# Ch3: Water

# Essential Knowledge

- 2.A.3 Organisms must exchange matter with the environment to grow, reproduce and maintain organization
  - a. Molecules and atoms from the environment are necessary to build new molecules
    - Essential elements moves from the environment to organisms where it is used to build:
      - Carbon: carbohydrates, proteins, lipids, or nucleic acids.
      - Nitrogen: proteins and nucleic acids
      - Phosphorous: nucleic acids and certain lipids
    - **Living systems depend on properties of water that result from its polarity and hydrogen bonding, such as: cohesion, adhesion, high specific heat capacity, universal solvent supports reactions, heat of vaporization**

# Emergent Properties

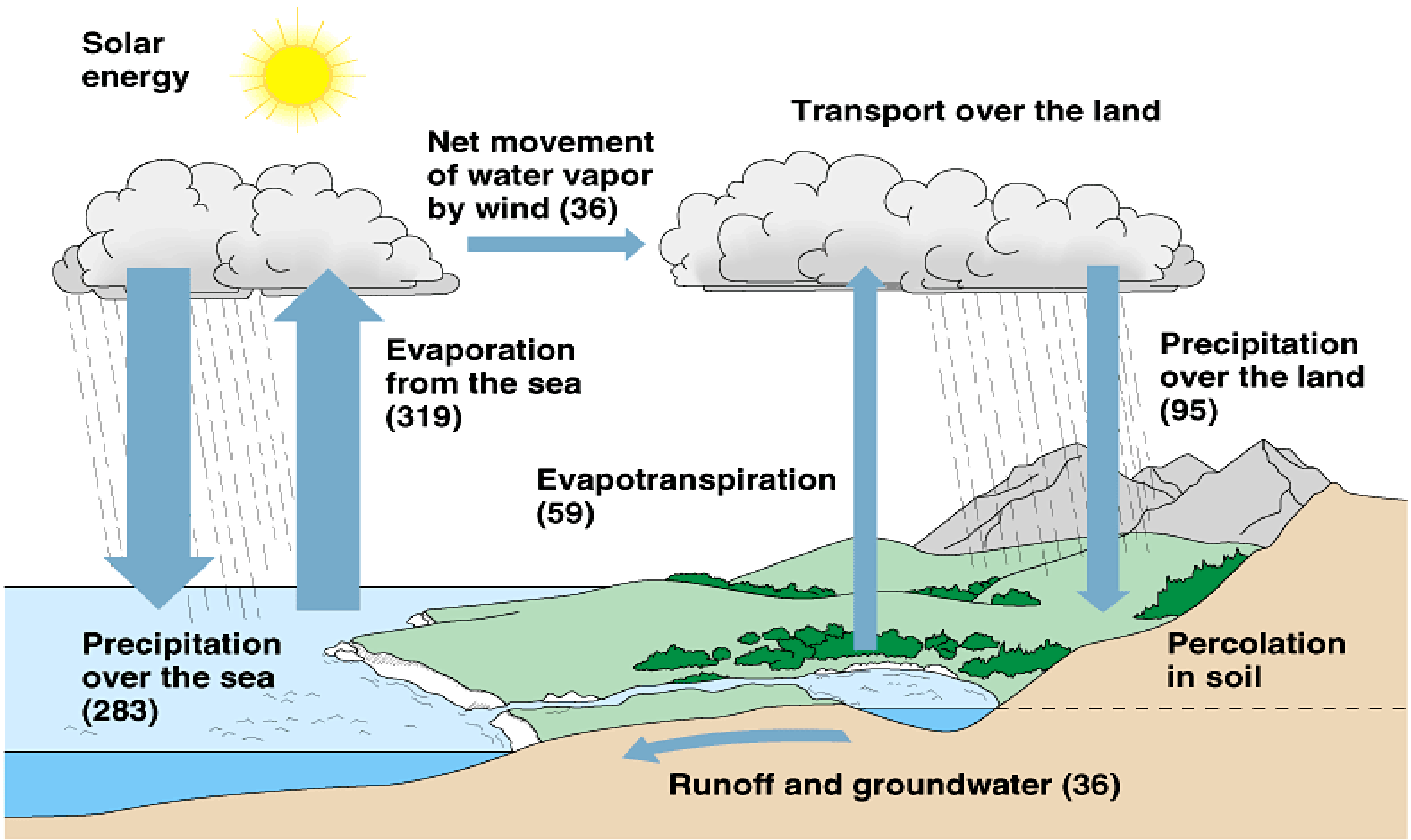
- The arrangement and interactions of parts creates novel properties that were not present at the preceding level of organization
  - Non-science example: Box of bicycle parts compared to a working bicycle
  - Science example: Na and Cl by themselves are toxic, but combined creates table salt and the arrangement of nucleotides in DNA combine to create heredity information that controls the cell

# Water – General Information

- Life on Earth started in water and evolved for 3 billion years before spreading on land
- Large bodies of water help moderate climate
  - ¾ earth's surface is water
    - Also present as ice and vapor
    - Only substance in all 3 states of matter

- Variations of water availability among habitats is an important factor in species distribution
- Since most cells are surrounded by water, osmoregulation is an important part of homeostasis in organisms
  - Cells are 70-95% water

# Water Cycle

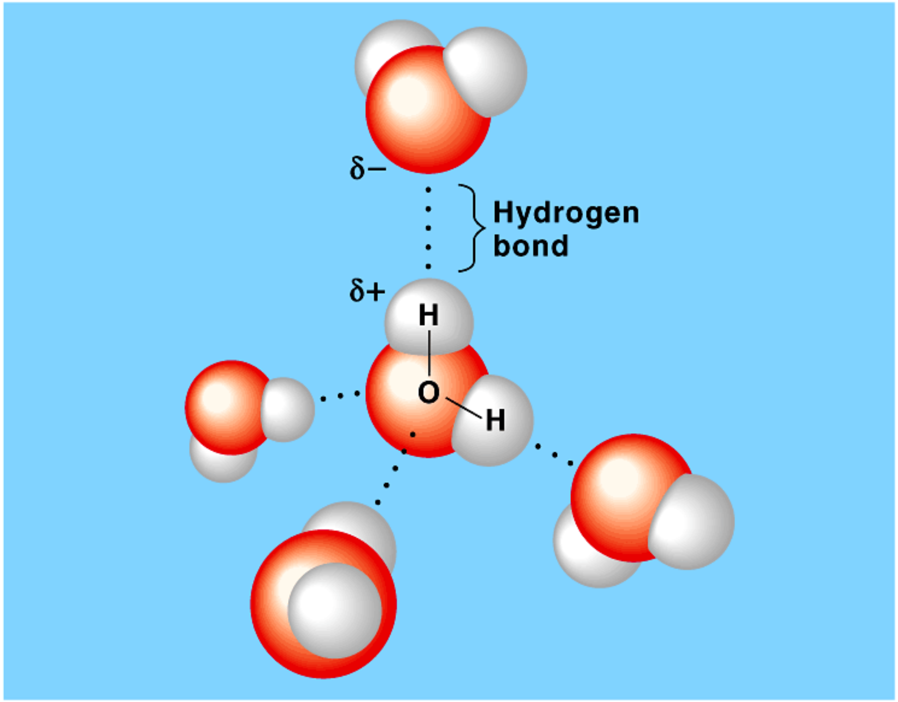

Solar energy
Net movement of water vapor by wind (36)
Transport over the land
Evaporation from the sea (319)
Precipitation over the land (95)
Evapotranspiration (59)
Precipitation over the sea (283)
Percolation in soil
Runoff and groundwater (36)

# Properties of Water

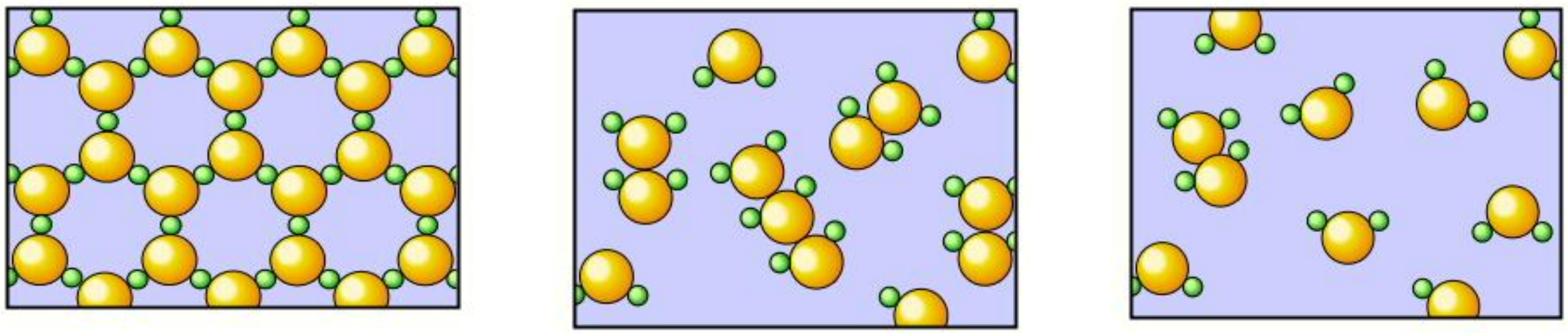
1. Cohesion & Adhesion
   - Surface tension
2. Moderation of Temperature
   - Kinetic energy
   - Heat
   - Temperature
   - Specific Heat
   - Heat of vaporization
   - Evaporative Cooling
3. Insulation
   - Ice floats
4. Solvent
   - Hydrophillic
   - Hydrophobic

# Polarity of Water

- Water is a polar molecule because of the slight negative charge of oxygen and slight positive charge of hydrogen.
- Water molecules can form H-bonds with other water molecules



# Three states of water



- **<u>Solid</u>** – crystal lattice structure –very little movement, ordered
- **<u>Liquid</u>** – molecules take shape of container – rapid movement, semi-ordered
- **<u>Gas</u>** – Random molecular structure, VERY rapid movement

# Cohesion & Adhesion

- **Cohesion**: H-bonds hold water together


- Surface tension is related to cohesion – reason insects can walk on water without sinking
  - Water behaves as an invisible film because of H-bonds

- **Adhesion**: clinging of one substance to another

- How water is moved from roots to the leaves of trees against gravity – water adheres to the cell walls of plants

# Temperature Moderation

- $H_2O$ moderates air temp by absorbing heat from warm air and releasing stored heat to cooler air
  - Related to hydrogen bonding in water

- **Kinetic Energy** = energy of motion – atoms and molecules in constant motion
  - Faster the movement, the greater the kinetic energy
- **Heat** = total amount of KINETIC ENERGY
- **Temperature** = intensity of heat due to average kinetic energy
  - Speed of molecules increases; then temp increases

# Specific Heat

- Water has a high specific heat
  - **Specific heat**: the amount of heat that must be absorbed or lost for 1g of that substance to change its temperature by 1 °C
  - Specific heat of water= 1cal/g/°C

  - Can be thought of as a measure of **how well a substance RESISTS changing** its temperature when it absorbs or releases heat.

- **Heat must be absorbed in order to break the hydrogen bonds, and heat is released when bonds break**
  - **Heat is used to break the hydrogen bonds before water molecules can start moving to increase the temperature**

# Specific Heat

- **Why do coastal regions generally have milder climates? What does this have to due with specific heat?**
  - Water moderates temperature on earth so coastal regions don't have huge influx of temp changes
- **How does water's high specific heat relate to life on Earth?**
  - creates a favorable, stable environment for marine life
  - our bodies are made of water, so we are more resistant to changes in our own temp

# Evaporative Cooling

- **Vaporization/Evaporation**: transformation from liquid to gas
- **Heat of Vaporization**: amount of heat a liquid must absorb for 1g of it to be converted to a gas.
- **Evaporative Cooling**: as a liquid evaporates, the surface of the liquid that remains behind cools down

- Water has a high heat of vaporization
  - Which will "disappear" faster a drop of water or a drop of rubbing alcohol? Why?
  - Why does a heated liquid evaporate faster than a room temperature liquid?

# Evaporative Cooling

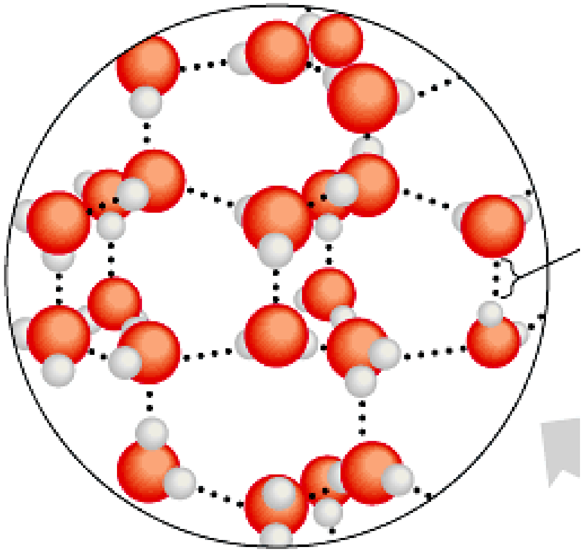
- Why is your skin still moist after a workout?
  - The "hottest" molecules evaporate as gas, but the liquid that remains behind cooled down; not enough speed to leave the surface
  - Organisms rely on heat of vaporization to remove heat.
  - Why do you feel hotter on a humid day?

# Water Insulates

- Why is the phrase, "ice floats" important?
  - **If ice sank….**
    - Eventually all ponds, lakes and even oceans would freeze solid
    - During summer, only the top few inches would thaw
  - **Surface ice insulates water below**
    - Allowing life to survive the winter
  - **Seasonal turnovers of lakes**
    - Nutrient cycling

# Water Insulates

- Most substances are more dense when they are solid.
  - not water – ice floats!
- Ice forms loose crystal structure when hydrogen bonds push away from each other



# Water as a Solvent

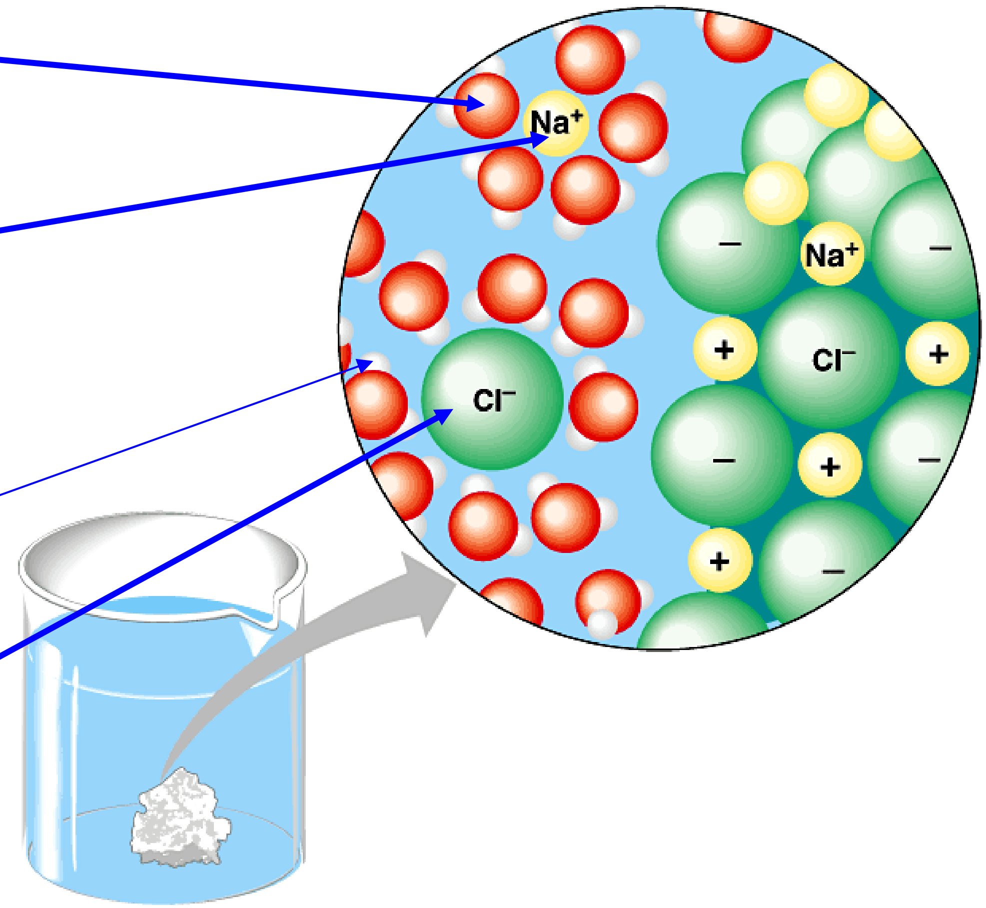
- Water can be used to do chemical reactions in the body
  - Dehydration or hydrolysis reactions

- Review:
  - Solution: liquid that is a completely homogeneous mixture of two or more substances.
  - Solvent: dissolving agent; ex: milk
  - Solute: substance that is dissolved; ex: chocolate
  - Aqueous solution: solution in which $H_20$ is solvent

# Water as a Solvent

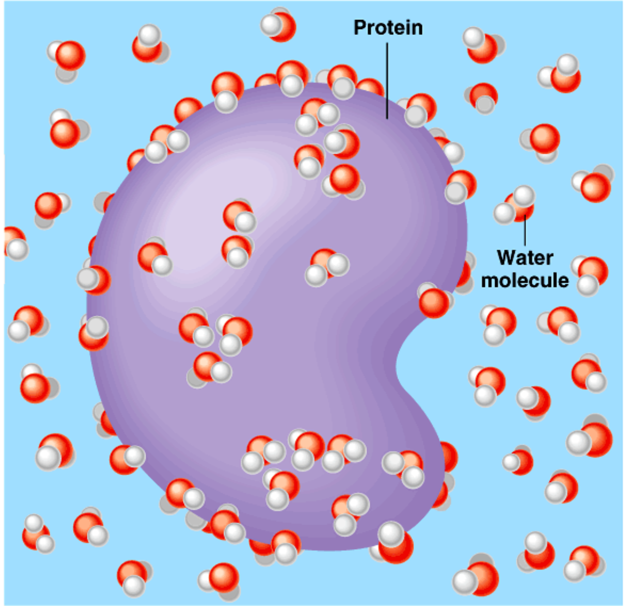
Negative oxygen regions of $H_2O$ are attracted to $Na^+$ cations

**Positive hydrogen regions cling to $Cl^-$ anions**



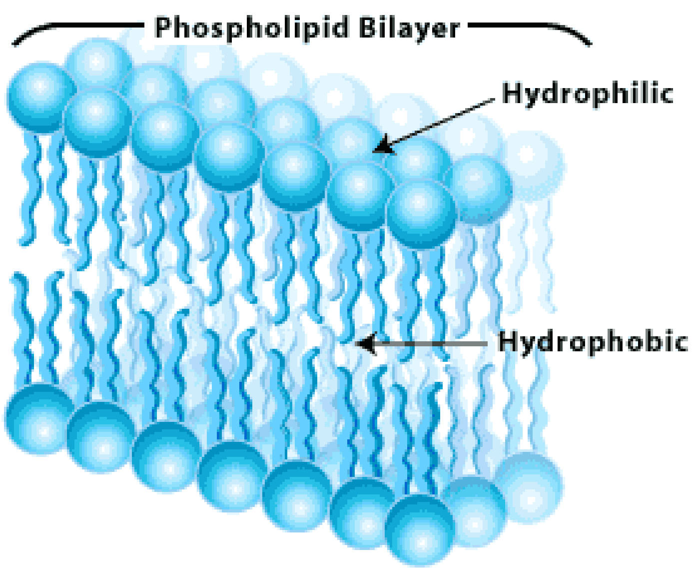
# Hydrophilic

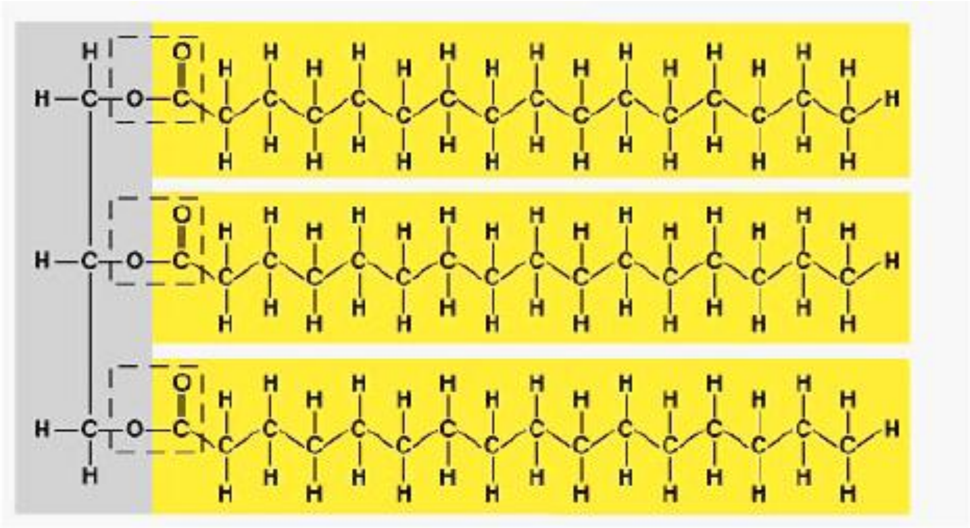
- **Hydrophilic substances** have a **HIGH AFFINITY** for water.
  - Ex: a cotton hand towel…easily adheres water because of the cellulose fibers of cotton




# Hydrophobic

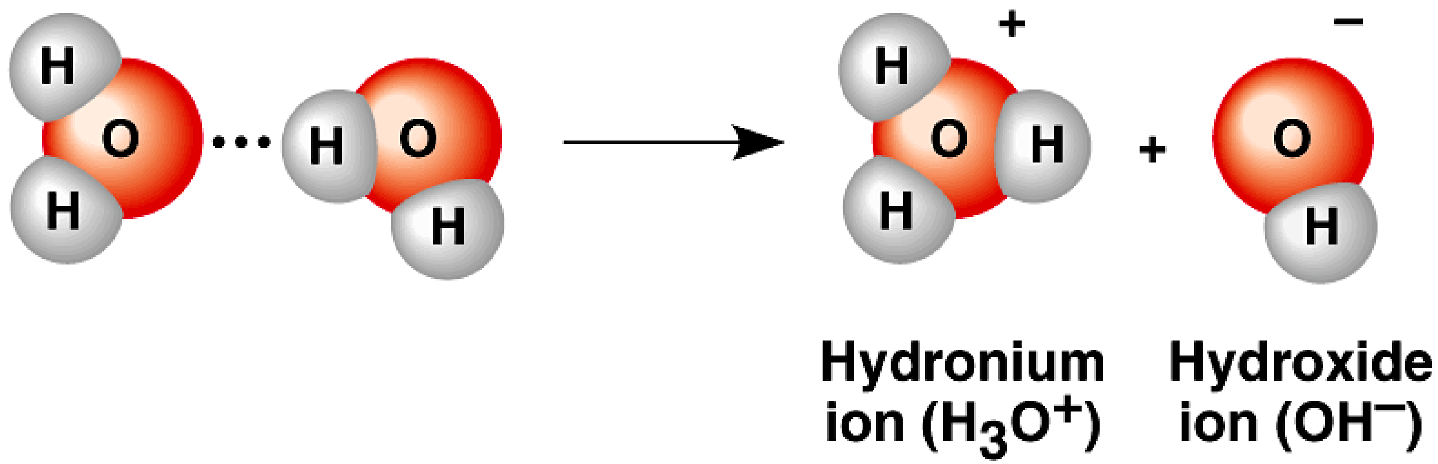
- **<u>Hydrophobic substances</u>** are usually nonionic and nonpolar; **REPELS WATER**
  - Ex: oil and fat



**Fat (triglycerol)**

# Dissociation of Water






- Water breaks up into Hydronium ($H_3O^+$) ions and Hydroxide (OH-) ions
  - One water molecule loses a proton (+) = ($OH^-$)
  - One water molecule gains a proton (+) = ($H_3O^+$)

# Why is this important?

$$H_2O \rightleftharpoons H^+ + OH^-$$

- $[H^+]$ & $[OH^-]$ are equal in pure water. $10^{-7}$ M each – pure water pH 7
  - M = Molarity is the number of moles of solute per liter of solution
- Hydroxide and hydrogen (protons) ions are highly reactive
- Changes in concentration affect cell's proteins and other molecules
- $[H^+]$ & $[OH^-]$ determine the pH of a solution

# pH General

- The product of $H^+$ and $OH^-$ concentrations is constant at $10^{-14}$

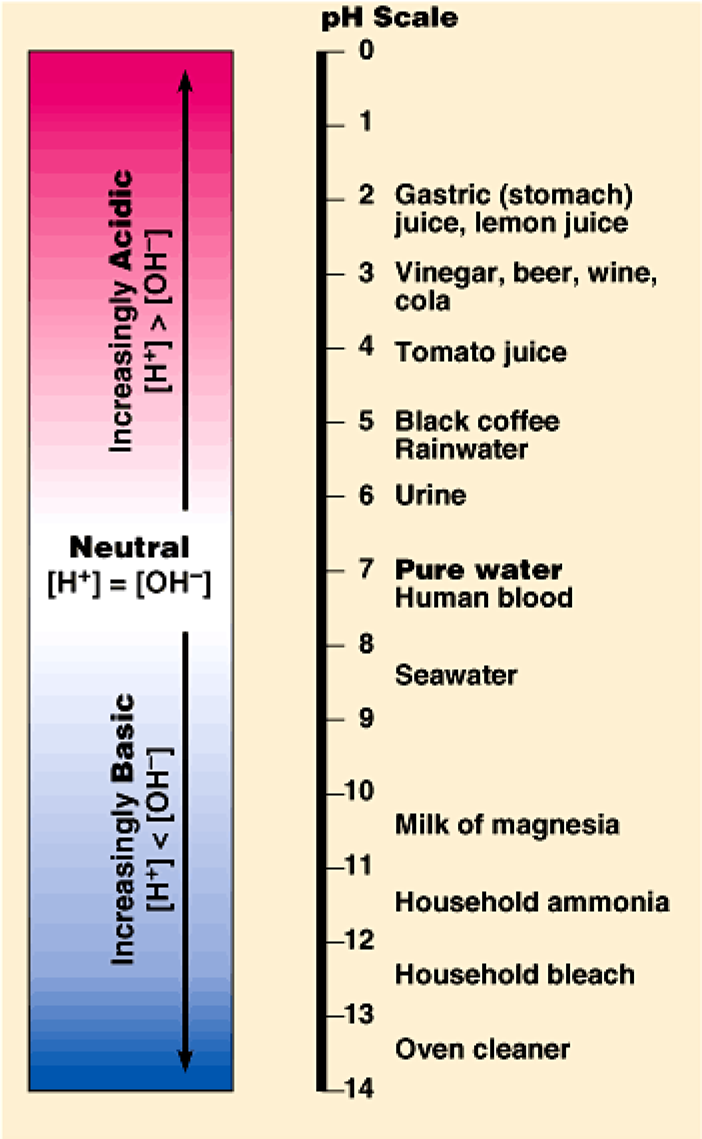
$$[H^+][OH^-] = 10^{-14}$$

  - Brackets indicate Molar concentration
- Neutral solution: $[H^+]=10^{-7}$ and $[OH^-] = 10^{-7}$

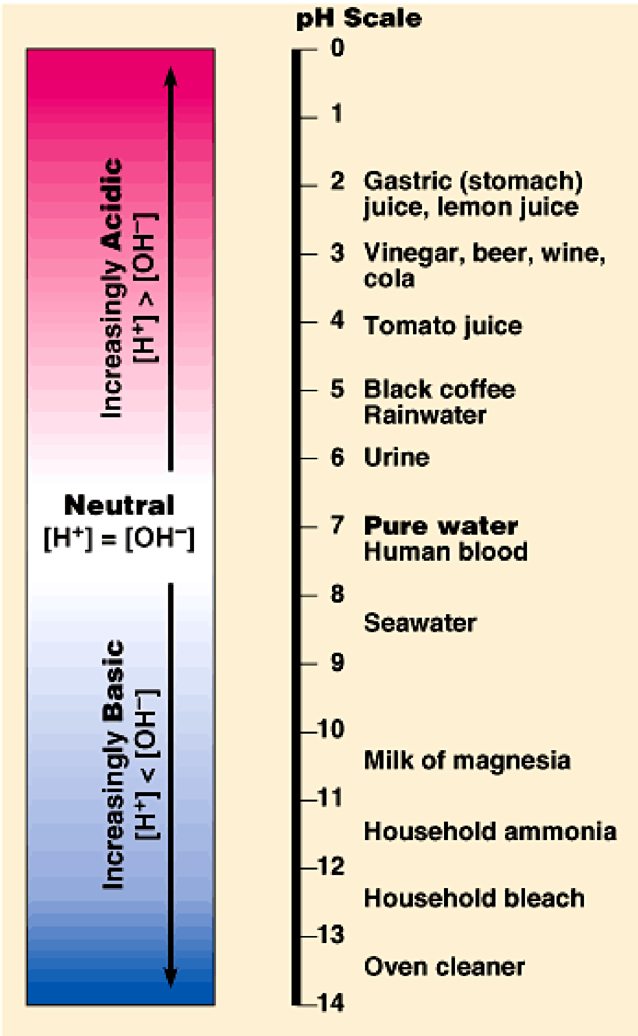
- If the concentration of one ion is known, we can determine the concentration of the other ion.
  - pH: $-\log 10^{-7} = -(-7) = 7$
  - pH < 7 is ACIDIC
  - pH > 7 is BASIC
  - pH units represent a TENFOLD DIFFERENCE!!
    - pH of 3 is NOT TWICE as acidic as pH 6, but 1000X

# Acids

- Ex: HCl dissociates in water to $H^+$ and $Cl^-$; adding more $H^+$ ions to the solution
- Ex: carbonic acid
- Acids have > $H^+$ than $OH^-$
- Acids reduce the $[OH^-]$



# Bases (Alkaline)






- Ex: NaOH dissociates to $Na^+$ ions and $OH^-$ ions
- Ex: Ammonia
- Bases have > $[OH^-]$ ions than $[H^+]$ ions
- Bases reduce the $[H^+]$

# Buffers

- pH in most cells is near NEUTRAL (pH=7)
- Small changes in pH can affect the cell

- BUFFERS help maintain the pH
  - Work by accepting excess $H^+$ from solution or donating $H^+$ when in depletion

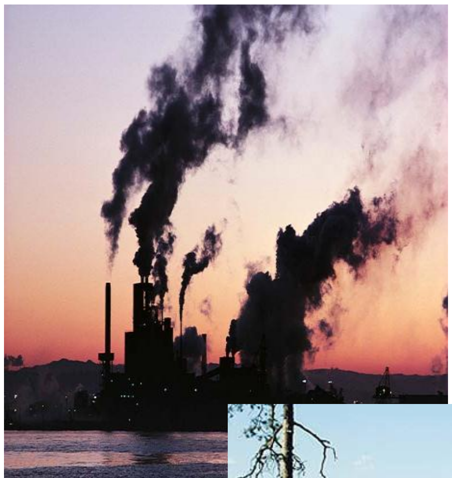
$$H_2CO_3\,(aq) \rightleftharpoons H^+\,(aq) + HCO_3^-\,(aq)$$

The symbol $\rightleftharpoons$ means that dissociation is slight.

A single arrow pointing to the right means complete dissociation (complete reaction)

**Buffers usually contain a weak acid and weak base, much like Carbonic Acid in blood**

# Acid Precipitation



- Uncontaminated rain; pH~5.6
- Acid precipitation has pH < 5.6
  - Caused by sulfur oxides and nitrogen oxides in the atmosphere
  - Sources include: burning fossil fuels (coal, gas, oil) in factories and cars
  - Coal produces the most pollutant