BIOLOGY 12 **NAME: ____________________________**

CHEMICAL COMPOUNDS

CELL COMPOUNDS

THE CHEMICAL COMPONENTS OF MATTER

To understand the nature of the substances found in cells, it is necessary to be familiar with the substances that make up all matter. These substances combine in different ways to produce the enormous variety of living and nonliving things.

MATTER = anything that takes up space and has mass

- Every object contains a certain amount of matter
- The measure of the amount of matter in an object is its mass

ATOMS : The building blocks of Matter

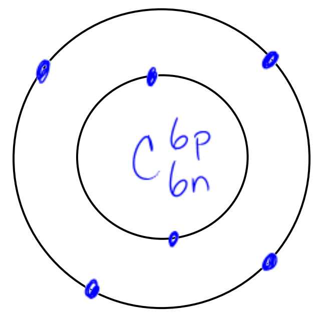
= the basic unit or building blocks of all matter are ATOMS.

- They are so small that only the most powerful electron microscope can detect individual atoms.

Atoms are made of even smaller components called SUBATOMIC PARTICLES.

- In the center of the atom is a dense area called the NUCLEUS, which consists of two types of subatomic particles:
- **PROTONS =** positively charged.
- **NEUTRONS =** neutral.
  - (Thus, the nucleus has an overall positive charge)
- Orbiting the nucleus are **ELECTRONS** which form a "shell" = negatively charged
- In all atoms, the number of electrons equals the number of protons.
- These opposite charges cancel each other making the atom electrically neutral.

("OCTET RULE" = first shell can contain up to 2 electrons; then each remaining shell can contain up to 8 electrons) 2, 8, 8, 18



IONS : Under certain conditions, an atom may gain or lose electrons. An atom that has gained or lost one or more *electrons* is called an **ion.**

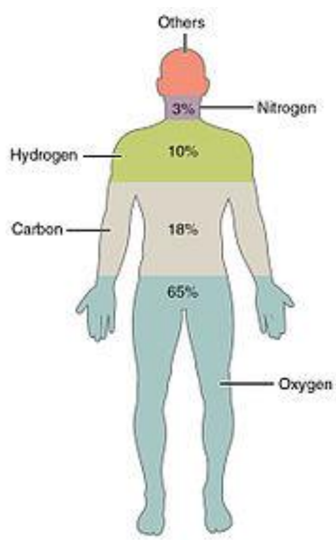
- Loses an electron = positively charged ion (cations) Na^+
- Gains an electron = negatively charged ion (anions) Cl^-

ELEMENTS : The Key Substance

Each basic type of atom makes up an **element:**

= A substance that cannot be changed into a simpler substance; contains just one kind of atom.

- For example, carbon is made entirely of carbon atoms. If you try to break down a lump of carbon – by heating it, for example – you will find that carbon does not turn into any other substance.



Element	Symbol	Percentage in Body
Oxygen	O	65.0
Carbon	C	18.5
Hydrogen	H	9.5
Nitrogen	N	3.2
Calcium	Ca	1.5
Phosphorus	P	1.0
Potassium	K	0.4
Sulfur	S	0.3
Sodium	Na	0.2
Chlorine	Cl	0.2
Magnesium	Mg	0.1
Trace elements include 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).		less than 1.0

There are 92 different elements that occur naturally on the earth.

The 3 most common elements in the Human Body are:

1. Oxygen (65%)
2. Carbon (19%)
3. Hydrogen (10%)

ELEMENTS CAN COMBINE TO FORM COMPOUNDS:

COMPOUND = A substance containing two or more elements in a fixed ratio.

- Each compound has its own special properties, which differ from the properties of the individual elements in that compound.
- For example: Sodium (Na^{+}) is a metal that reacts explosively with water and chlorine (Cl^{-}) is a poisonous green gas. Yet when these two elements are combined chemically, they form a compound called *sodium chloride (NaCl)* – ordinary table salt.

FORMATION OF COMPOUNDS:

Atoms have a tendency to combine, or react, with other atoms to form compounds. When they combine, the atoms are held together by __bonds__, which are formed by interactions between the outer electrons of different atoms.

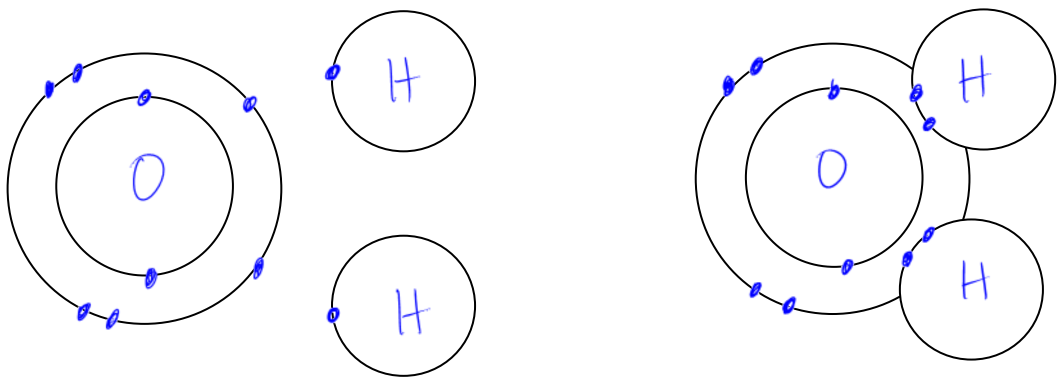
There are 2 major types of chemical bonds that form between atoms:

1. __covalent__ = Share Electrons
2. __Ionic__ = Gain/Lose (Transfer) Electrons

1. **COVALENT BONDS:**

   = a chemical bond formed by the sharing of electrons.

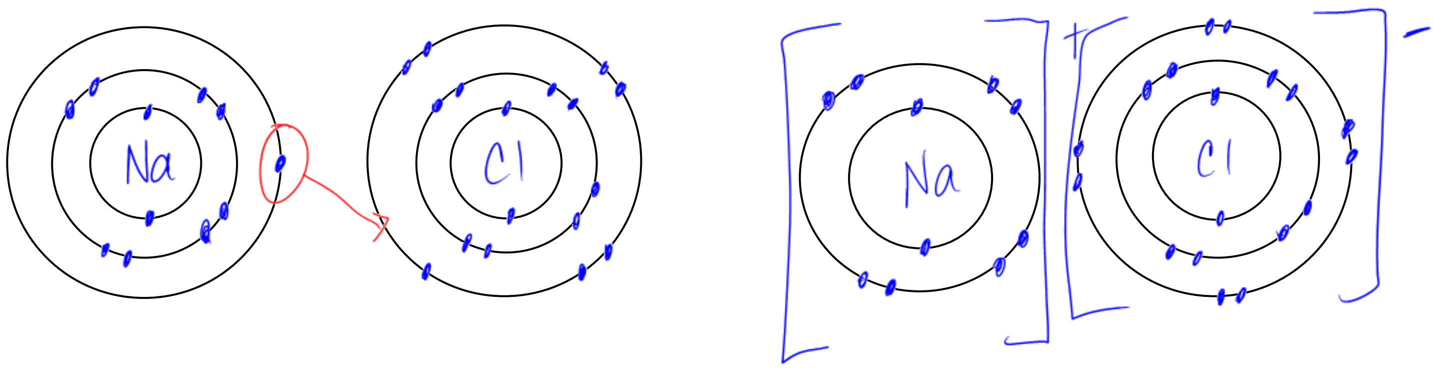
- By sharing electrons, each atom fills up its outermost energy level.
- This produces a strong bond that is characteristic of most of the chemical bonds found in living organisms.



2. **IONIC BONDS:**

   = a chemical bond formed by the transfer of electrons.

- An ionic bond gets its name from the word **ion,** which means charged particle. Ions are formed when an ionic bond occurs.
- The transfer of an electron produces oppositely charged ions that are strongly attracted to each other – much like opposite poles of a magnet.



CHEMICAL COMPOUNDS OF LIFE:
There are two principal kinds of compounds that are important in the proper functioning of the living organism:

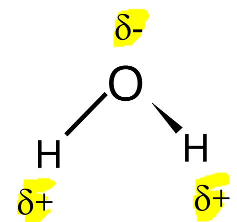
INORGANIC	ORGANIC
- Do not contain **carbon**	- contain the elements **carbon** and **hydrogen**
- Usually **ionic** bonding (except water)	- always have **covalent** bonding
- Always contain a **small** number of atoms	- may be quite **large** with many atoms
- Make up 70% of the cell	- make up 30% of the cell
- Often associated with **nonliving** elements	- often associated with **living** organisms
ie: water, acids, bases, salts	ie: carbohydrates, proteins, lipids, nucleic acids - DNA, RNA

INORGANIC COMPOUNDS

WATER

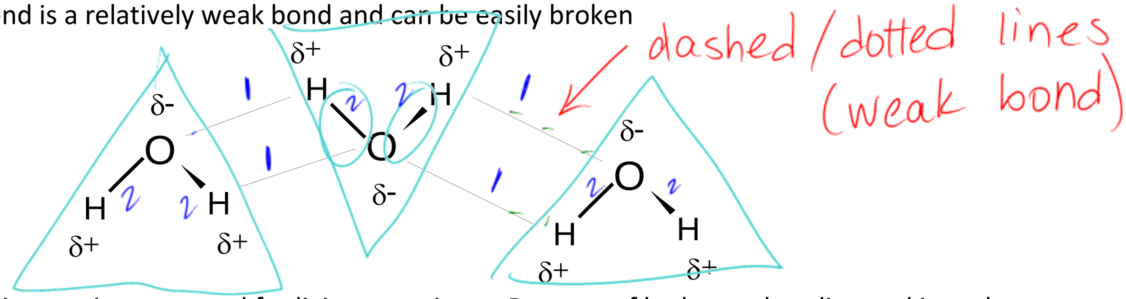
Water, or H_2O, is not an organic compound because it does not contain carbon (C); however, the atoms in water are covalently bonded, as they are in organic compounds.

- Sometimes, covalently bonded atoms share electrons evenly, but in water, the electrons spend more time circulating the larger oxygen (O) than the small hydrogen (H). Therefore, there is a slight __positive__ charge on the hydrogen atoms and a slight __negative__ charge on the oxygen atom.
- When this situation arises between two atoms, the bond between them is called a __polar__ bond, and the molecule itself is called a __polar__ molecule because it carries charges.



__Hydrogen Bonding__ occurs between polar water molecules. A hydrogen bond occurs whenever a covalently bonded hydrogen is attracted to a negatively charged atom (like oxygen or nitrogen), some distance away.

- The hydrogen bond is a relatively weak bond and can be easily broken



Water is the most important inorganic compound for living organisms. Because of hydrogen bonding and its polar nature, water has many characteristics beneficial to life.

1 INTERMOLECULAR FORCES- are forces of attraction or repulsion which act between neighboring particles (atoms, molecules or ions). between 2 or more molecules

2 INTRAMOLECULAR FORCES- is any force that holds together the atoms making up a molecule or compound. They are stronger than intermolecular forces. within a molecule

PROPERTIES OF WATER:

PROPERTY #1: __WATER IS A UNIVERSAL SOLVENT__

EXPLANATION: __water is excellent at dissolving all polar (charged) substances/molecules__

= This is because water is polar and attracts the electrical charges of other polar molecules causing them to stay in solution. Even non-polar molecules dissolve in water to some extent, if they are small (ie. O_2 in water allows fish to breathe)

SIGNIFICANCE IN BIOLOGY: __facilitates chemical reaction in/outside the body.__

- Reactions that occur in solution are more rapid than in solid or gas. This allows for easy movement of chemicals between cells and within cells (efficient transport of essential chemicals)
- For example, blood contains mostly water, and carries many different dissolved substances (ie. Hormones, antibodies, nutrients, metabolic wastes, etc.)

Hydrophilic: molecules which interact with water = "water-loving"
Hydrophobic: molecules which do not interact with water = "water-fearing" (oils)

PROPERTY #2: WATER HAS A HIGH HEAT CAPACITY
WATER HAS A HIGH HEAT OF VAPORIZATION.

EXPLANATION: it takes a lot of heat energy for water to change state liquid above 0°C, below 100°C
= When water is heated, most of the heat energy is used first in breaking the hydrogen bonds, with only a small amount of heat energy available to increase the movement of the water molecules and raise the temperature.
- Water also holds heat well and releases it slowly (ie. Large oceans keep coastal temperatures mild in the winter)

SIGNIFICANCE IN BIOLOGY: H_2O protects organisms from rapid temp changes
= Despite external changes, internal temperature can be kept relatively constant (Note: Cellular biochemical processes, especially enzyme associated processes, can tolerate only a narrow range in temperature) (ie. Metabolism Safeguard)
- SWEATING in mammals = takes a lot of heat energy to sweat, therefore cooling us down when sweat evaporates.
- TRANSPIRATION in plants = loss of water by evaporation (takes a lot of heat to evaporate just a little water)

PROPERTY #3: WATER MOLECULES ARE COHESIVE
EXPLANATION: H_2O molecules stick together due to Hydrogen Bonding
= The basic functions of a lubricant are reduction of friction and removal of heat.
- Water reduces friction by maintaining a film of lubricant between surfaces that are moving with respect to each other, thereby preventing the surfaces from coming into contact and subsequently causing surface damage.
- Water also acts as a coolant, removing heat generated by either friction or other sources such as metabolic wastes.

SIGNIFICANCE IN BIOLOGY:
- Synovial Fluid = (Joint Fluid); lubricates the ends of bones (joints) so that they can move freely.
- Vitreous Humour = lubricates the eyes
- Mucous = lubricates the respiratory system and gastrointestinal tracts

ACIDS AND BASES
Most inorganic substances, and many organic molecules, act as either *acids* or *bases* in water solution. Acids and bases are substances that affect the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-). In pure water, the number of hydrogen ions equals the number of hydroxide ions.

- **ACIDS =** molecules that dissociate in H_2O to release H^+ ions $HCl \rightarrow H^+ + Cl^-$
  = "PROTON DONORS" (H^+)
- The greater the degree of dissociation, the greater the strength of the acid.
- For example, hydrogen chloride (hydrochloric acid) is a strong acid, since nearly all of it is dissociated in water.
- The addition of HCl to water results in a solution with more H^+ than OH^-
- **BASES =** molecules that dissociate in H_2O to release OH^- ions $NaOH \xrightarrow{H_2O} Na^+ + OH^-$

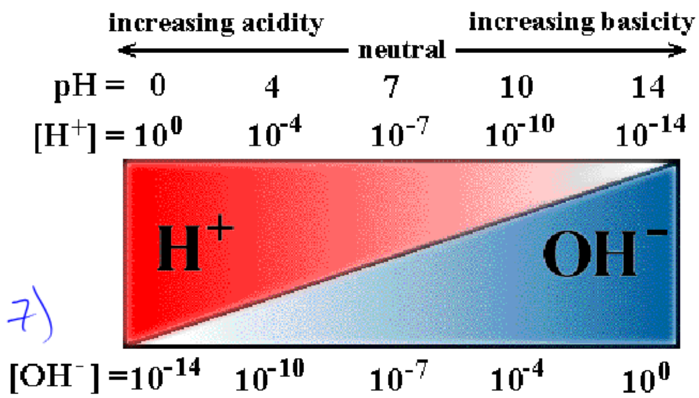
= "PROTON ACCEPTORS"
- The greater the degree of dissociation, the greater the strength of the base.
- For example, sodium hydroxide is a strong base, since nearly all of it is dissociated in water.
- The addition of NaOH to water results in a solution with more OH^- than H^+

- **pH SCALE**

Chemists use a pH scale to indicate the strength of acids and bases.

The figure to the right shows the pH scale, which ranges from 0 to 14 and indicates the proportional concentration of hydrogen (H^+) and hydroxide ions (OH^-) at the various pH values.

- When the concentration of H^+ increases, the concentration of OH^- decreases and vice versa.
- A change of one (1.0) in the pH number indicates a 10-fold change in the hydrogen ion concentration because the pH scale is a logarithmic scale.
    - For example, compared to a solution of pH 3, a solution of pH 2 is ten times as acidic. A solution of pH 1 is one hundred times as acidic as one of pH 3.



Pure water has a pH of 7, the point where the concentration of H^+ and OH^- are equal.

- Acids have a pH < 7 (less than 7)
  = the greater the concentration of hydrogen ions, the stronger the acid and the lower the pH number.
- Bases have a pH > 7 (greater than 7)
  = the greater the concentration of hydroxide ions, the stronger the base and the higher the pH number.

BUFFERS:

Living organisms are sensitive to the concentrations of hydrogen and hydroxide ions and must maintain the pH of their cells within narrow limits.

- Human blood for example, has a pH of 7.4; stomach acid has a pH of 2.0.
- Organisms control the pH of cellular and body fluids by buffers:

***Buffer =** a compound or a combination of compounds that can take up excess H^+ or OH^- to keep the pH of a solution relatively constant.*

Most buffers are weak acids or weak bases that combine reversibly with H^+ ions.

- For example, carbonic acid (H_2CO_3) is an example of a buffer that occurs in the human blood stream, which serves to regulate the H^+ concentration in the blood. Carbonic acid is a weak acid that minimally dissociates and then re-forms in the following manner:

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

carbonic acid — hydrogen ion — bicarbonate ion.

- Blood always contains some carbonic acid and some bicarbonate ions. When hydrogen ions (an acid) are added to blood (and pH falls), the following reaction occurs:

(acidic)

$$H^+ + HCO_3^- \longrightarrow H_2CO_3$$

- When hydroxide ions (a base) are added to blood (and pH rises), this reaction occurs:

(basic)

$$OH^- + H_2CO_3 \longrightarrow HCO_3^- + H_2O$$

- Together, these reactions prevent any dramatic change in blood pH = (BUFFER THE BLOOD)

Most buffers act in this way. Proteins containing histidine and cysteine, two amino acids which contribute most of the buffering capacity of proteins, are the most abundant buffers in animal systems.