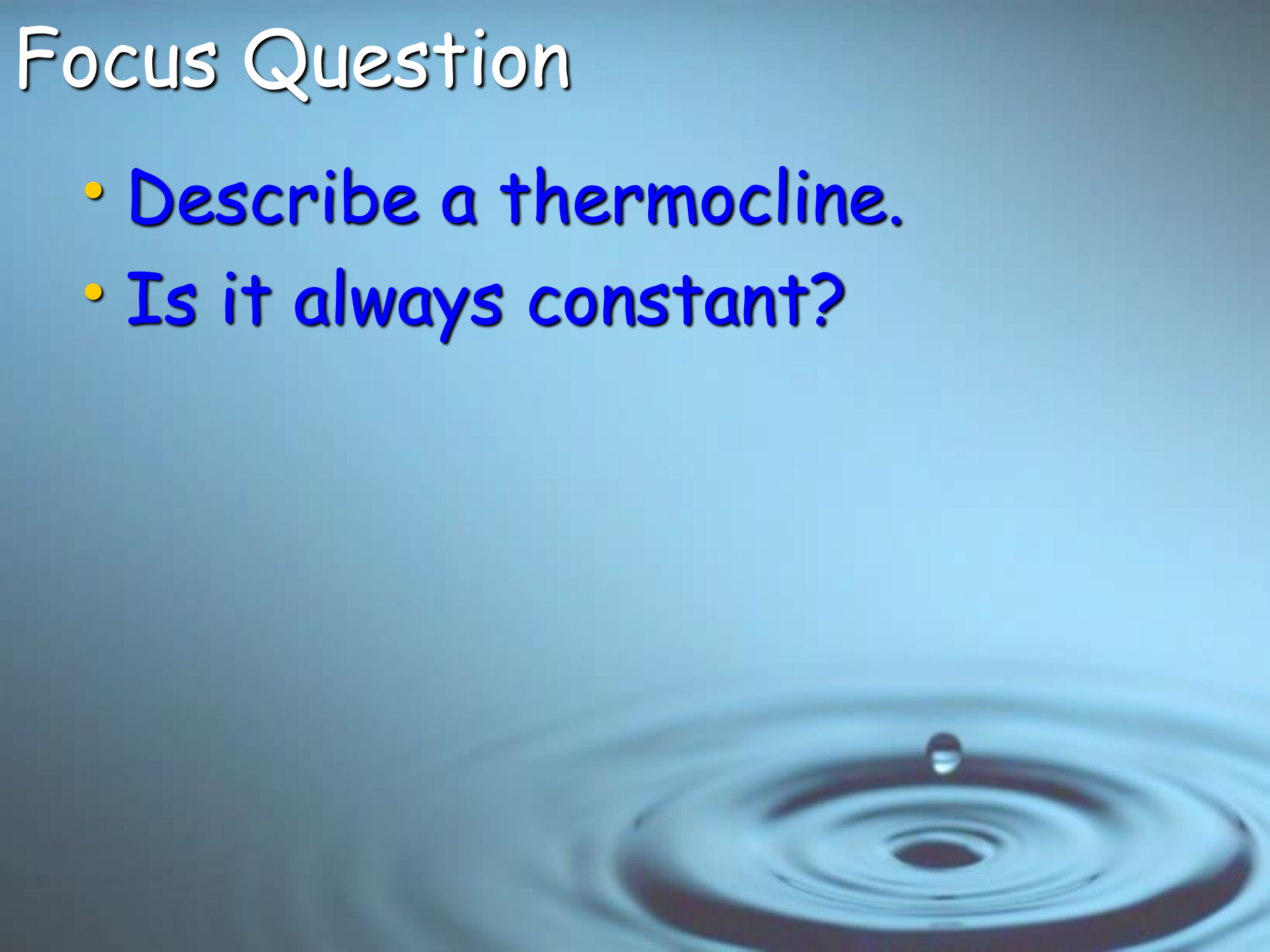
Surface Currents Flow around the Periphery of Ocean Basins



The effect of Ekman spiraling and the Coriolis effect cause the water within a gyre to move in a circular pattern.

Focus Question

- Describe a thermocline.
- Is it always constant?



Focus Question

- **Describe a thermocline.**
  - A thin but distinct layer in a large body of fluid in which temperature changes more rapidly with depth than it does in the layers above or below. In the ocean, the thermocline divides the upper mixed layer from the calm deep water below.
- **Is it always constant?**
  - Varies with location.

Surface Currents Are Driven by the Winds

A combination of four forces – surface winds, the sun's heat, the Coriolis effect, and gravity – circulates the ocean surface clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere, forming gyres.

Surface Currents Are Driven by the Winds

What are some effects of ocean currents?

- Transfer heat from tropical to polar regions
- Influence weather and climate
- Distribute nutrients and scatter organisms

Surface currents are driven by wind:

- Most of Earth's surface wind energy is concentrated in the easterlies and westerlies.
- Due to the forces of gravity, the Coriolis effect, solar energy, and solar winds, water often moves in a circular pattern called a **gyre.**

Ocean Circulation

- Both winds and the currents they drive are affected by the Coriolis Effect.

- Because the earth spins continuously, anything that passes over the earth is deflected.

Major Surface Currents of the Ocean

The Coriolis Effect

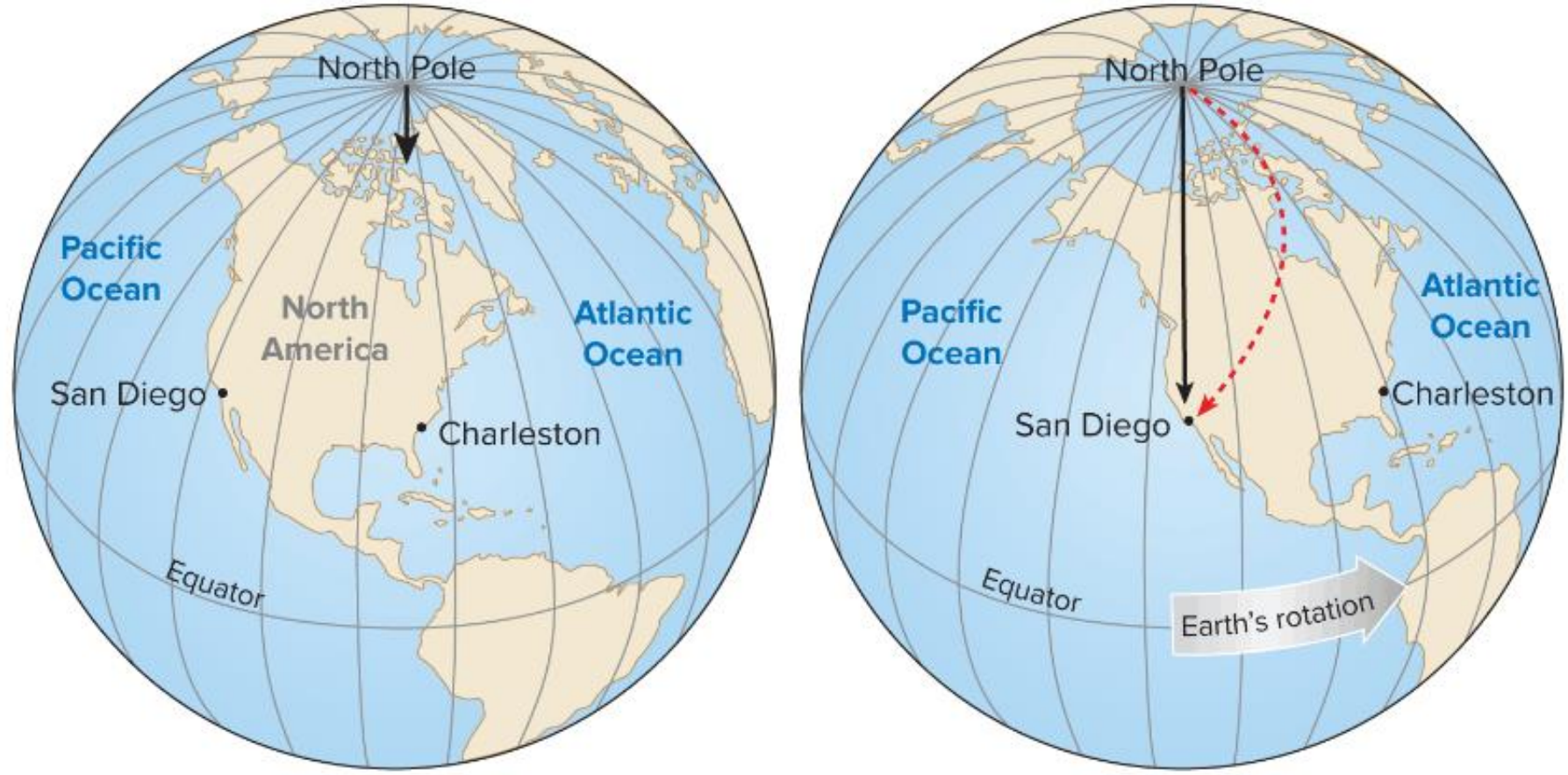


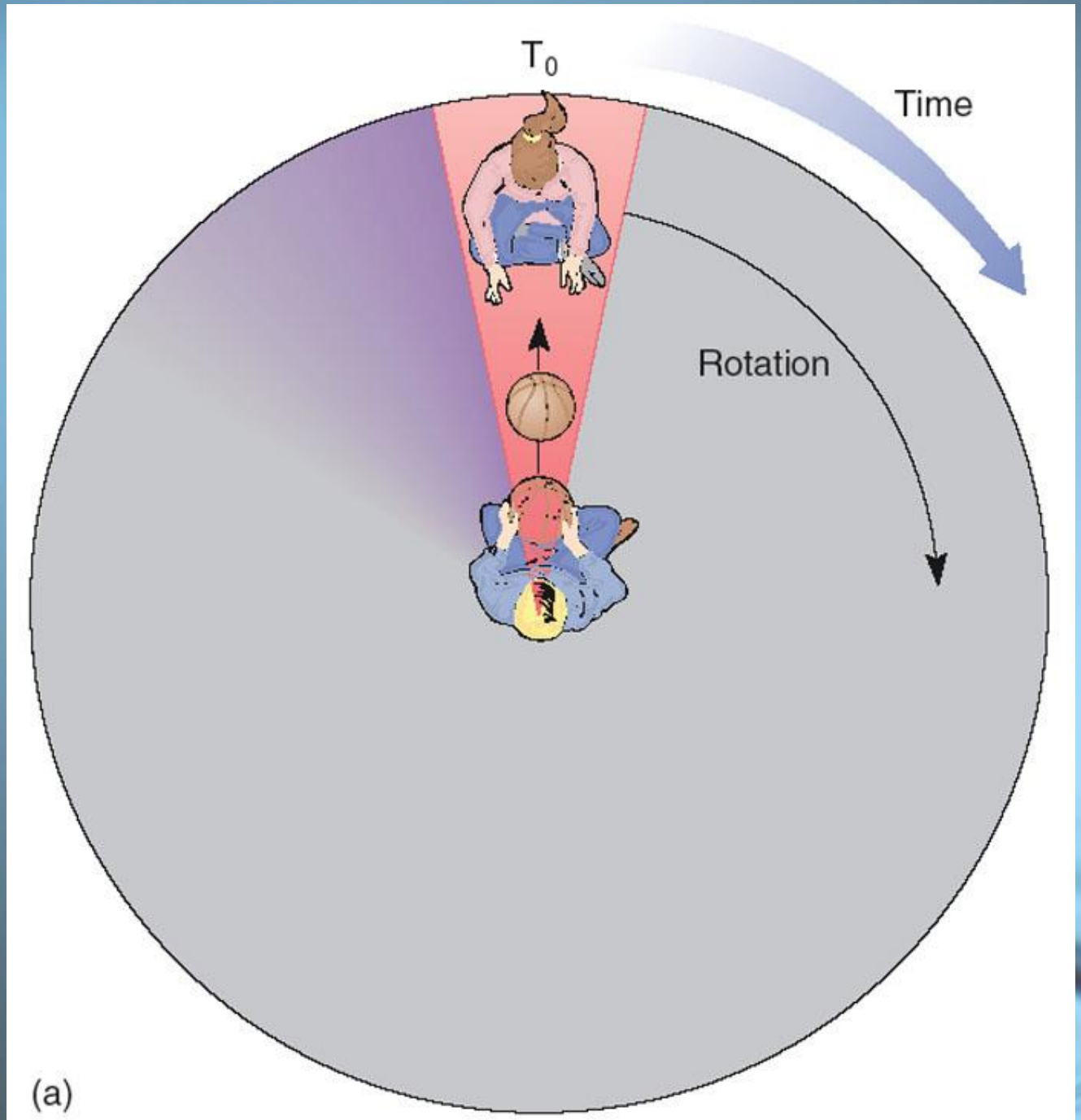
FIGURE 3.16 The Coriolis effect. (*a*) Imagine someone fires a missile at Charleston, North Carolina, from the North Pole. As the missile takes 2½ h to reach Charleston (*b*) Earth rotates under the missile while it is in the air so that the missile ends up hitting San Diego, California. From space it is clear that the missile moved in a straight line (black arrows) and Earth rotated, but to an observer on Earth it looks like the missile curved (red arrow). The Coriolis effect would still apply if the missile was fired from east to west. Can you think of ways to explain this?

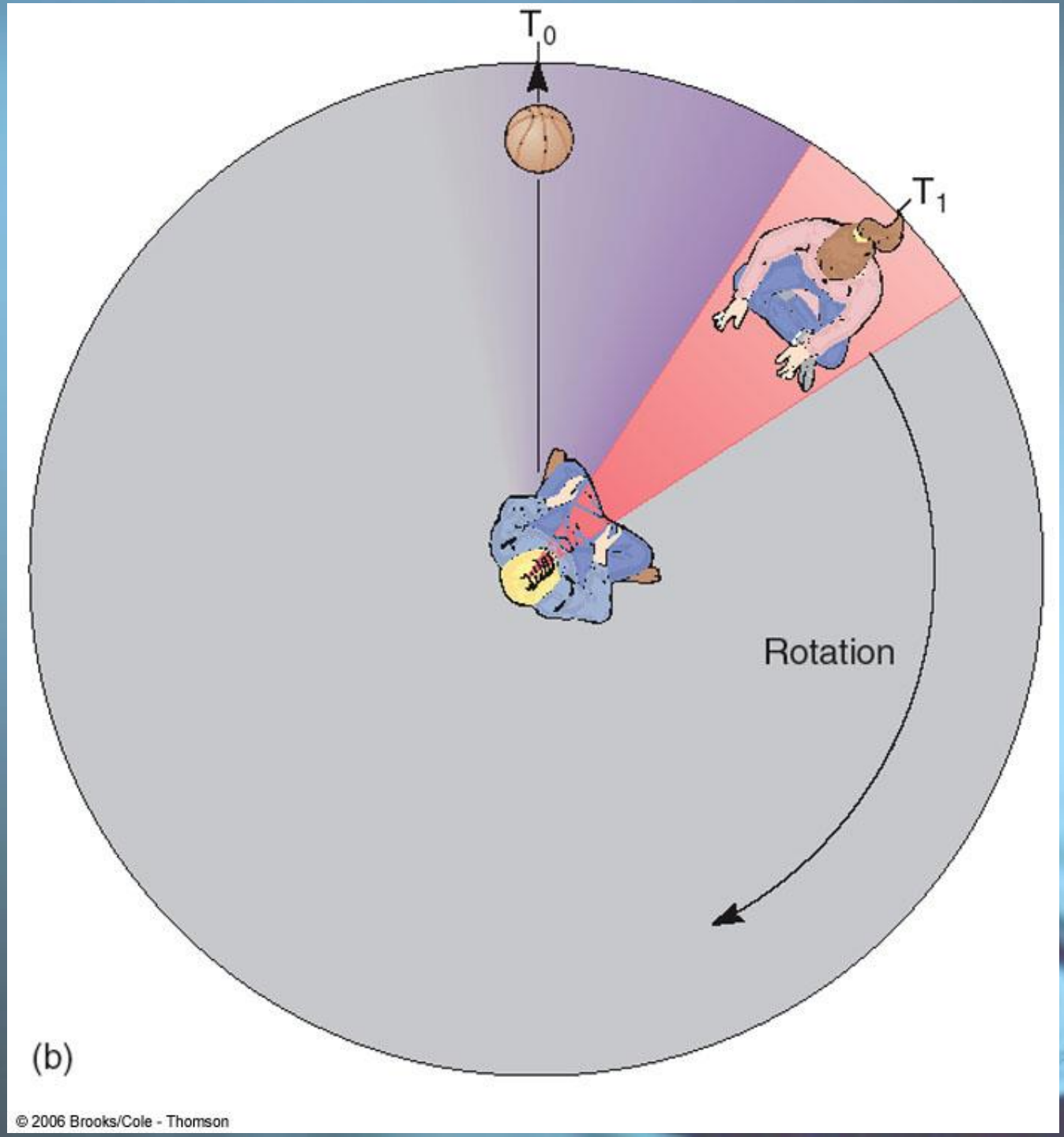
(a & b): Source: Bill Ober

The Coriolis Effect

Winds and Currents

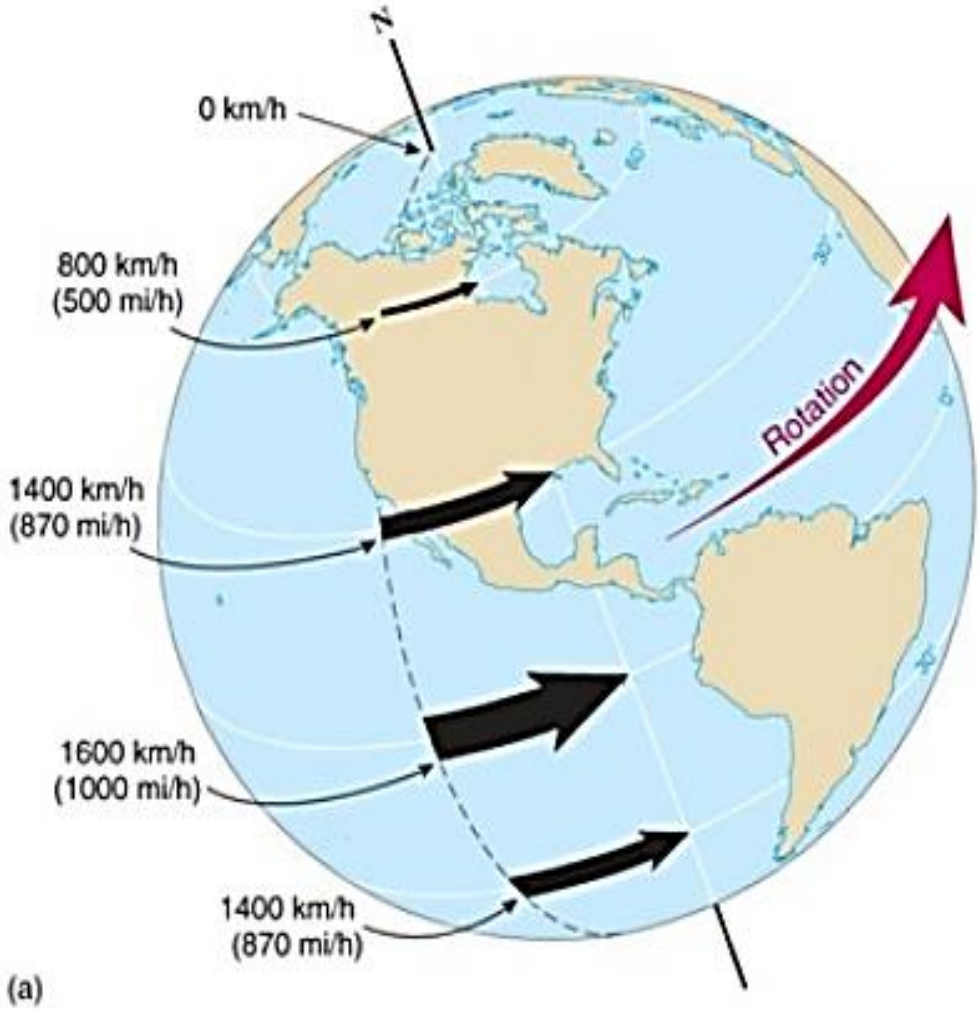
- Winds ~ Coriolis effect
  - a point rotating at the equator moves faster than a point at a higher latitude
  - path of air mass appears to curve relative to the earth's surface—to the right in the Northern Hemisphere, left in the Southern





The Coriolis Effect

The Coriolis Effect



Ocean Circulation

- In the northern hemisphere, winds and currents are deflected to the right.

- In the southern hemisphere, winds and currents are deflected to the left.

Ocean Circulation

- This deflection termed the Coriolis Effect. Since the Earth is spinning, it causes this deflection of winds and currents.

- This deflection often causes currents to travel in circular patterns called gyres.

Ocean Circulation

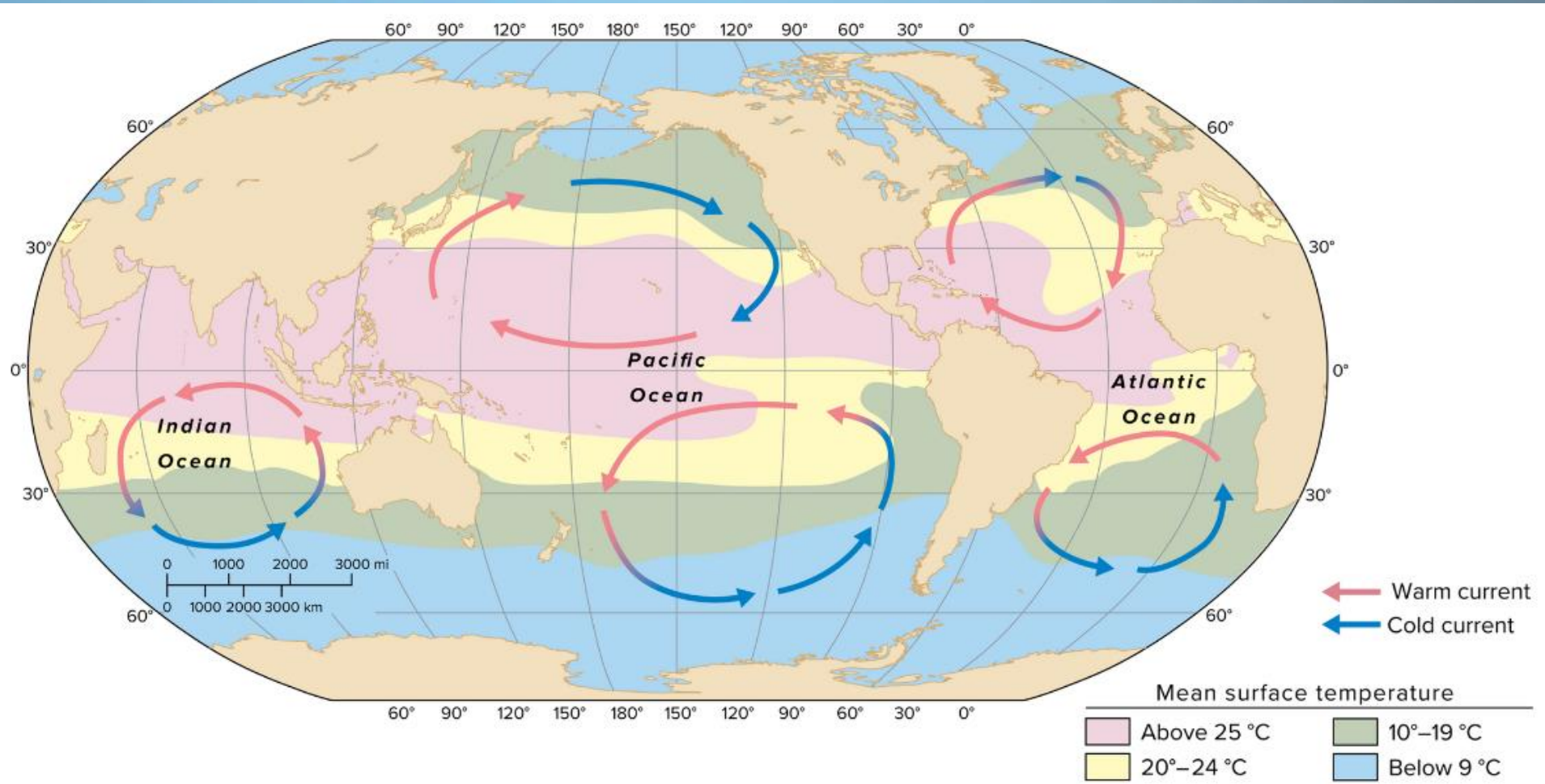
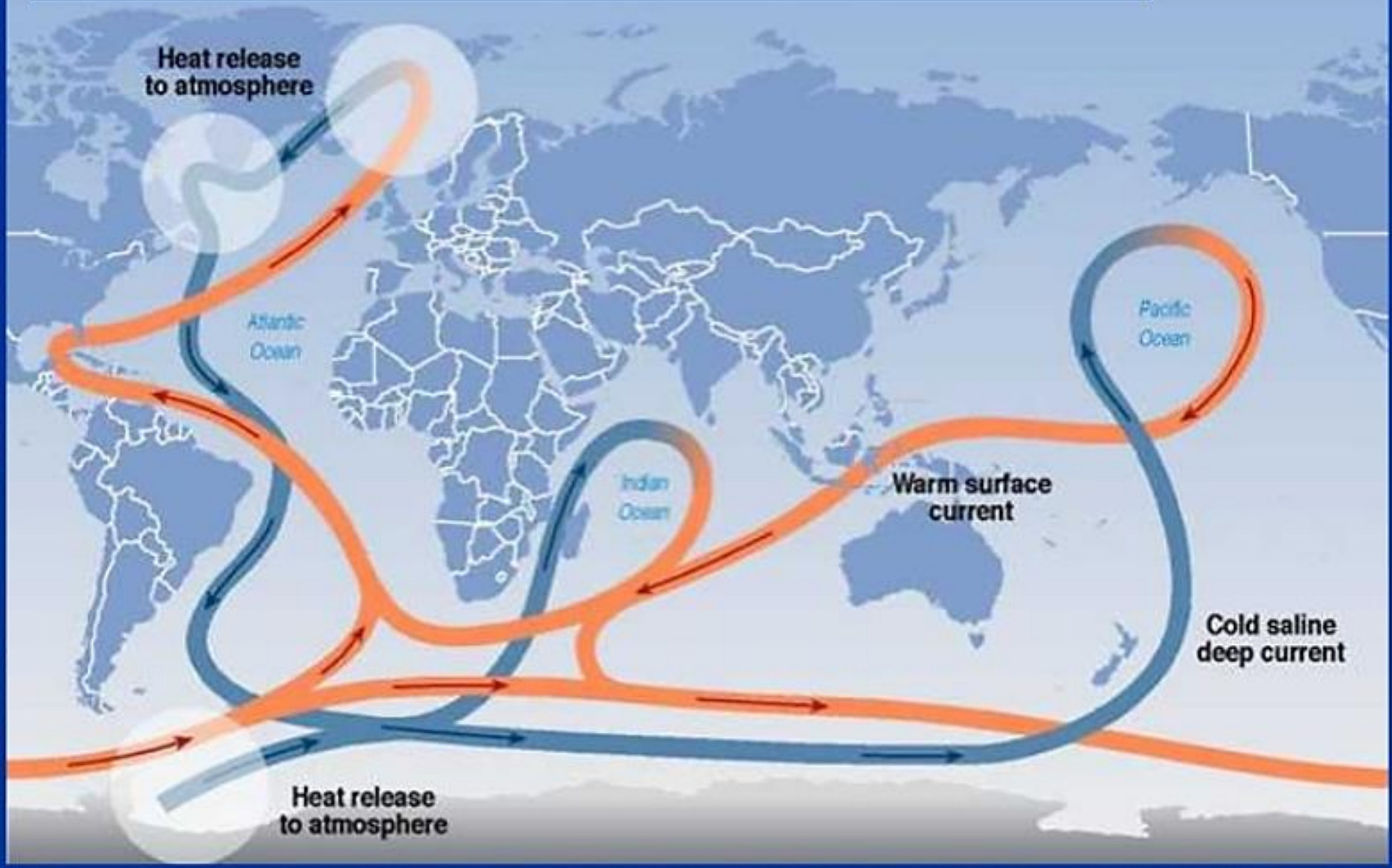


FIGURE 3.21 The average sea-surface temperature of the oceans is strongly affected by the ocean gyres.

Source: Bill Ober

Thermohaline Circulation



Major Surface Currents of the Ocean

- 5:29 – 16:43

Ocean Circulation

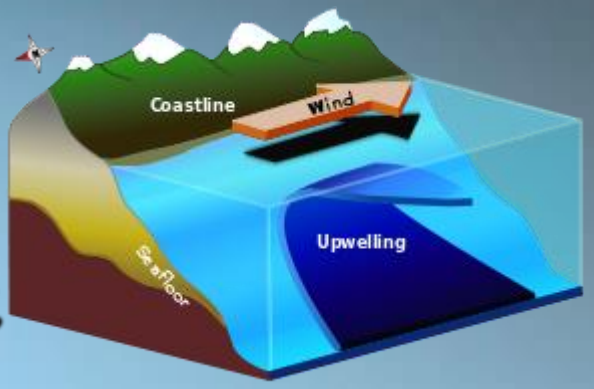
- Some of the differences seen in different parts of the ocean are due to circulation patterns.

- Circulation can occur as waves, tides, currents and gyres.

Ocean Circulation

- In some locations, large volumes of water may sink or rise.
- Water sinks due to changes in temperature and salinity – this is known as an area of down-welling.
- Down-welling brings gases from the surface to deeper layers.

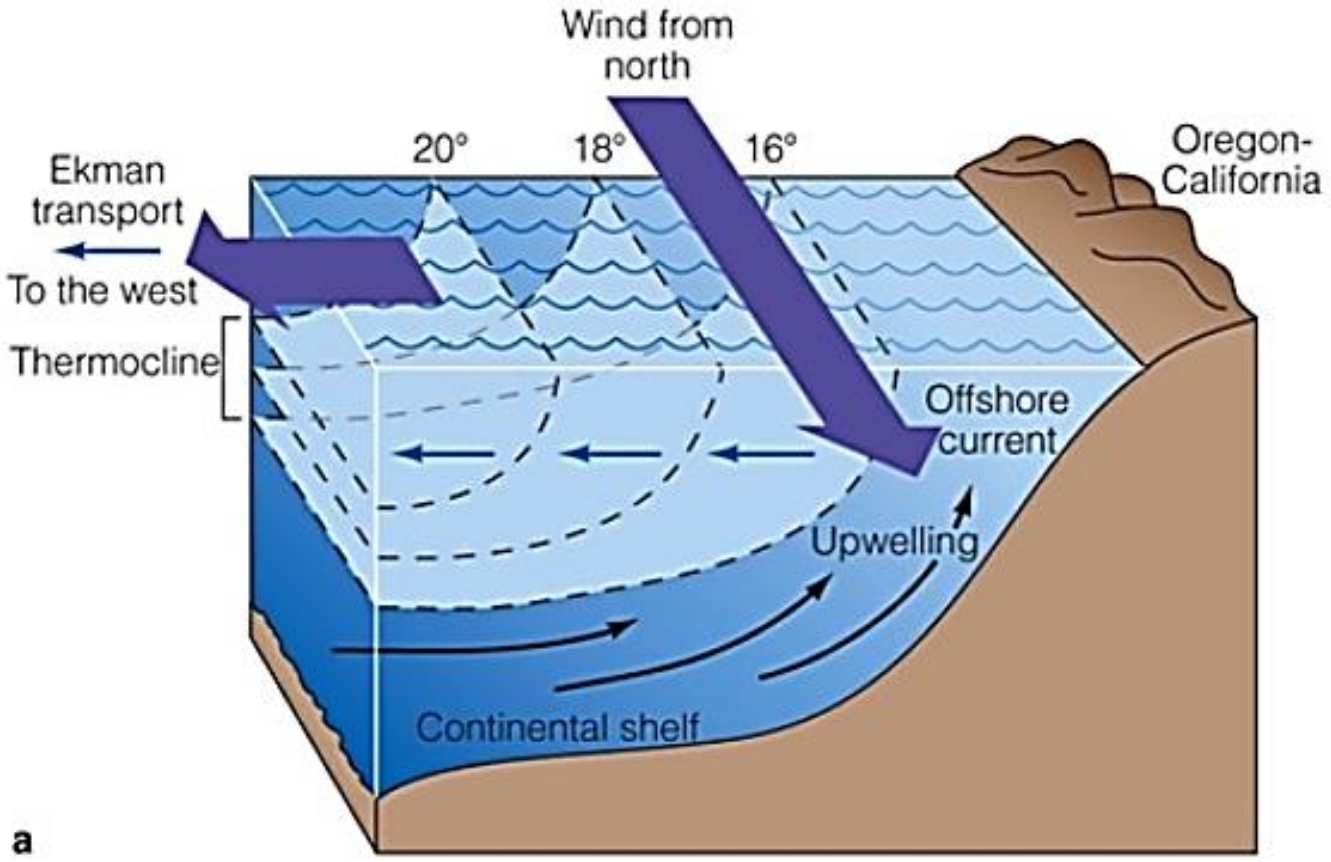
Ocean Circulation



- Areas of upwelling come from currents that push deeper waters toward the surface.
- Nutrients are much more plentiful in the deeper layers, so these areas of upwelling are beneficial for organisms in an upwelling area.

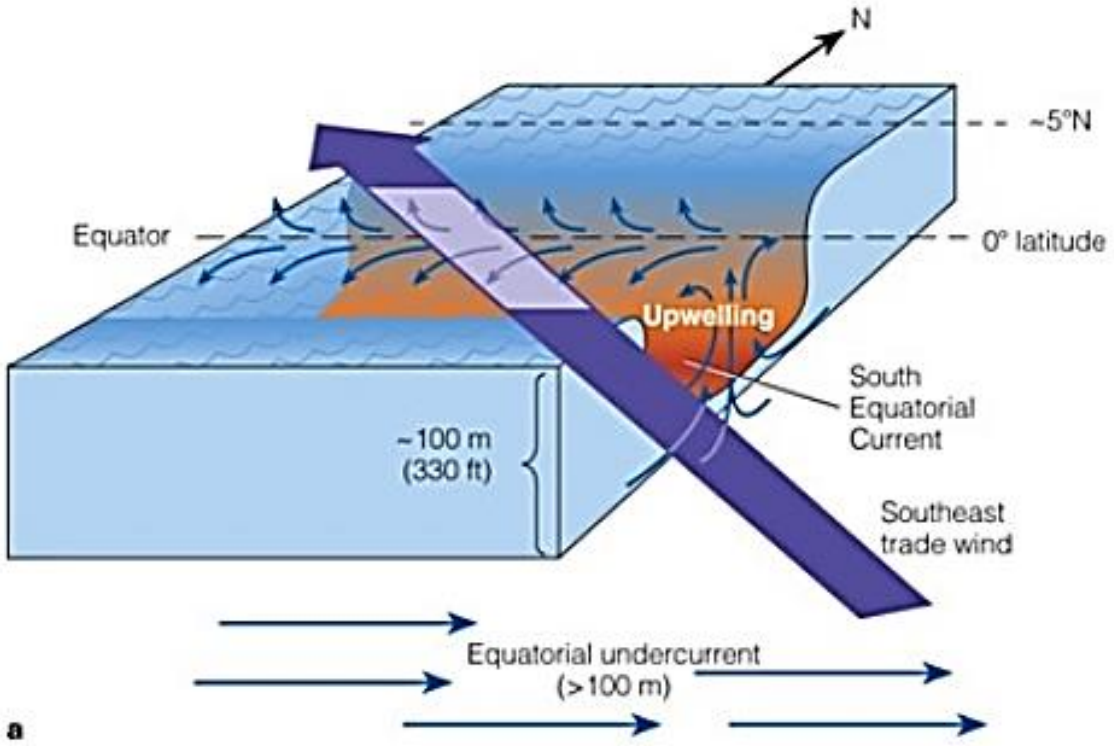
Wind Can Induce Upwelling near Coasts

Coastal upwelling: Northern Hemisphere: caused by winds from the north blowing along the west coast of a continent.



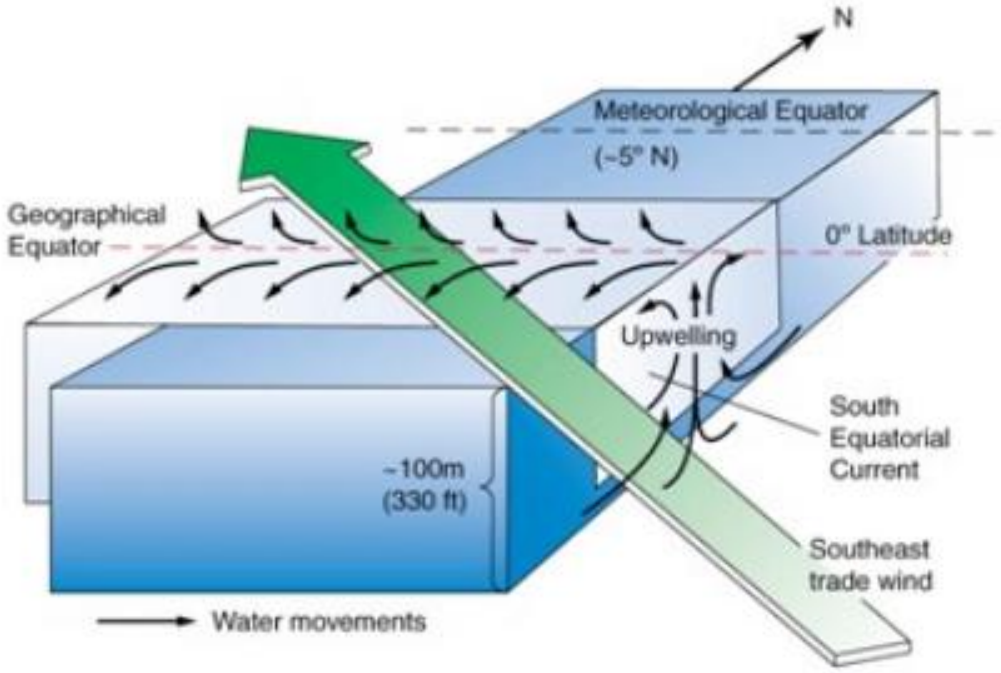
Nutrient-Rich Water Rises near the Equator

- ***Upwelling*** is the upward motion of water. This motion brings cold, nutrient rich water towards the surface.



Other types of upwelling

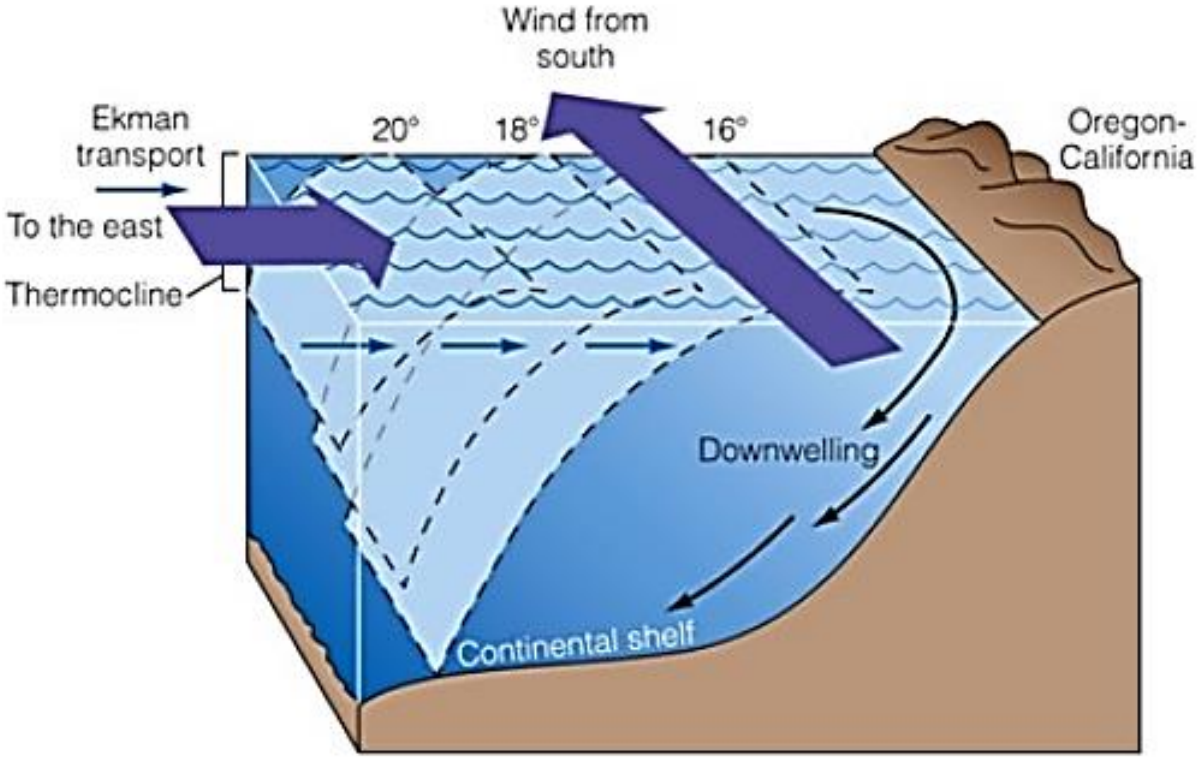
- Equatorial upwelling
- Offshore wind
- Sea floor obstruction
- Sharp bend in coastal geometry



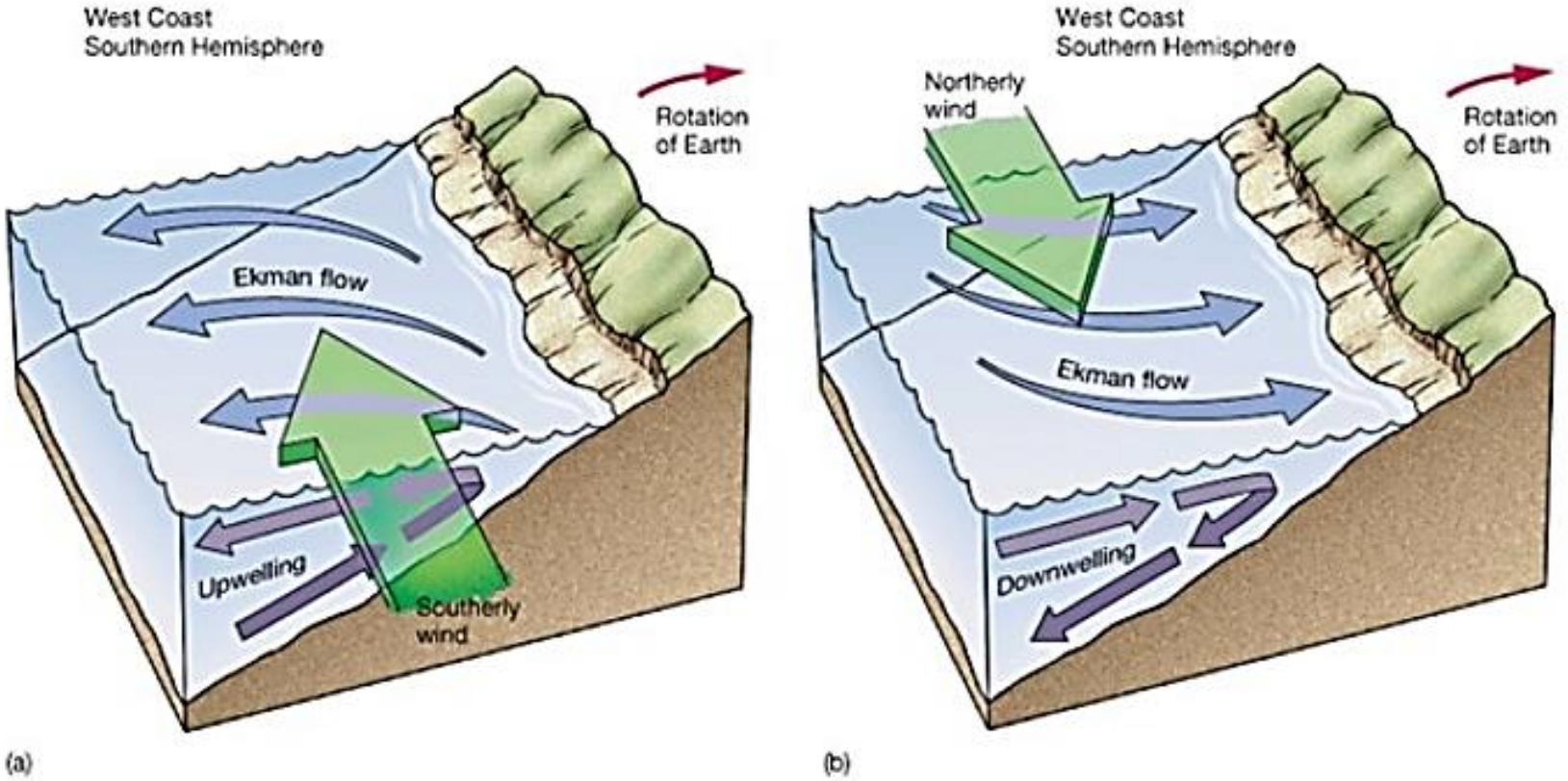
Equatorial upwelling

Wind Can Also Induce Coastal Downwelling

Coastal Downwelling : Areas of downwelling are often low in nutrients and therefore relatively low in biological productivity.



Coastal upwelling and downwelling



Waves

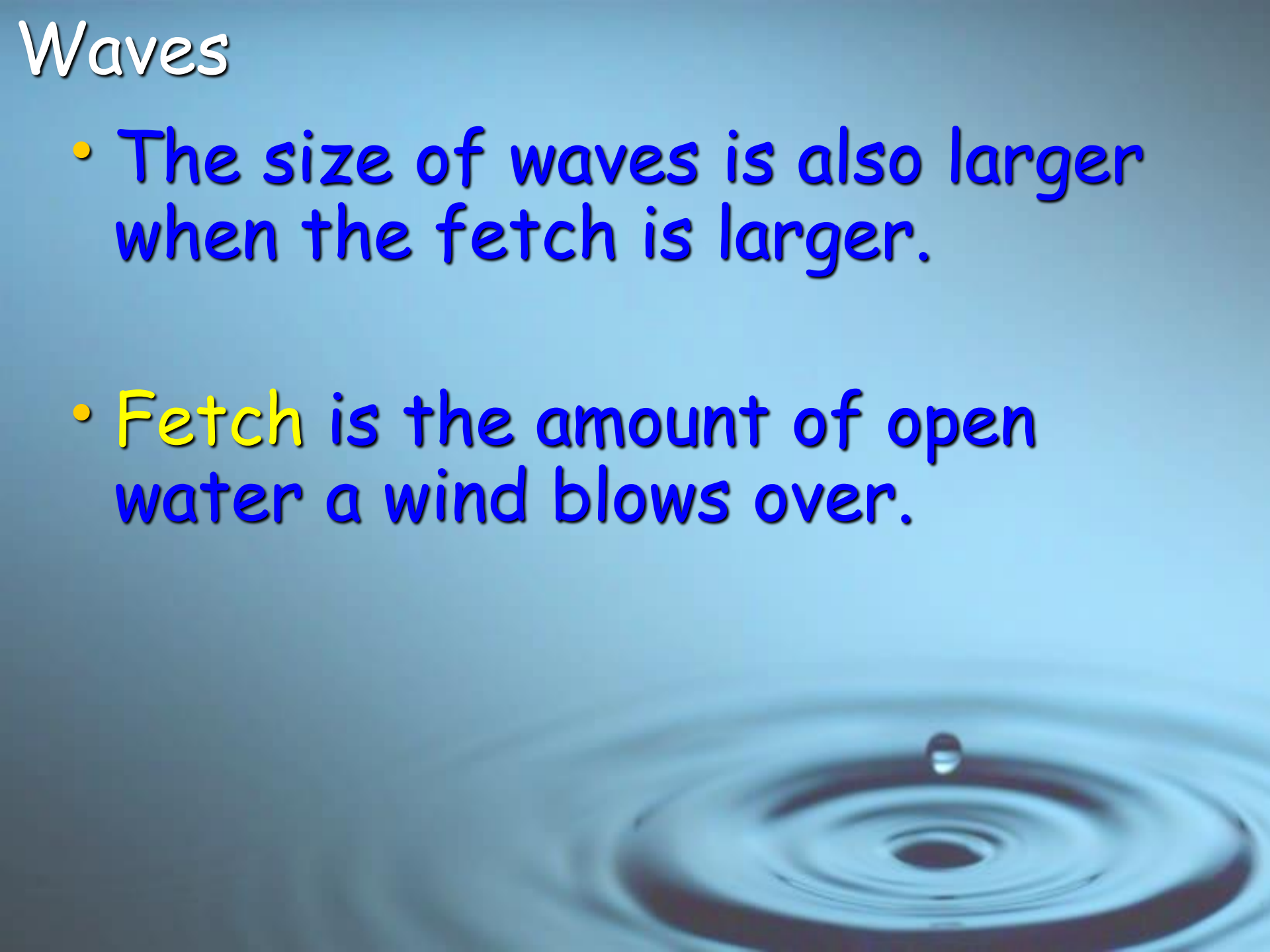
- Waves are the result of wind blowing over the water's surface.

- The size of waves depends on how long and fast the wind blows; longer and faster equals a larger wave.

Waves

- The size of waves is also larger when the fetch is larger.

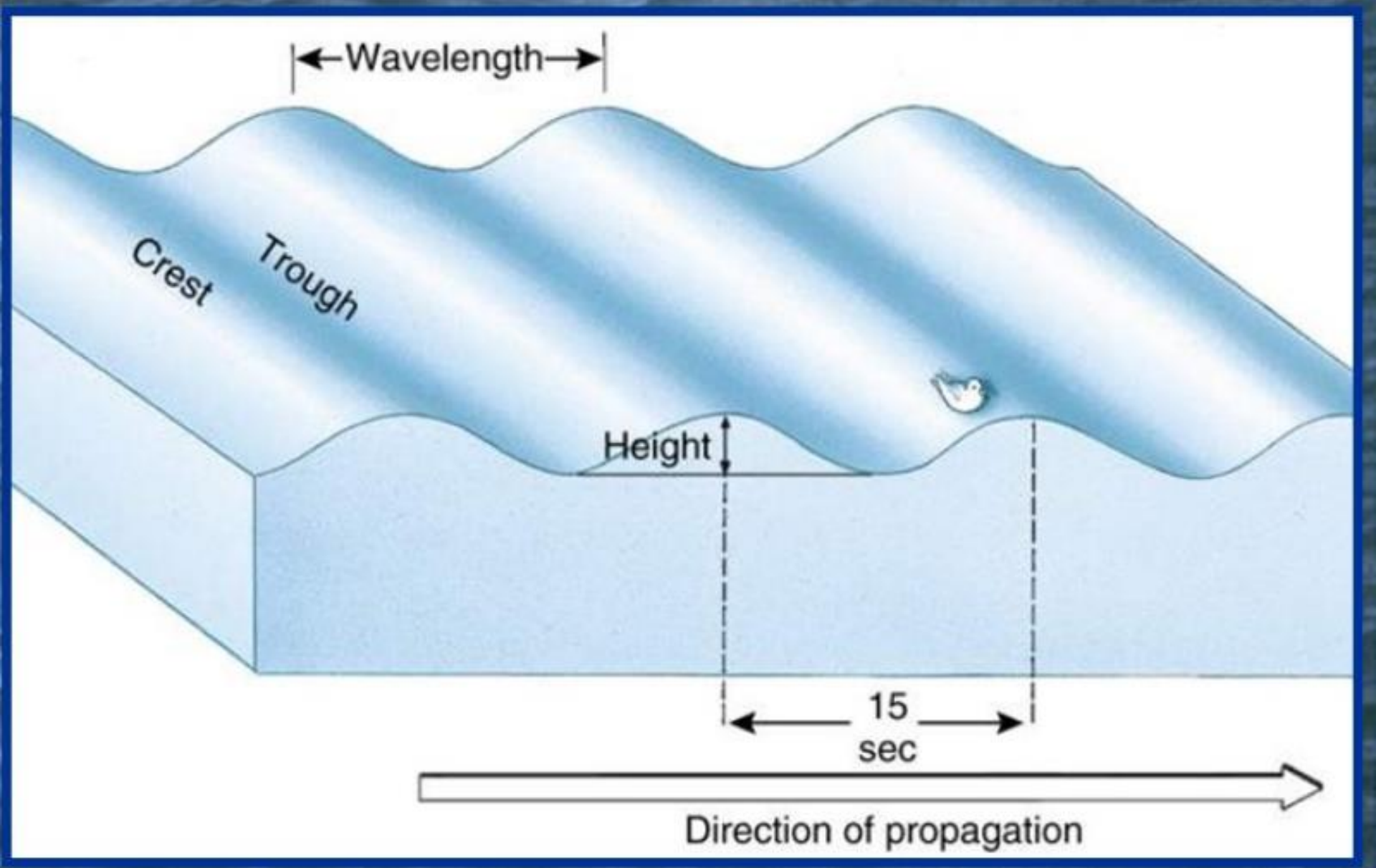
- Fetch is the amount of open water a wind blows over.



Waves

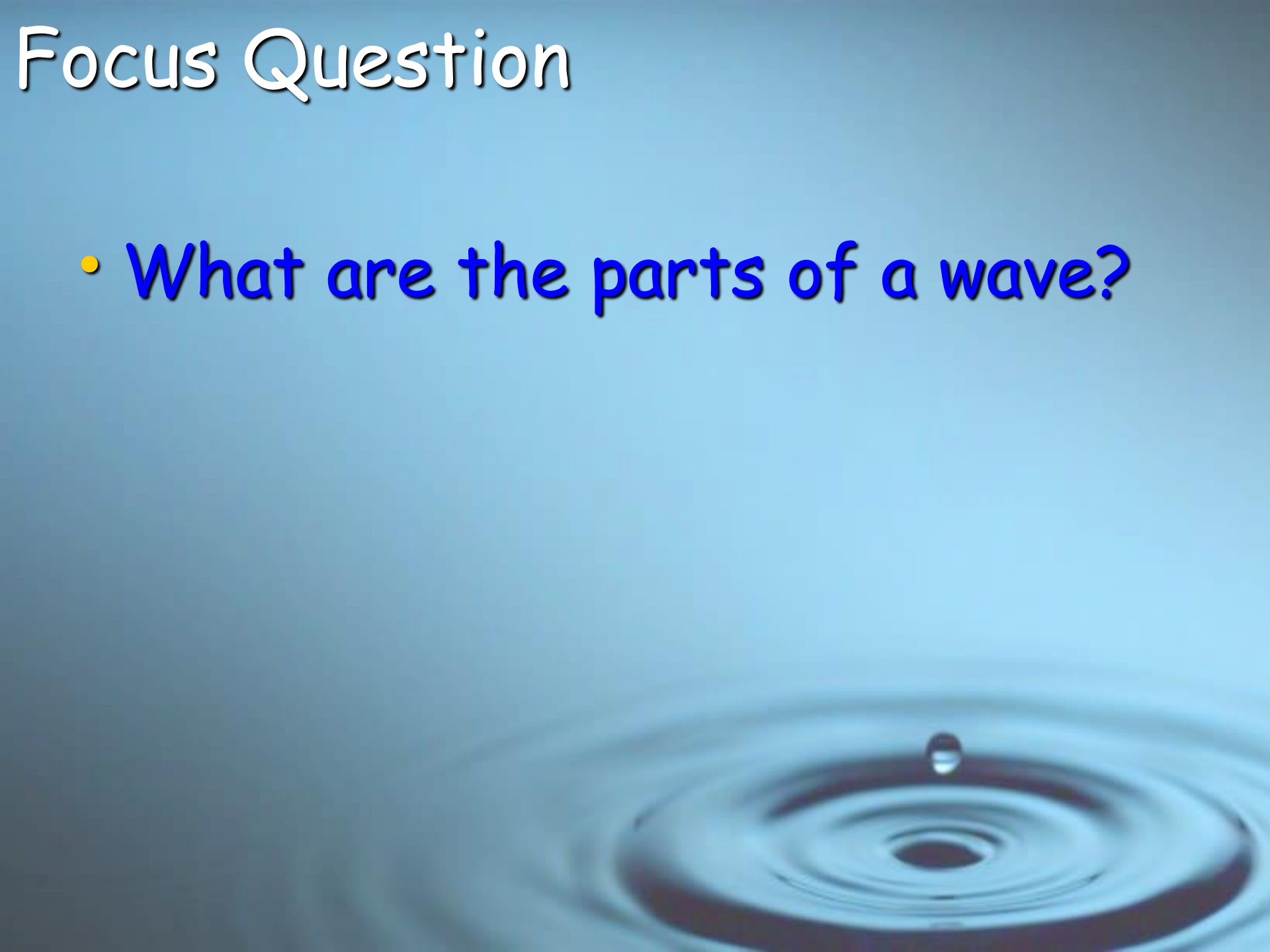
- The highest point of a wave is the crest, the lowest point is the trough.
- The distance between two crests (or two troughs) is the wavelength.
- The time is takes for a wave to pass by a set point is the wave period.

Wave Structure

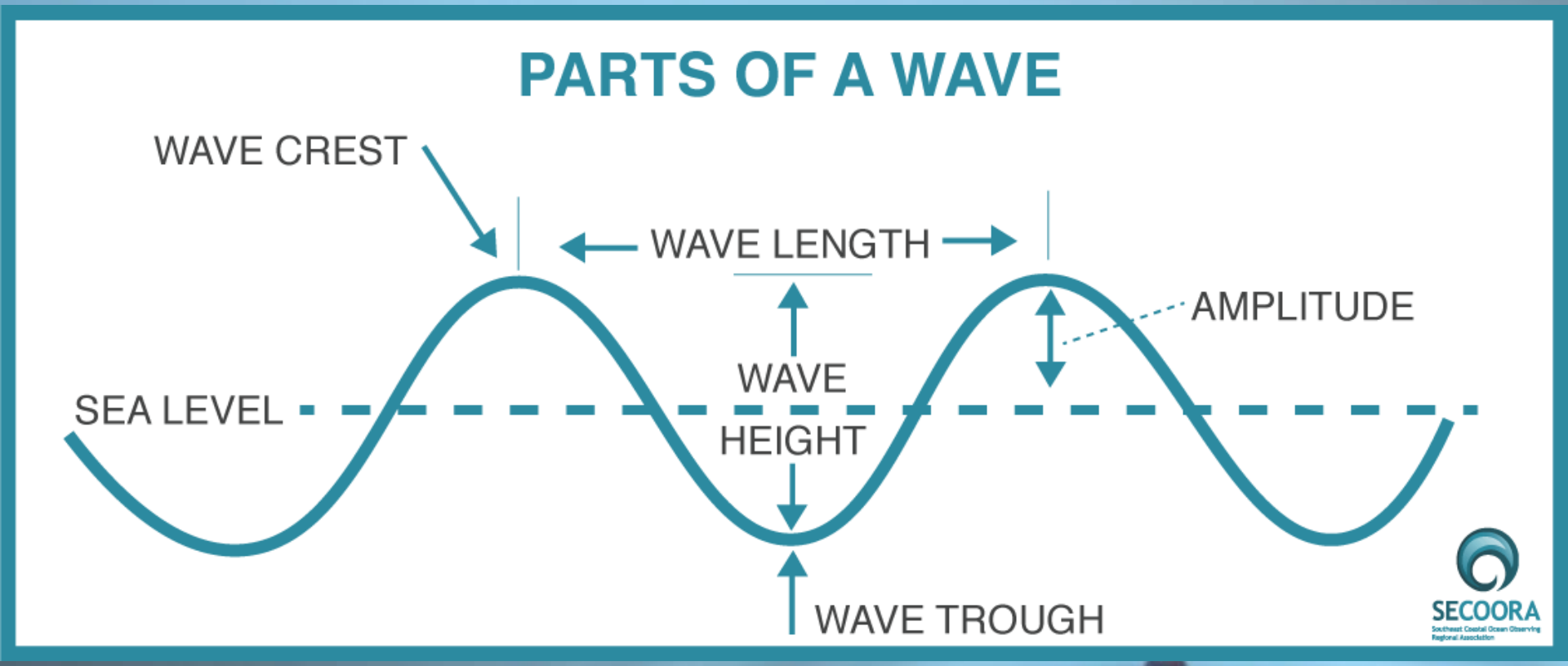


Focus Question

- What are the parts of a wave?



Focus Question



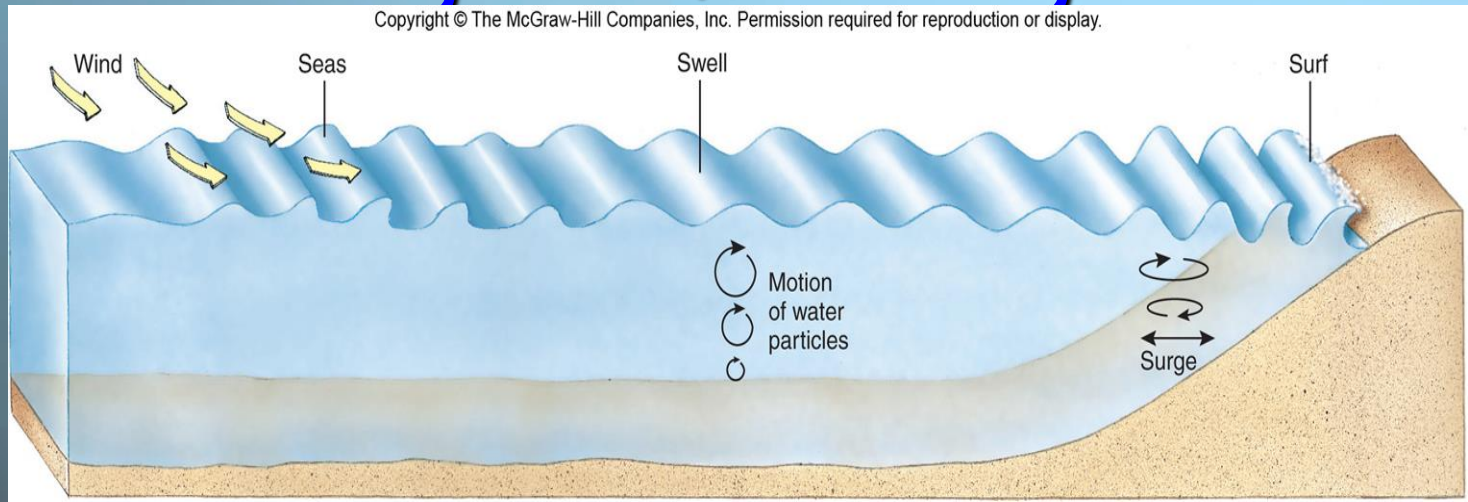
Tides

- As waves near the shore (shallower water), the bottom of the wave "drags" the bottom.

- This forces the waves to slow and move closer together (shorter wavelength).

Tides

- Eventually, the "drag" causes the wave crest to fall over - we call this a wave break. The surf caused from breaking waves displaces lots of sand which affects the organisms living there.



Tides

Tides

- $=>_{df}$ The periodic short term changes in the height (rise or fall) of the ocean surface at a particular place.

- Caused by a combination of:
  - Distance between the Earth, moon and sun
  - Gravitational force of the moon and the sun and the motion of the Earth
  - Moon's influences 2x's the sun's (it is closer to the Earth).

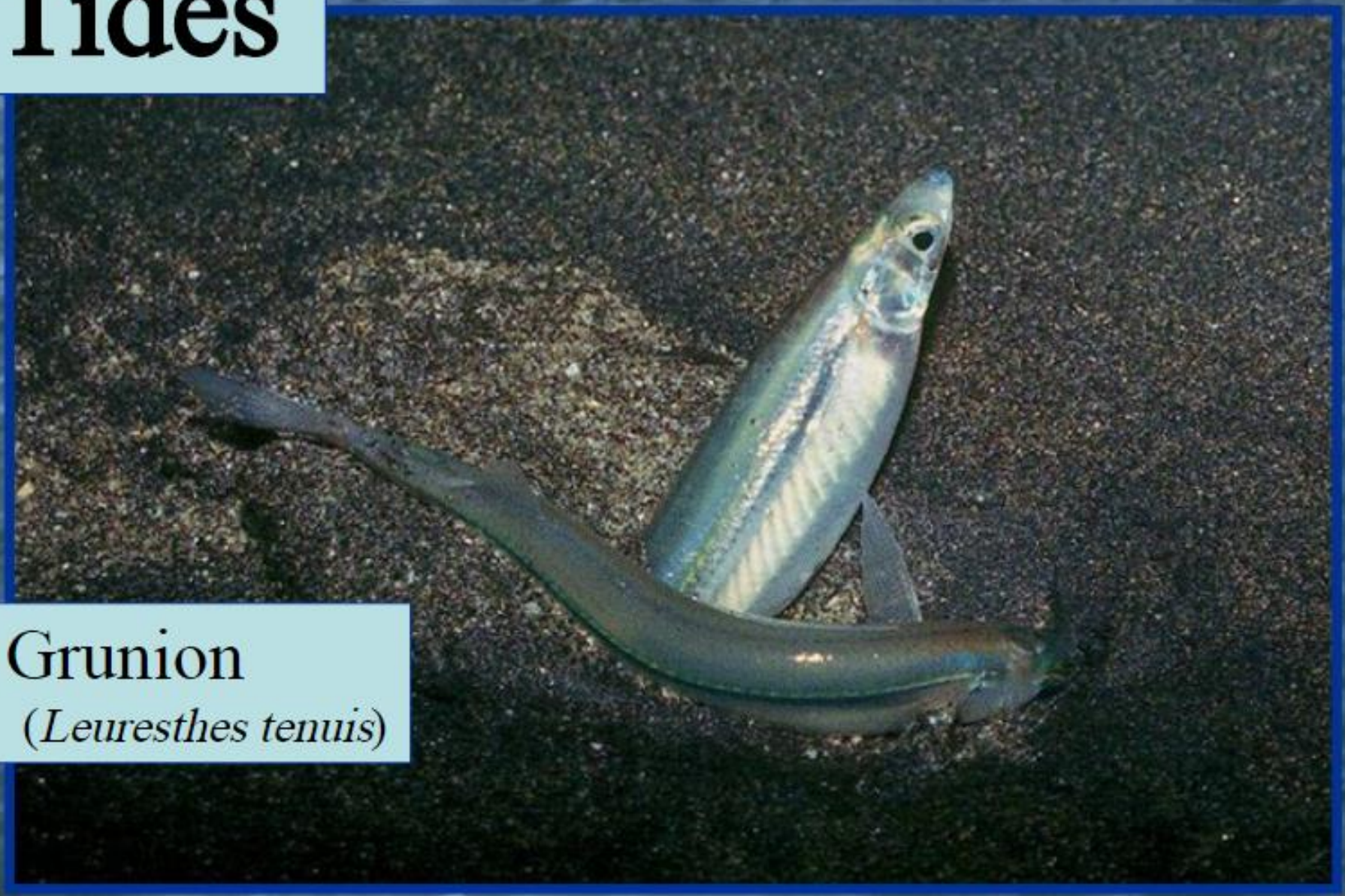
Tides

- The longest of all waves
- Wavelength = ½ Earth's circumference
- They are always in shallow water
- The fastest
  - Roughly 1,600 km/hr (1,000 mph)
- Speed is proportional to wavelength

Tides

- 0 – 12:13

Tides

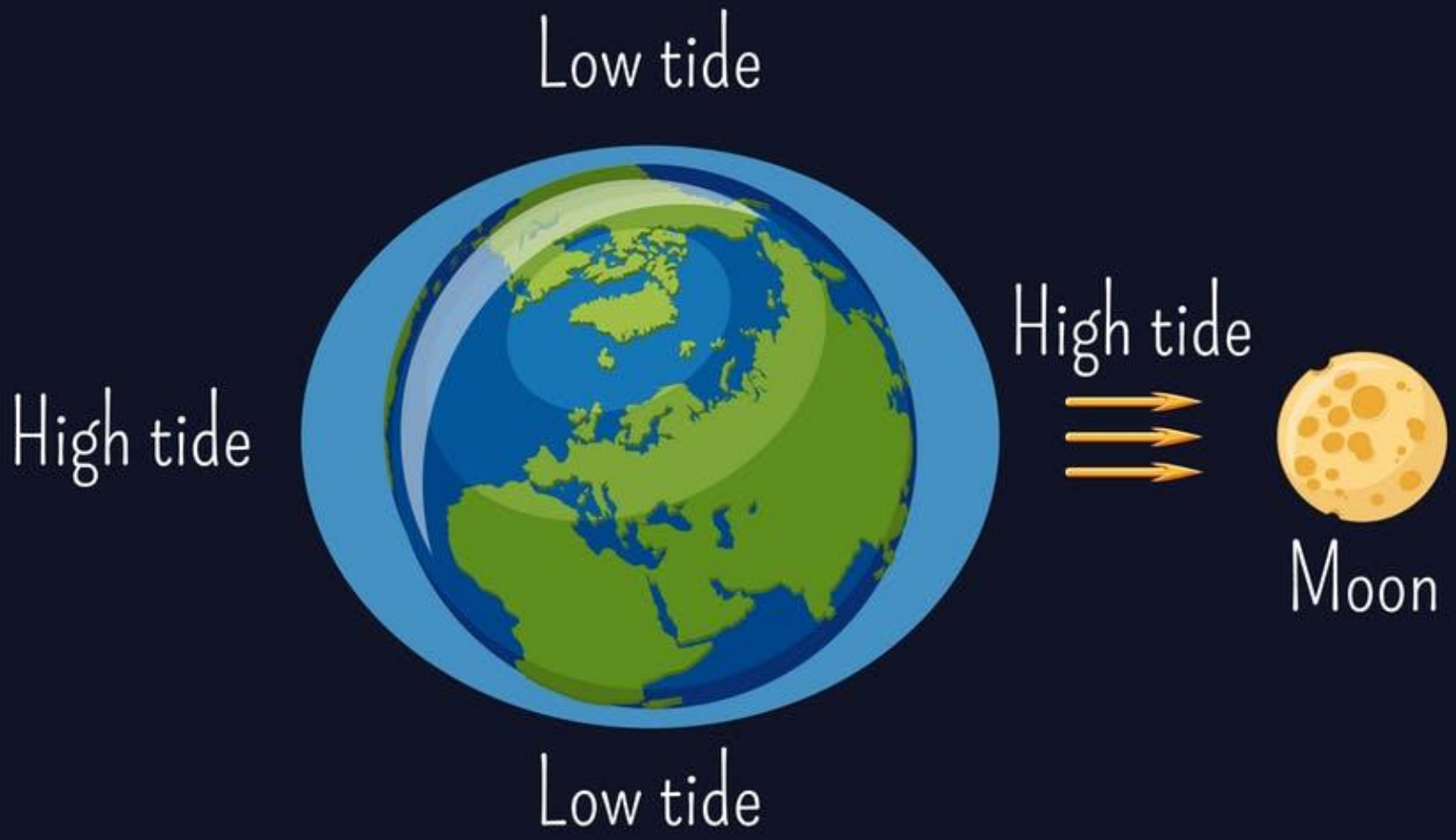


Grunion
(*Leuresthes tenuis*)

Tides

- What causes the tides?
  - Tides are caused by the interaction of the Earth, Moon, and the Sun.
  - Gravity is the reason for tides.
  - Gravity is the force exerted by an object that pulls other objects toward it.

TIDES



Tides

- The Moon's gravity affects the water pm Earth's surface.

- Since the Moon is close to the Earth, it has a strong gravitational pull on it (closer objects have stronger gravitational pull).

Tides

- The Moon pulls on the water on the side nearest to it and creates a bulge of water called a tidal bulge.

- The water on the side of the Earth facing away from the Moon has a less strong pull. This water is "left behind" and forms a second bulge.

Tides

Tides

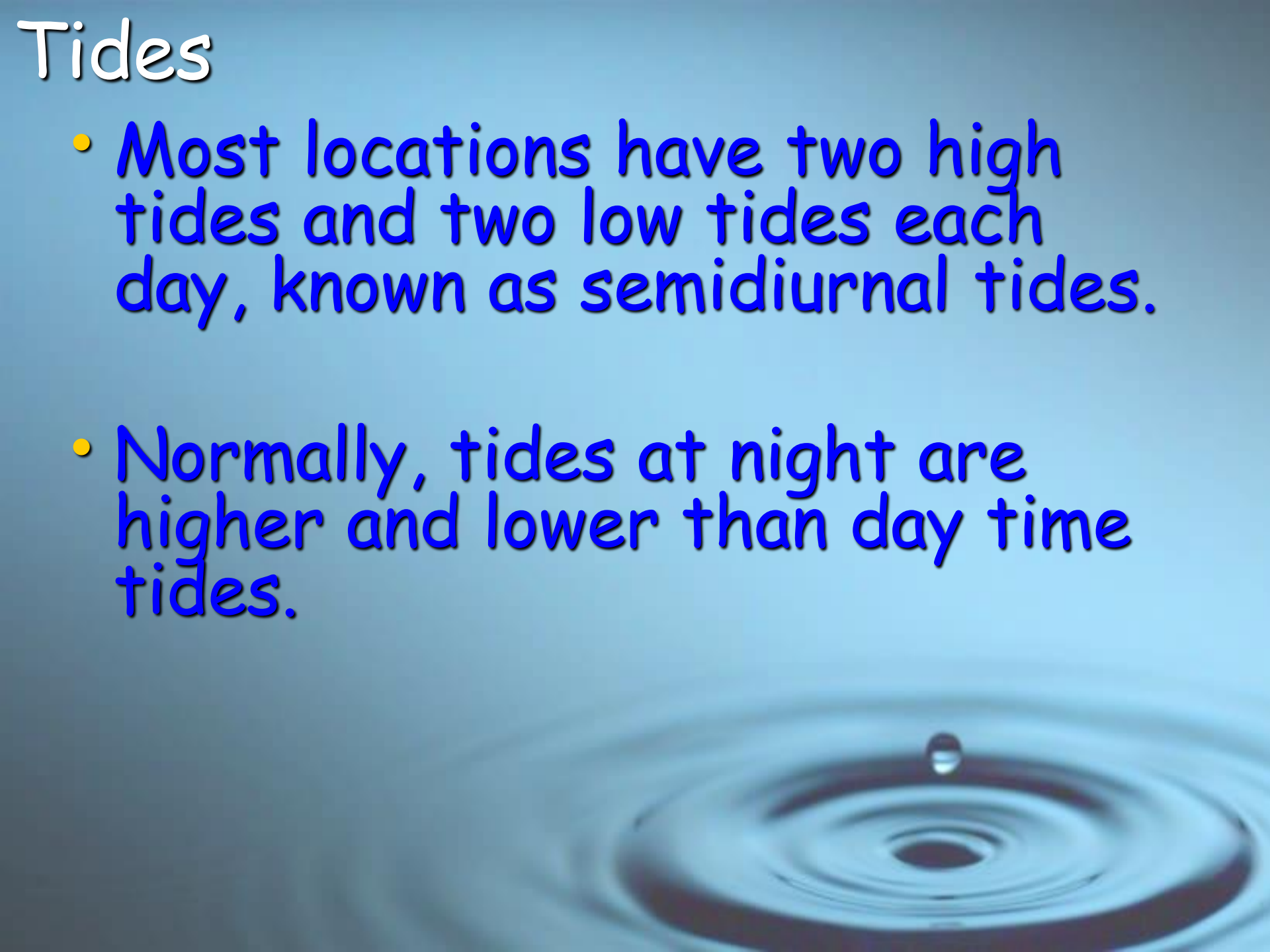
- As Earth rotates, different place on the planet's surface pass through the areas of the tidal bulges and have the change in water levels.

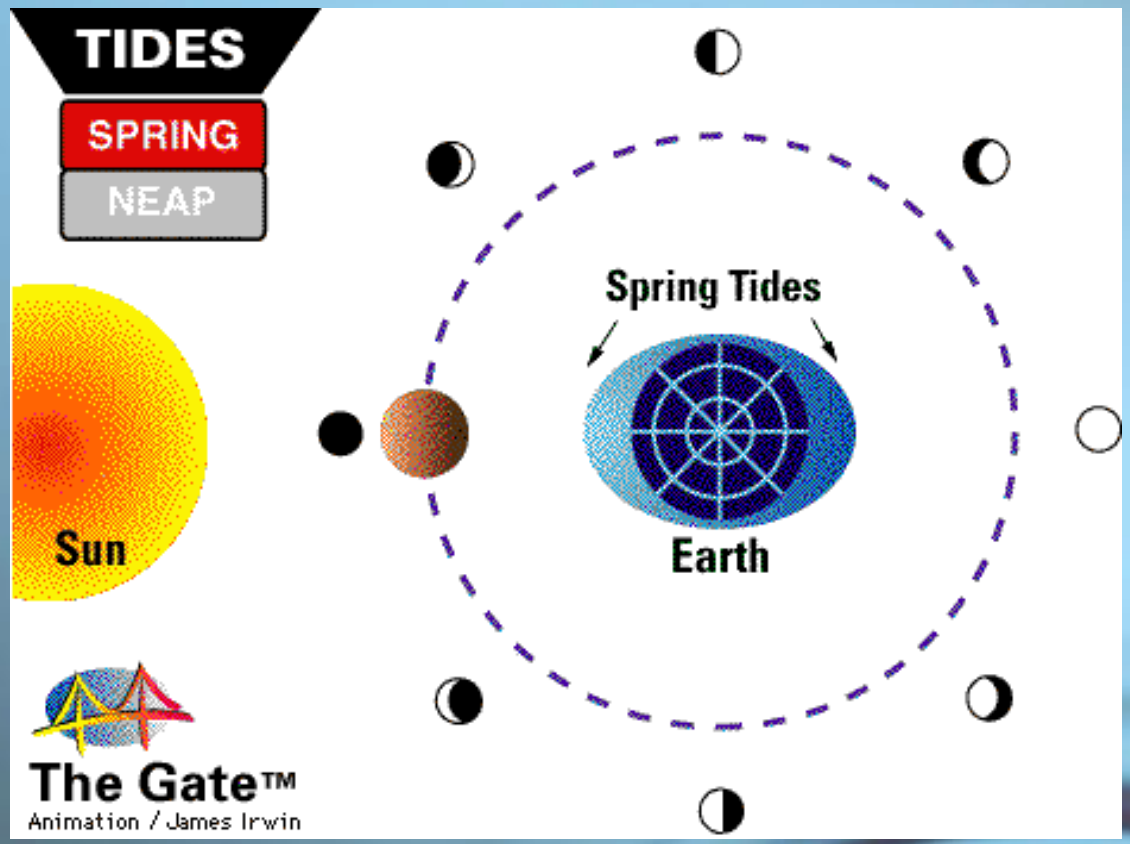
- So …. In places where there are tidal bulges, high tide is occurring along their coastlines.

Tides

- Most locations have two high tides and two low tides each day, known as semidiurnal tides.

- Normally, tides at night are higher and lower than day time tides.



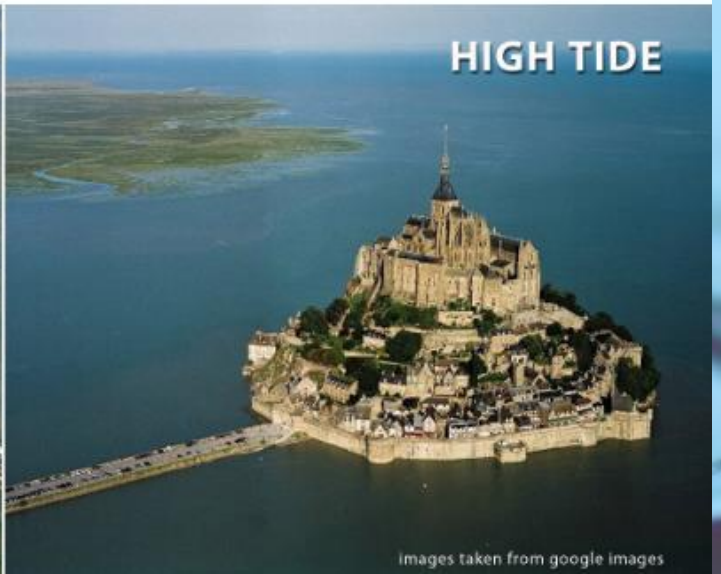

TIDES
SPRING
NEAP
Spring Tides
Sun
Earth
The Gate™
Animation / James Irwin

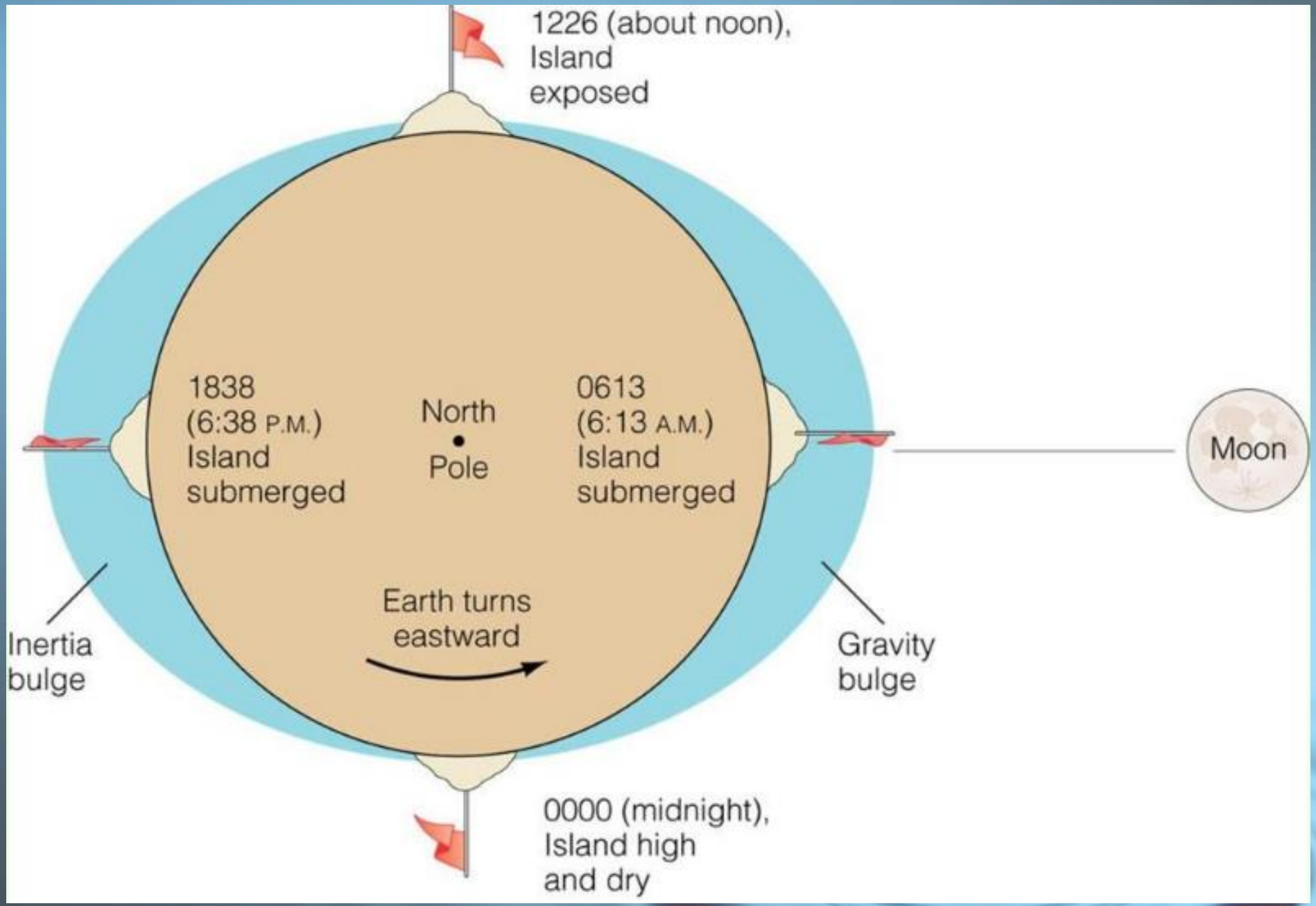
Tidal range is the difference between high and low tide.

The Bay of Fundy, Nova Scotia has the greatest range in the world ~53 feet.

High tide (left) and low tide (right) in the Bay of Fundy in Canada. Image credit: Wikimedia Commons, Tttrung. Photo by Samuel Wantman.


LOW TIDE


HIGH TIDE
images taken from google images


1226 (about noon),
Island
exposed
1838
(6:38 P.M.)
Island
submerged
North
Pole
0613
(6:13 A.M.)
Island
submerged
Moon
Earth turns
eastward
Inertia
bulge
Gravity
bulge
0000 (midnight),
Island high
and dry

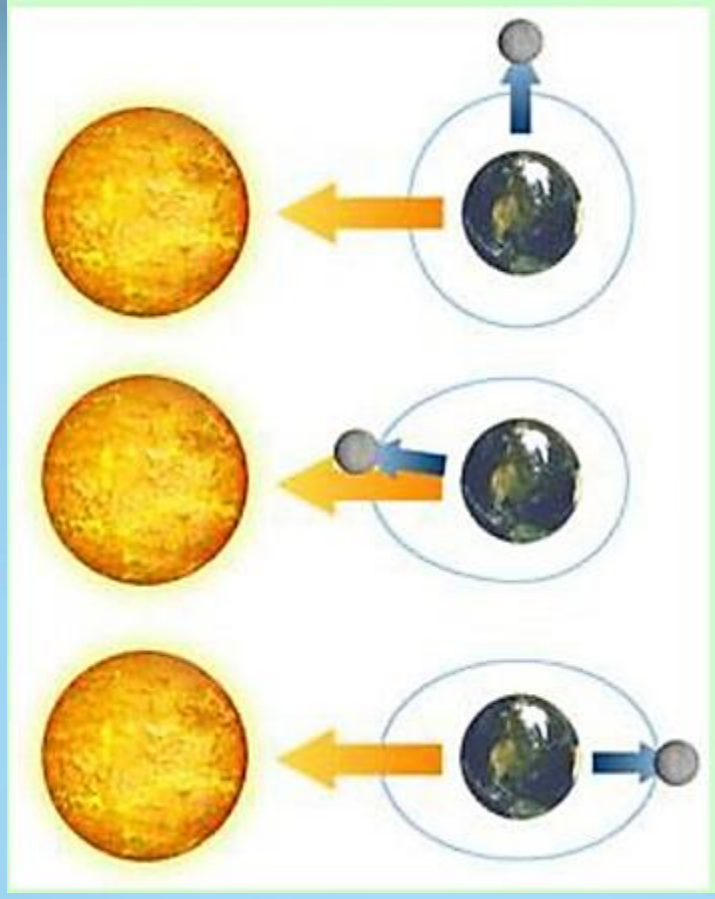
Tides

- Number and size of tides can be affected by bottom features, geographic features such as islands, canyons, reefs, etc.

- The amount of difference between the high and low tide (tidal range) is also affected by the bottom features.

Tides

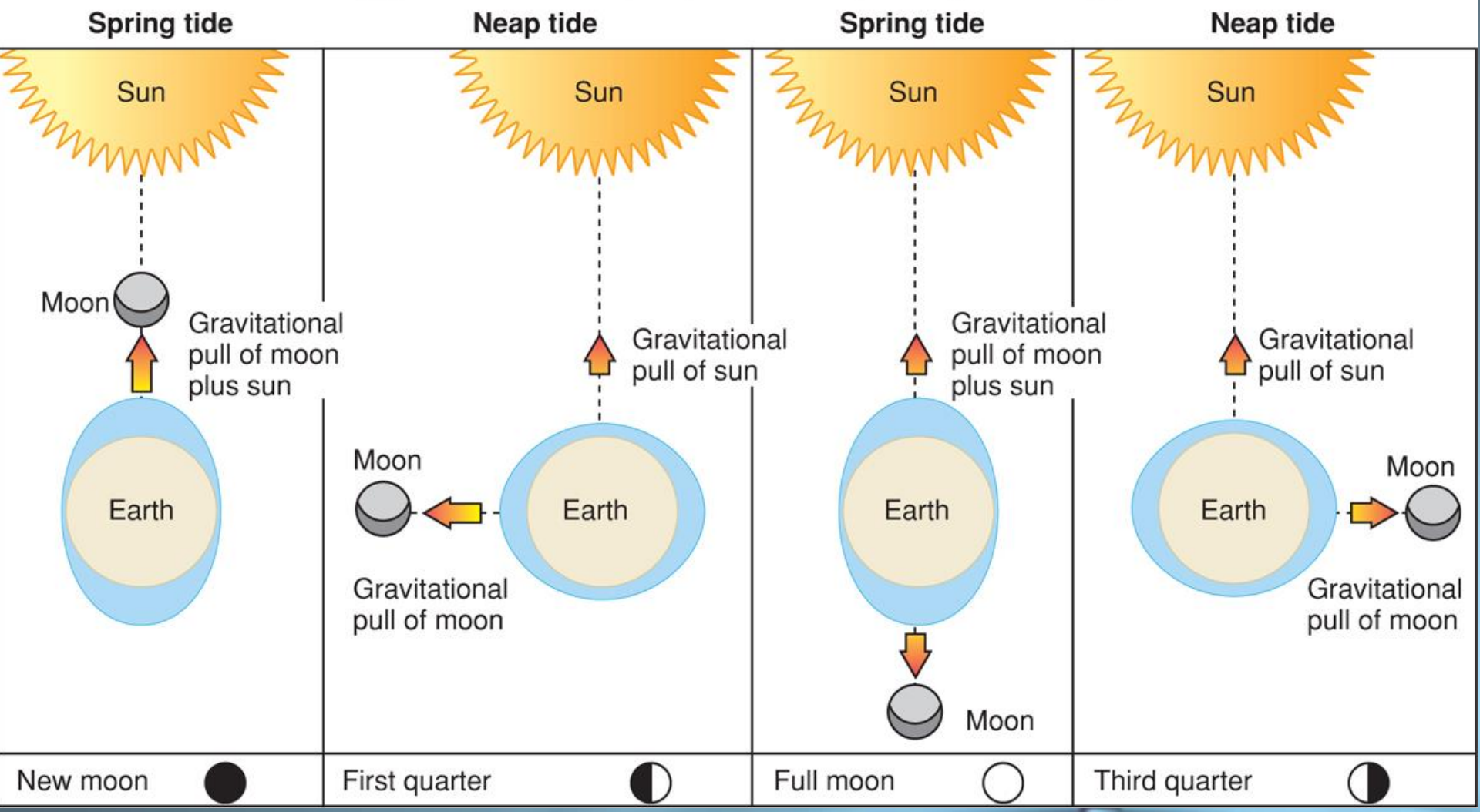
- The Sun is so large that its gravity also affects tides
- At times, the Sun and Moon pull together on Earth's waters in the same direction.
- At other times they pull in different directions.



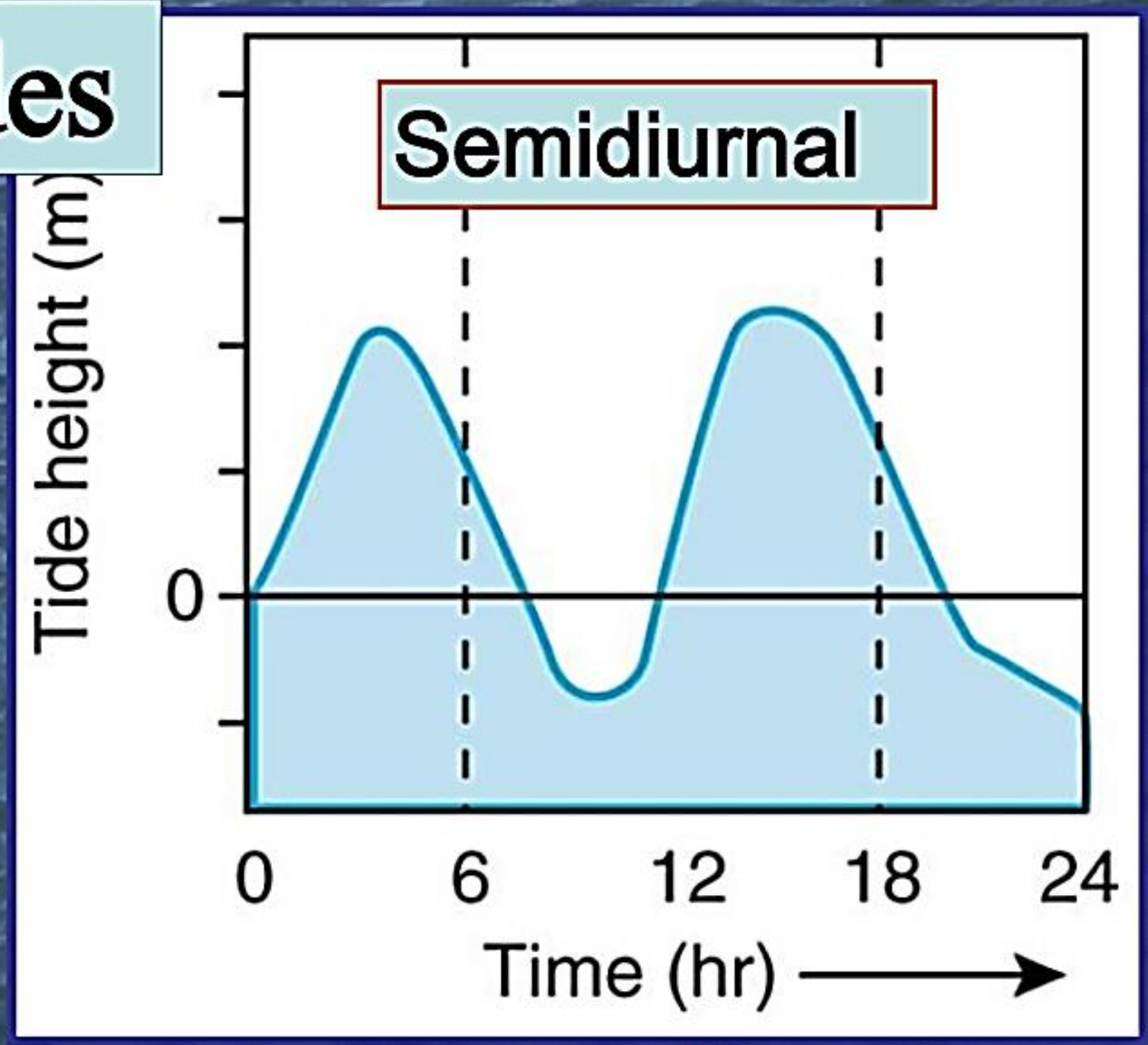
Tides

- Spring tides occur when the Moon and Sun are pulling together.

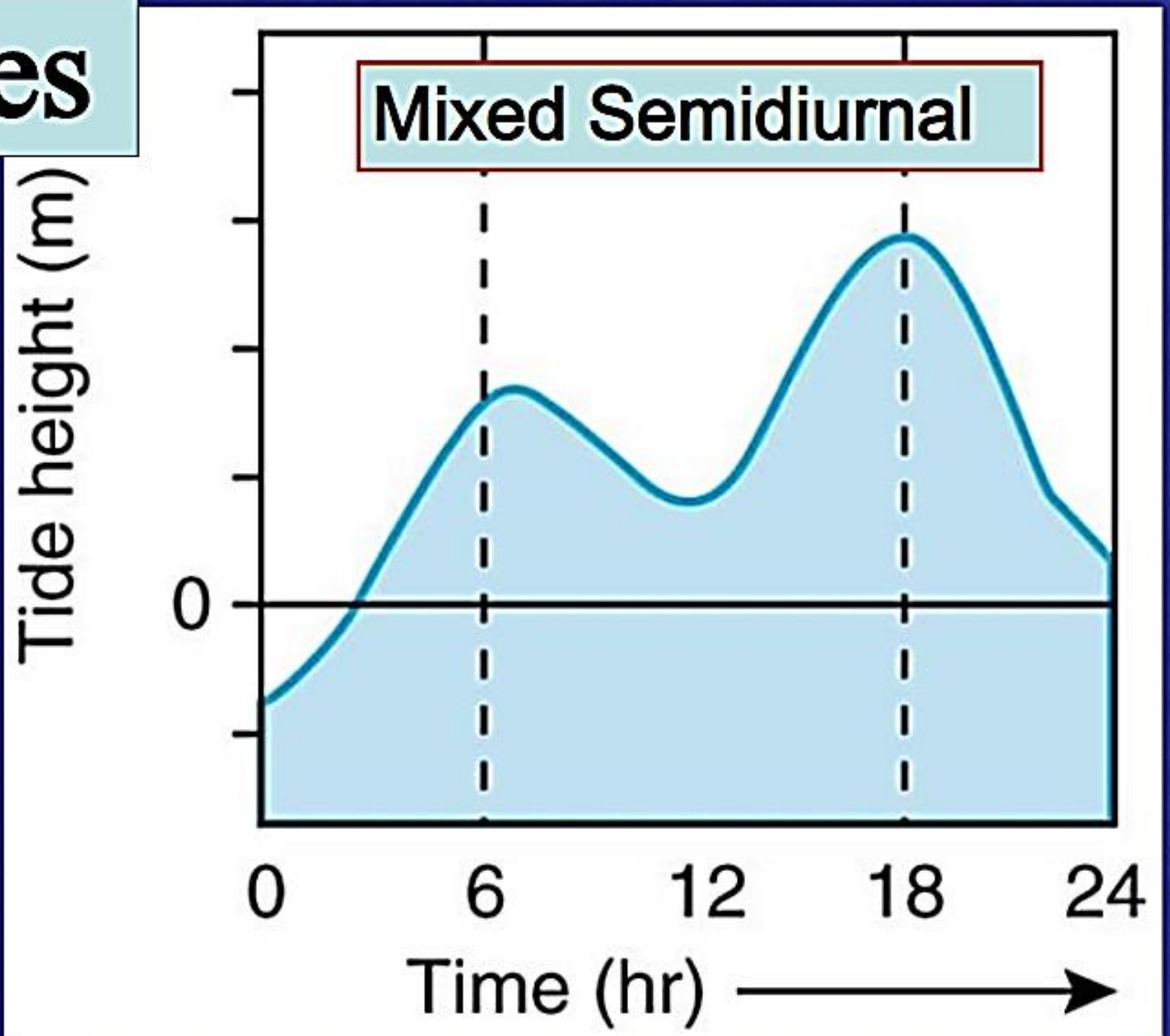
- Neap tides occur between the spring tides when the sun and moon are not in alignment.



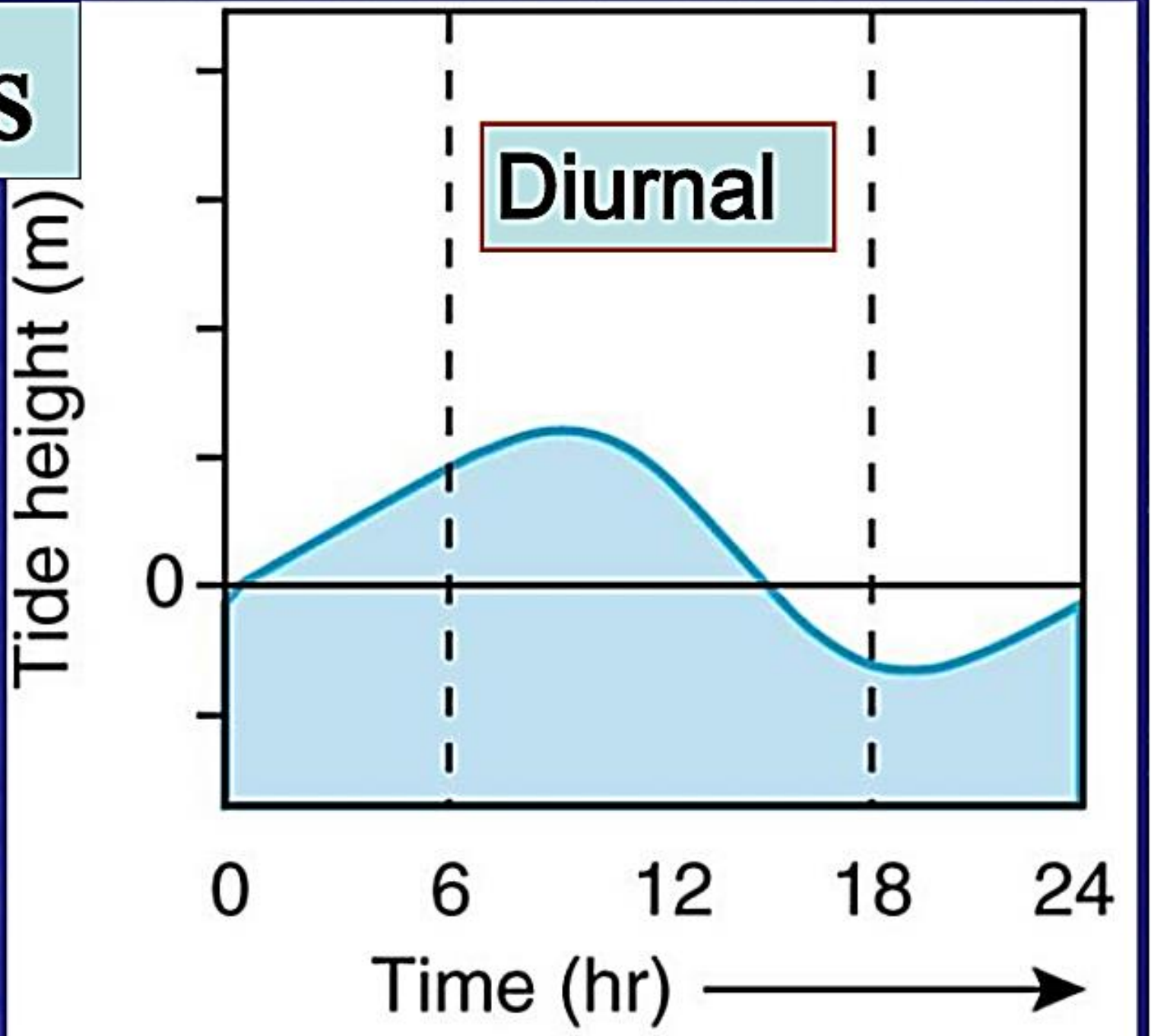
Tides



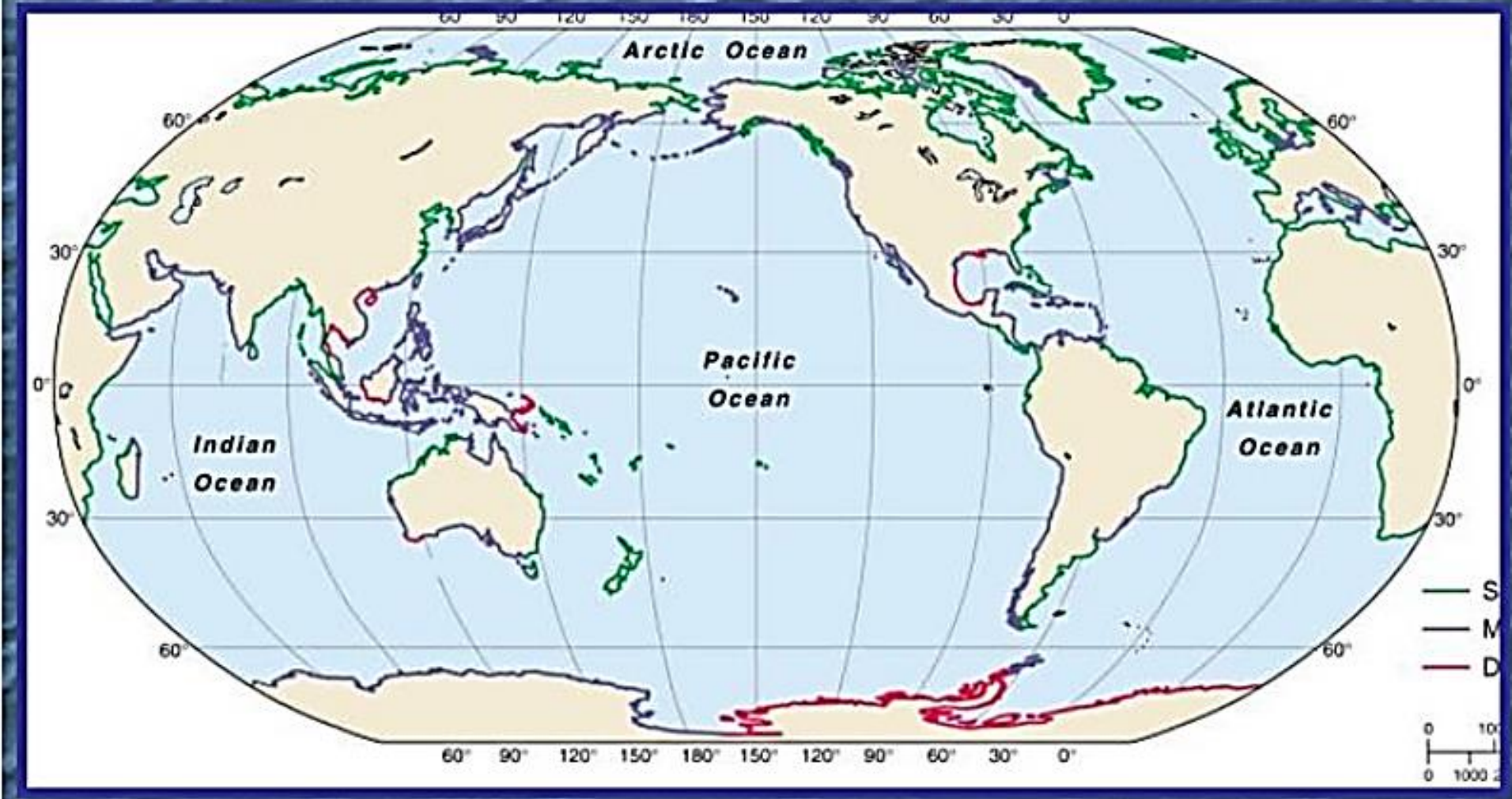
Tides



Tides



Tides


Semidiurnal tide
Mixed semidiurnal tide
Diurnal tide
Arctic Ocean
Pacific Ocean
Atlantic Ocean
Indian Ocean
60°
30°
0°
60° 90° 120° 150° 180° 150° 120° 90° 60° 30° 0°

Tsuamis