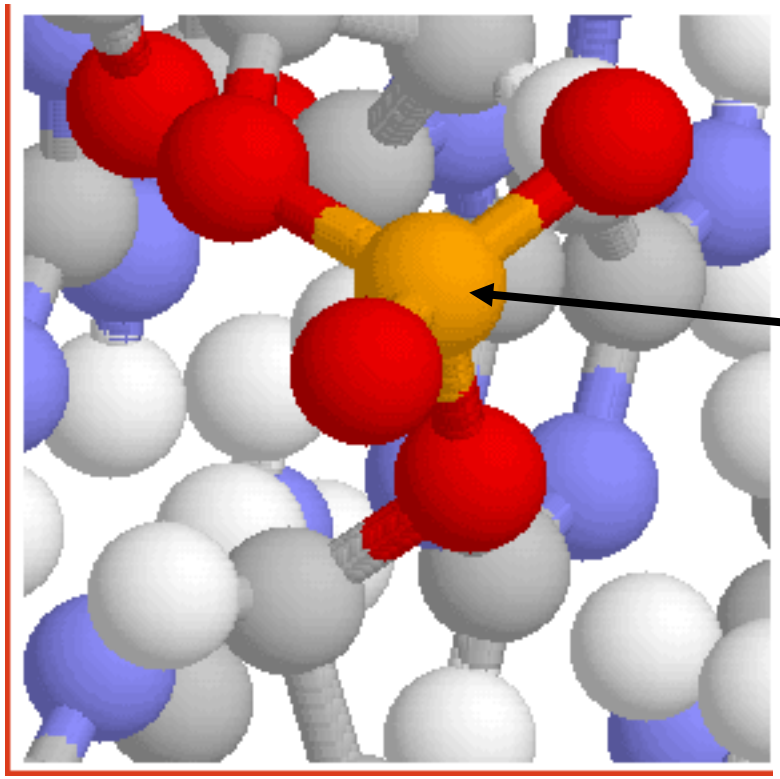
Chapter 2: The Chemical Context of Life

Basic Chemistry Review

Molecular Level (DNA)



Atomic Level (Phosphorus)

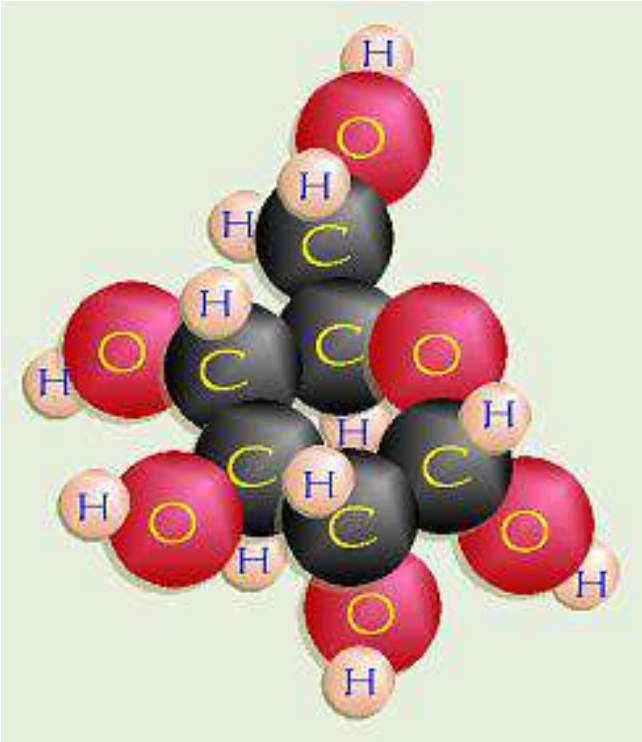
Nitrogen vs. No Nitrogen

Element: substance that cannot be broken down into other substances by chemical reactions

Enlarged thyroid gland
caused by iodine deficiency.

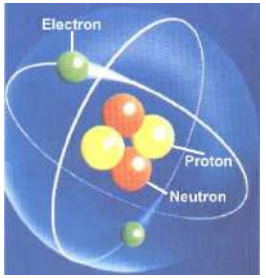
Compound: pure substance composed of 2 or more elements combined in a fixed ratio

- example: **NaCl**
- have unique properties beyond those of the combined elements



glucose

Atom: smallest unit of matter that retains the physical and chemical properties of its element



- three subatomic particles:

Particle	Charge	Location	Mass
Proton	+	nucleus	1.009 amu
Neutron	**0**	nucleus	1.007 amu
Electron	**-**	electron cloud	1/2000 amu

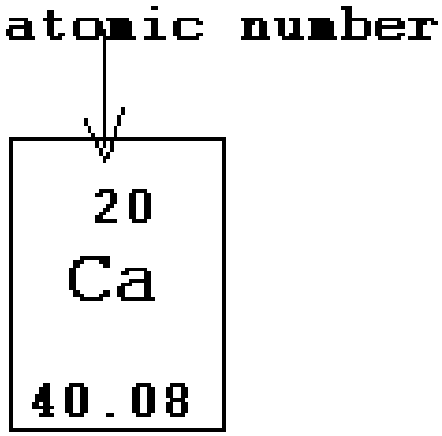
Atomic number: **# of protons** in an atom of an element

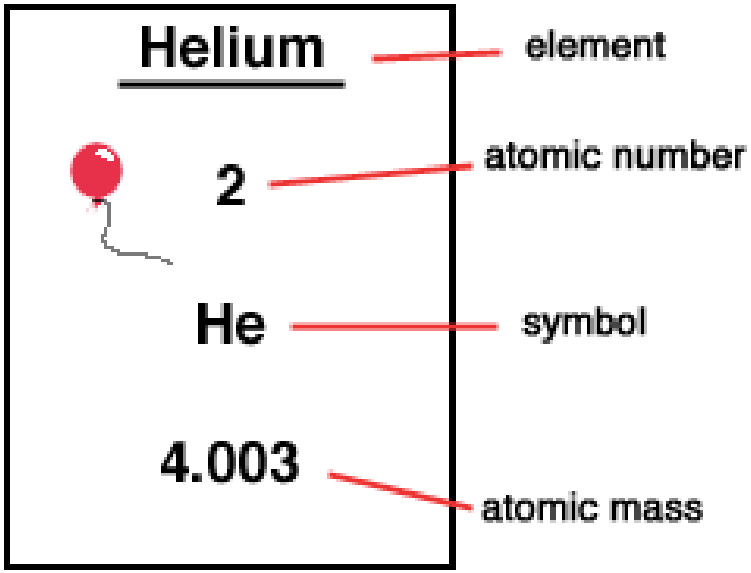
-all atoms of an element have the same atomic #

-written as a subscript next to the element's symbol

-in a **neutral** atom,

protons = # electrons





Mass number =

# of protons + # of neutrons

-written as a superscript next to element's symbol

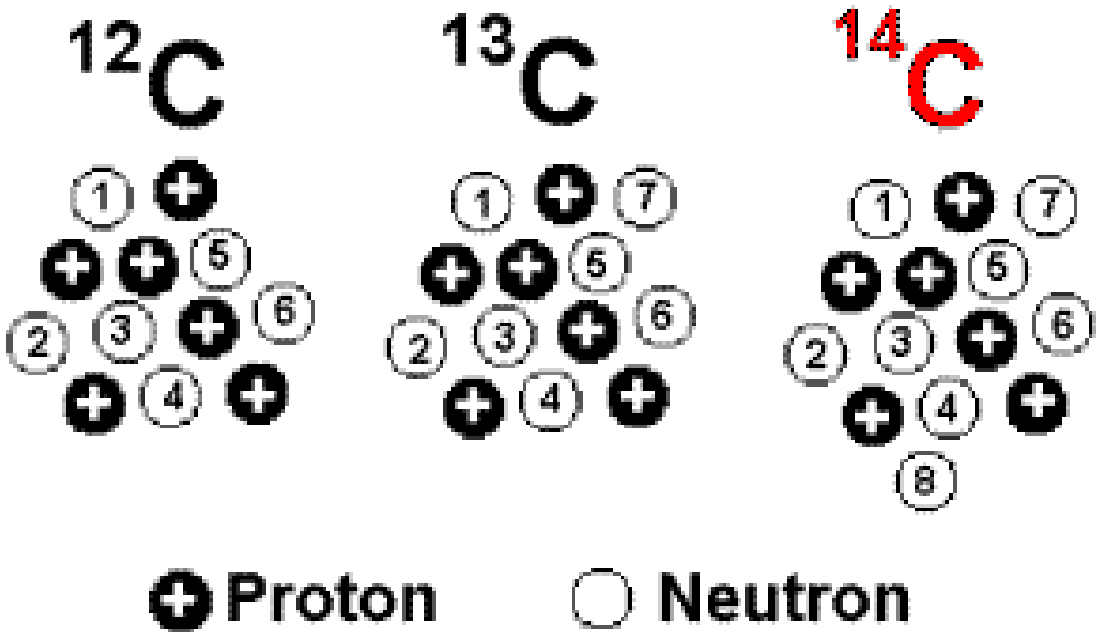
-# of neutrons can vary in an element, but proton # is constant

Isotopes: atoms of an element that have different # of neutrons

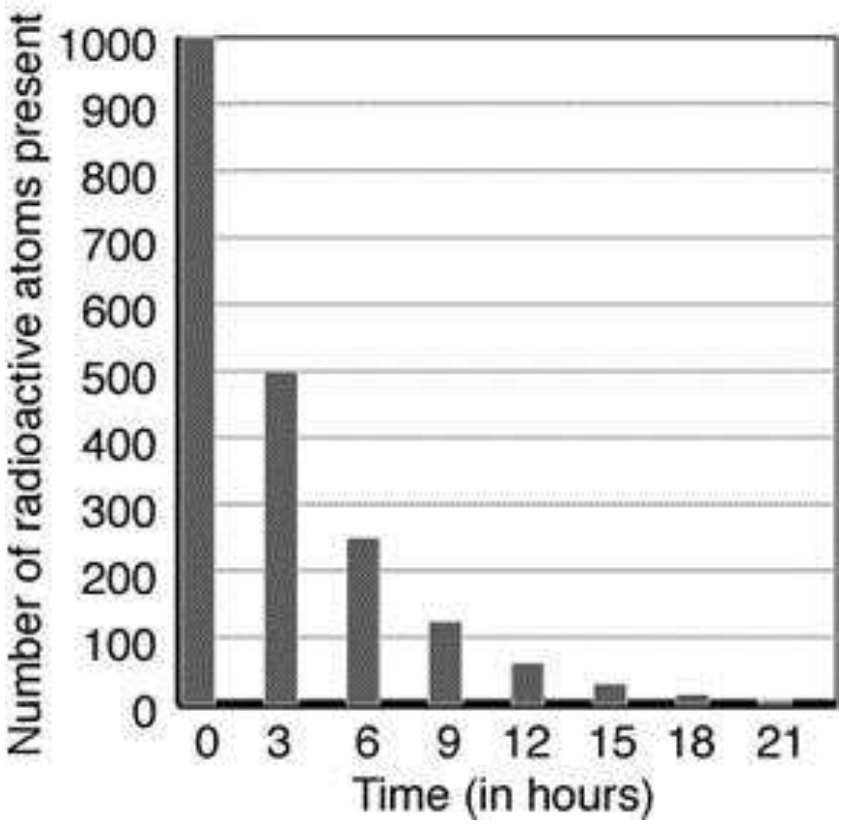
-in nature, elements occur as mixtures of isotopes

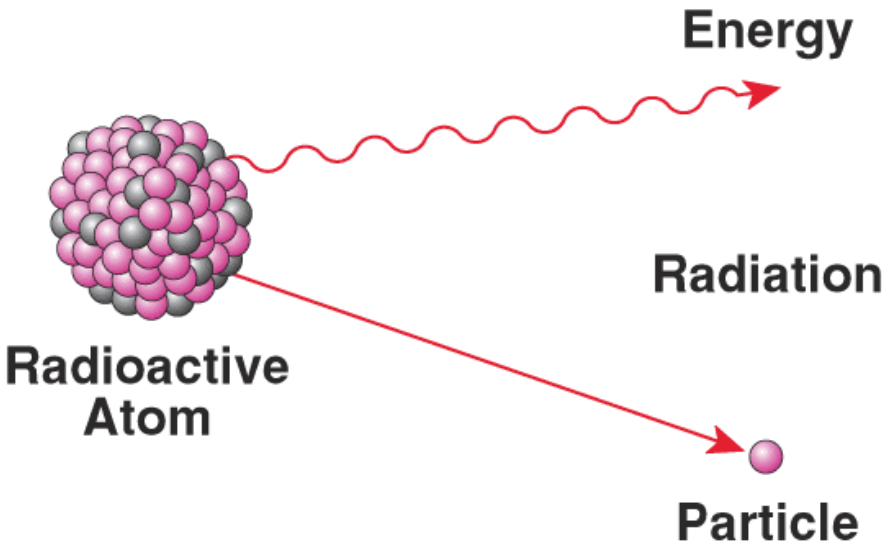
-some are ***RADIOACTIVE***: unstable isotope where nucleus decays emitting sub-atomic particles and/or energy as radioactivity, causing one element to transform into another element

Atomic Nuclei of Three Isotopes of Carbon



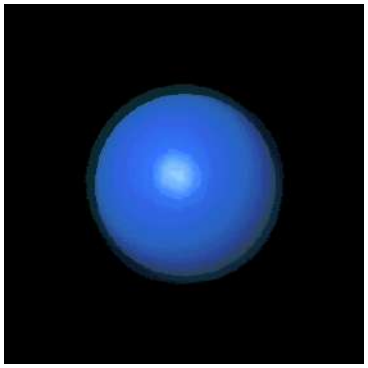
Half-life: the time it takes for 50% of the radioactive atoms in a sample to decay

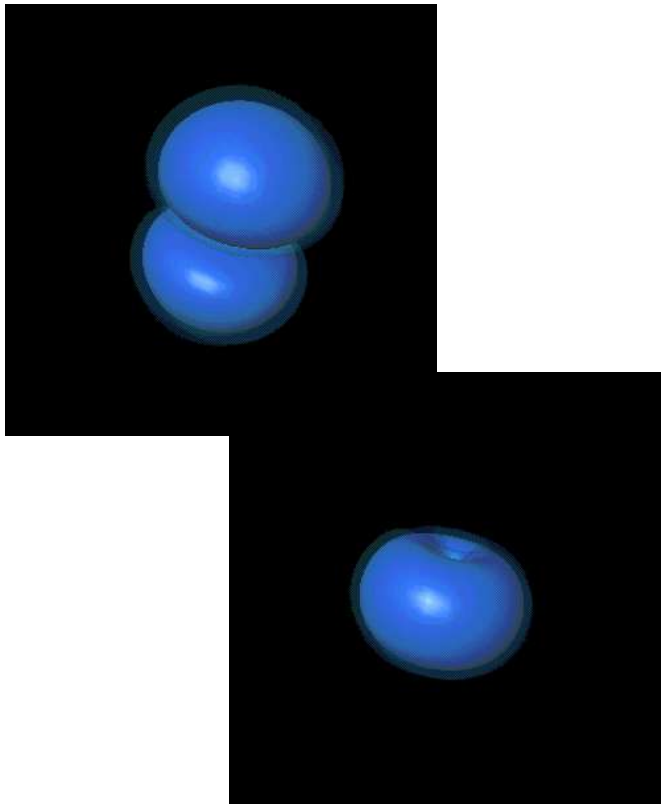


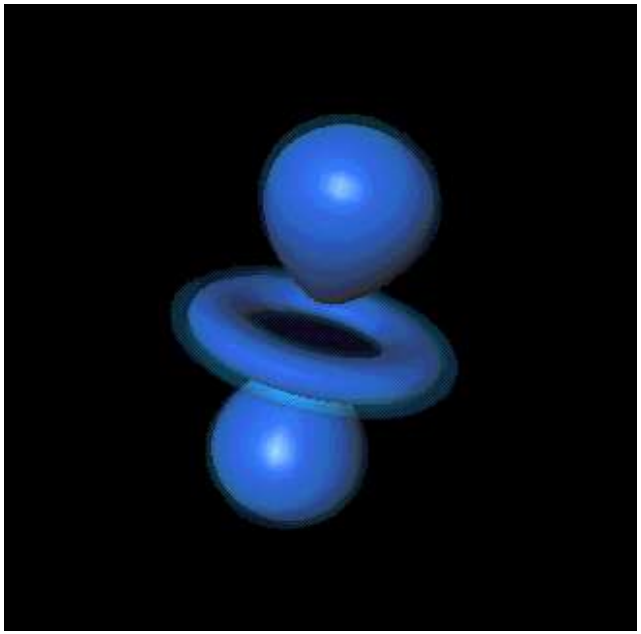


Energy Levels of Electrons

- **ELECTRONS** are the only subatomic particle involved in chemical reactions because they occupy energy levels surrounding the nucleus

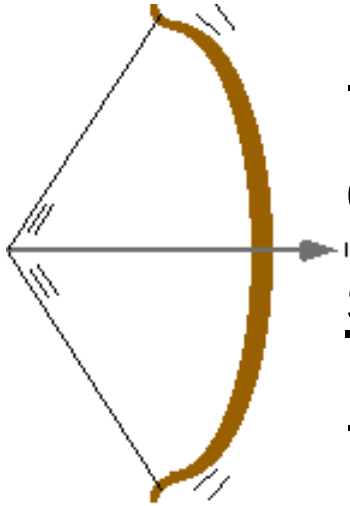






<u>Potential energy</u>: energy that matter stores because of its <u>position or location</u>

-matter will move to the lowest state of potential energy



-there are fixed potential energy states for electrons: **<u>energy levels or electron shells</u>**

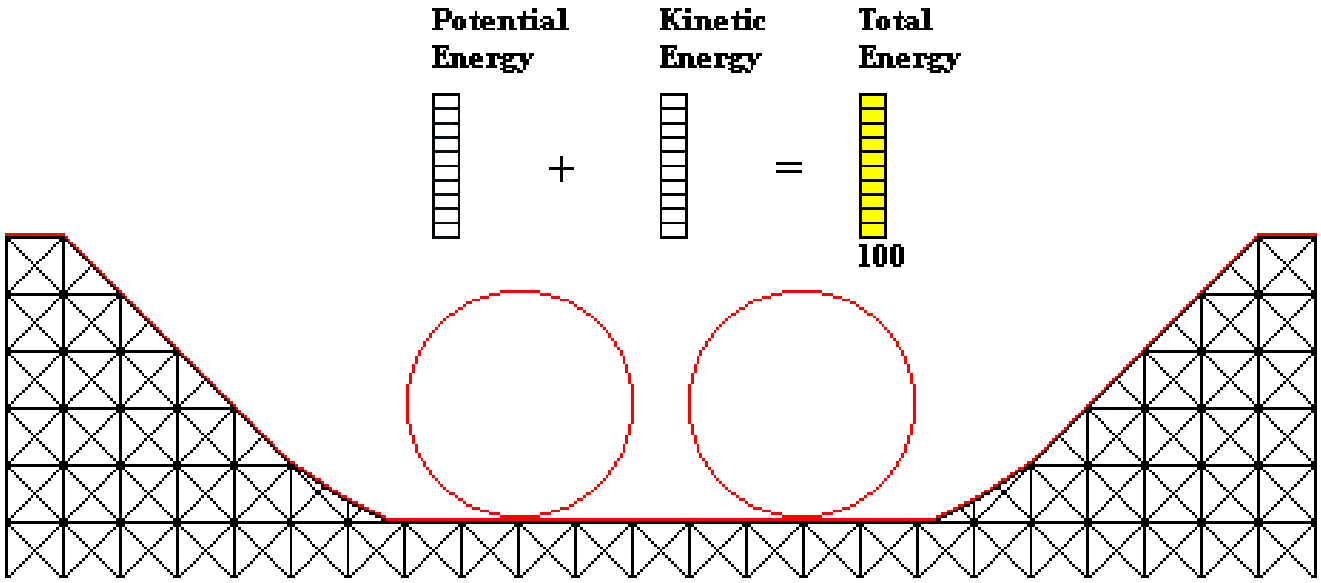
-electrons with lowest PE are closest to nucleus

-electrons may move from one level to another and in the process they gain or lose energy

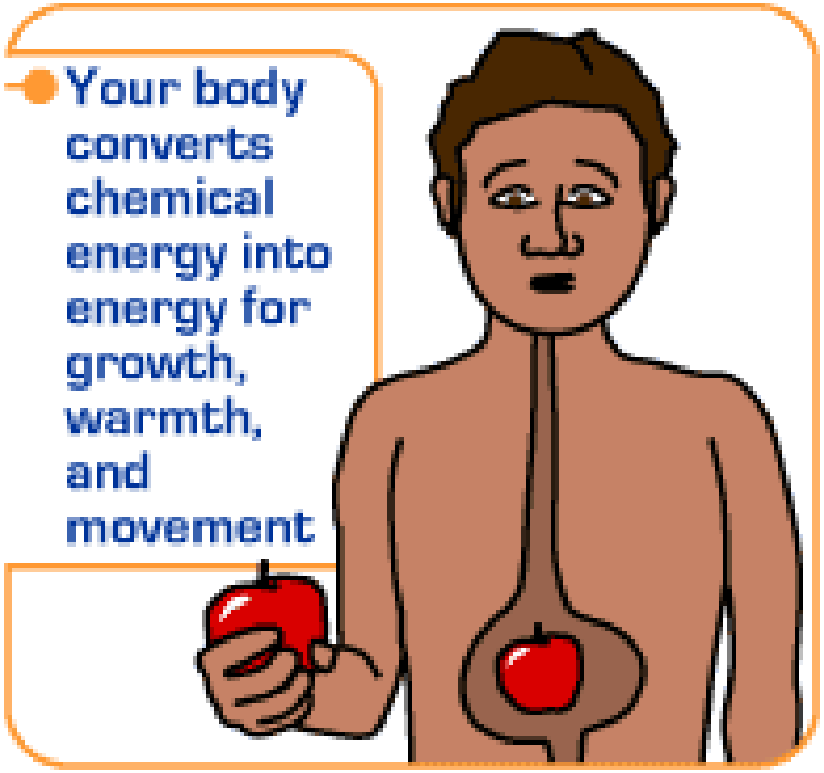
Potential energy (continued):

-an atom's electron configuration determines it's chemical behavior

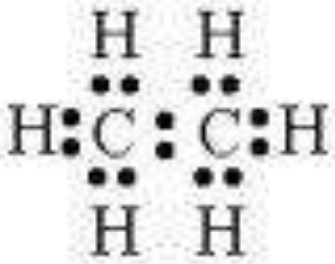
-chemical properties of an atom depend upon the number of valence (outermost shell) electrons



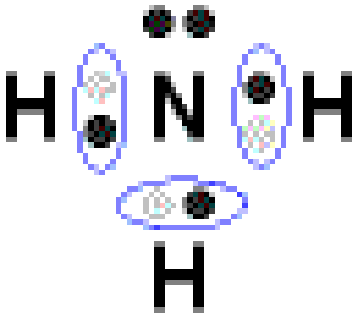
Potential Energy In Living Things

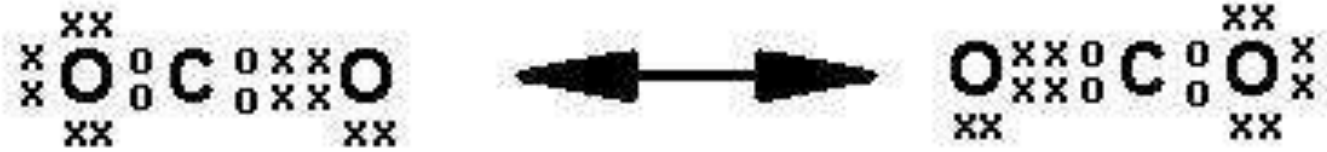


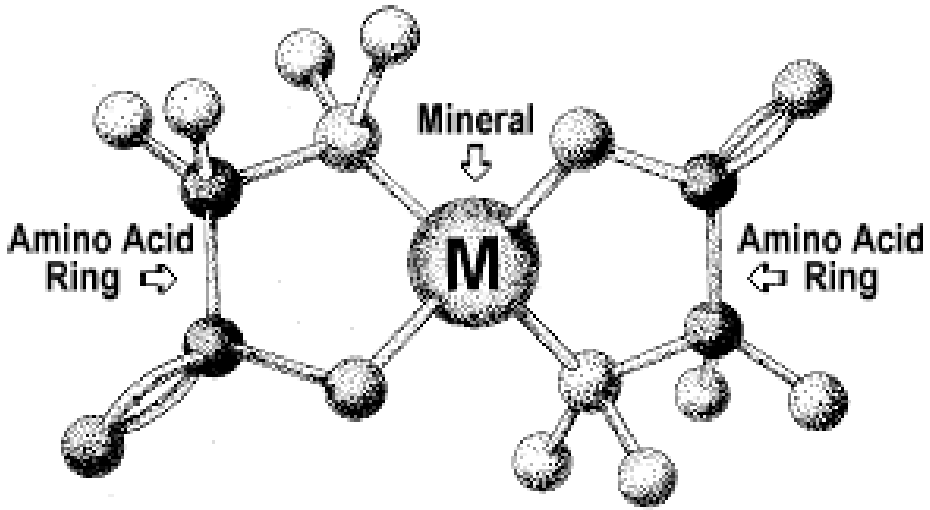
Chemical Bonding



***Octet Rule**: atoms will share, gain, or lose electrons in order to achieve a stable electron configuration of 8 (like a noble gas)



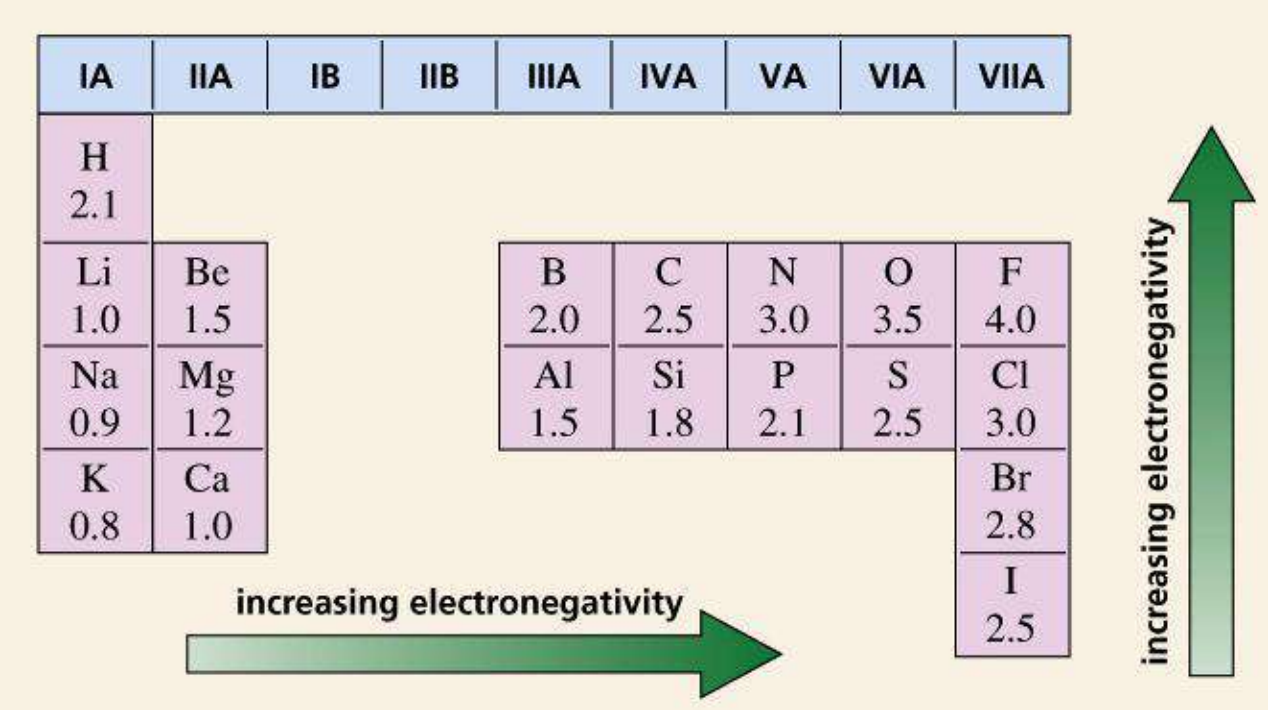




***Covalent bond**: strong chemical bond between atoms formed by **sharing a pair of valence electrons**

***<u>Electronegativity</u>**: atom's ability to attract and hold **ELECTRONS**

-the more electronegative an atom, the more strongly it attracts shared electrons



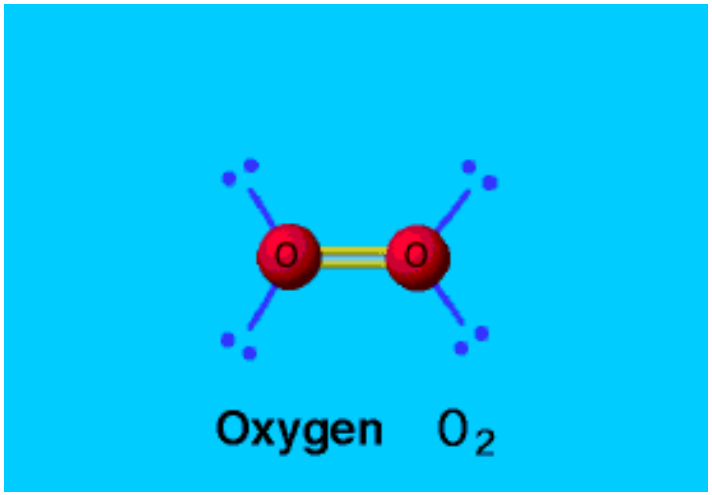
-examples:

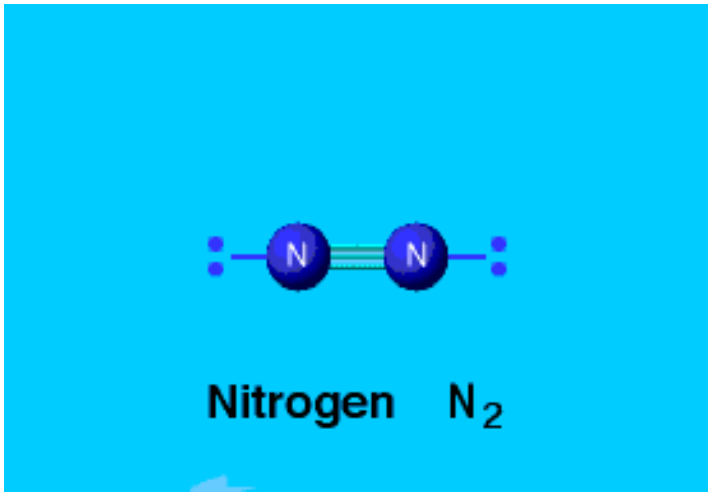
<u>O = 3.5; N = 3.0; C = 2.5; H = 2.1</u>

***Nonpolar covalent bond**: covalent bond formed by an equal sharing of electrons between atoms

-occurs when electronegativity of both atoms is about the same

-molecules made of one element contain nonpolar covalent bonds

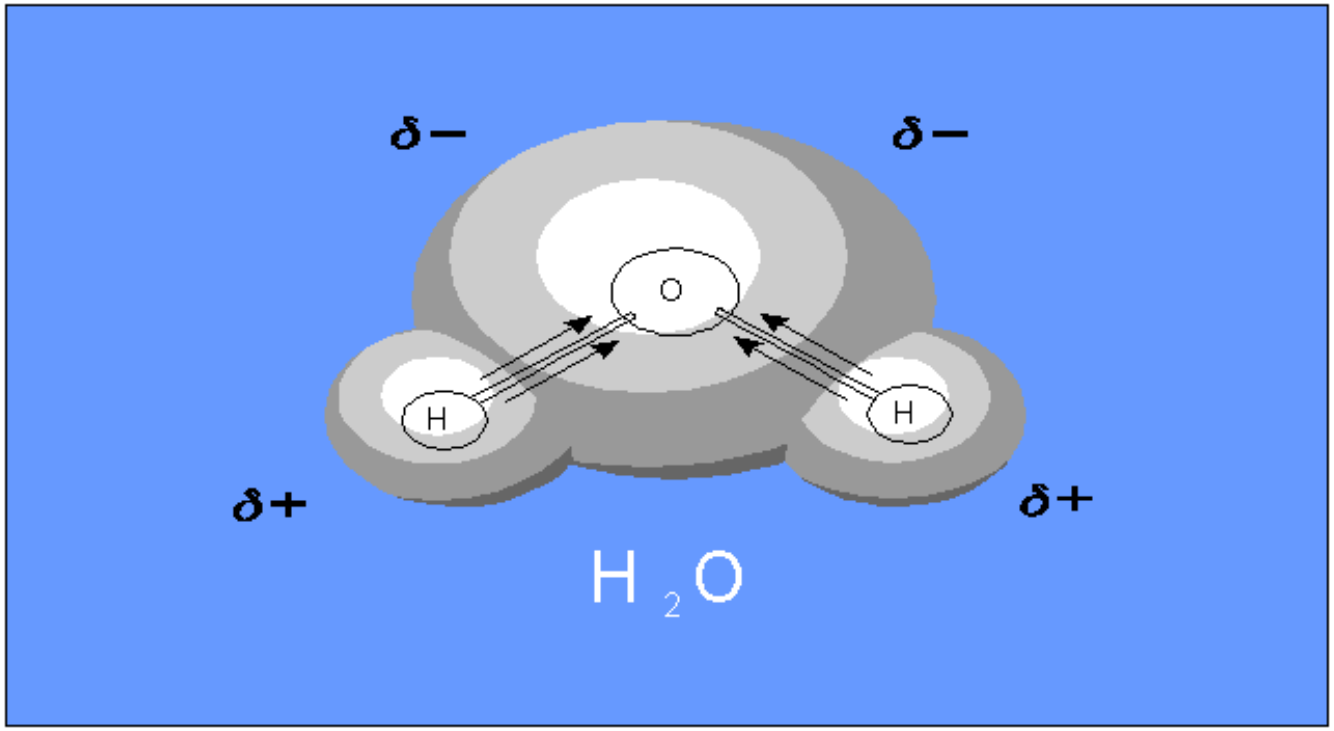




***Polar covalent bond**: unequal sharing of electrons

-occurs between 2 atoms with different electronegativities

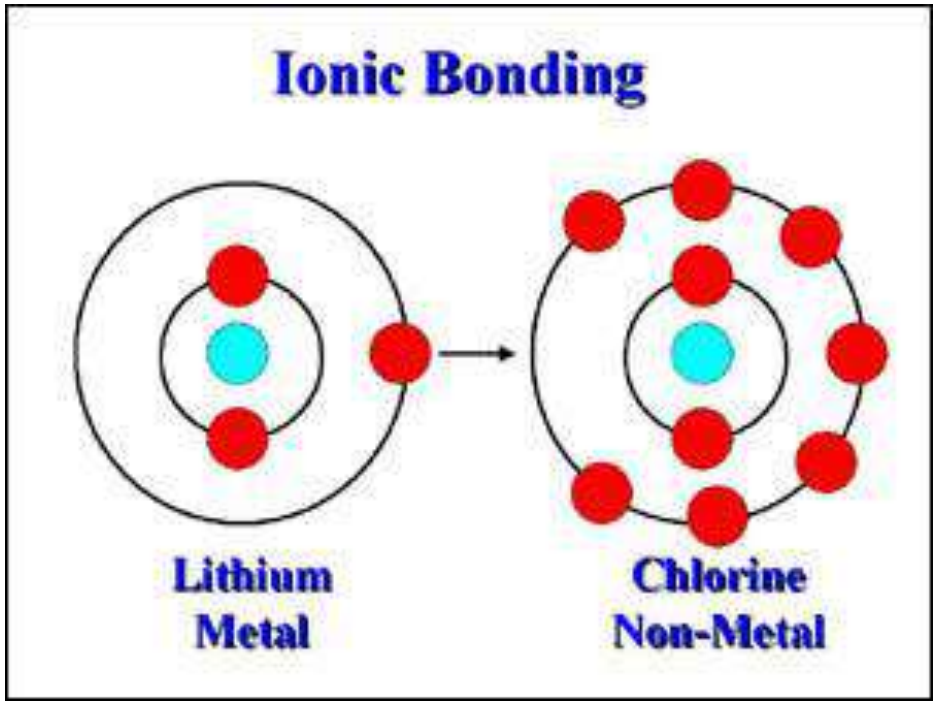
-shared electrons spend more time around the more electronegative atoms



***Ionic bond**: bond formed by the electrostatic attraction after the complete transfer of one or more electrons from a donor atom to an acceptor

-**anion**: negatively charged ion; has gained 1 or more electrons

-**cation**: positively charged ion; has lost 1 or more electrons

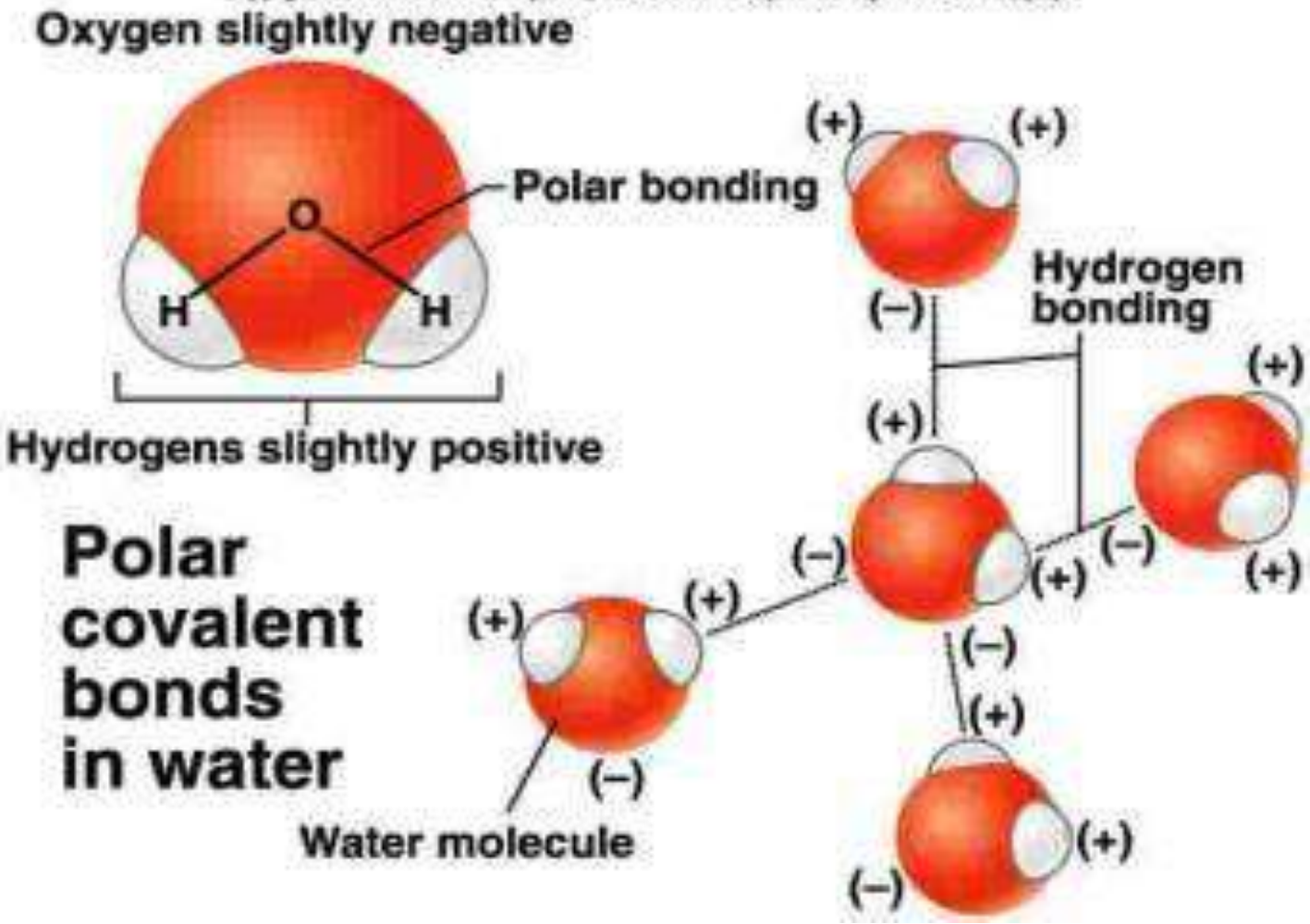


***Hydrogen bond**: weak bond between a hydrogen atom covalently bonded to a more electronegative atom, and an unshared pair of electrons on an adjacent molecule

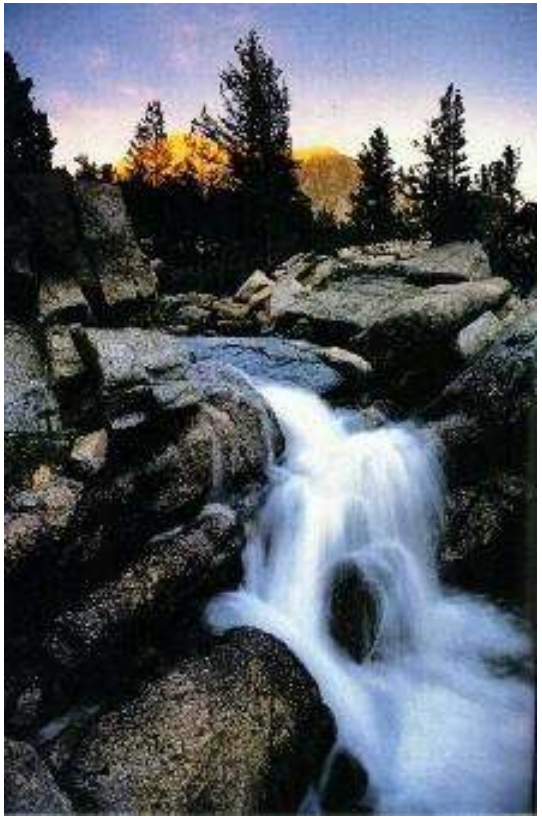
-a charge attraction between oppositely charged regions of polar molecules

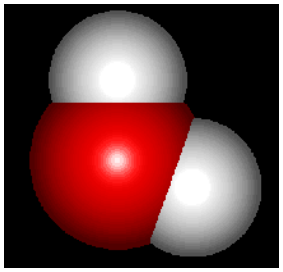
-short-lived

-numerous (make up in # what they lack in strength and duration)



Polar covalent bonds in water

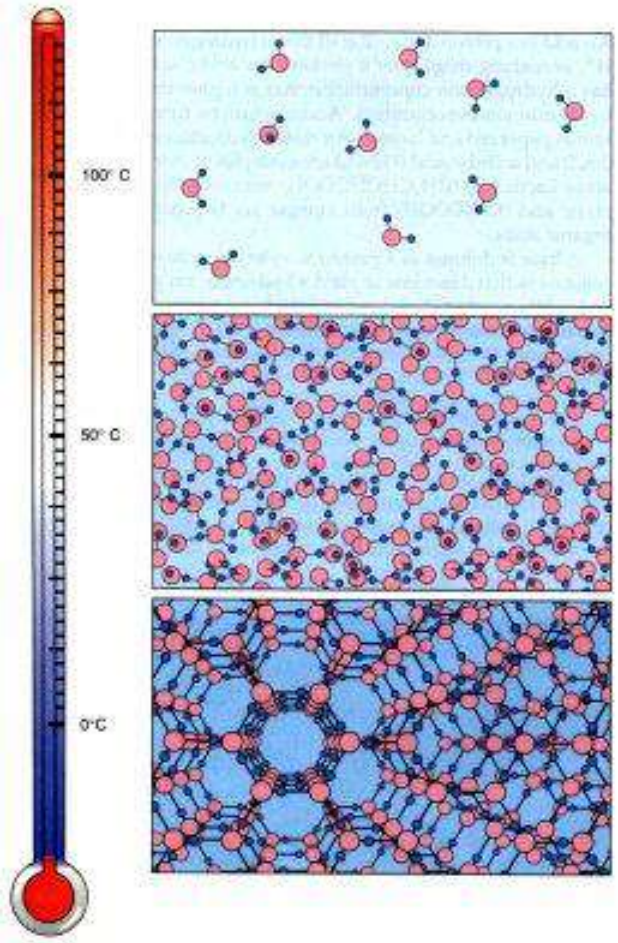


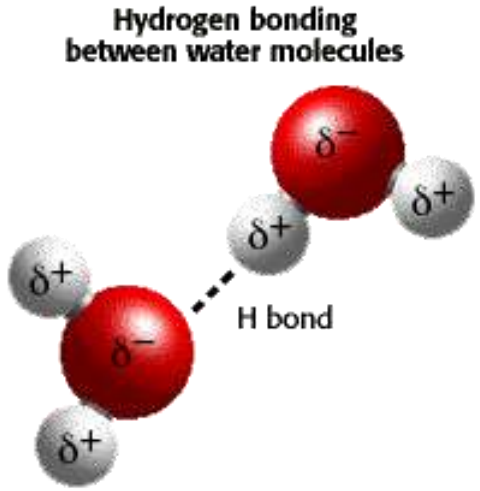


Chapter 3: Water and the Fitness of the Environment

Water…

- Life on earth probably evolved in water
- Living cells are 70%-90% water
- Water covers approx. ¾ of earth.
- In nature, water naturally exists in all 3 states of matter: solid, liquid and gas



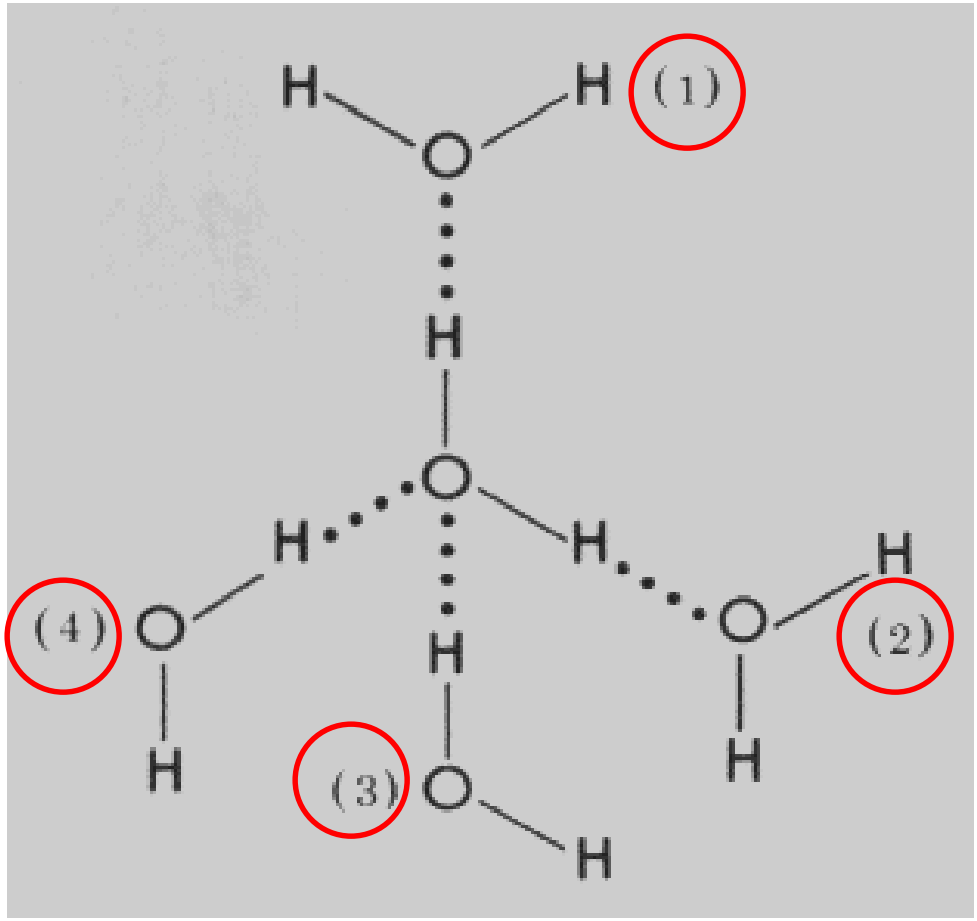


Water is a **POLAR** molecule

-The polarity of water molecules results in…

HYDROGEN BONDING

-Each water molecule can form a maximum of 4 hydrogen bonds with neighboring water molecules


(1)
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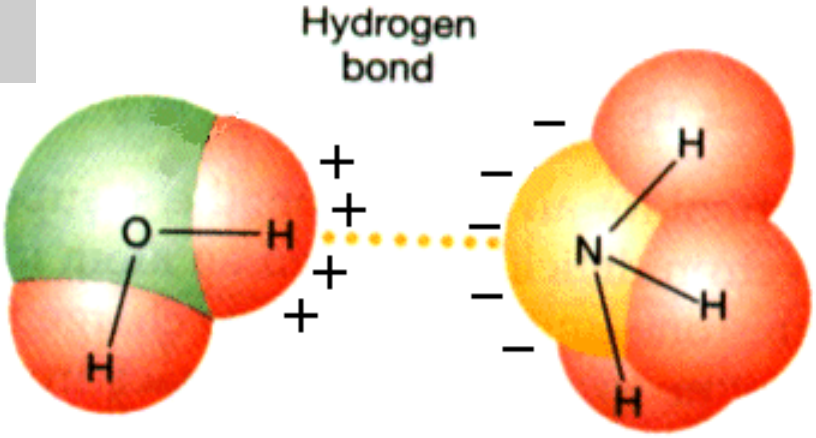
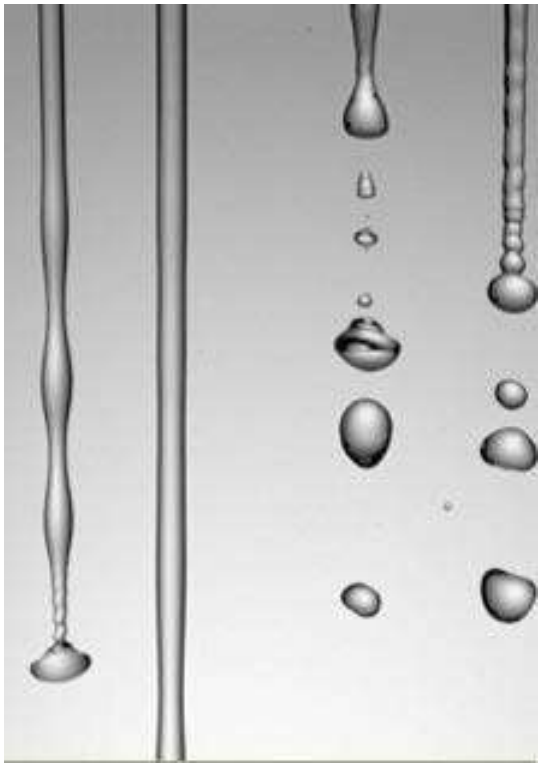
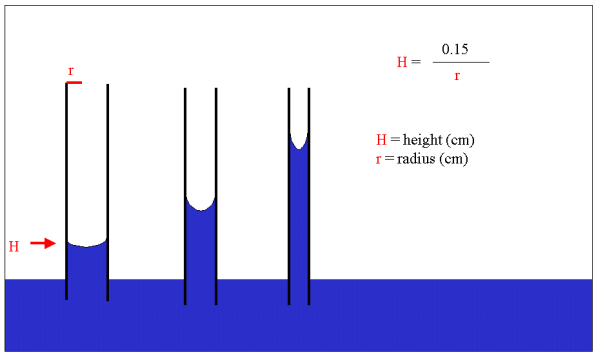

Hydrogen bond

Properties of Water (as a result of polarity and H-bonding):

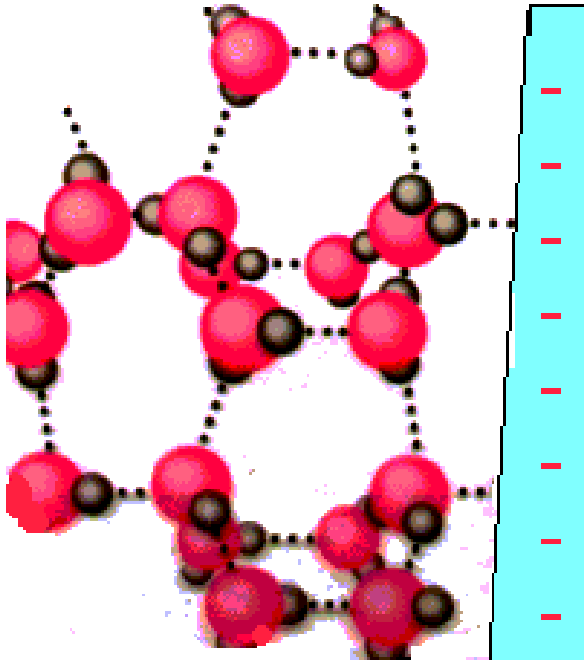
1) **<u>COHESION</u>**: molecules are <u>held together by H bonds</u>

   -contributes to upward movement of water in plants from roots to leaves





Properties of Water



2) <u>ADHESION</u>: <u>water sticks to other surfaces</u> (by polarity or H bonds); can counteract gravity in plant vessels

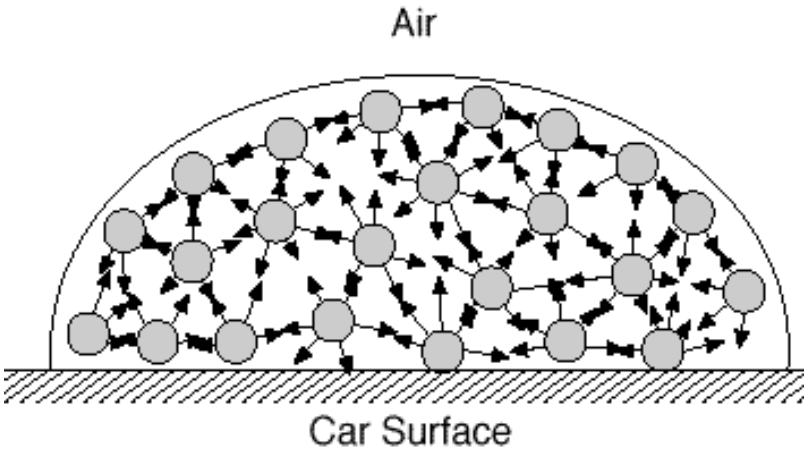
Properties of Water

3) **<u>SURFACE TENSION</u>**: measure of how difficult it is to stretch the surface of a liquid

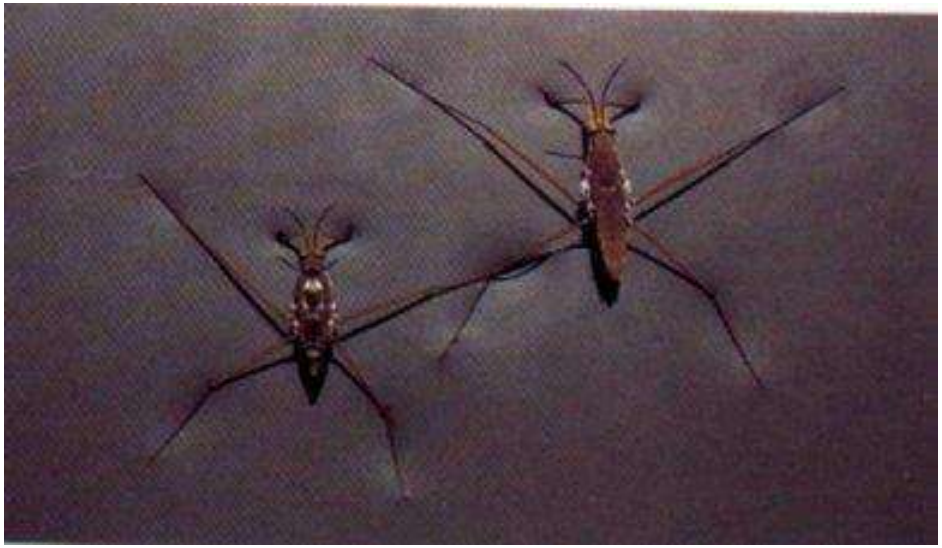
-water has greater surface tension than most liquids because at the air/water interface the surface water molecules are H-bonded to each other and to the water molecules below

-causes water to “bead”

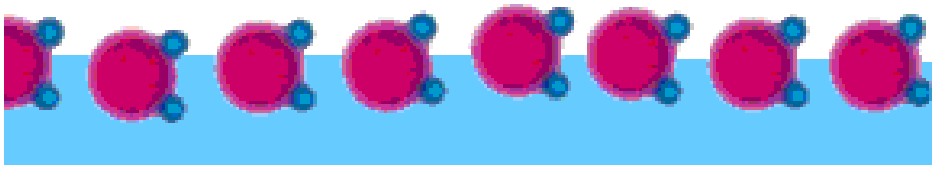
-creates a “skin” on the surface



Molecules inside a water drop are attracted in all directions. Dro
are attracted to the sides and inward.



Surface Tension



Properties of Water

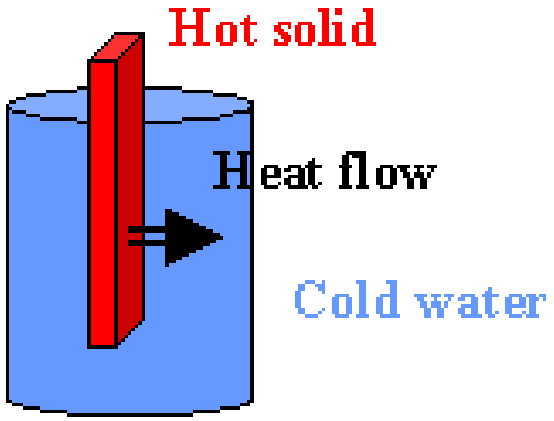
4) <u>HIGH SPECIFIC HEAT</u> (resists changes in temp)

-<u>Specific Heat</u>: amt. of heat that must be absorbed or lost for 1 gram of a substance to change its temp by 1°C

-Water's high specific heat means that it resists temp. changes when it absorbs or releases heat

**Heat is absorbed to break H-bonds; and given off when they form*

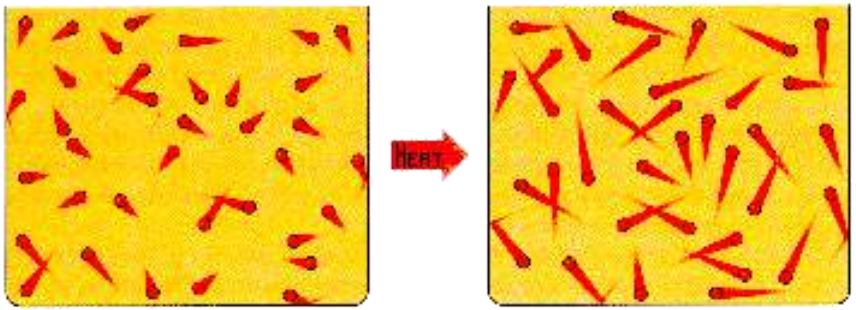
Specific Heat



$$(\text{heat lost})_{\text{hot object}} = (\text{heat gained})_{\text{cold object}}$$

$$(\text{sp. heat} \times \text{mass} \times \Delta T)_{\text{hot object}} = (\text{sp. heat} \times \text{mass} \times \Delta T)_{\text{cold object}}$$

Properties of Water



5) <u>HIGH HEAT OF VAPORIZATION</u>

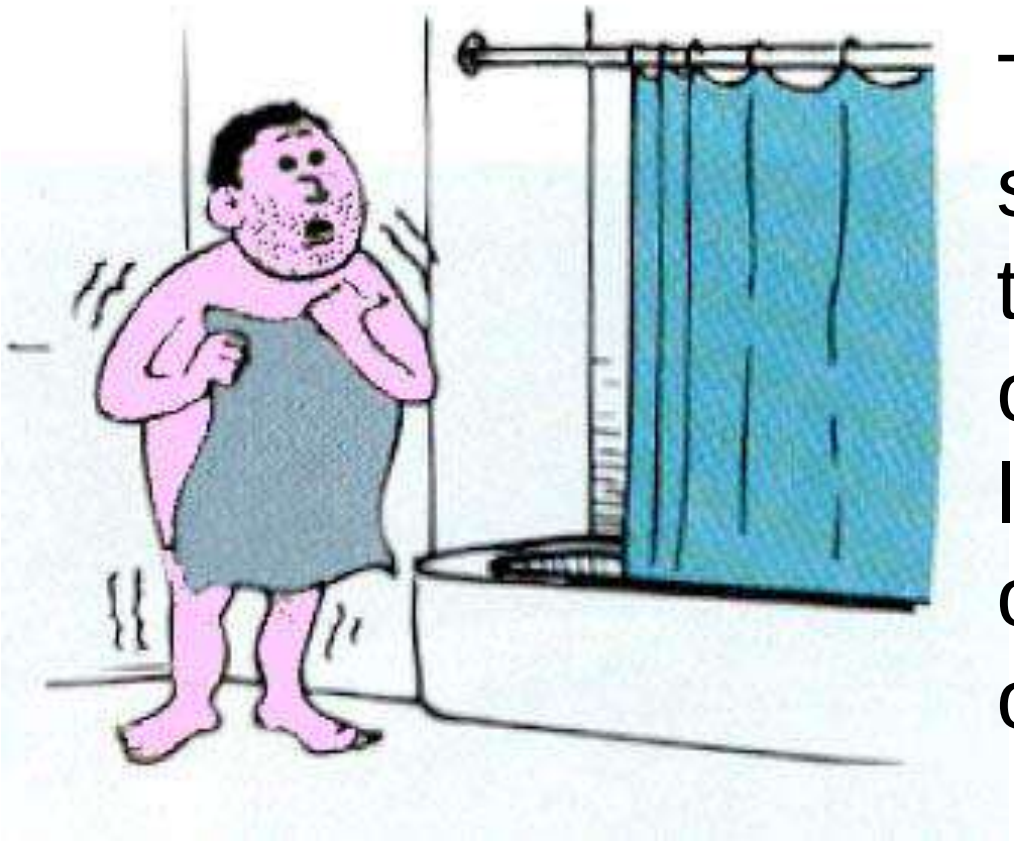
-Heat of vaporization = amt. of heat a liquid must absorb for 1 g to be converted to gas state

-for water molecules to evaporate, H-bonds must be broken, which requires heat energy

- **EVAPORATIVE COOLING**: after high temp. molecules have evaporated, the remaining liquid is cooler (ex: sweating)

  -stabilizes temp. in aquatic ecosystems

  -protects organisms from overheating (as 1 g of water evaporates from our skin, 539g of body cools by 1°C)

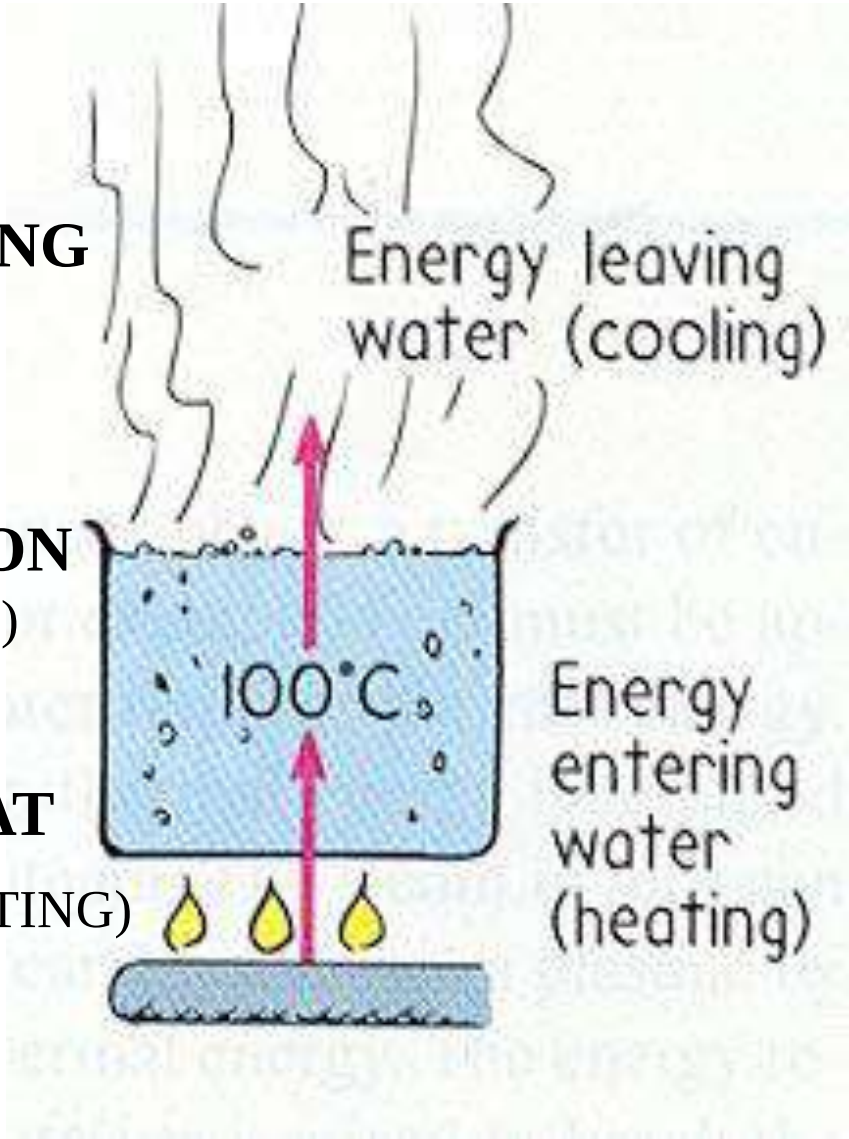


The air in the shower stall is at the same temperature as the air outside, but there's less water vapor outside to condense on the skin.

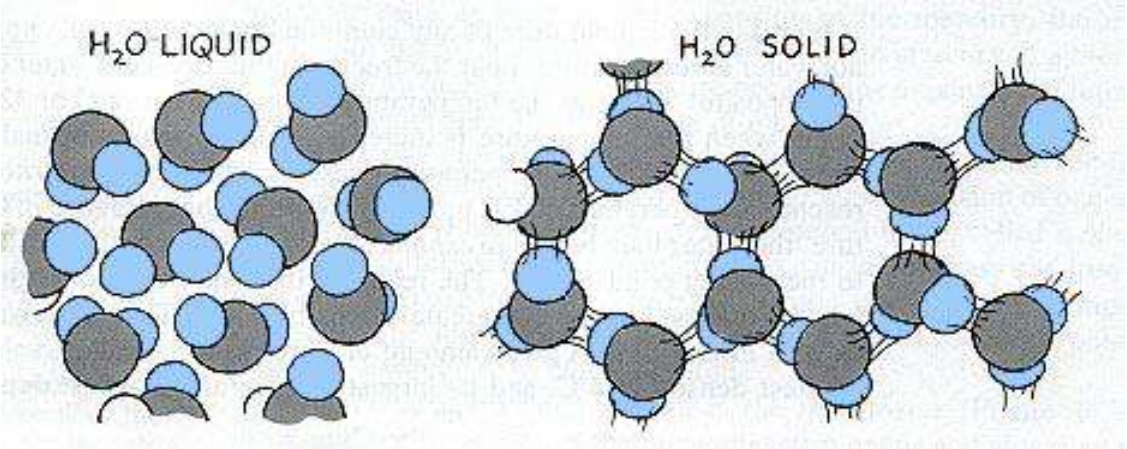
EVAPORATIVE COOLING

HEAT OF VAPORIZATION
(WHILE CHANGING STATE)

SPECIFIC HEAT
(WHILE WATER IS HEATING)



Properties of Water



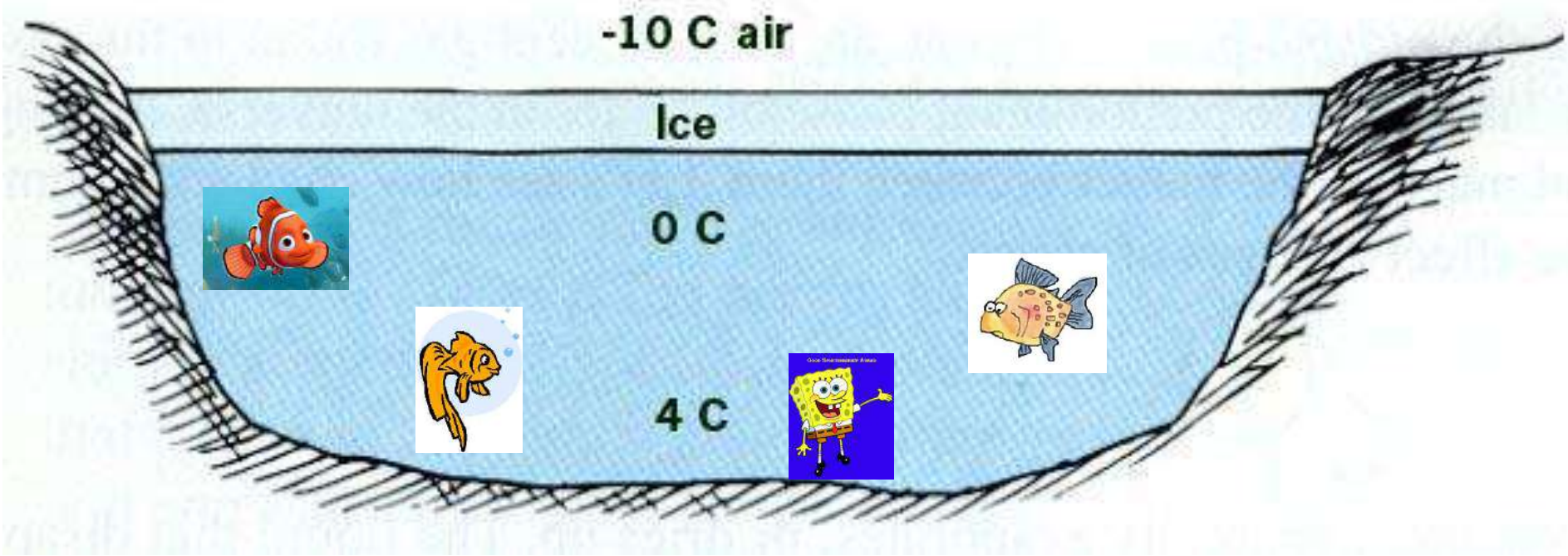
6) <u>WATER EXPANDS WHEN IT FREEZES</u>

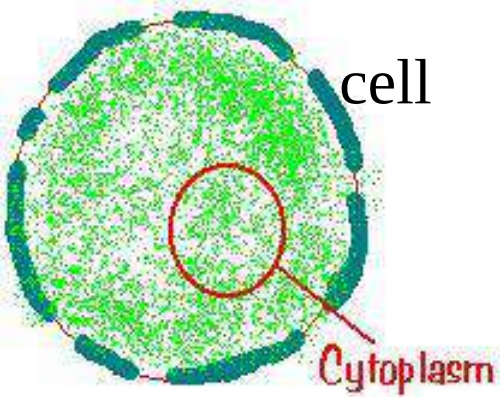
-because of H-bonding, water is less dense as a solid than it is as a liquid...ice floats!

-since ice is less dense, it forms on the surface at first

-as water freezes, <u>it releases heat to the water below and insulates it</u>!

-Oceans and lakes don’t freeze solid!!

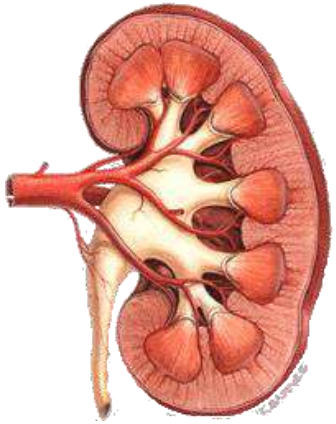

-10 C air
Ice
0 C
4 C

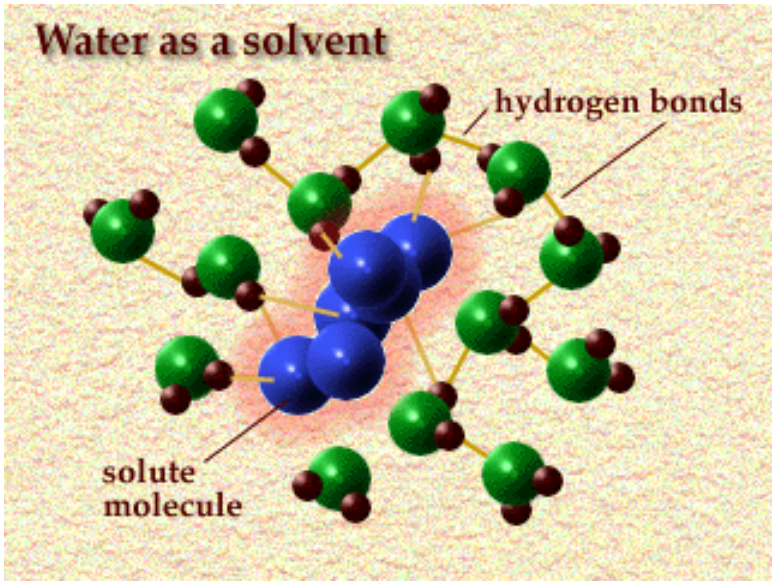


Properties of Water

7) **WATER IS THE SOLVENT OF LIFE**

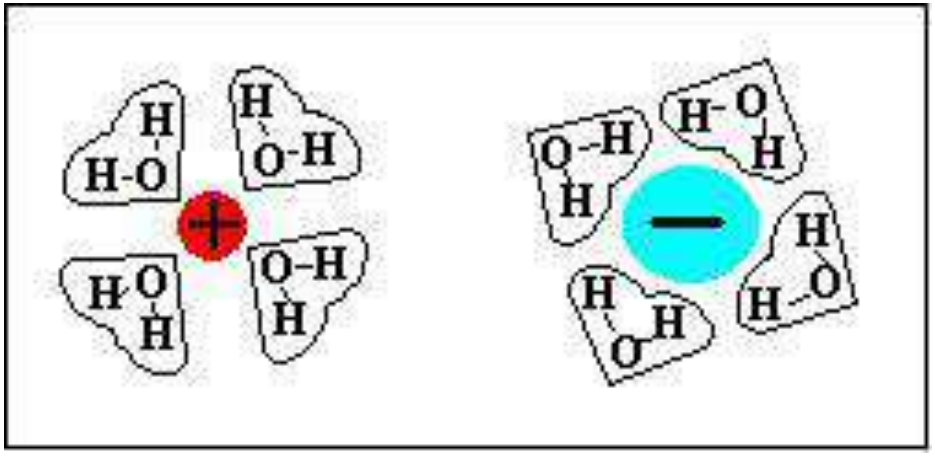
-due to its polarity, water is a versatile solvent





- Compounds that are **HYDROPHILIC** (“water loving”), <u>are soluble in water</u>:

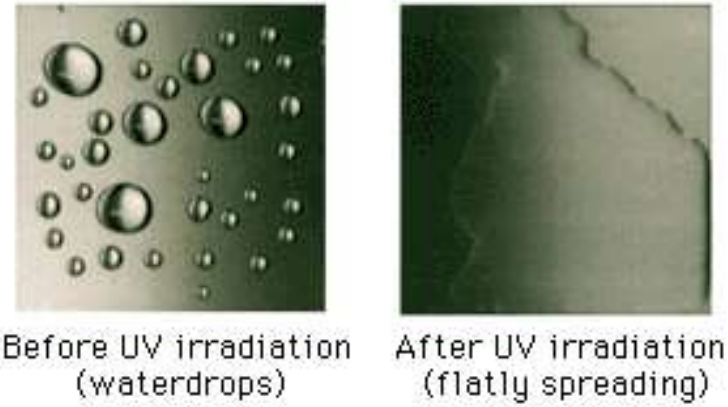
  -<u>ionic compounds</u>: charged regions of polar water molecules have an electrical attraction to charged ions



  -<u>polar compounds</u>: charged regions of polar water molecules are attracted to oppositely charged regions of other polar molecules

Fig. 1 Shape of waterdrops on the surfaces of glass, resin and hydrophobic resin

- Compounds that are **HYDROPHOBIC** ("water fearing") are insoluble in water:
  - Nonpolar compounds: symmetric distribution in charge, or composed of nonpolar bonds



Before UV irradiation (waterdrops)

After UV irradiation (flatly spreading)

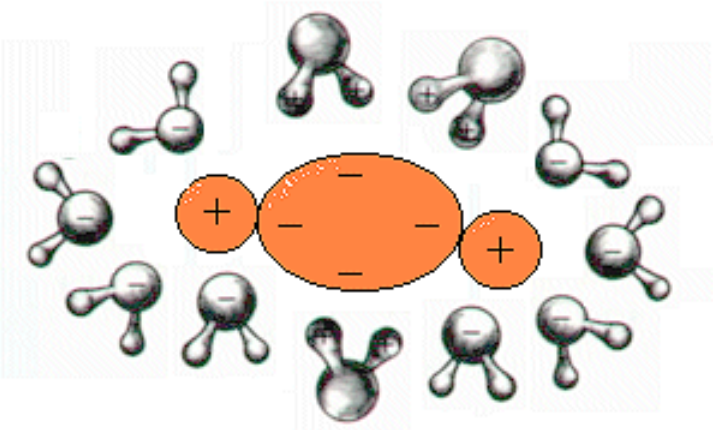
Solutions and Concentration

- Quantitative Information:

  -mole

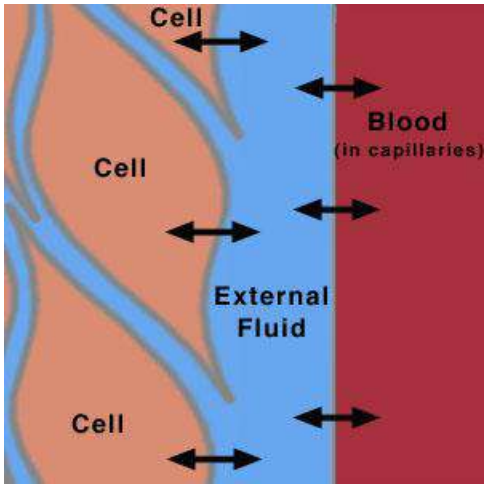
  -molecular weight (molar mass, g/mol)

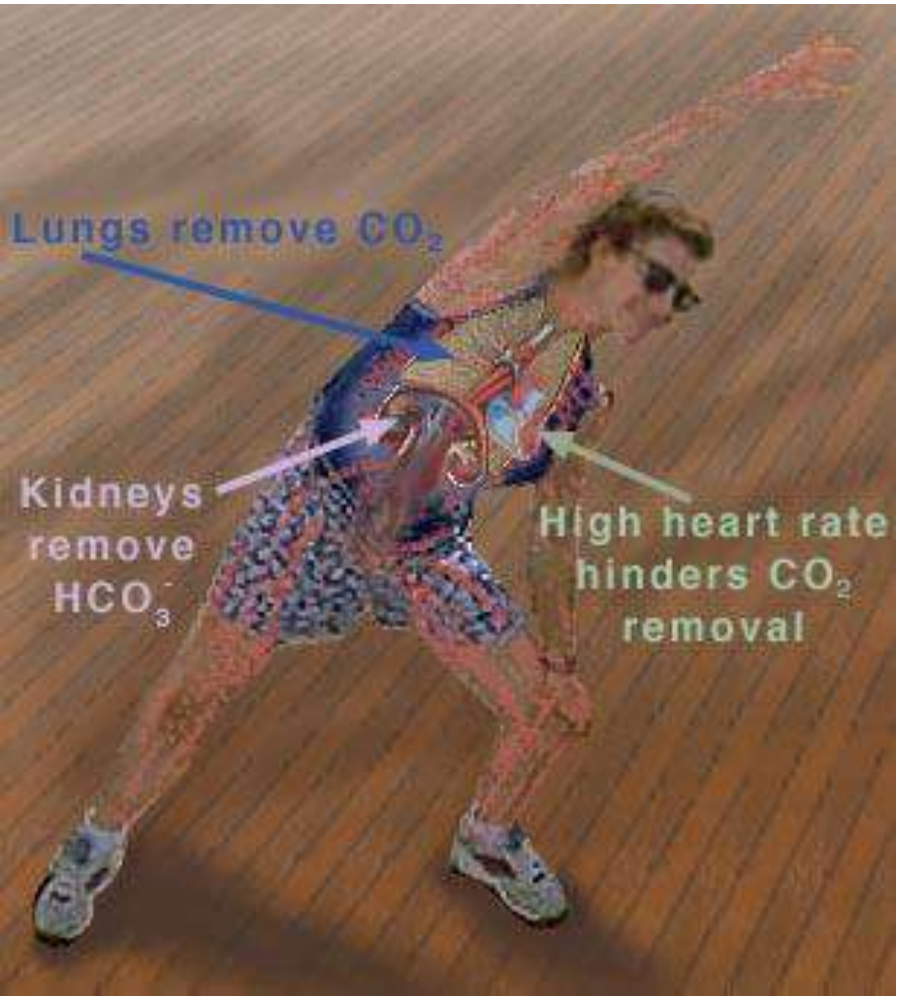
  -molarity: # of moles solute per liter of solution



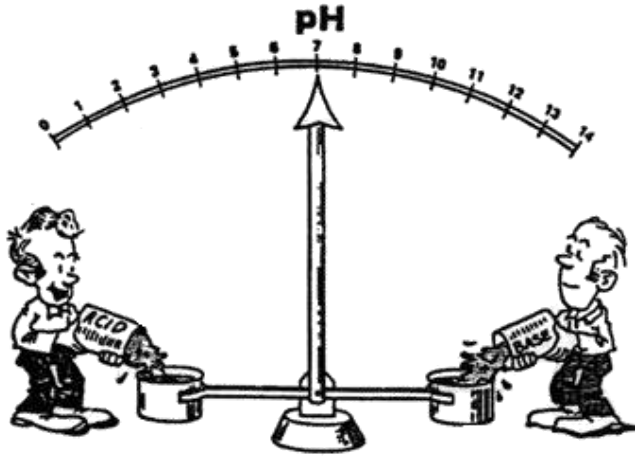
Acids, Bases, and pH

- in neutral water: $[H^+] = [OH^-] = 10^{-7}M$
- acids increase $[H^+]$; bases decrease $[H^+]$
- in any solution, $[H^+] \bullet [OH^-] = 1 \times 10^{-14}$
- $pH = -\log [H^+]$

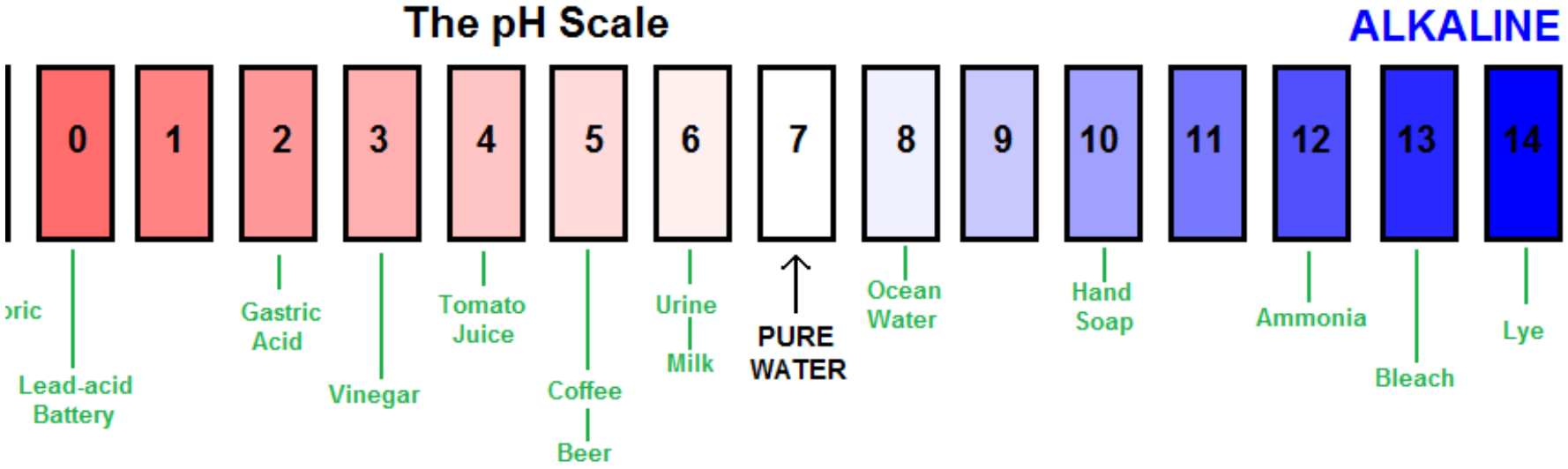


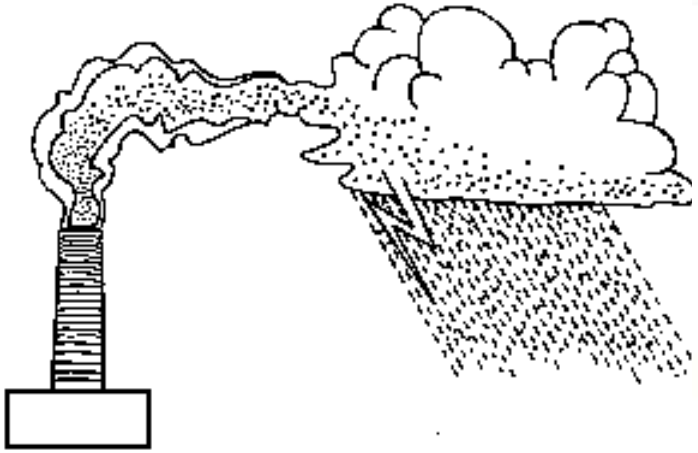

Lungs remove CO_2
Kidneys remove HCO_3^-
High heart rate hinders CO_2 removal

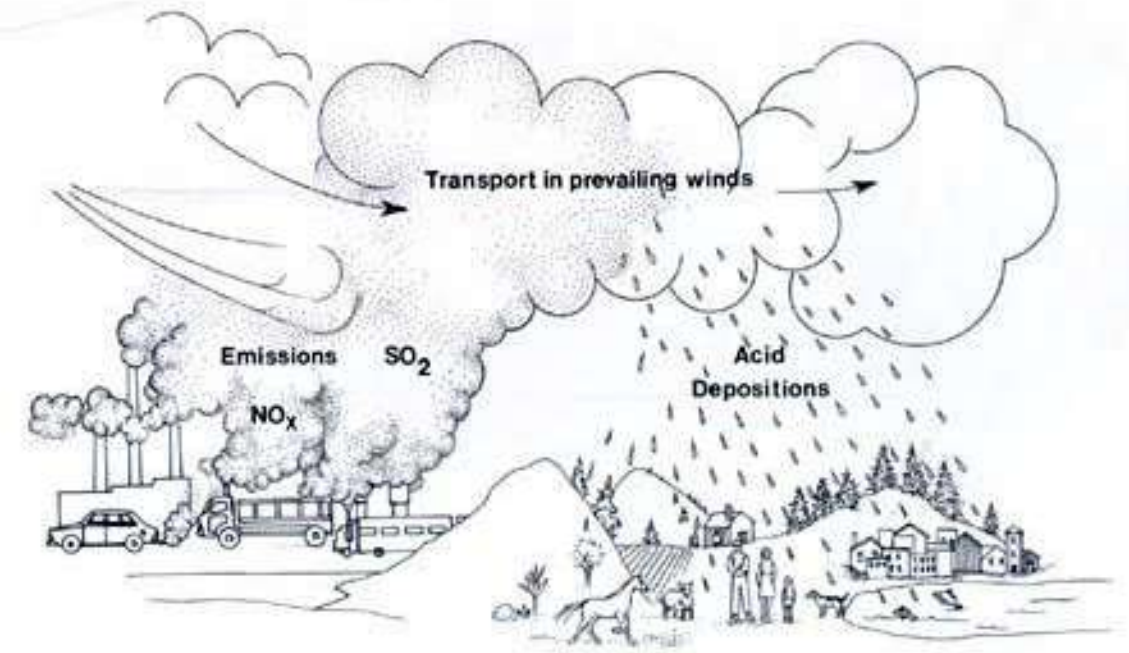

Other effects:
Breathing rate increased
Heart rate increased
Changes in blood:
O_2 used up
CO_2 produced
H^+ produced
Lactic acid produced
Temperature increased
pH lowered


pH
ACID
BASE

pH scale


The pH Scale
ALKALINE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Lead-acid Battery
Gastric Acid
Vinegar
Tomato Juice
Coffee
Beer
Urine
Milk
PURE WATER
Ocean Water
Hand Soap
Ammonia
Bleach
Lye





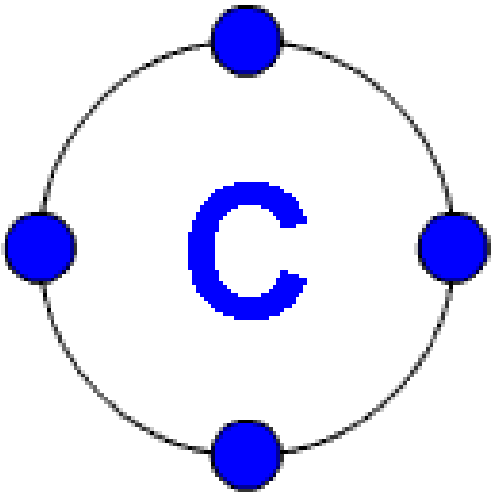
Acid precipitation

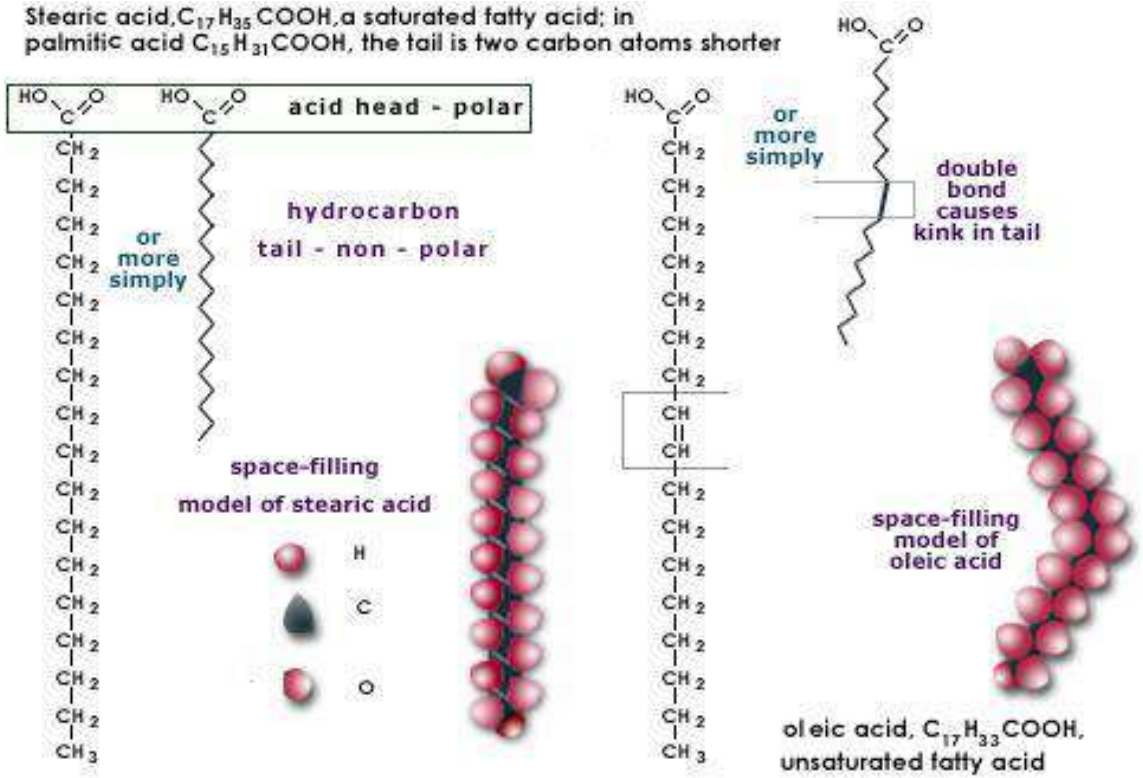
- rain, snow, or fog with pH less than 5.6

  -sulfur oxides and nitrogen oxides in the atmosphere react with water to form acid

Chapter 4:

Carbon and the Molecular Diversity of Life



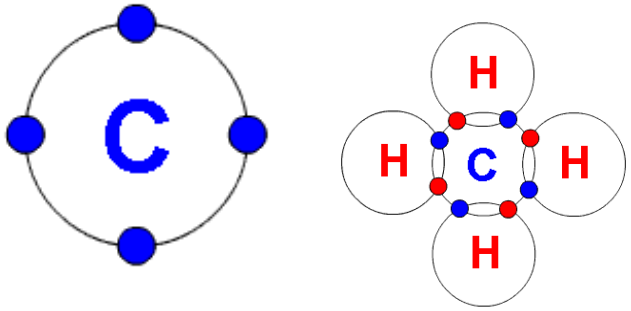


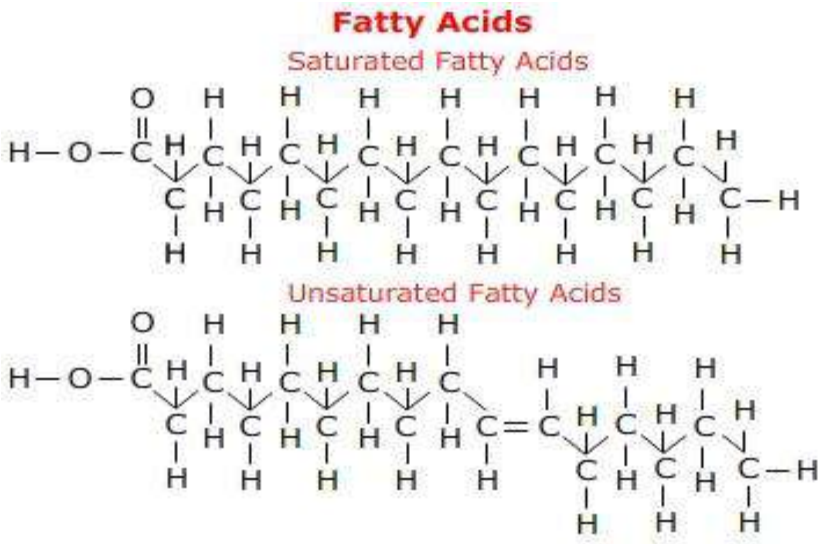
Overview: Carbon—The Backbone of Biological Molecules

- Although cells are 70–95% water, the rest consists mostly of carbon-based compounds
- Carbon is unparalleled in its ability to form large, complex, and diverse molecules
- Proteins, DNA, carbohydrates, and other molecules that distinguish living matter are all composed of carbon compounds

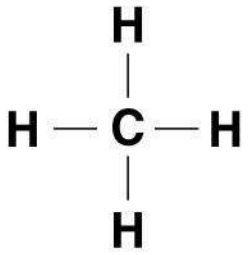
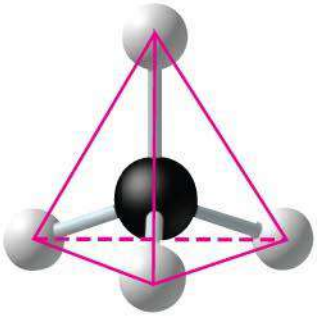
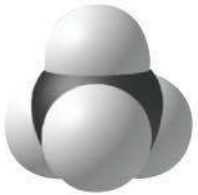
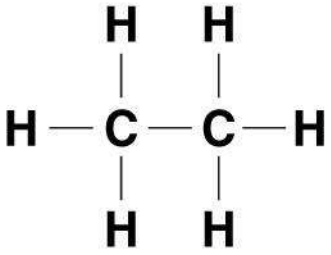
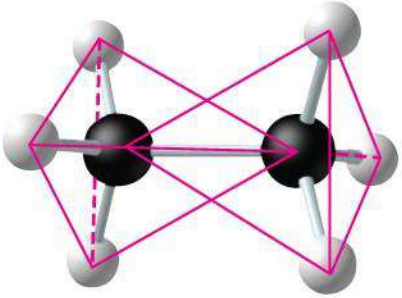
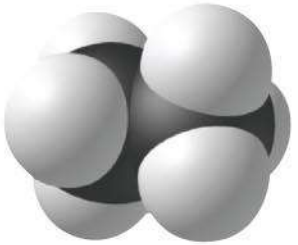
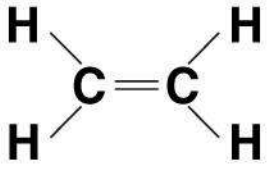
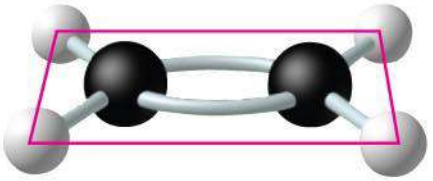
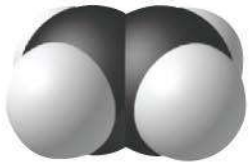
The Formation of Bonds with Carbon

- With four valence electrons, carbon can form four covalent bonds with a variety of atoms
- This tetravalence makes large, complex molecules possible





LE 4-3

Molecular Formula	Structural Formula	Ball-and-Stick Model	Space-Filling Model
CH_4 (a) Methane			
C_2H_6 (b) Ethane			
C_2H_4 (c) Ethene (ethylene)			

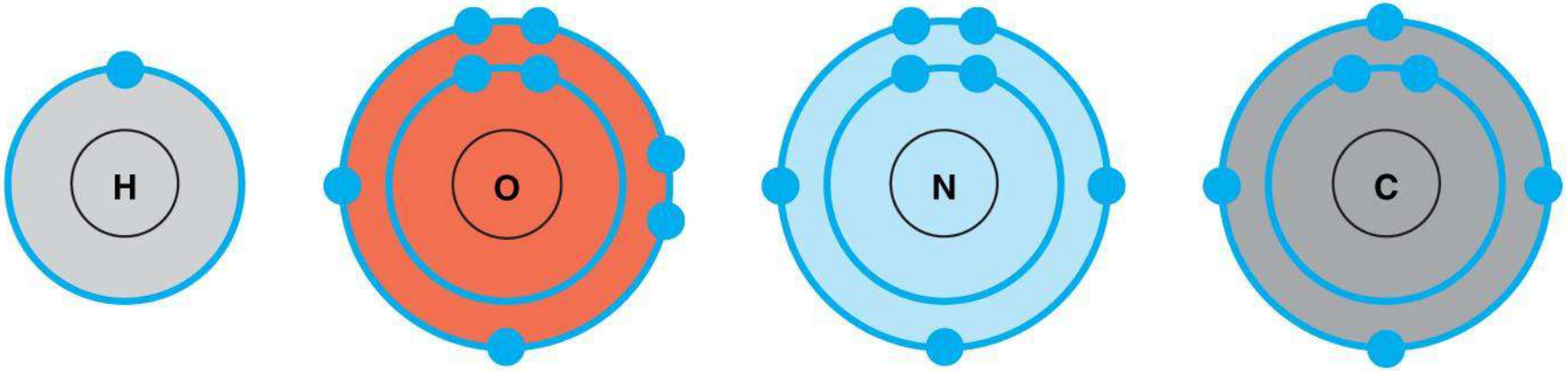
LE 4-4

Hydrogen (valence = 1)

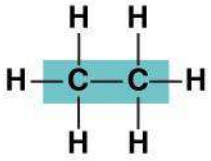
Oxygen (valence = 2)

Nitrogen (valence = 3)

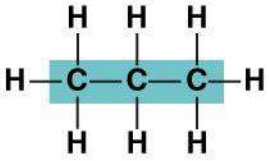
Carbon (valence = 4)



LE 4-5

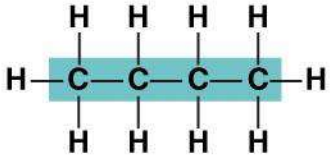


Ethane

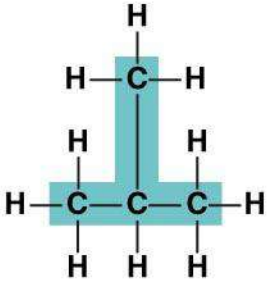


Propane

(a) Length

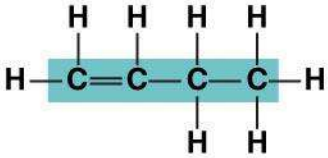


Butane

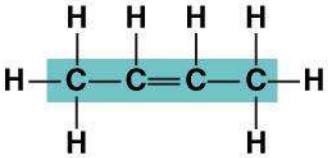


2-methylpropane
(commonly called isobutane)

(b) Branching

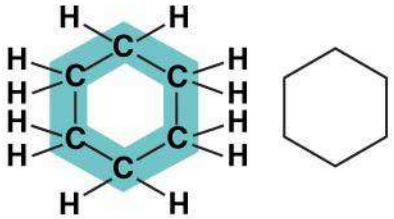


1-Butene

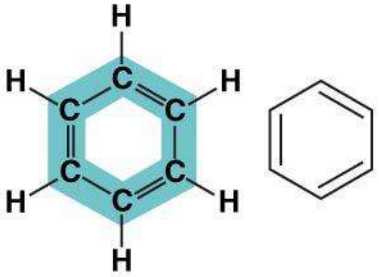


2-Butene

(c) Double bonds



Cyclohexane

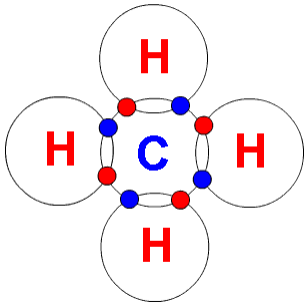


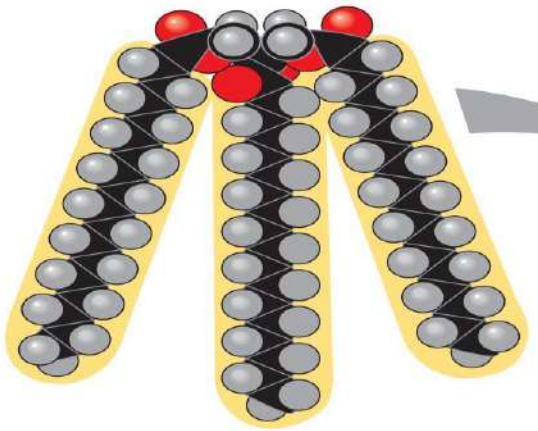
Benzene

(d) Rings

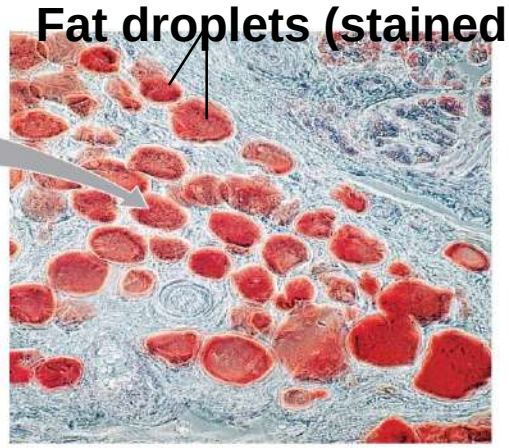
Hydrocarbons:

- Hydrocarbons are organic molecules consisting of only **carbon and hydrogen** (ex. fats)
- Hydrocarbons can undergo reactions that release a large amount of energy





(a) **A fat molecule**

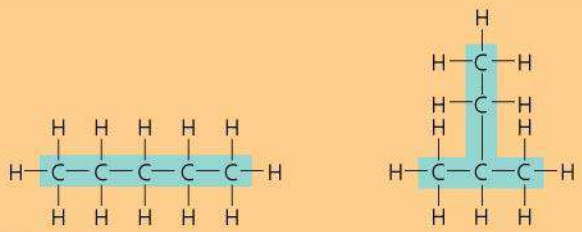


(b) **Mammalian adipose cells**

Isomers:

- **Isomers** are compounds with the *same molecular formula but different structures and properties*:
  - Structural isomers have different covalent arrangements of their atoms
  - Geometric isomers have the same covalent arrangements but differ in spatial arrangements
  - Enantiomers are isomers that are mirror images of each other

LE 4-7

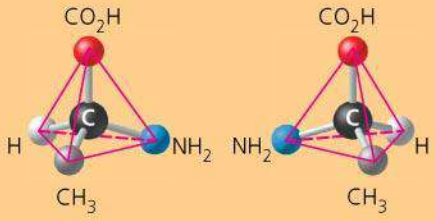


(a) Structural isomers differ in covalent partners, as shown in this example of two isomers of pentane.

***cis* isomer: The two Xs are on the same side.**

***trans* isomer: The two Xs are on opposite sides.**

(b) Geometric isomers differ in arrangement about a double bond. In these diagrams, X represents an atom or group of atoms attached to a double-bonded carbon.



L isomer

D isomer

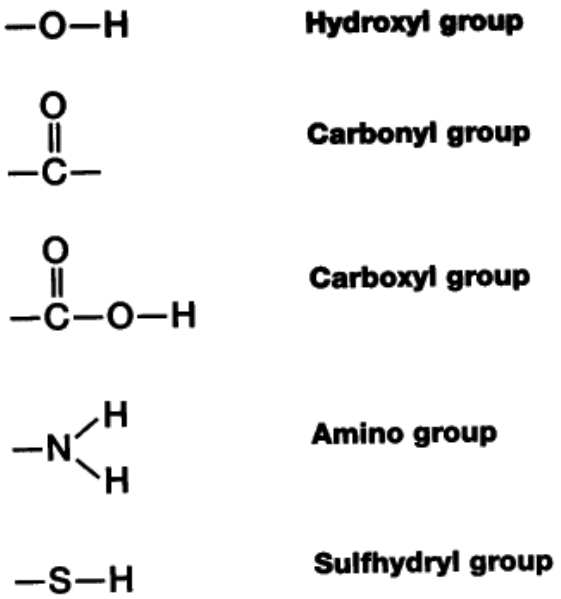
(c) Enantiomers differ in spatial arrangement around an asymmetric carbon, resulting in molecules that are mirror images, like left and right hands. The two isomers are designated the L and D isomers from the Latin for left and right (*levo* and *dextro*). Enantiomers cannot be superimposed on each other.

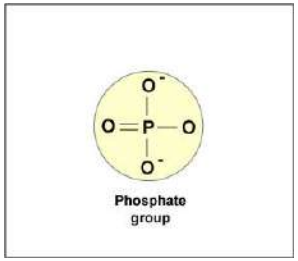
The Functional Groups Most Important in the Chemistry of Life:

- Functional groups are the components of organic molecules that are most commonly involved in chemical reactions
- The number and arrangement of functional groups give each molecule its unique properties

- The six functional groups that are most important in the chemistry of life:
  - Hydroxyl group
  - Carbonyl group
  - Carboxyl group
  - Amino group
  - Sulfhydryl group
  - Phosphate group

  *****check your chart!!!***

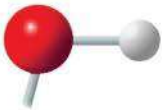




LE 4-10aa

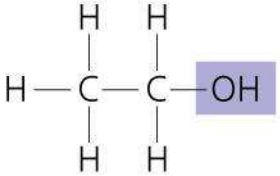
HYDROXYL

STRUCTURE



—OH

(may be written HO—)



Ethanol, the alcohol present in alcoholic beverages

NAME OF COMPOUNDS

Alcohols (their specific names usually end in *-ol*)

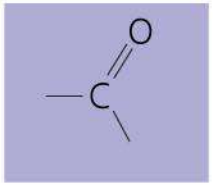
FUNCTIONAL PROPERTIES

- **Is polar as a result of the electronegative oxygen atom drawing electrons toward itself.**
- **Attracts water molecules, helping dissolve organic compounds such as sugars (see Figure 5.3).**

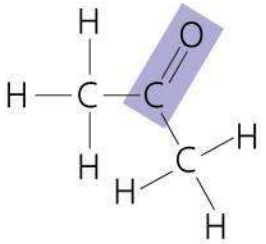
LE 4-10ab

CARBONYL

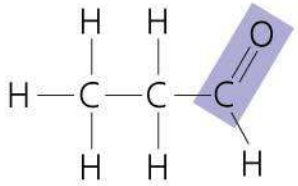
STRUCTURE



EXAMPLE



Acetone, the simplest ketone



Propanal, an aldehyde

NAME OF COMPOUNDS

Ketones if the carbonyl group is within a carbon skeleton

Aldehydes if the carbonyl group is at the end of the carbon skeleton

Acetone, the simplest ketone

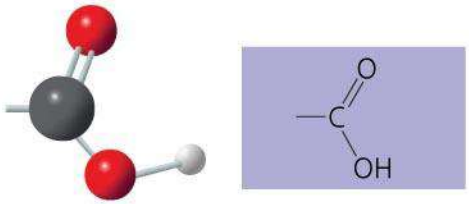
FUNCTIONAL PROPERTIES

- **A ketone and an aldehyde may be structural isomers with different properties, as is the case for acetone and propanal.**

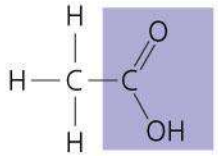
LE 4-10ac

CARBOXYL

STRUCTURE



EXAMPLE



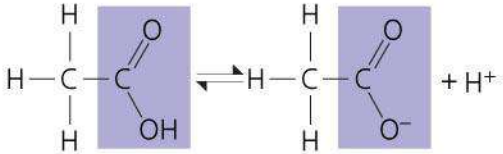
Acetic acid, which gives vinegar its sour taste

NAME OF COMPOUNDS

Carboxylic acids, or organic acids

FUNCTIONAL PROPERTIES

- **Has acidic properties because it is a source of hydrogen ions.**
- **The covalent bond between oxygen and hydrogen is so polar that hydrogen ions (H^+) tend to dissociate reversibly; for example,**



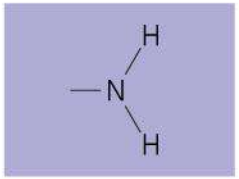
Acetic acid **Acetate ion**

- **In cells, found in the ionic form, which is called a carboxylate group.**

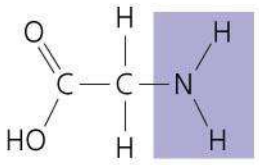
LE 4-10ba

AMINO

STRUCTURE



EXAMPLE



Glycine

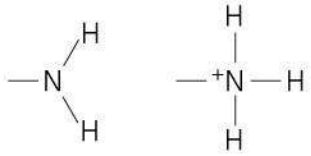
Because it also has a carboxyl group, glycine is both an amine and a carboxylic acid; compounds with both groups are called amino acids.

NAME OF COMPOUNDS

Amine

FUNCTIONAL PROPERTIES

- **Acts as a base; can pick up a proton from the surrounding solution:**



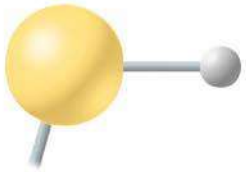
(nonionized) (ionized)

- **Ionized, with a charge of 1+, under cellular conditions**

LE 4-10bb

SULFHYDRYL

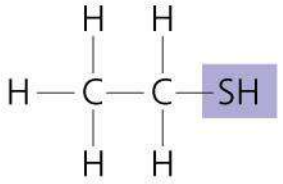
STRUCTURE



—SH

(may be written HS—)

EXAMPLE



Ethanethiol

NAME OF COMPOUNDS

Thiols

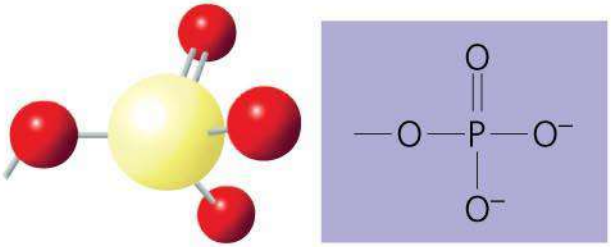
FUNCTIONAL PROPERTIES

- **Two sulfhydryl groups can interact to help stabilize protein structure (see Figure 5.20).**

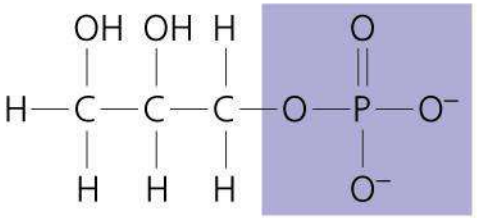
LE 4-10bc

PHOSPHATE

STRUCTURE



EXAMPLE



Glycerol phosphate

NAME OF COMPOUNDS

Organic phosphates

FUNCTIONAL PROPERTIES

- **Makes the molecule of which it is a part an anion (negatively charged ion).**
- **Can transfer energy between organic molecules.**

ATP: An Important Source of Energy for Cellular Processes

- One phosphate molecule, adenosine triphosphate (ATP), is the primary energy-transferring molecule in the cell
- ATP consists of an organic molecule called adenosine attached to a string of <u>three phosphate groups</u>