# Chapter 2 – The Chemical Context of Life

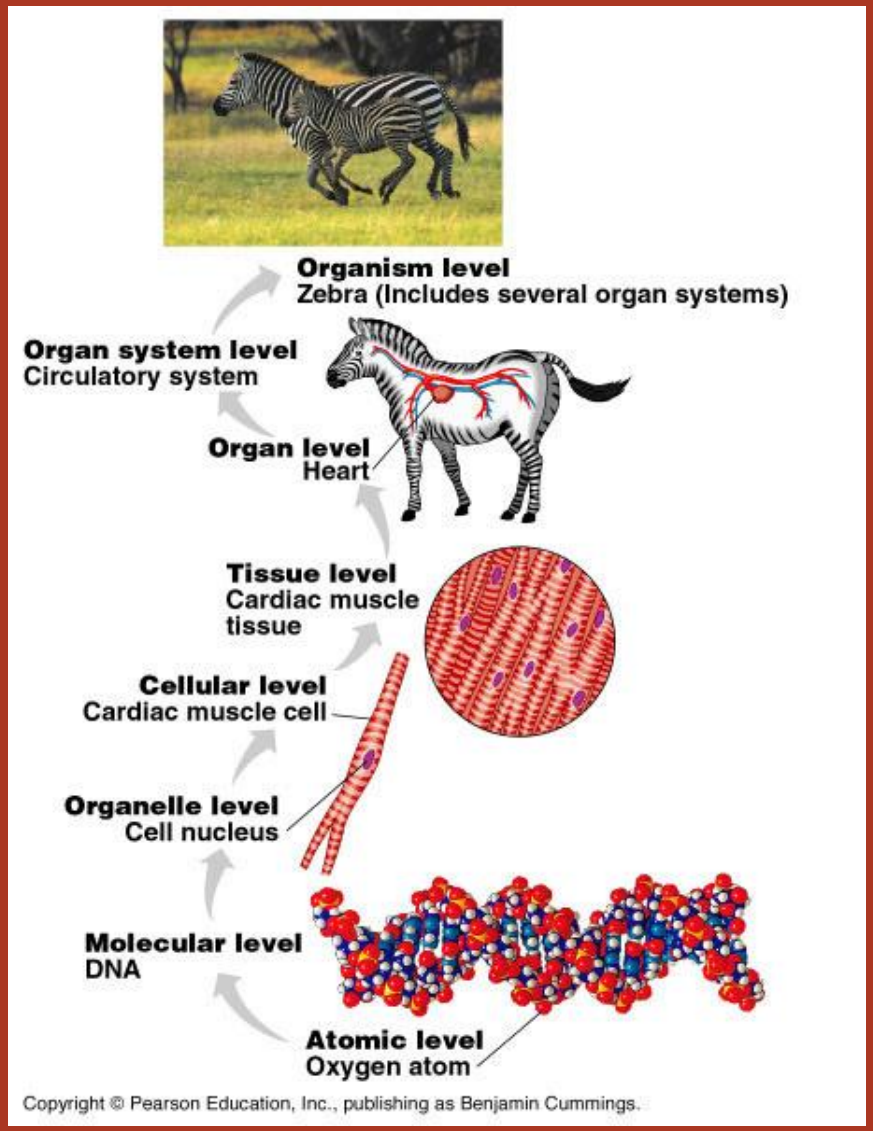
# Chemical Foundations of Biology

- Life depends on chemical reactions

Spray contains irritating chemicals generated in two sets of glands.

Bombardier beetle – uses chemicals for defense

# Biological Hierarchy




- REMEMBER: life follows a hierarchy of increasing complexity
- Chemical components make up all matter – living or nonliving.

# Essential Elements of Life

- C – Carbon
- H – Hydrogen
- O - Oxygen
- N – Nitrogen

**MAKE UP 96% of living matter!**

**Account for remaining 4%**

**Table 2.1 Naturally Occurring Elements in the Human Body**

| Symbol | Element | Atomic Number (See p. 29) | Percentage of Human Body Weight |
|---|---|---|---|
| O | Oxygen | 8 | 65.0 |
| C | Carbon | 6 | 18.5 |
| H | Hydrogen | 1 | 9.5 |
| N | Nitrogen | 7 | 3.3 |
| Ca | Calcium | 20 | 1.5 |
| P | Phosphorus | 15 | 1.0 |
| K | Potassium | 19 | 0.4 |
| S | Sulfur | 16 | 0.3 |
| Na | Sodium | 11 | 0.2 |
| Cl | Chlorine | 17 | 0.2 |
| Mg | Magnesium | 12 | 0.1 |

Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

# Emergent Properties

- Compound: a substance existing of two or more different elements combined in a fixed ratio.

# Essential Elements of Life

- C – Carbon
- H – Hydrogen
- O - Oxygen
- N – Nitrogen

**MAKE UP 96% of living matter!**

**Account for remaining 4%**

**Table 2.1 Naturally Occurring Elements in the Human Body**

| Symbol | Element | Atomic Number (See p. 29) | Percentage of Human Body Weight |
|---|---|---|---|
| O | Oxygen | 8 | 65.0 |
| C | Carbon | 6 | 18.5 |
| H | Hydrogen | 1 | 9.5 |
| N | Nitrogen | 7 | 3.3 |
| Ca | Calcium | 20 | 1.5 |
| P | Phosphorus | 15 | 1.0 |
| K | Potassium | 19 | 0.4 |
| S | Sulfur | 16 | 0.3 |
| Na | Sodium | 11 | 0.2 |
| Cl | Chlorine | 17 | 0.2 |
| Mg | Magnesium | 12 | 0.1 |

Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

# Element Deficiencies

Plate 1. Nitrogen deficiency in bamboo palm ( *Chamaedorea seifrizii* ) seedlings.

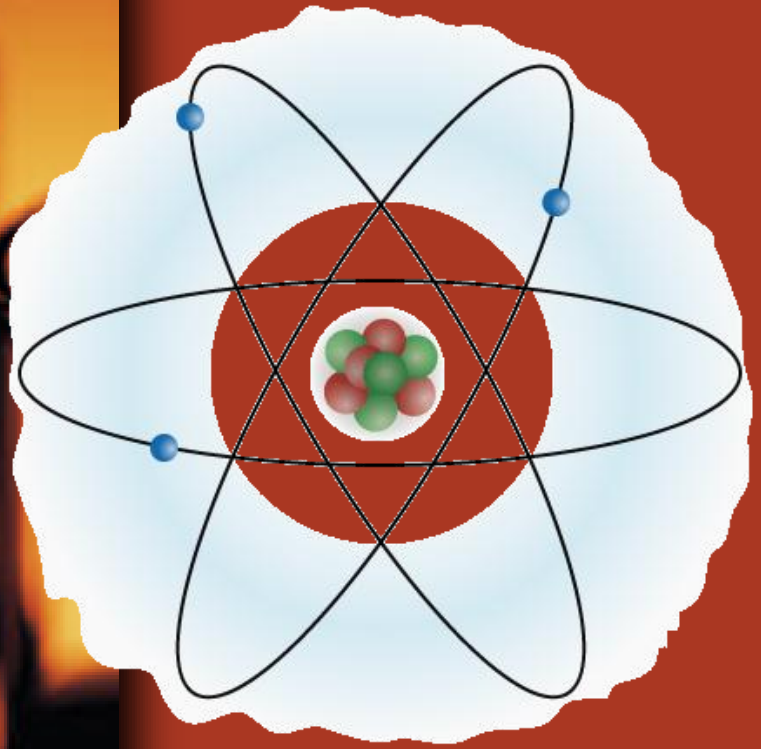
# ATOMS

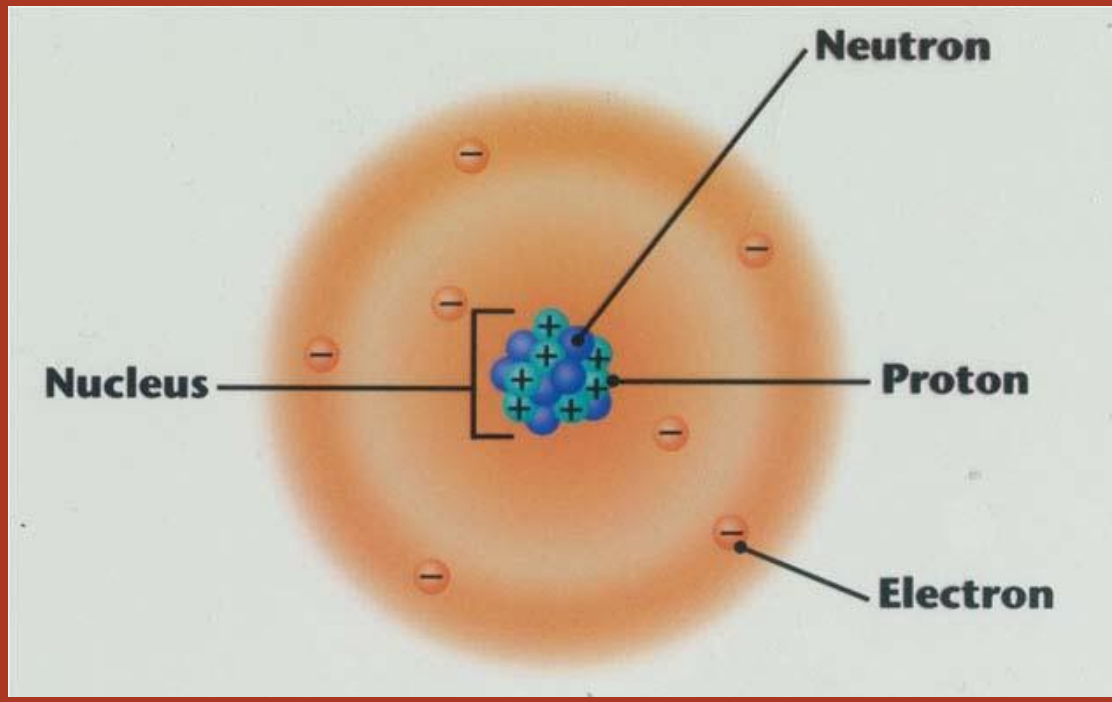
- Smallest unit having properties of an element
- Composed of 3 subatomic particles:
  - Electrons (-) charge (located in orbitals around nucleus)
  - Protons (+) charge
  - Neutrons – no charge (neutral)

**Nucleus of atom**

  - Charge is measured in daltons (1.7X10-24)

# Atom Structure





# ATOMIC NUMBER

- Indicates the number of protons in a particular atom
- Indirectly indicates the number of electrons
- Represented as a subscript to the left of the symbol
  - Ex: $_{2}He$ (2 protons, 2 electrons)

# MASS NUMBER

- (Mass number – atomic number) = number of NEUTRONS.
- Represented as a superscript on an element
  - Ex: $^{4}He$
  - (4-2) = 2 neutrons

# ATOMIC MASS

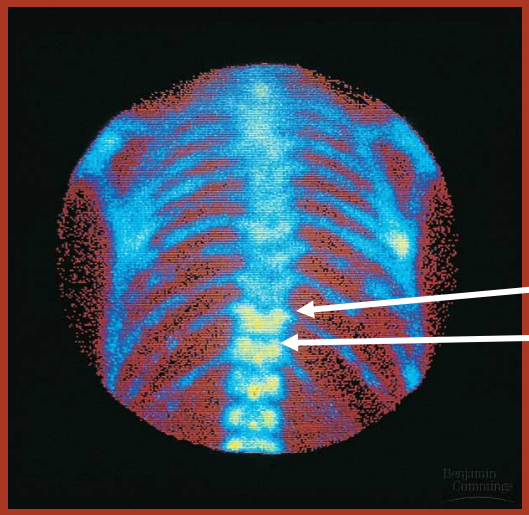
- Most of an atom's mass is located in the nucleus
- What subatomic particles make up the majority of the mass of an atom?
  - Protons + neutrons = mass number
  - Therefore, the mass number is an approximation of the mass of an atom

# ISOTOPES

- Elements with varying numbers of neutrons.
- Which number will vary -- The atomic number or mass number?
  - Ex: $^{14}C$ (what is this isotope used for?)
  - Ex: $^{13}C$
  - Ex: $^{12}C$ (most common isotope of carbon – 99% of carbon in nature)

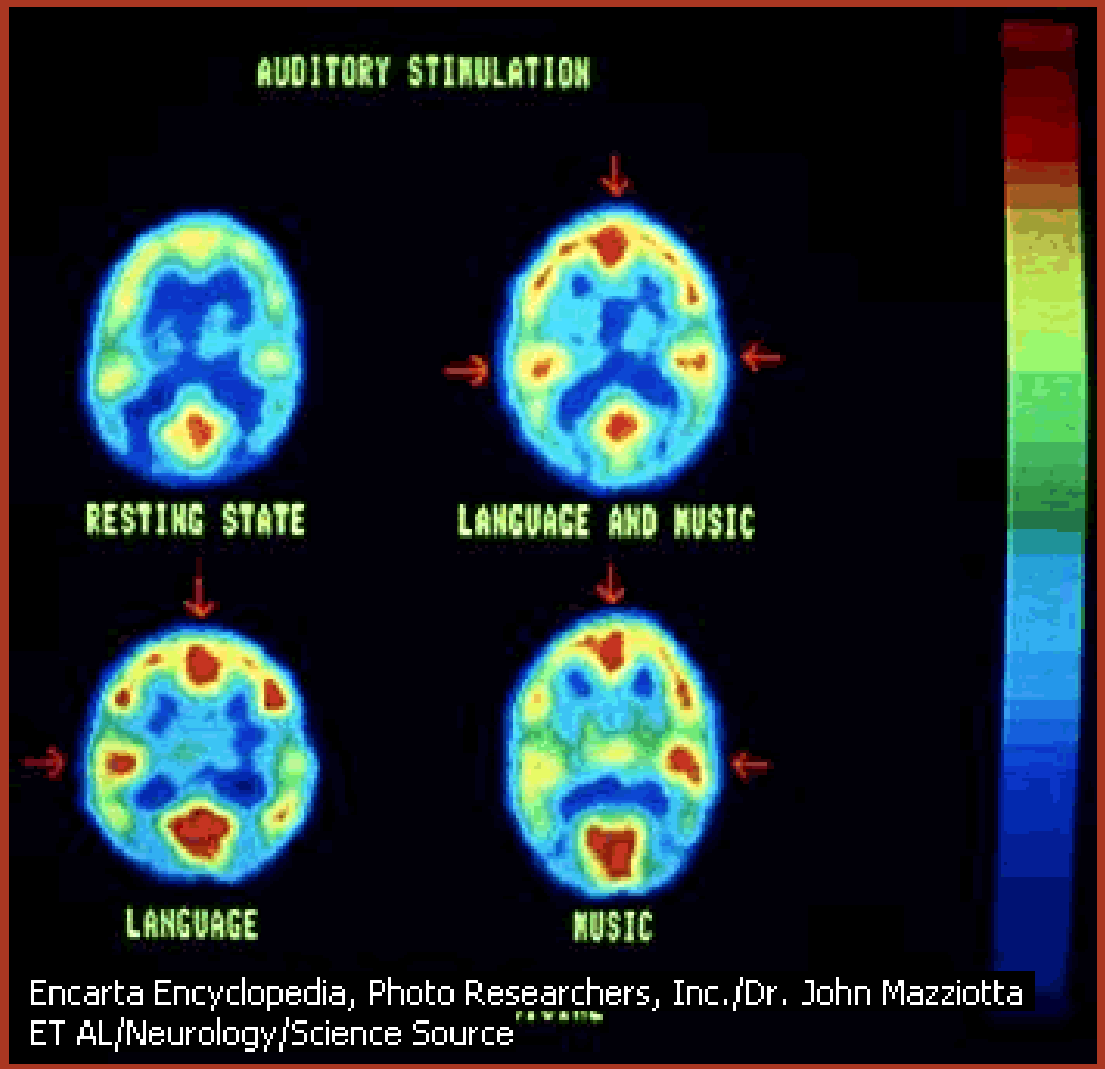
# Isotopes as Radioactive tracers

- Uses:
  - Measure decay to date rocks & fossils
  - Diagnostic measures such as kidney disorders and treatment of thyroid cancer
  - PET scans cancerous growth



**Bright areas indicate abnormal growths**

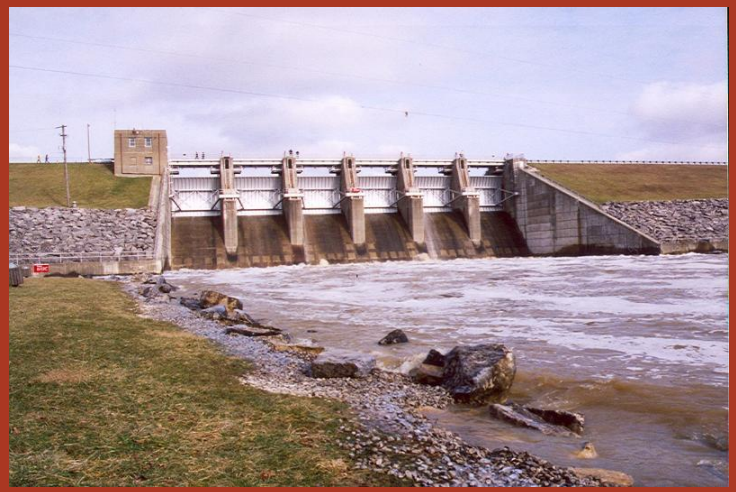
# Isotopes and Radioactive Tracers




Encarta Encyclopedia, Photo Researchers, Inc./Dr. John Mazziotta ET AL/Neurology/Science Source

# Energy of Atoms

- Energy = the capacity to cause change; as in the ability to do work
- Potential energy = stored energy due to location or structure.



**Olentangy River – potential energy – dam closed**

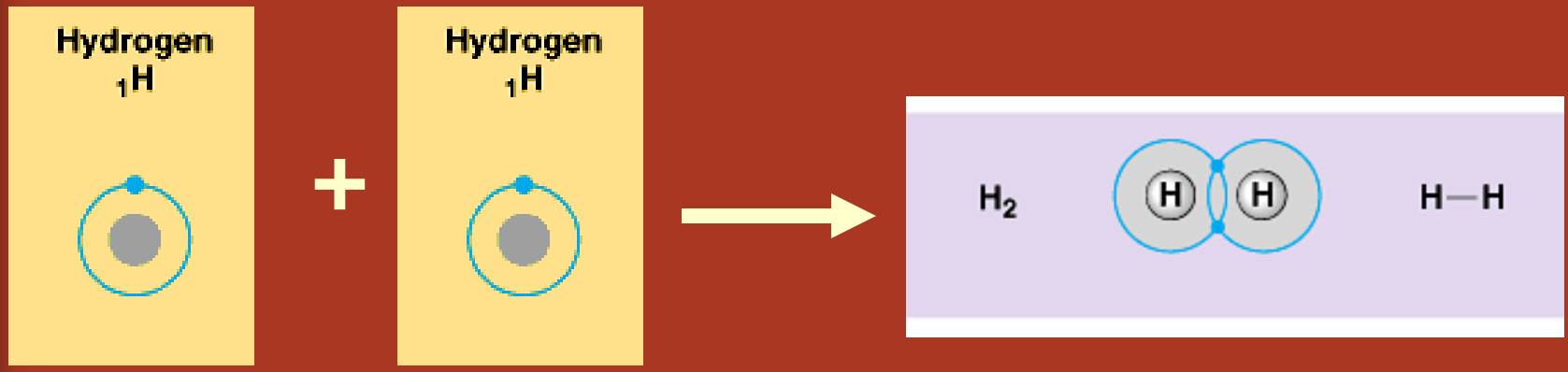
**Hoover dam – open locks = released energy**

# Electron Behavior

- Based on the electrons in the outermost energy shell
- **Ex:  Hydrogen**
  - Is H highly reactive with other elements? Why or why not?
  - Lets take a closer look

# ELECTRON BEHAVIOR

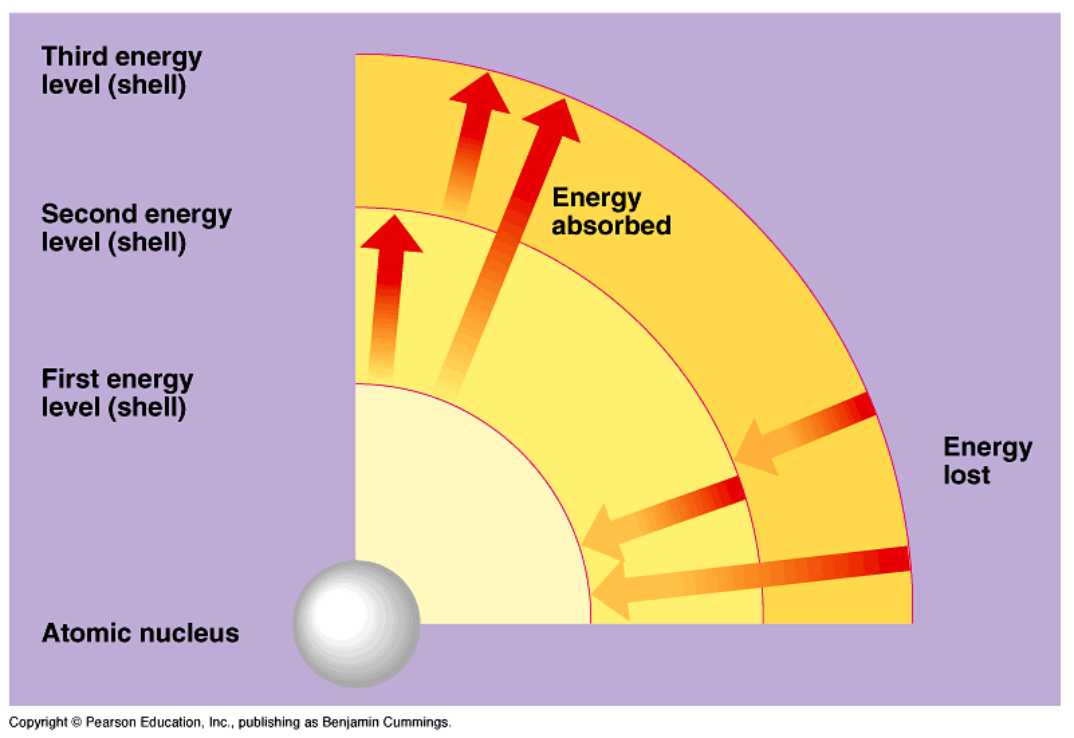
- Reactivity of atoms is determined by UNPAIRED ELECTRONS




- What type of bond is this?

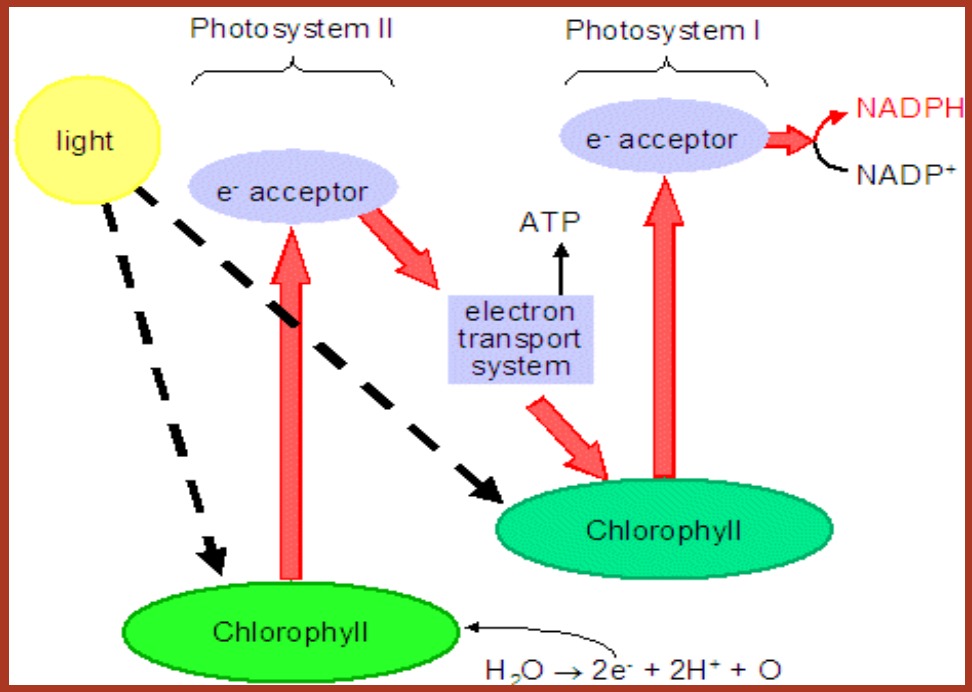
# Bonds between atoms

- Nature of chemical bonds
  - Union between atoms when e-'s are gained, lost, or shared



# Electron Excitation

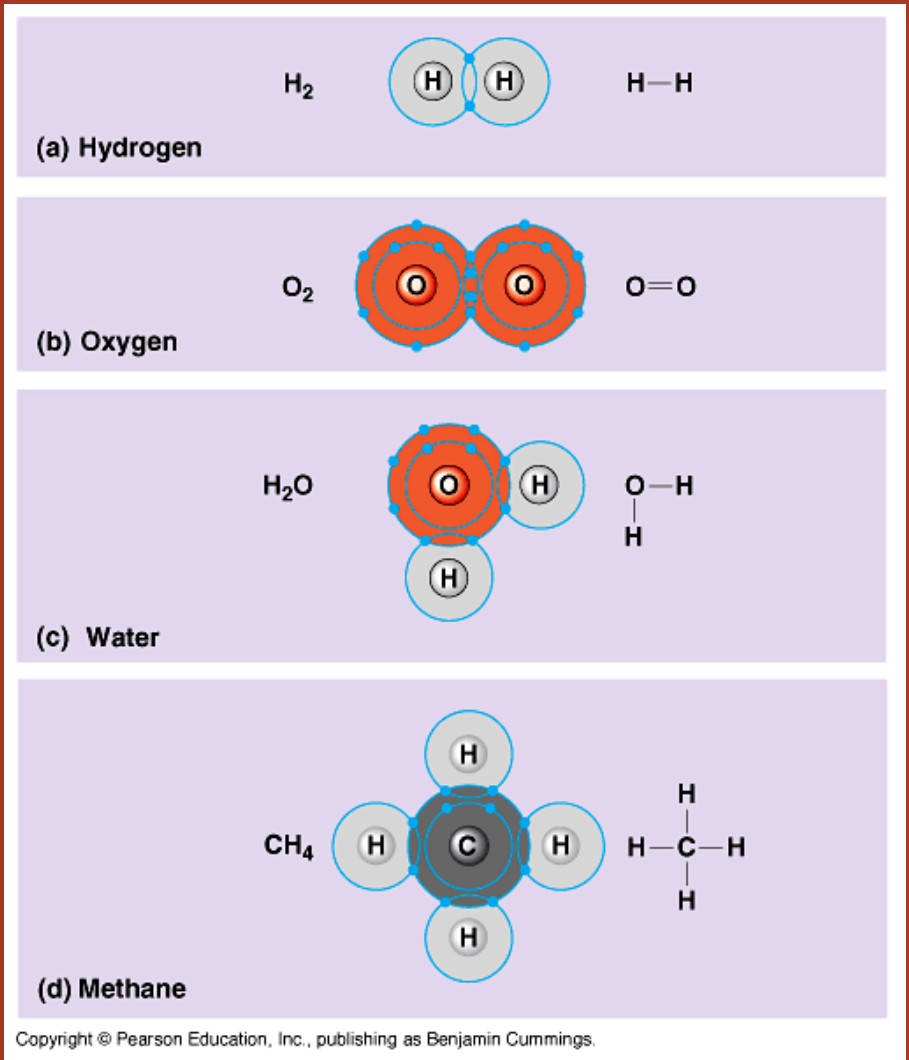
- When atoms absorb energy, electrons may move into an orbital at a higher energy level
  - Ex: When a photon of light strikes a photosynthetic pigment, an electron in an atom contained within the molecule becomes excited.



# 3 types of chemical bonds

- Covalent Bonds
- Ionic Bonds
- Hydrogen Bonds

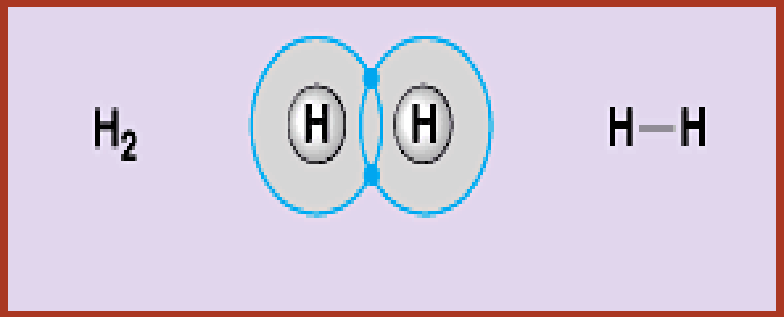
# Covalent Bonds

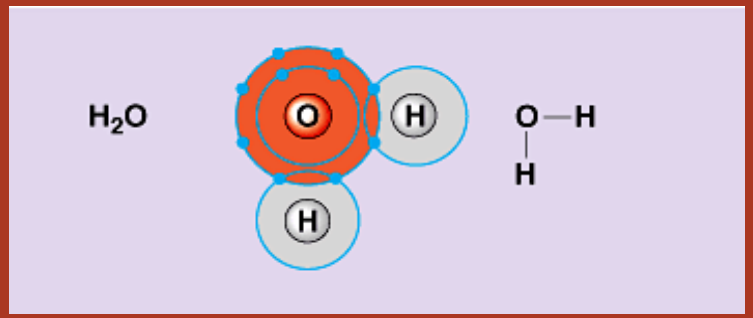




- Holds together two atoms that share one **OR MORE** pairs of electrons
- Two or more atoms held together by <u>covalent bonds</u> = <u>**MOLECULE**</u>

# Types of Covalent Bonds

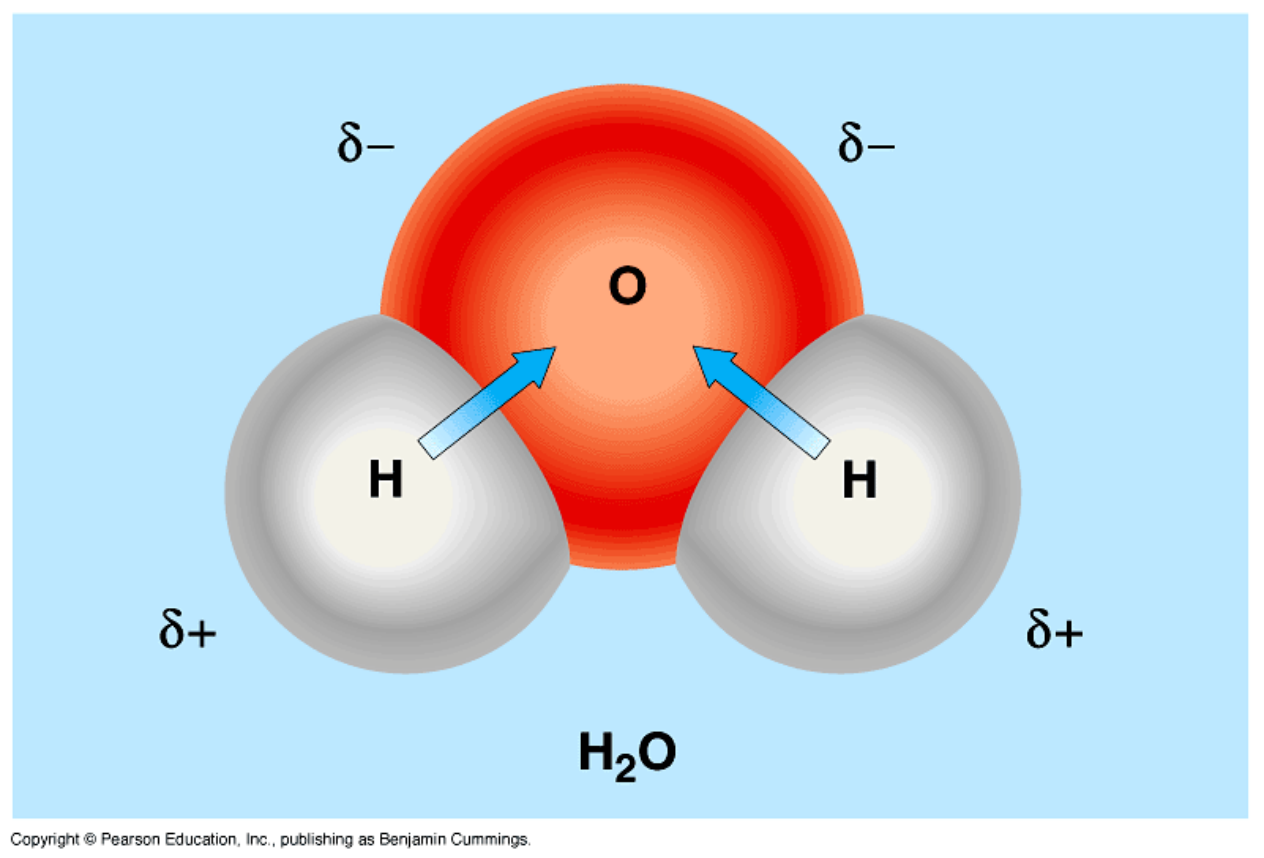



- Nonpolar covalent: atoms share electrons equally.
- Polar covalent: atoms share e-'s unequally ® there is a difference in charge between the poles of the bond

**Electro-negativity** = the attraction of a particular kind of atom for the electrons of a covalent bond

# WATER

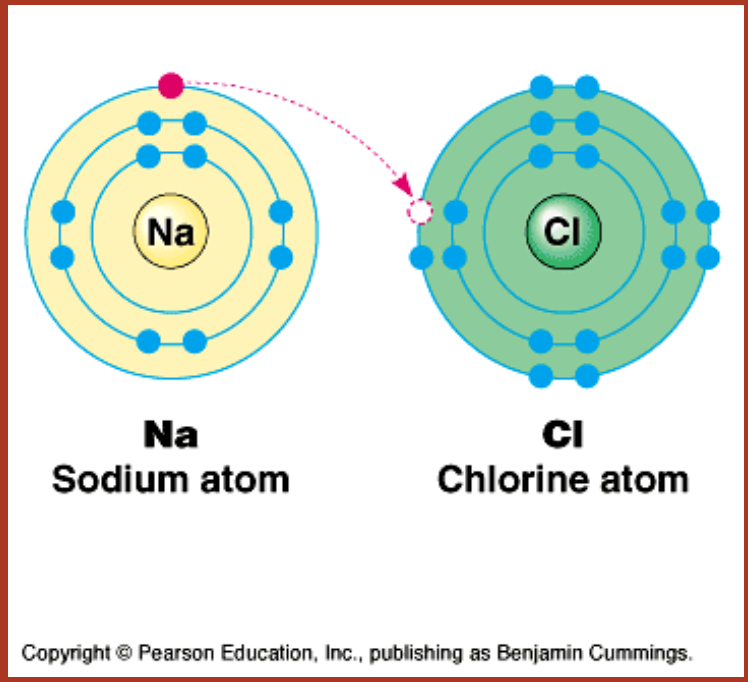




**Oxygen is more ELECTRONEGATIVE and has a greater "pull" from its electrons than Hydrogen.**

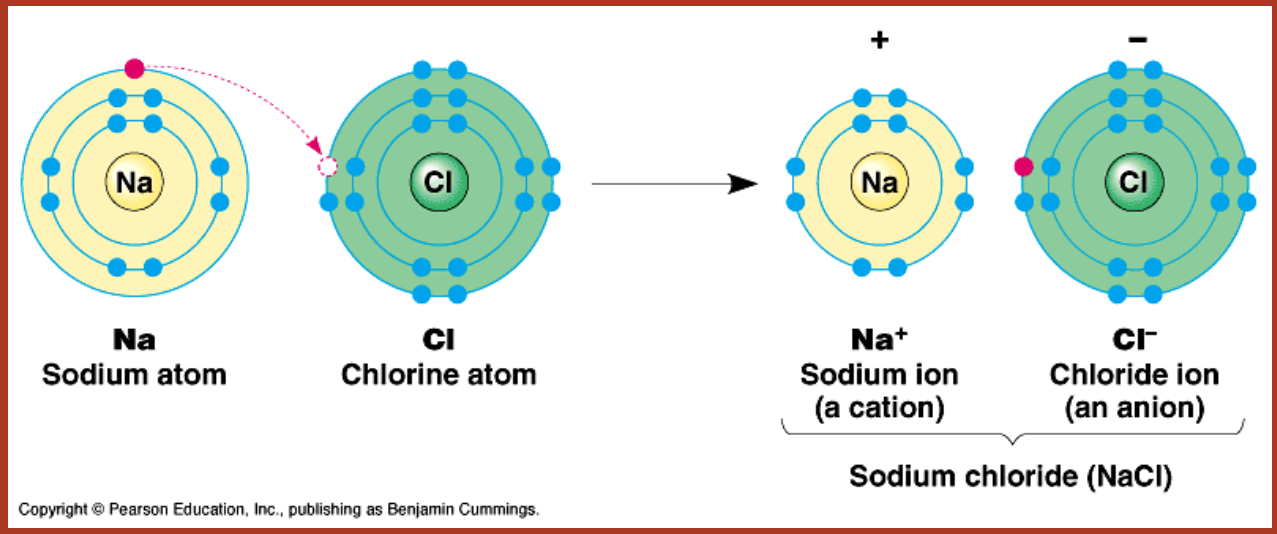
# IONS

- **Charged atoms or molecules**
- **Cation**: ion with a positive charge
  - Ex: $Na^+$ ($Na^+$ has 11 protons and 10 electrons; has a net (+) charge.
- **Anion**: ion with a negative charge
  - Ex. $Cl^-$



# Ionic Bonds

- When an atom loses or gains one or more e-'s, it becomes more (+) or more (-) = ION.
- cations & anions ions are linked by mutual attraction of opposite charges, as in NaCl.
  - Compounds formed by ionic bonds = <u>ionic compounds/salts</u>



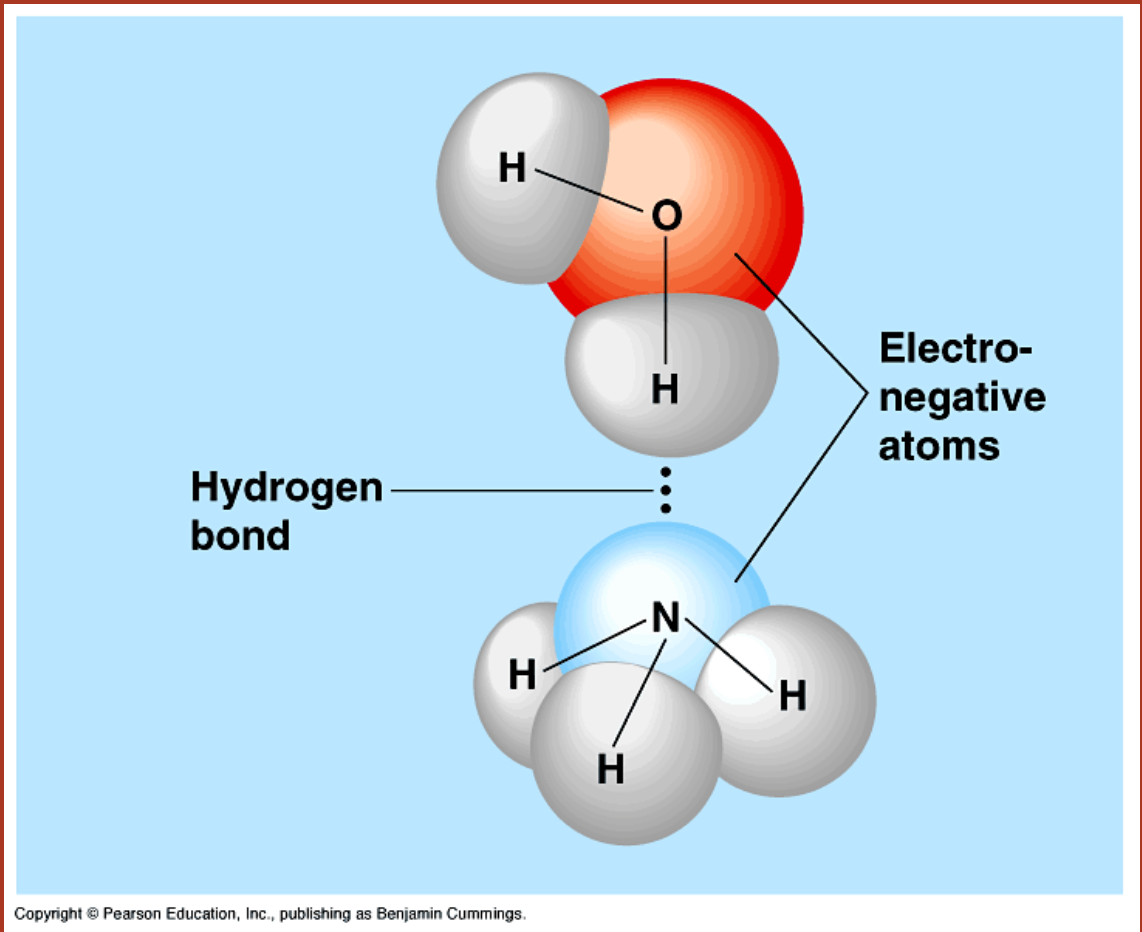


**IS NaCl a MOLECULE? Why or Why not?**

# Hydrogen Bonds

- Weak bond
- Forms when a (H) atom covalently bonded to one electronegative atom it can then be attracted to ANOTHER electronegative atom
- H's electronegative partners are usually Oxygen (O) and Nitrogen (N)
  - Analogy: A person sees someone they are attracted to, but a more attractive individual walks by, and the initial attraction is no longer needed.

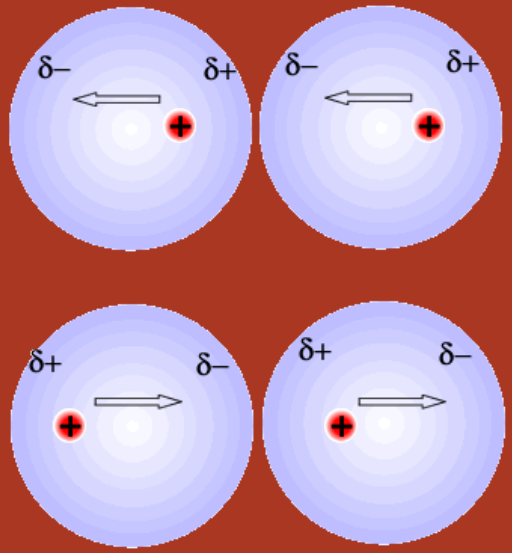
# Hydrogen Bonds

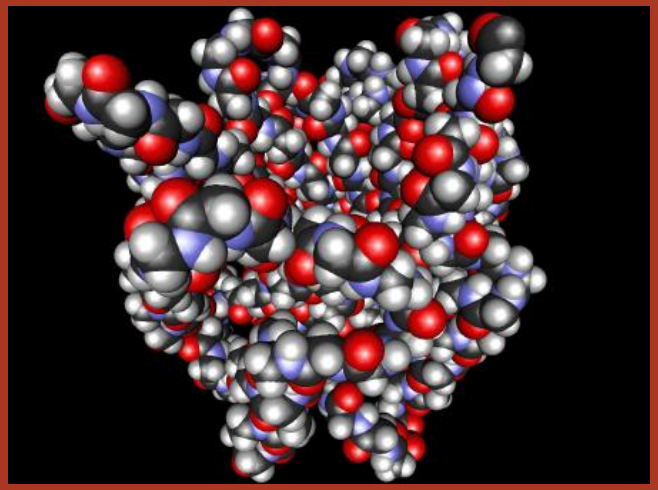


# Van der Waals Interactions

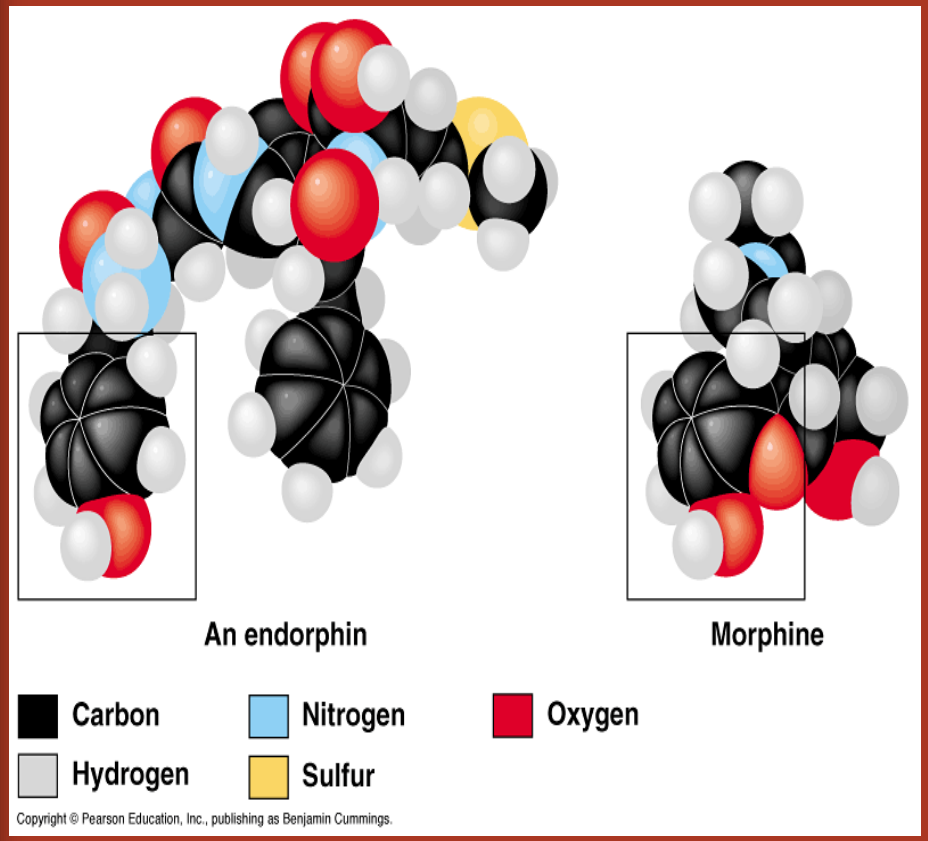
- Occurs when there is a momentary uneven e- distribution
  - This creates changing positive and negative regions
  - Weak attractions are formed

# Van der Waals Interactions



# Molecular Shape & Function

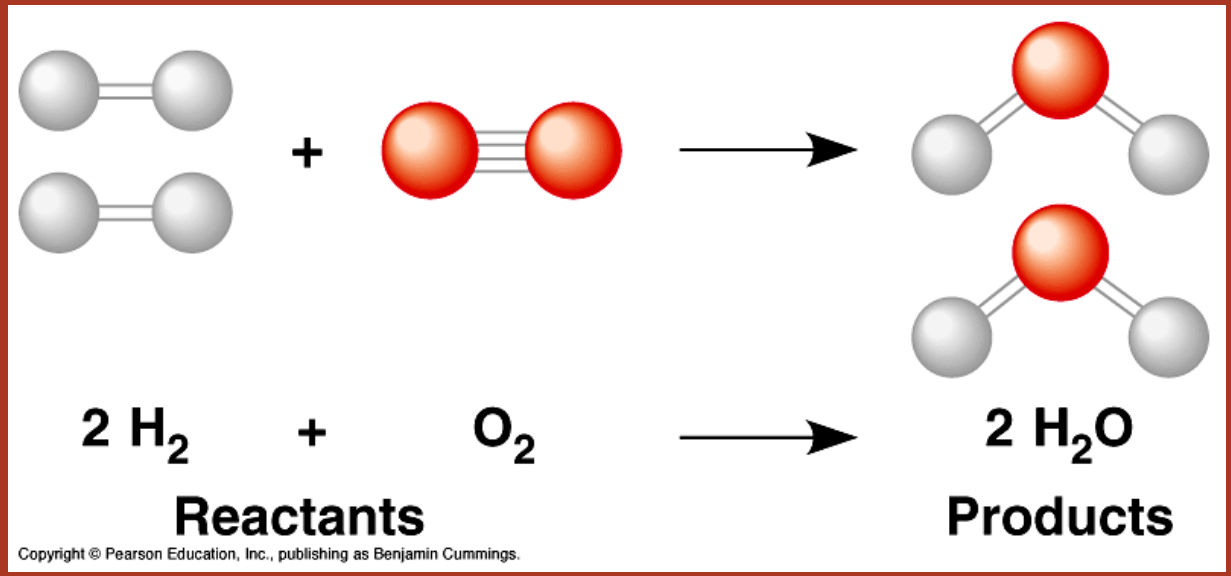



**Endorphins** bind to the surface of brain cells to relieve pain. Similarly shaped drugs have same affect.
**Ex: morphine, heroin, opiates,etc.**

- Molecules have characteristic shapes and sizes (remember **form correlates to function** in living organisms)
- Molecular shape determines how biological molecules recognize and respond to one another.

# Chemical Reactions

- Making and/or breaking of chemical bonds.



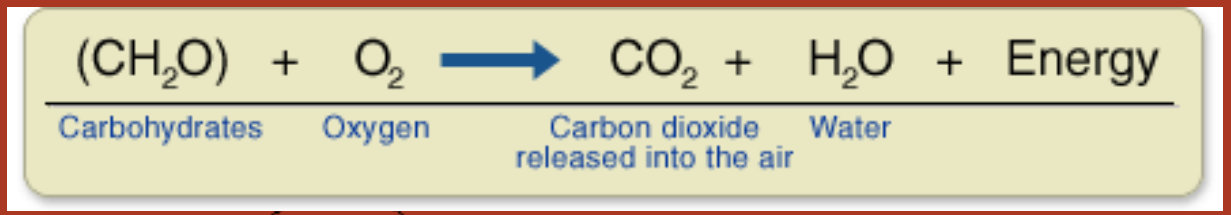


**Why a single arrow pointing in one direction?**

# Chemical Equilibrium

- When forward and reverse reactions happen at the same time or rate

# Chemical Reactions




ATP → ADP + Phosphate + energy.

$$2H_2 + O_2 \rightarrow 2H_2O$$

*reactants* *products*

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$