The Nature of Water

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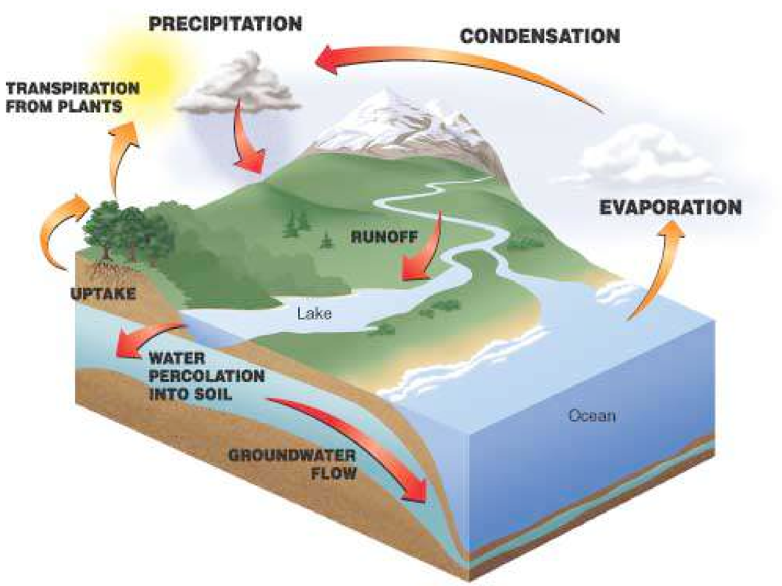
The Water Planet

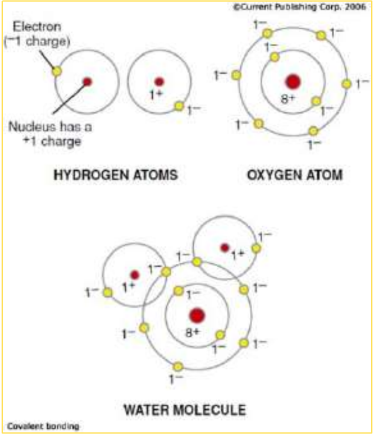
- Water covers about 71% of the Earth's surface. Considering the depth and volume, the world's oceans provide more than 99% of the **biosphere** – the habitable space on Earth.
- The vast majority of water on Earth can't be used directly for drinking, irrigation, or industry because it's salt water.
- As the population increases, so does the need for water.
- Part of the solution to meeting this demand lies in understanding *what* water is, *where* it goes, and *how* it cycles through nature.

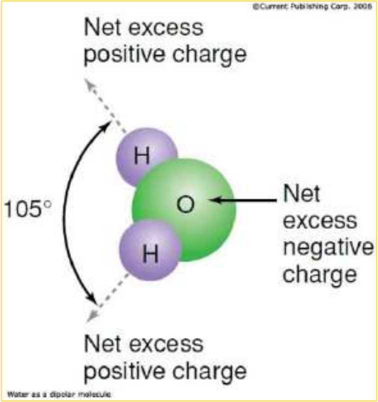


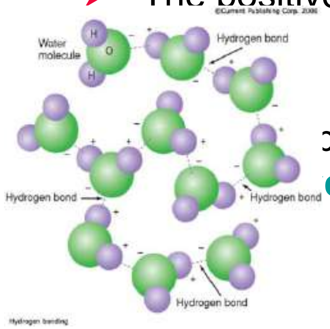
The cycle of water

The Polar Molecule

- Water is a simple molecule; the way it's held together gives it unique properties.
- The hydrogen atoms bond to the oxygen atoms with a **covalent bond**.
  - A covalent bond is formed by atoms sharing electrons. This makes water a very stable molecule.
  - A molecule with positive and negative charged ends has polarity and is called a **polar molecule**.
- The water molecule's polarity allows it to bond with adjacent water molecules.
  - The positively charged hydrogen end of one water molecule attracts the negatively charged oxygen end of another water molecule.
  - etween water molecules is **drogen bond**.

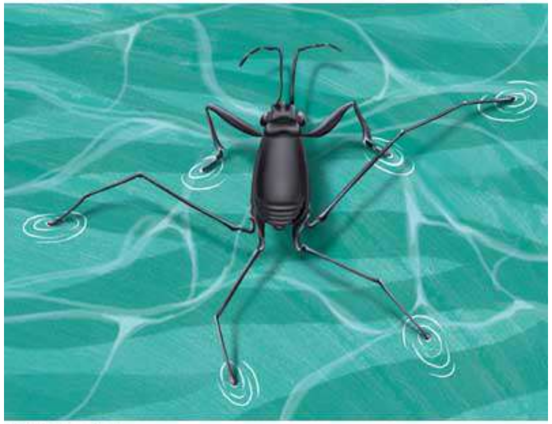






The Effects of Hydrogen Bonds

- Being a polar molecule, water has these characteristics:
  - **Liquid Water**. The most important characteristics of the hydrogen bonds is the ability to make water a liquid at room temperature. Without them, water would be a gas.
  - **Cohesion/Adhesion**. Because hydrogen bonds attract water molecules to each other, they tend to stick together. This is **cohesion**. Water also sticks to other materials due to its polar nature. This is **adhesion**.
  - **Viscosity**. This is the tendency for a fluid to resist flow. The colder water gets, the more viscous it becomes. It takes more energy for organisms to move through it, and drifting organisms use less energy to keep from sinking.
  - **Surface Tension**. A skin-like surface formed due to the polar nature of water. Surface tension is water's resistance to objects attempting to penetrate its surface.



Surface tension

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The Effects of Hydrogen Bonds *(continued)*

- **Ice Floats**: as water cools enough to turn from a liquid into solid ice, the hydrogen bonds spread the molecules into a crystal structure that takes up more space than liquid water, so it floats.
  - If ice sank, the oceans would be entirely frozen – or at least substantially cooler – because water would not be able to retain as much heat.
  - The Earth's climate would be colder – perhaps too cold for life.

Rear Admiral Harley D. Nygren, NOAA Corps Collection

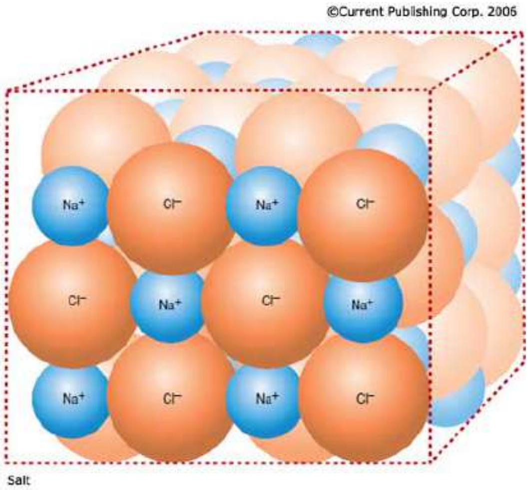
Ice floats

Solutions and Mixtures in Water

- A **solution** occurs when the molecules of one substance are homogeneously dispersed among the molecules of another substance.
- A **mixture** occurs when two or more substances closely intermingle, yet retain their individuality.

Salts and Salinity

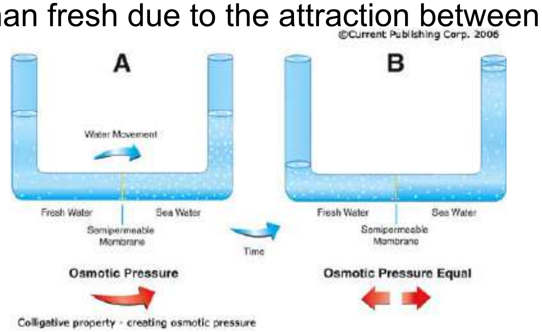
Salinity includes the total quantity of all inorganic solids in seawate



- **Sodium chloride** (rock salt or halite) is the most common and abundant sea salt.
- Scientist's measure salinity in various ways – expressed in parts per thousand (‰).
- The ocean's salinity varies from near zero at river mouths to more than 40‰ in confined, arid regions.
- The proportion of the different dissolved salts never change, only the relative amount of water.

The Colligative Properties of Seawater

- **Colligative properties** are properties of a liquid that may be altered by the presence of a solute and are associated primarily with seawater. Pure water doesn't have colligative properties. Fresh water, with some solutes, can have colligative properties to some degree.
- The colligative properties of seawater include:
  - **Ability to conduct an electrical current.** A solution that can do this is called an **electrolyte**.
  - **Decreased heat capacity.** Takes less heat to raise the temperature of seawater.
  - **Raised boiling point.** Seawater boils at a higher temperature than pure fresh water.
  - **Decreased freezing temperature.** Seawater freezes at a lower temperature than fresh water due to increased salinity.
  - **Slowed evaporation.** Seawater evaporates more slowly than fresh due to the attraction between ions and water molecules.
  - **Ability to create osmotic pressure.** Liquids flow or diffuse from areas of high concentration to areas of low concentration until the concentration equalizes. **Osmosis** occurs when this happens through a semi-permeable membrane, such as a cell wall. Because it contains dissolved salts, water in seawater exists in lower concentration than in fresh water.



The Principle of Constant Proportions

- In seawater no matter how much the salinity varies, the proportions of several key inorganic elements and compounds do not change. Only the amount of water and salinity changes.
- This constant relationship of proportions in seawater is called the **principle of constant proportions**.
  - This principle does not apply to everything dissolved in seawater – only the dissolved salts.

Dissolved Solids in Seawater

(Cl^-) Chloride	18.98 g
(Na^+) Sodium	10.56 g
(SO_4^{2-}) Sulfate	2.65 g
(Mg^{2+}) Magnesium	1.28 g
(HCO_3^-) Bicarbonate	.14 g
(Ca^{2+}) Calcium	.40 g
(K^+) Potassium	.38 g
Other	.61 g

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Determining Salinity, Temperature, and Depth

- If you know how much you have of any one seawater chemical, you can figure out the salinity using the **principle of constant proportions**.
- Chloride accounts for 55.04% of dissolved solids – determining a sample's chlorinity is relatively easy.
- The formula for determining salinity is based on the chloride compounds:

salinity ‰ = 1.80655 x chlorinity ‰

Sample of seawater is tested at 19.2‰ chlorinity:

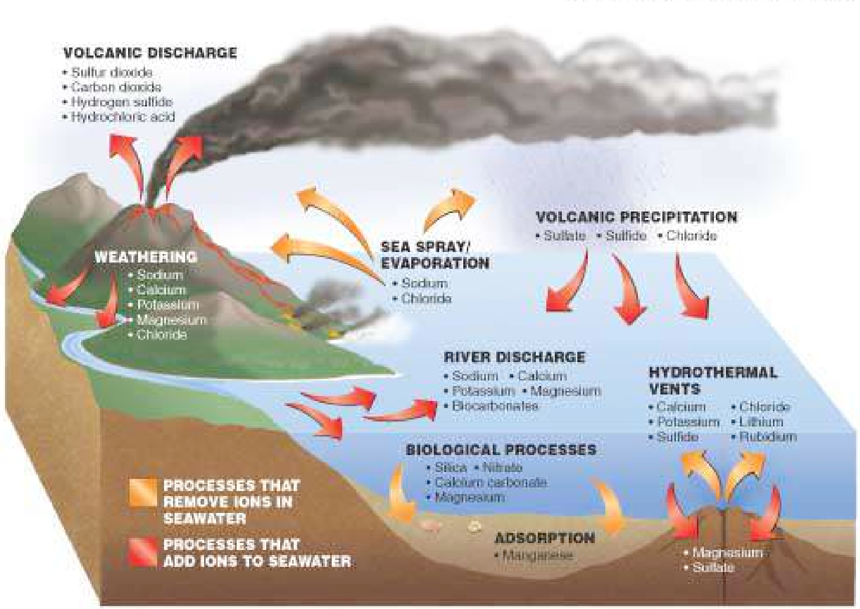
salinity ‰ = 1.80655 x 19.2‰

salinity ‰ = 34.68‰

- Most commonly, salinity is determined with a **salinometer**. This device determines chlorinity and calculates the salinity based on the water's electrical conductivity. It is accurate.
- The primary tool to measure the properties of seawater is the **conductivity, temperature, and depth (CTD) sensor**. The CTD profiles temperature and salinity with depth.
- Another less accurate way to determine salinity is with a **refractometer**.

Why the Seas Are Salty

- A source of sea salts appears to be **minerals** and **chemicals** eroding and dissolving into fresh water flowing into the ocean.
- **Waves** and **surf** appear to contribute by eroding coastal rock
- **Hydrothermal vents** change seawater by adding some materials while removing others.
- Scientists believe these processes all counterbalance so the average salinity of seawater **remains constant**.
- The ocean is said to be in **chemical equilibrium**.

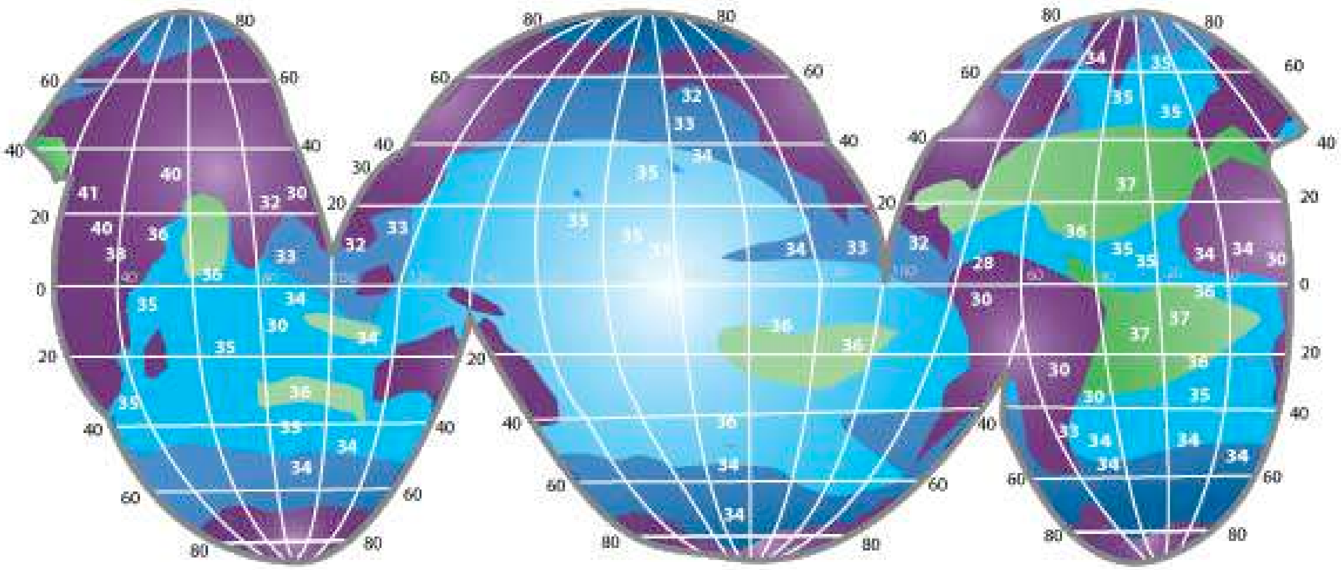


Sources of salt in the ocean

Salinity, Temperature, and Water Density

- Although the ocean's average salinity is about 35‰, it isn't uniform.
- Precipitation and evaporation have opposite effects on salinity.
  - Rainfall decreases salinity by adding fresh water.
  - Evaporation increases salinity by removing fresh water.
  - Freshwater input from rivers lowers salinity.
  - Abundant river input and low evaporation results in salinities well below average.
- Salinity and temperature also vary with depth.
  - Density differences causes water to separate into layers.
  - High-density water lies beneath low-density water.
- Water's density is the result of its temperature and salinity characteristics:
  - Low temperature and high salinity are features of high-density water.
  - Relatively warm, low-density surface waters are separated from cool, high-density deep waters by the **thermocline**, the zone in which temperature changes rapidly with depth.
  - Salinity differences overlap temperature differences and the transition from low-salinity surface waters to high-salinity deep waters is known as the **halocline**.
  - The thermocline and halocline together make the **pycnocline**, the zone in which density increases with increasing depth.

Salinity, Temperature, and Water Density *(continued)*



Salinity greater than 36 parts per thousand | Salinity 34-36 parts per thousand | Salinity less than 34 parts per thousand

Global salinity

Acidity and Alkalinity

- **pH** measures **acidity** or **alkalinity**.
- Seawater is affected by solutes. **The relative concentration of positively charged hydrogen ions and negatively charged hydroxyl ions determines the water's acidity or alkalinity**.
  - It can be written like this: $H_2O \longrightarrow H^+ + OH^-$
- Acidic solutions have a lot of hydrogen ions, it is considered an acid with a pH value of 0 to less than 7.
- Solutions that have a lot of hydroxyl ions are considered alkaline. They are also called basic solutions. The pH is higher than 7, with anything over 9 considered a concentrated alkaline solution.

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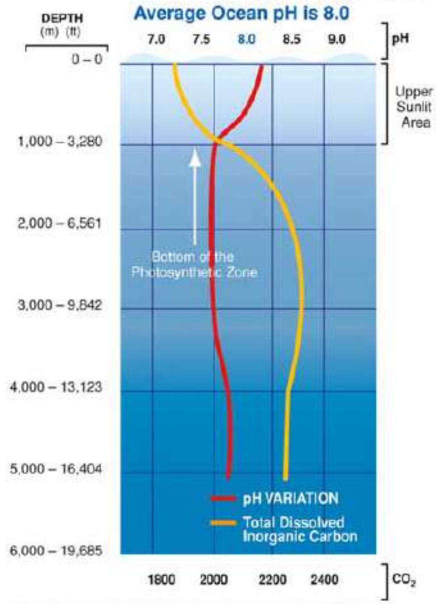
Acidity and Alkalinity *(continued)*

- Seawater is fairly stable, but **pH changes with depth** because the amount of carbon dioxide tends to vary with depth.
- Shallow depths have less carbon dioxide with a pH around 8.5.
  - This depth has greatest density of photosynthetic organisms which use the carbon dioxide, making the water slightly less acidic.
    - Middle depths have more carbon dioxide and the water is slightly more acidic with a lower pH.
  - More carbon dioxide present from the respiration of marine animals and other organisms, which makes water somewhat more acidic with a lower pH.
    - Deep water is more acidic with no photosynthesis to remove the carbon dioxide.
  - At this depth there is less organic activity, which results in a decrease in respiration and carbon dioxide. Mid-level seawater tends to be more alkaline.
    - At 3,000 meters (9,843 feet) and deeper, the water becomes more acidic again.
  - This is because the decay of sinking organic material produces carbon dioxide, and there are no photosynthetic organisms to remove it.



The variation in pH and total dissolved inorganic carbon with depth

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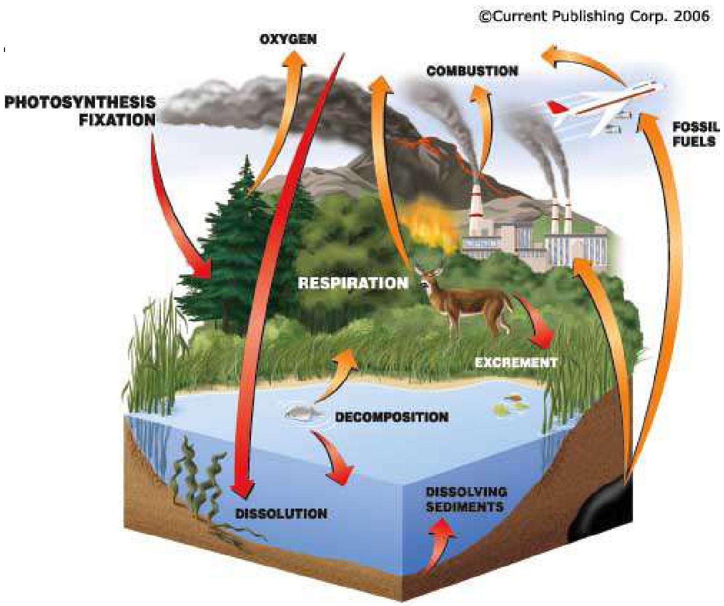
Biogeochemical Cycles

- Proportions of organic elements in seawater differ from the proportions of sea salts because:
- The **principle of constant proportions** does not apply to these elements.
  - These **nonconservative constituents** have concentrations and proportions that vary independently of salinity owing to biological and geological activity.
  - All life depends on material from the nonliving part of the Earth.
- The continuous flow of elements and compounds between organisms (**biological form**) and the Earth (**geological form**) is the **biogeochemical cycle**.
  - Organisms require specific elements and compounds to stay alive.
- Aside from gases used in respiration or photosynthesis, those substances required for life are called nutrients.
  - The primary nutrient elements related to seawater chemistry are carbon, nitrogen, phosphorus, silicon, iron, and a few other trace metals.
    - Not all nutrients and compounds cycle at the same rate.
    - The biogeochemical cycle of the various nutrients affects the nature of organisms and where they live in the sea.

Carbon

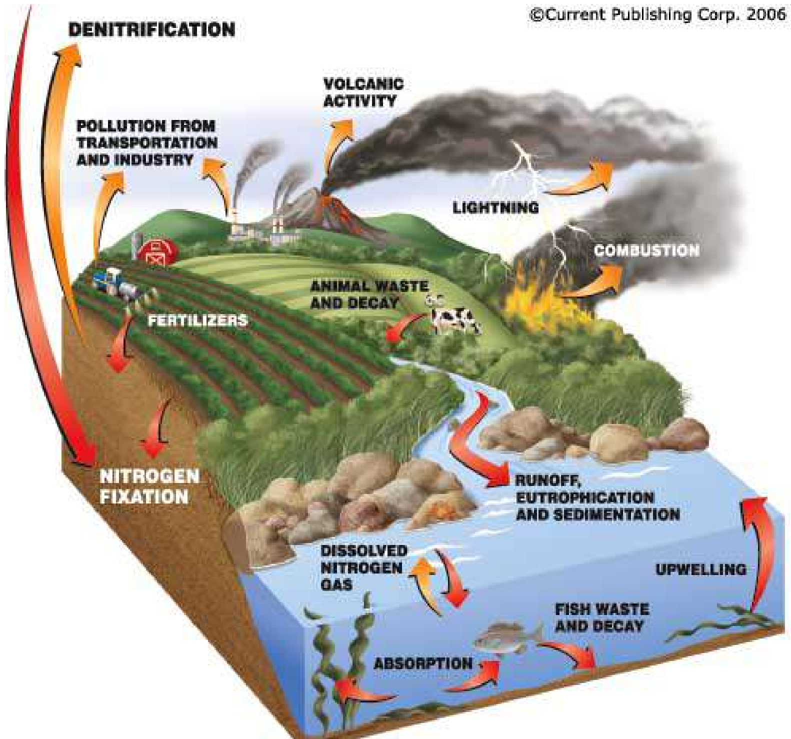
- **Carbon** is the fundamental element of life.
- Carbon compounds form the basis for **chemical energy** and for **building tissues**.
- Carbon dioxide must be transformed into other carbon compounds for use by heterotrophs.
  - The movement of carbon between the **biosphere** and the nonliving world is described by the carbon cycle.



The carbon cycle

Nitrogen

- **Nitrogen** is another element crucial to life on Earth.
- Organisms **require nitrogen for organic compounds** such as protein, chlorophyll, and nucleic acids.
- Nitrogen makes up about 78% of the air and 48% of the gases dissolved in seawater.



The nitrogen cycle

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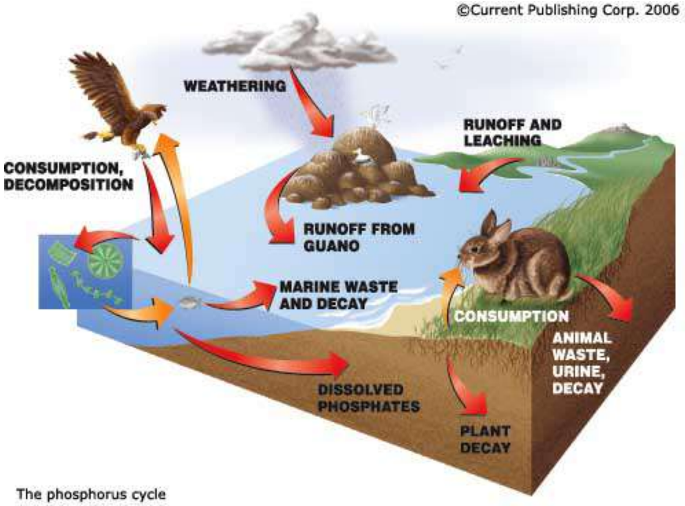
Phosphorus and Silicon

- **Phosphorus** is another element important to life because it is **used in the ADP/ATP cycle**, by which cells convert chemical energy into the energy required for life.
  - Phosphorus combined with calcium carbonate is a primary component of bones and teeth.



The phosphorus cycle

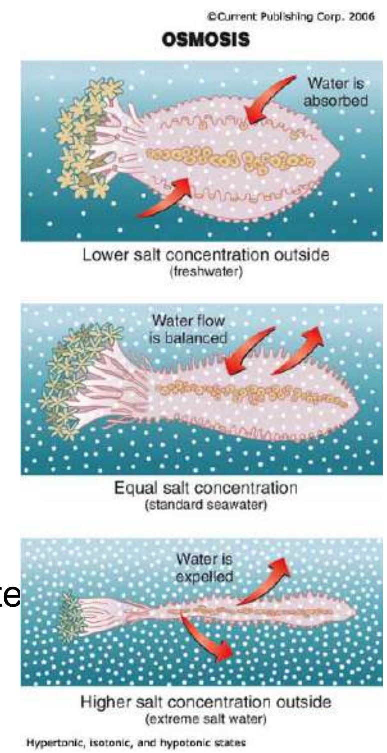
- **Silicon** is used similarly by some organisms in the marine environment (including diatoms and radiolarians) for their shells and skeletons.
- Silicon exists in these organisms as silicon dioxide, called silica.

➢ Iron and Trace Metals

Iron and **other trace metals** fit into the definition of a **micronutrient**.

- These are essential to organisms for **constructing specialized proteins**, including **hemoglobin** and **enzymes**.
  - Other trace metals used in enzymes include **manganese**, **copper**, and **zinc**.

Diffusion and Osmosis



- **Diffusion** is the tendency for a liquid, gas, or solute to flow from an area of high concentration to an area of low concentration.
- **Osmosis** is diffusion through a semipermeable cell membrane.
- This has important implications with respect to marine animals.
- **Hypertonic** - having a higher salt concentration, and the water will diffuse into the cells.
  - It is what happens when you put a marine fish into fresh wate
    - **Isotonic** - when water concentration inside the cell is the same as the surrounding water outside the cell. There is no osmotic pressure in either direction.
  - Marine fish cells are isotonic.
    - **Hypotonic** - having a lower salt concentration than the surrounding water.
  - It is what happens when you put a freshwater fish into seawater.

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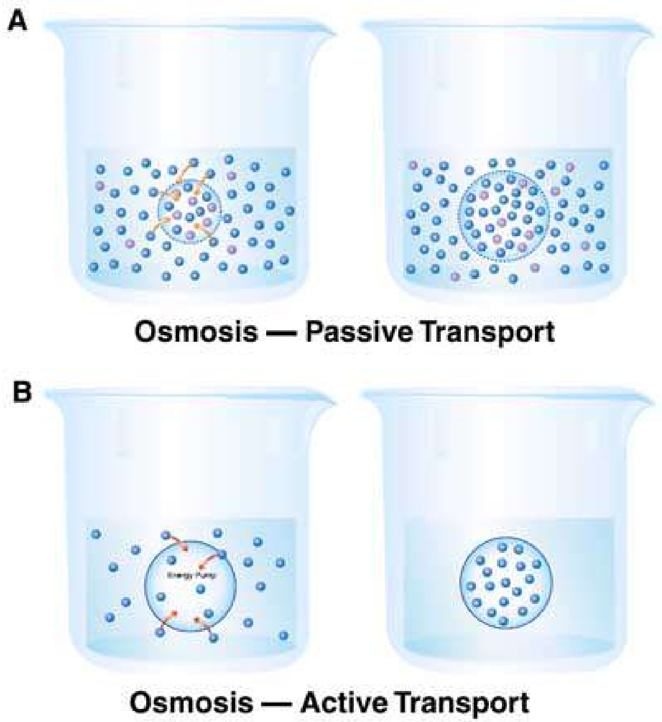
Active Transport, Osmoregulators, and Osmoconformers

- **Osmosis** through a semipermeable cell membrane is called **passive transport**.
- Passive transport moves materials in and out of a cell by normal diffusion.
  - The process of cells moving materials from low to high concentration is called **active transport**.
- Active transport takes energy because it goes against the flow of diffusion.

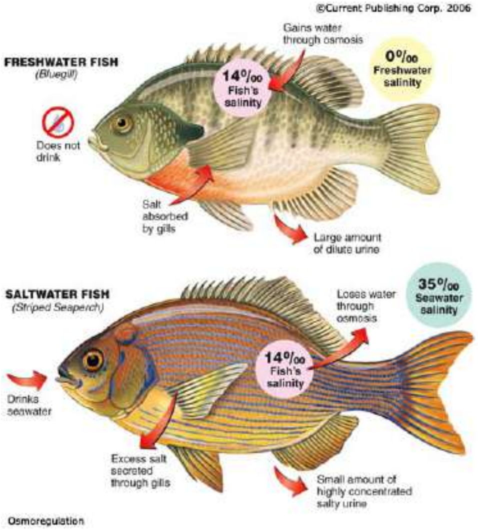


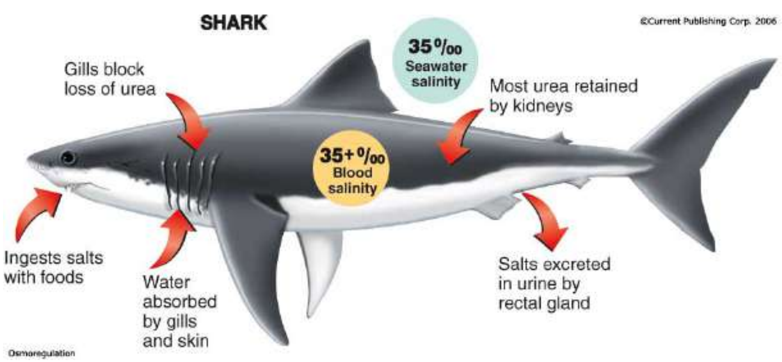
Active and passive transport

Active Transport, Osmoregulators, and Osmoconformers *(continued)*

- Marine fish that have a regulation process that allows them to use **active transport** to adjust water concentration within their cells are **osmoregulators**.

- Marine organisms that have their internal salinity rise and fall along with the water salinity are **osmoconformers**.





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