BIO-103:
Chemistry of Life

BIOLOGY 1

LECTURE: 04

Life depends on chemistry!

- When you eat food or inhale oxygen, your body uses these materials in chemical reactions that keep you alive

- Just as buildings are made from bricks, steel, glass, and wood, living things are made from chemical compounds

- Wouldn't you want an architect to understand building materials? Same idea applies to geneticists, ecologists, zoologists, botanists, biologists, and etc.

Let's learn from a real life example why chemistry of life is important…

Fat: Fear of frying

- What is fat?
- Is fat always bad for health?
- How can you differentiate good and bad fat?

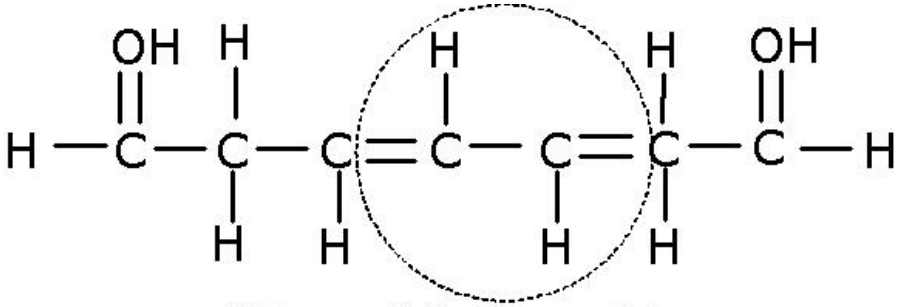
Food for thoughts

- We might need only a tablespoon of fat/day to stay healthy
- But the scenario is different in developed countries
- Americans consume 100lb./year (reason of obesity and overweight)

 The total **quantity** of fat we eat may be of **less importance** to health than the **kinds of fats** we eat

Fat: Fear of frying

- Fats with a certain arrangement of hydrogen atoms around that carbon chain are called **trans fats**
- Eating as little as **2 grams a day** of hydrogenated vegetable oils increases a person's risk of atherosclerosis (hardening of the arteries), heart attack, and diabetes
- A small serving of French-fries made with hydrogenated vegetable oil contains about **5 grams of trans fats.**



"Trans" fatty acid

How?

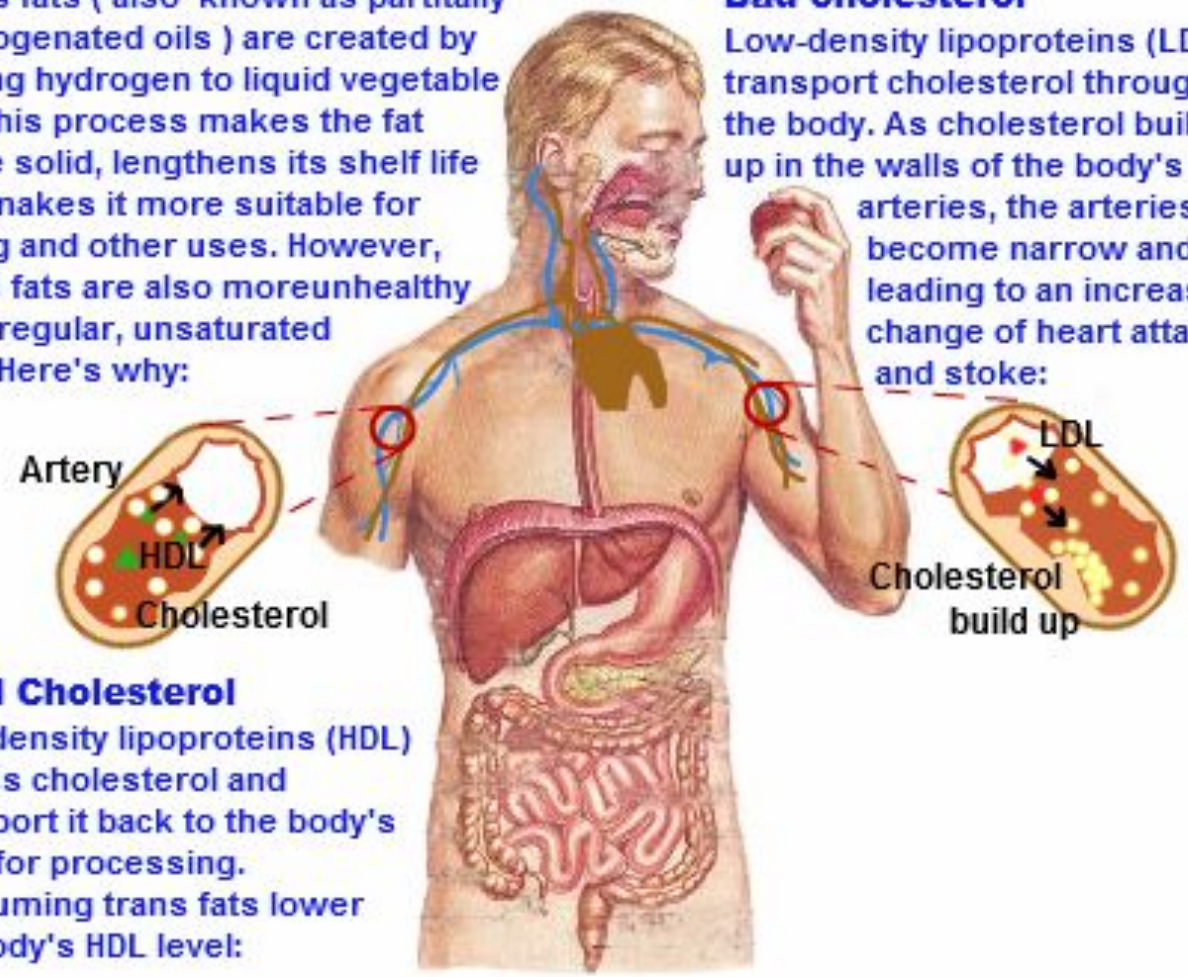
Small differences in the way molecules are put together can have big effects in a living organism.

Trans fats and the body

Trans fats (also known as partitally hydrogenated oils) are created by adding hydrogen to liquid vegetable oil. This process makes the fat more solid, lengthens its shelf life and makes it more suitable for frying and other uses. However, trans fats are also moreunhealthy than regular, unsaturated fats. Here's why:

Bad cholesterol

Low-density lipoproteins (LDL) transport cholesterol throughout the body. As cholesterol builds up in the walls of the body's arteries, the arteries become narrow and leading to an increased change of heart attack and stoke:



Good Cholesterol

High-density lipoproteins (HDL) excess cholesterol and transport it back to the body's liver for processing. Consuming trans fats lower the body's HDL level:

So…lets learn about the chemistry of life!

Chemistry of Life

Life

Atom

Oxygen (O)

Molecule

Dioxide (O_2)

Macromolecule

Phospholipid

Cell

Clara Cell

Tissue

Epithelial tissue

Organ

Lung

Organ System

Respiratory System

Organism

Panthera leo (Lion)

Population

Pride of Lions

Community

Lions and Zebras

Ecosystem

Lions, Zebras, and the Environment

Biosphere

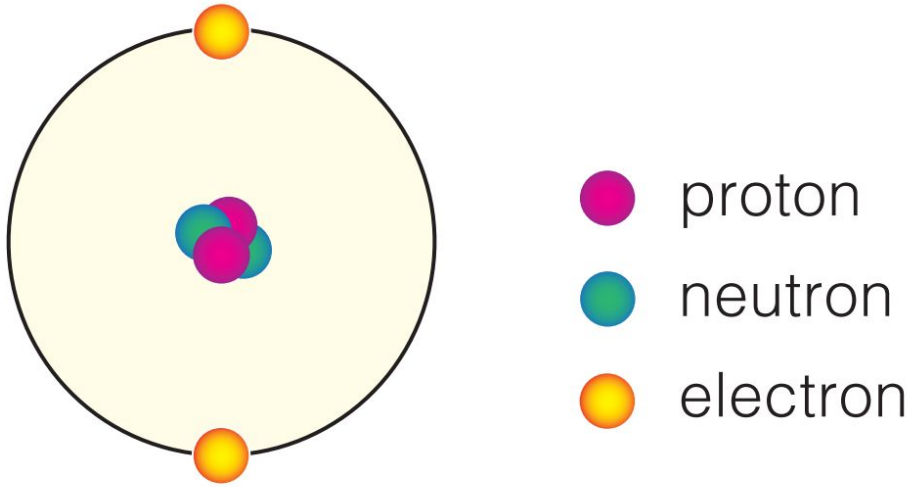
Life on Earth

Terminologies: To understand chemistry of life!

Atom Electron Proton Atomic Number Neutron Mass Number Nucleus Charge Element Isotopes Radioisotopes Radioactive-decay

Terminologies

- **Atom** : Particle that is a fundamental building block of matter
- **Atomic number:** Number of protons in the atomic nucleus; determines the element.
- **Charge:** Electrical property of some subatomic particles. Opposite charges attract; like charges repel.
- **Electron:** Negatively charged subatomic particle that occupies orbitals around the atomic nucleus.
- **Element**: A pure substance that consists only of atoms with the same number of protons.



Terminologies

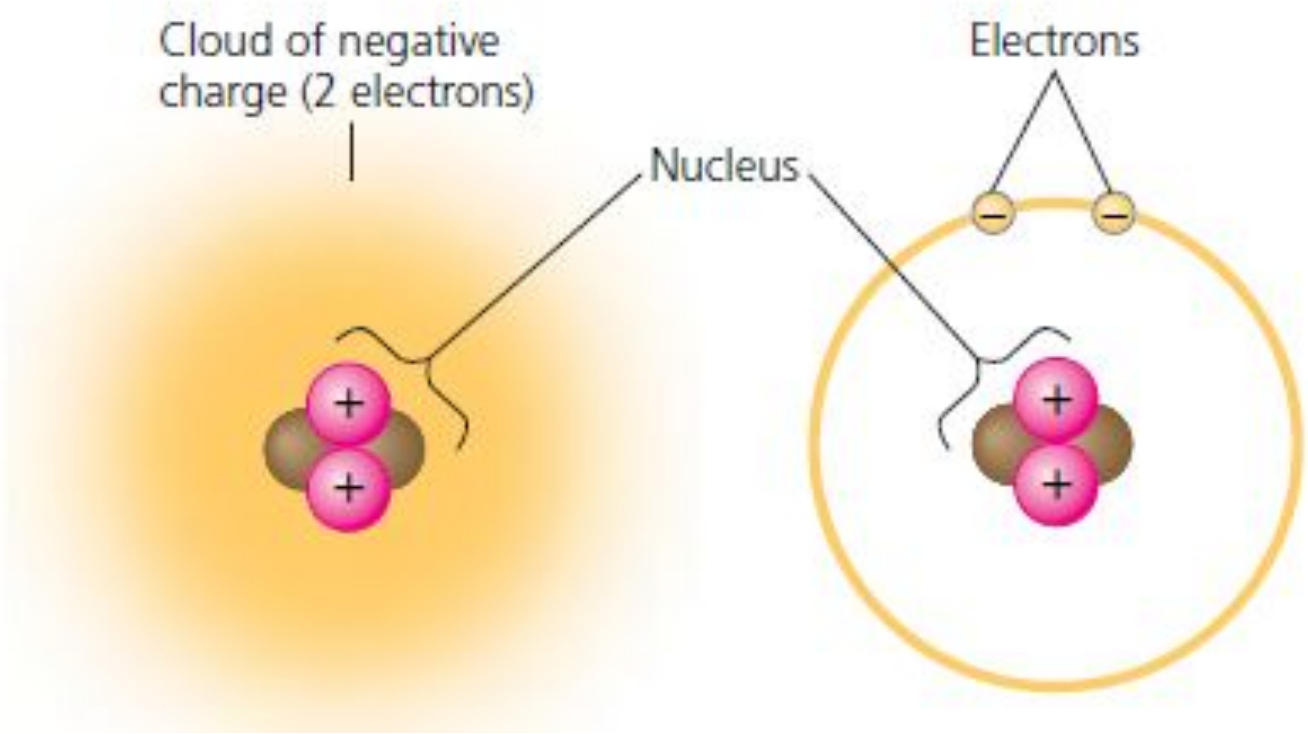
- **Isotopes:** Forms of an element that differ in the number of neutrons their atoms carry
- **Mass number:** Total number of protons and neutrons in the nucleus of an element's atoms.
- **Neutron:** Uncharged subatomic particle in the atomic nucleus.
- **Nucleus**: Core of an atom; occupied by protons and neutrons.
- **Proton:** Positively charged subatomic particle that occurs in the nucleus of all atoms.
- **Radioactive decay:** Process by which atoms of a radioisotope spontaneously emit energy and subatomic particles when their nucleus disintegrates.
- **Radioisotope:** Isotope with an unstable nucleus.

Let's learn in details….

Atomic Structure

Atoms are neutral

Numbers of e- and p+ are same in one atom



Number of proton is fixed for an atom of an element

ISOTOPES

Differ in numbers of neutron

^{12}C

Carbon-12

6 protons
6 neutrons

^{13}C

Carbon-13

6 protons
7 neutrons

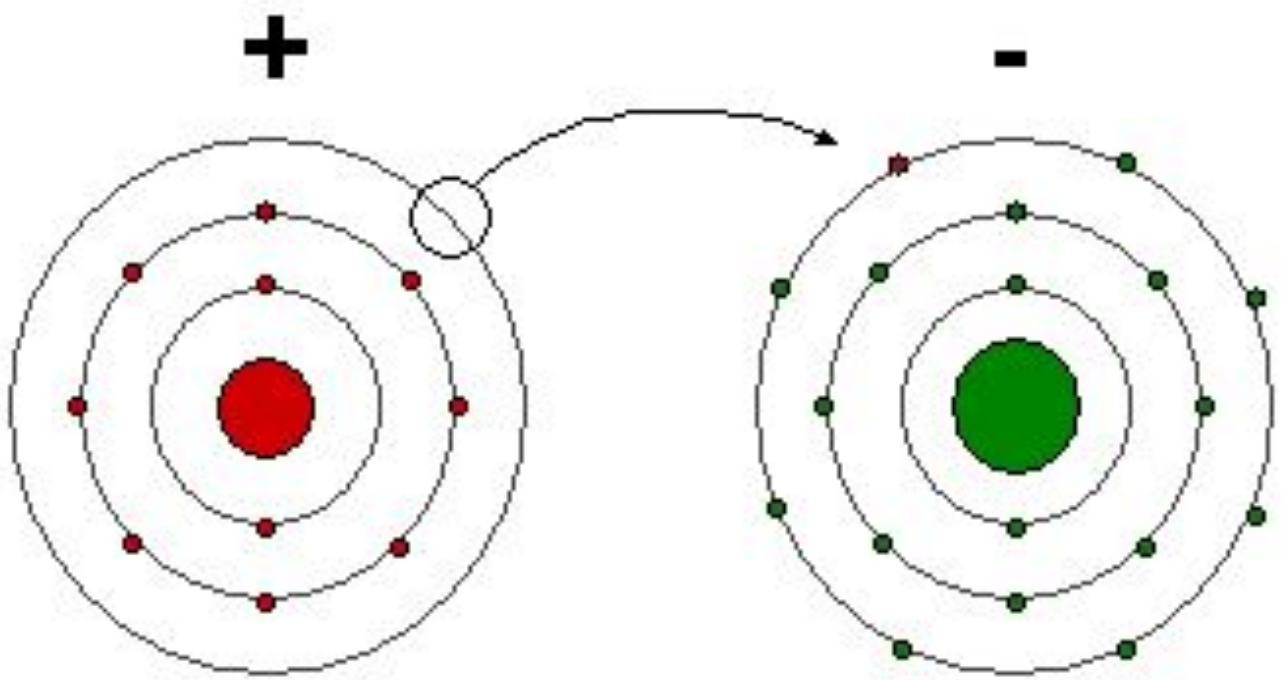
^{14}C

Carbon-14

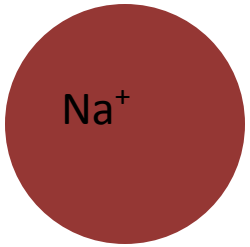
6 protons
8 neutrons

Ions

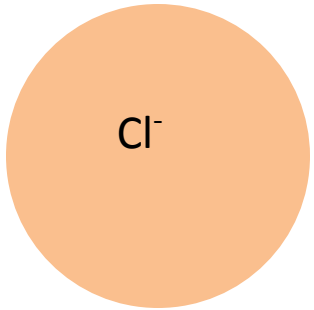
- An Ion is an atom or a group of atoms that has a net ***positive*** or ***negative*** charge.
- The number of “Proton” in the nucleus remains same during chemical reaction.
- “electrons” are lost/gained during a reaction.
  - The loss of 1/more electrons from a neutral atom results “cation” : an ion with (+) charge .
  - The gain of 1/more electrons from a neutral atom results “anion”: an ion with (-) charge.



Cation



11 protons
10 electrons

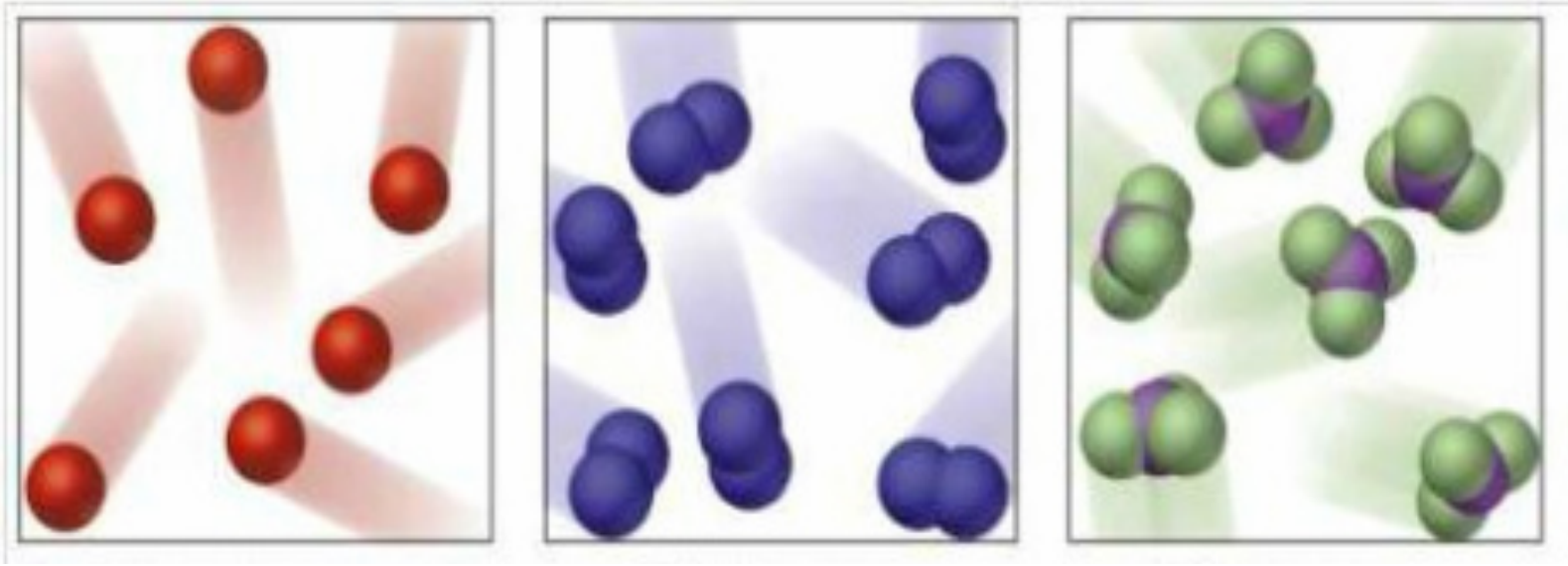


17 protons
18 electrons

anion

Molecule

- **Molecule** is an aggregate of at least two atoms in a definite arrangement held together by chemical forces (bonds)
- Molecules can contain atoms of same elements or different elements.
- They should join in a fixed ratio.
- **Electrically *neutral* like atom.**
- **Example: O_2, H_2, H_2O, $C_6H_{12}O_6$ etc.**



Atoms

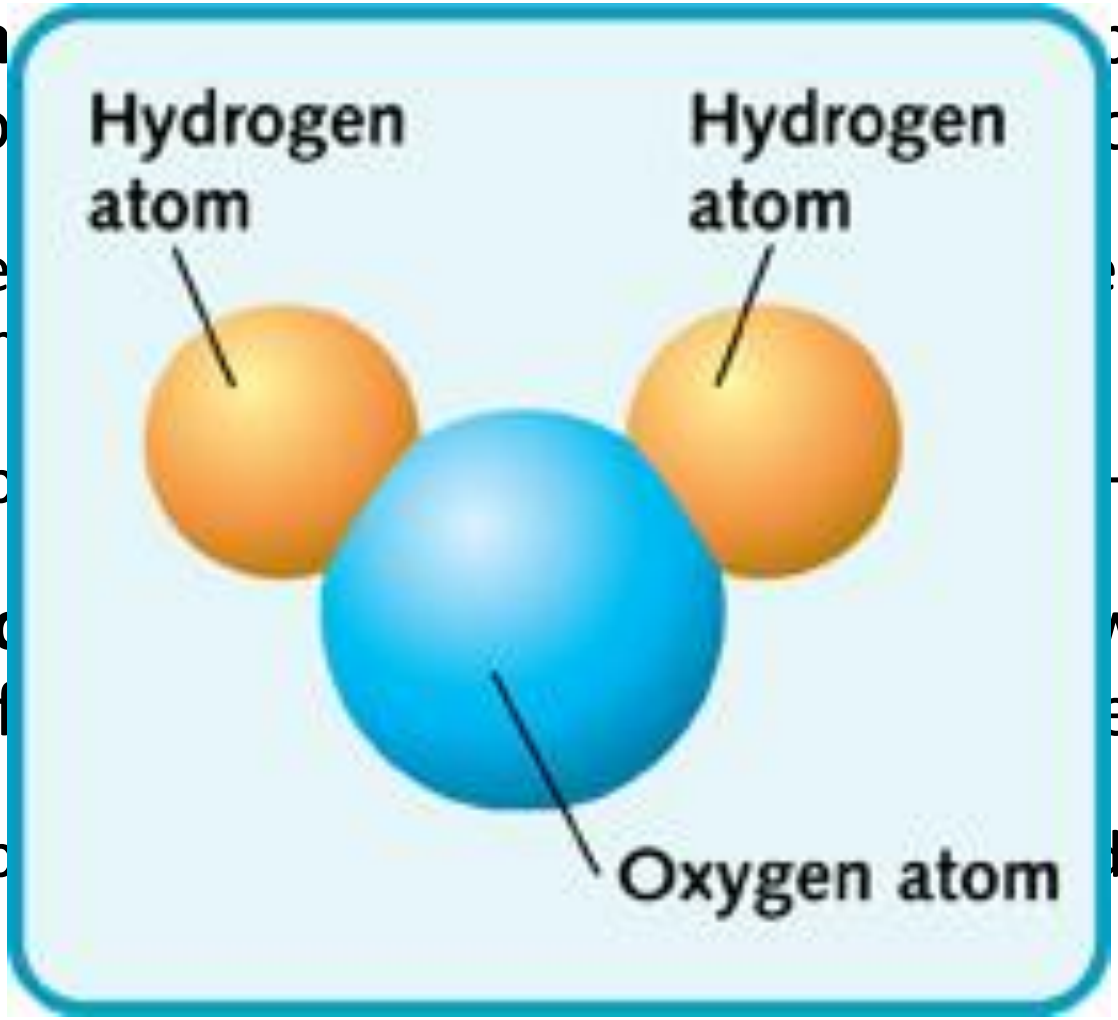
Molecules of an element

Molecules of a compound

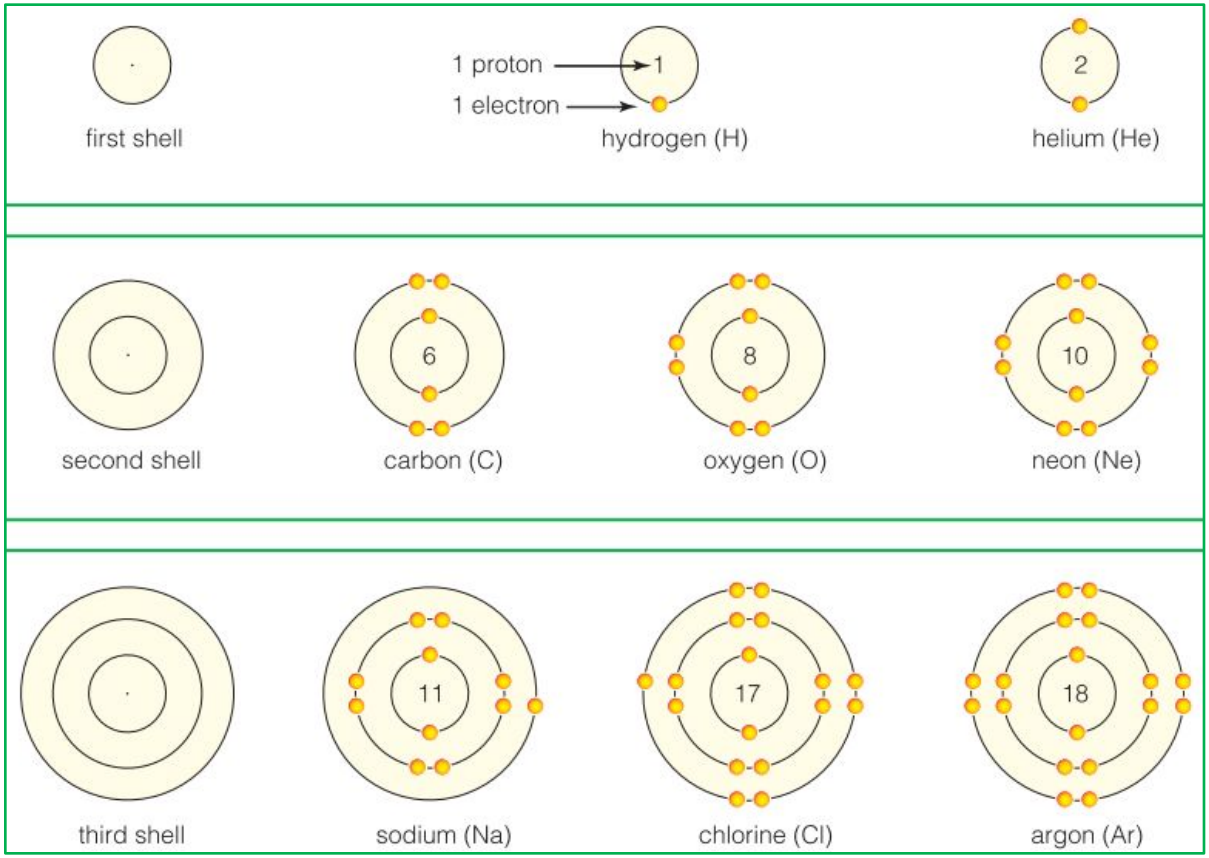
Look carefully how element and compound differ….??

Element vs. Compound

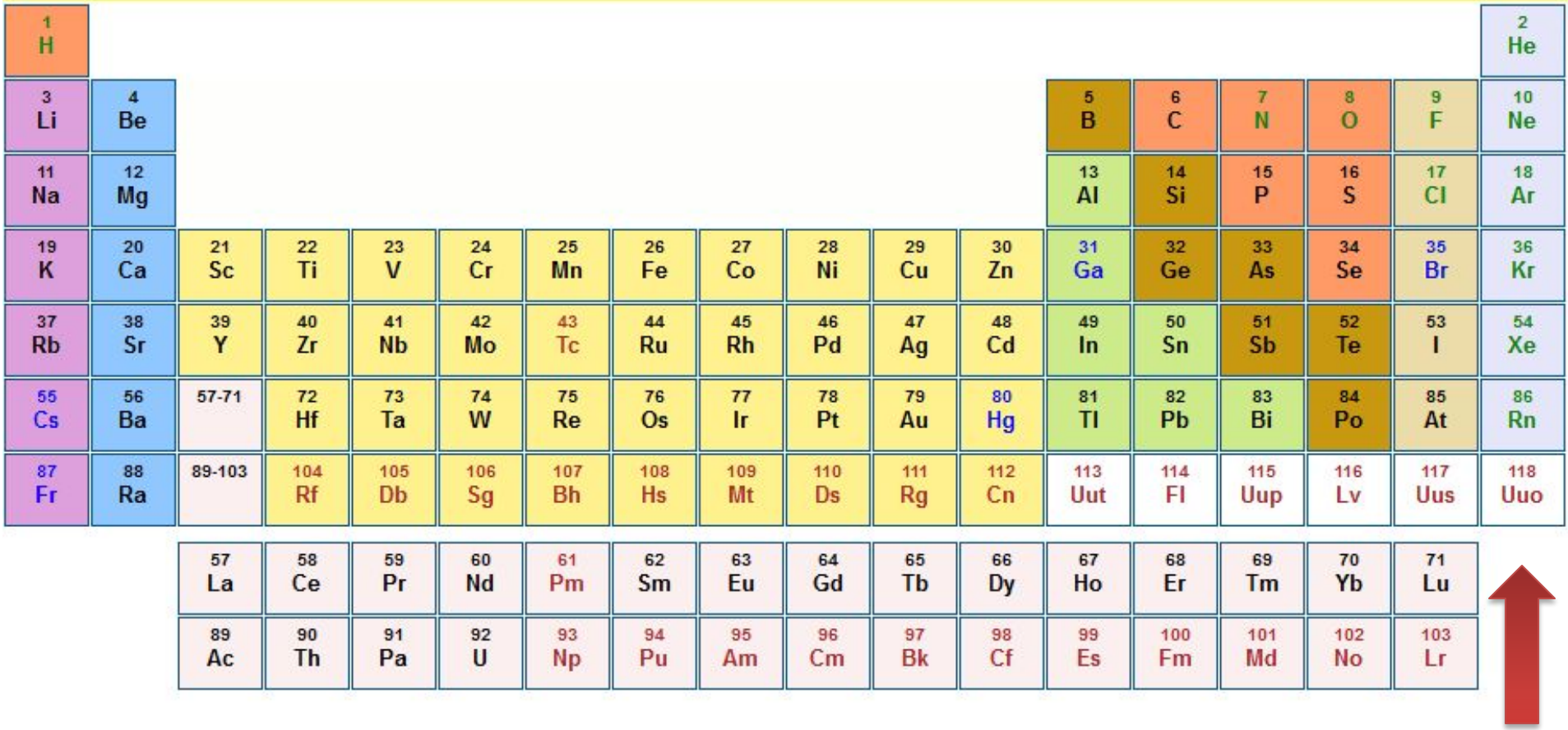
- An **elem** broken down to ctions.
  - Each e tter or two of its r
  - Examp H) etc.
- A **compo** wo or more dif ed ratio.
  - Examp d composed of the in a 1:1 ratio.



- **Atoms with vacancies tend to interact with other atoms: They give up, acquire, or share electrons until they have no vacancies in their outermost shell. Any atom is in its most stable state when it has no vacancies.**



The Periodic Table



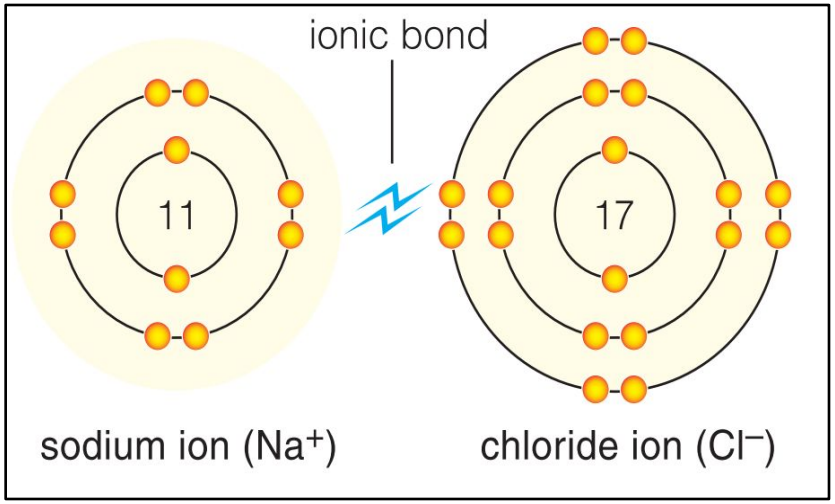
No-vacancy state

Chemical Bond

- A molecule is a particle composed of two or more atoms of same or different elements.
- The force that holds the atoms together in a molecule is called a chemical bond.
- Most common and significant bonds are-
  - **Ionic bonds**
  - **Covalent bonds**
  - **Hydrogen bonds**

Ionic Bond

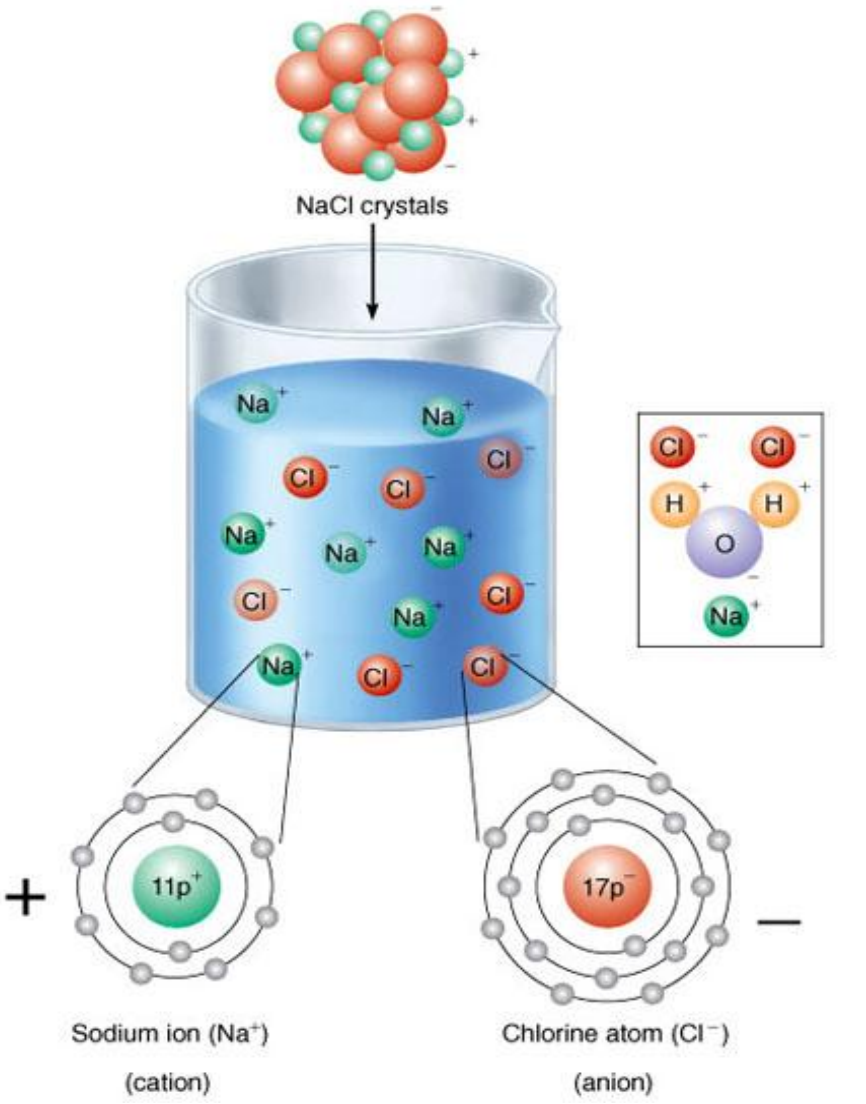
- Transfer of Electron from the outer most shell.
- atom donate **e^-** and become **cation.**
- another atom receive that e- and become **anion.**
- Ionic bond is strong.
- Example: NaCl is an ionic compound.



Ionization

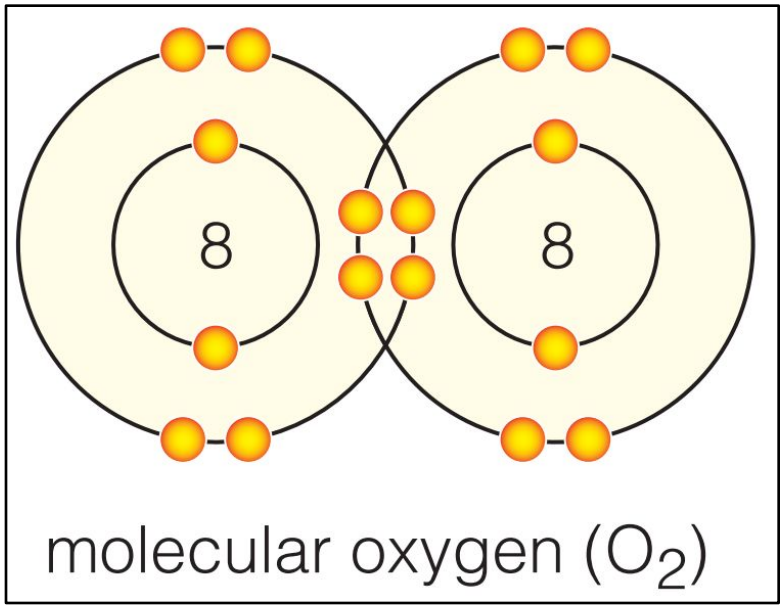
- Molecules formed by ionic bonding breakup (**ionization**) when dissolved in water (**solvent**), producing separate positive (**cation**) and negative (**anion**) ions.

- These ions conduct electricity and thus called electrolytes.



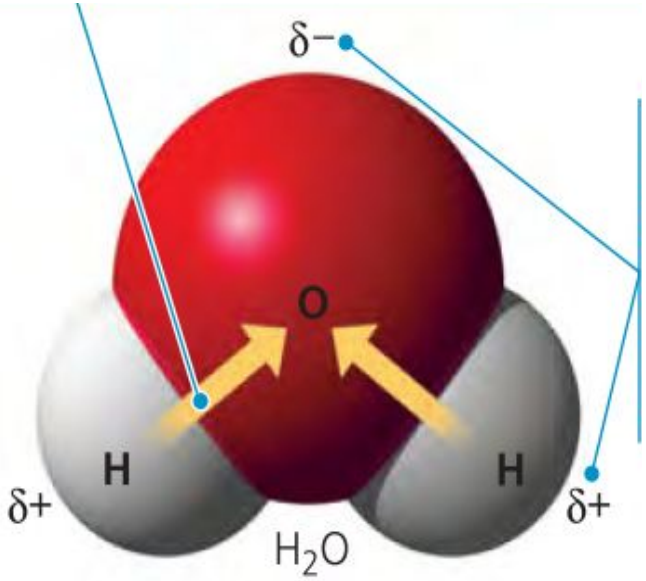
Covalent Bond

- Outer most electron is shared.
- when transfer is not possible.
- Example: O_2, H_2 etc are covalent compounds.



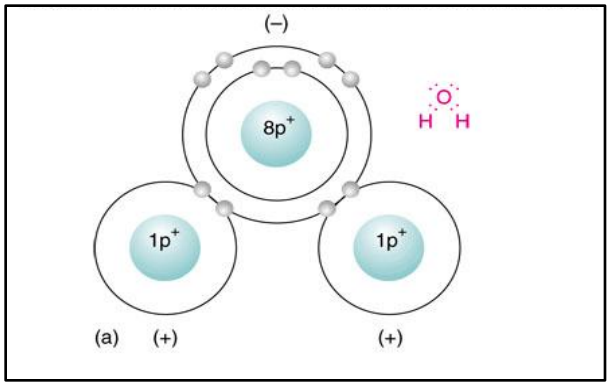
Electronegativity

- Atoms in a molecule attract shared electrons to varying degrees, depending on the element.
- The attraction of a particular atom for the electrons of a covalent bond is called its electronegativity.
- The more electronegative an atom is, the more strongly it pulls shared electrons toward itself.

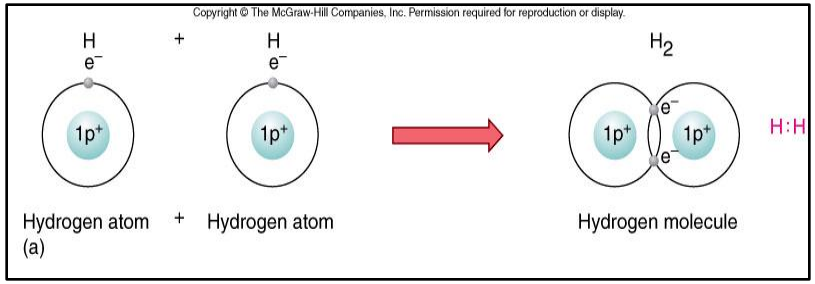


Types of Covalent Bond

- **Polar Covalent Bond**: Atoms participating in the bonds do not share electrons equally.

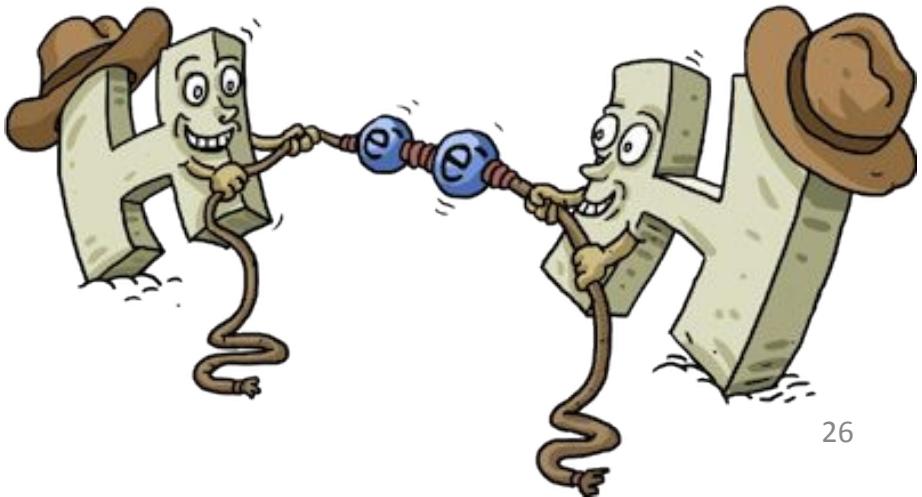


- **Non Polar Covalent Bond**: The atoms participating in the bond are sharing electrons equally. There is no difference in charge between the two ends of such bonds.



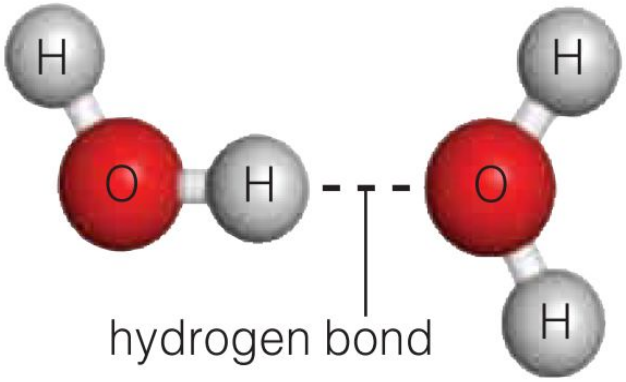
Polar Covalent Bond

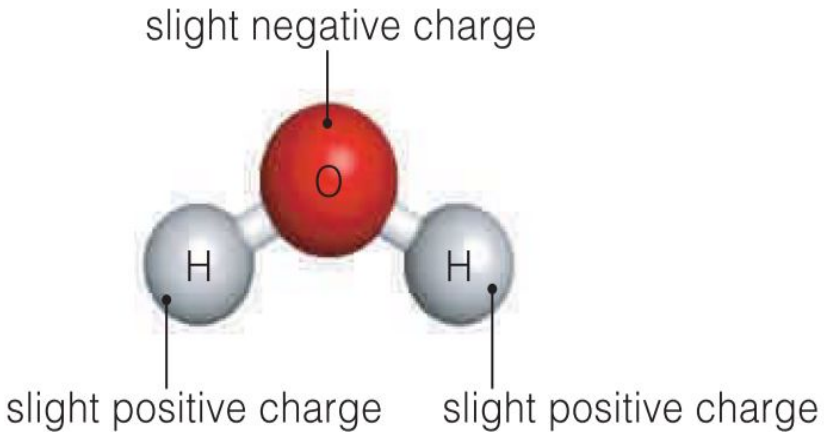
Non-Polar Covalent Bond



Hydrogen Bonds

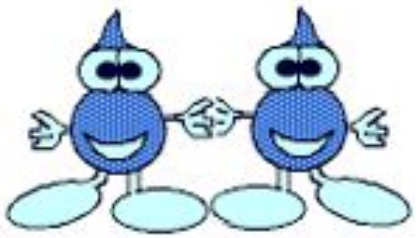
- A hydrogen bond is **a weak attraction** between a **hydrogen atom** and **another atom** taking part in **a separate polar covalent bond**
- ***Like ionic bonds, hydrogen bonds form by the mutual attraction of opposite charges.***
- Unlike ionic bonds, hydrogen bonds do not make molecules out of atoms, so they are not chemical bonds
- **Hydrogen bonds form and break much more easily**





Water

- Water: **Polar covalent bonds** gives water its **unique properties** that make life possible
- Water is an excellent solvent
  - Hydrophilic substances
  - Hydrophobic substances
- Water is stable in high temperature
  - Why ice floats on water?
- Water is cohesive/adhesive
- Water evaporates

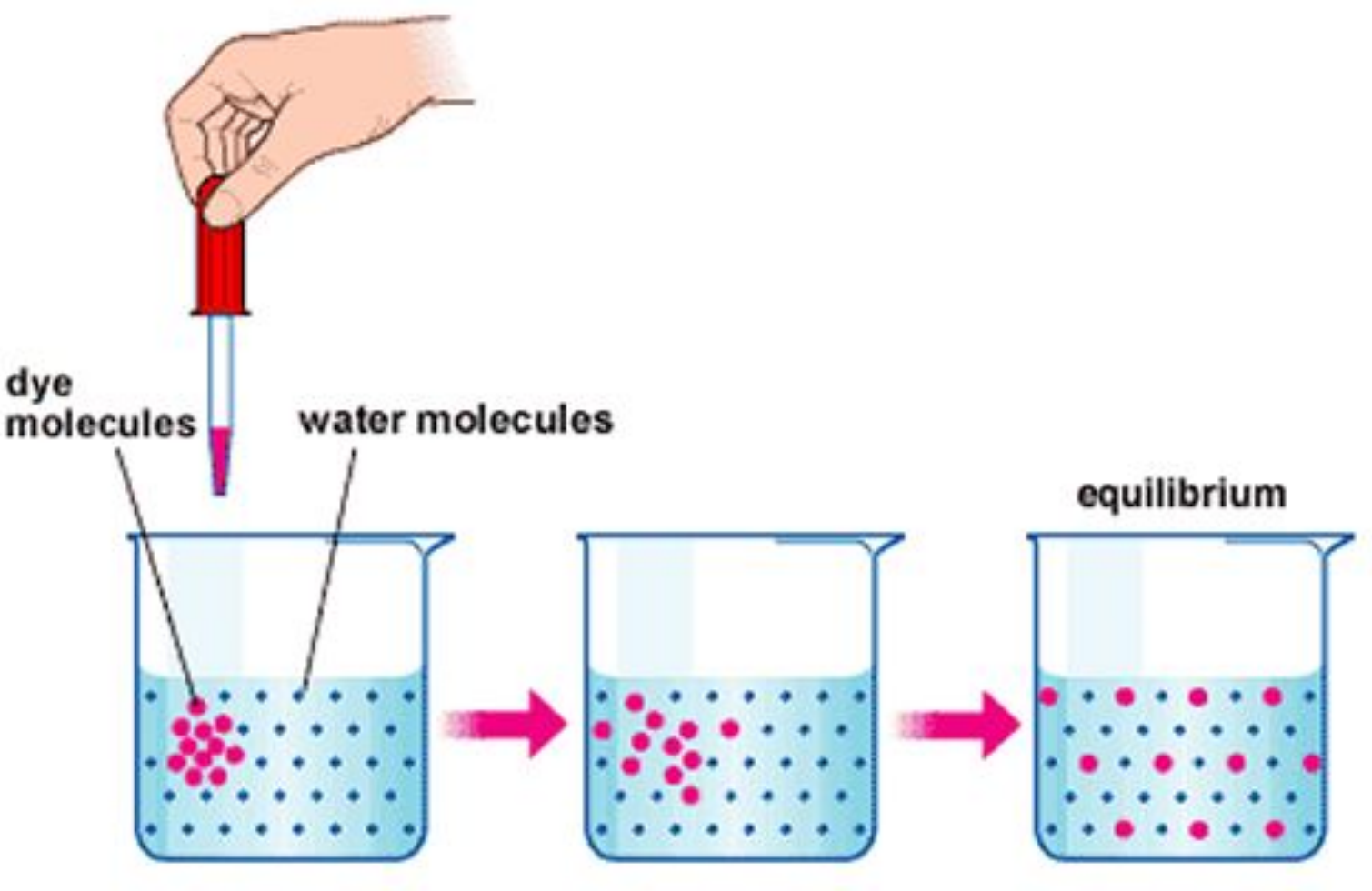


Cohesion

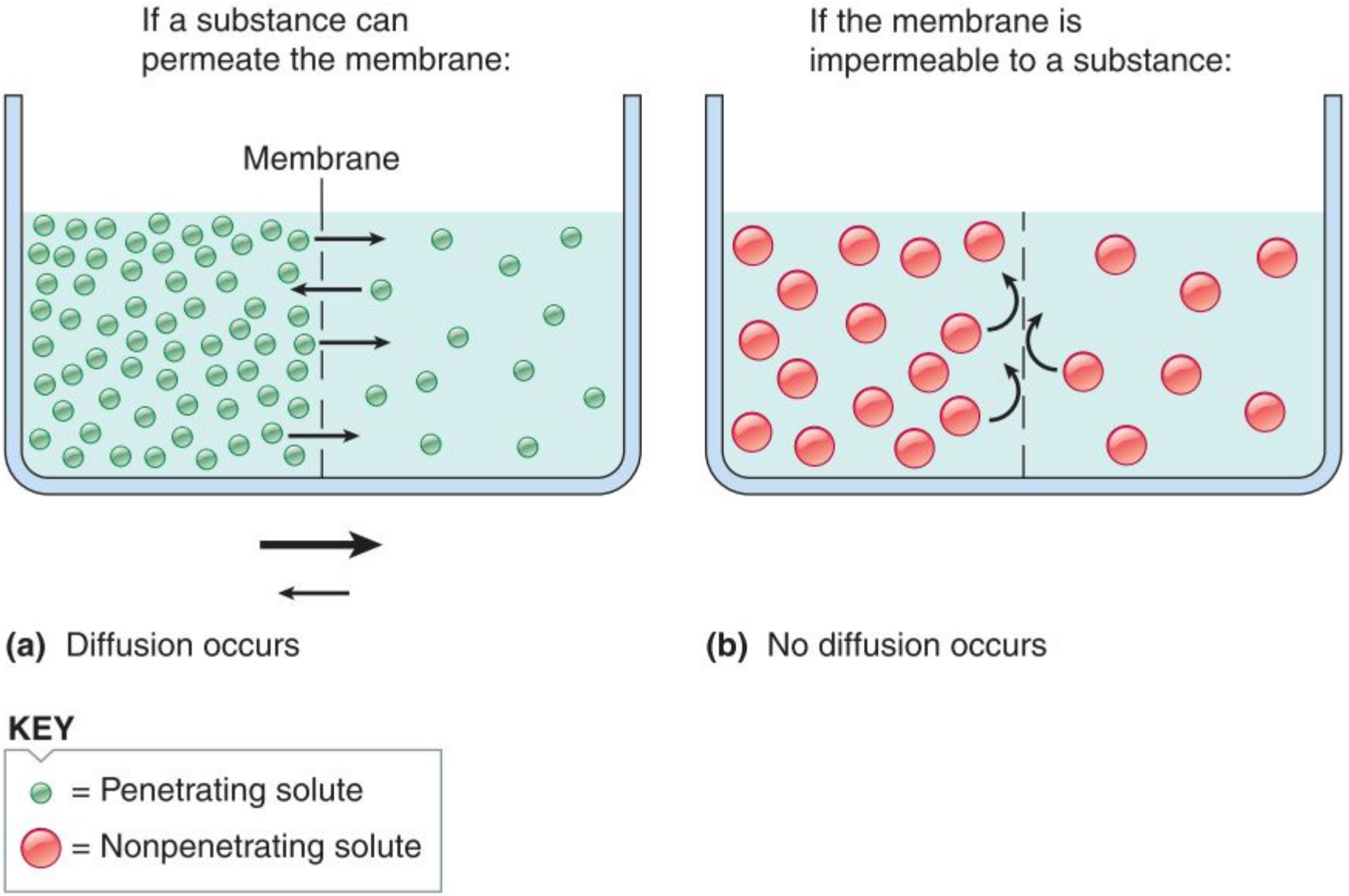
Adhesion

Diffusion

The process by which molecules spread from areas of high concentration, to areas of low concentration.

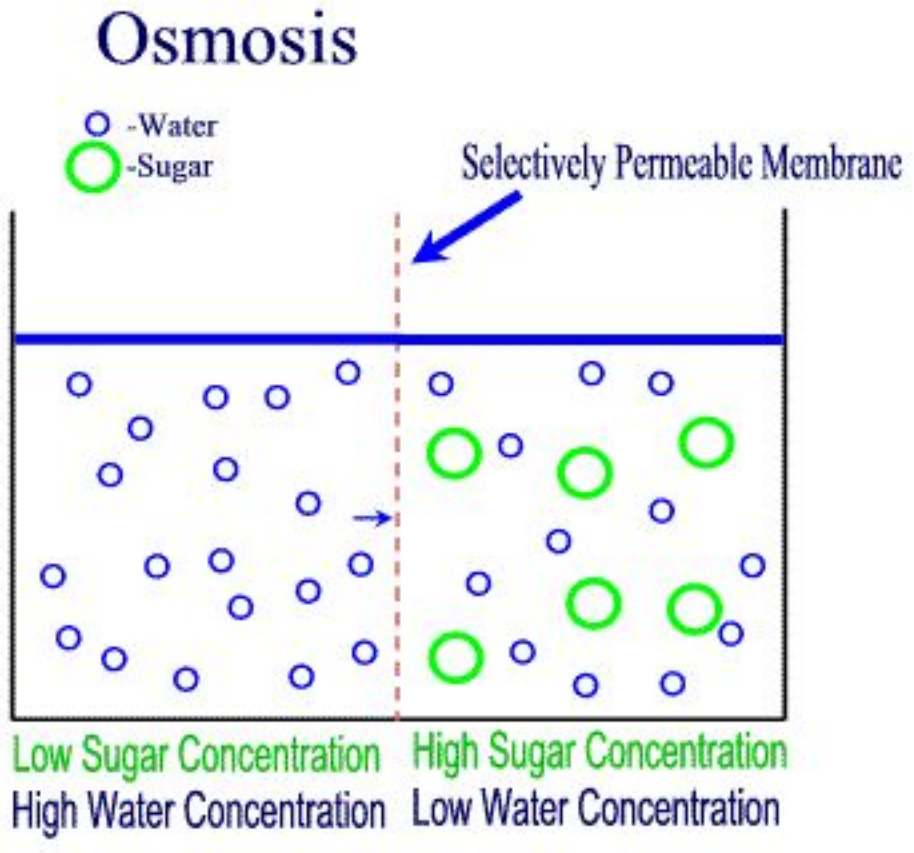


Diffusion

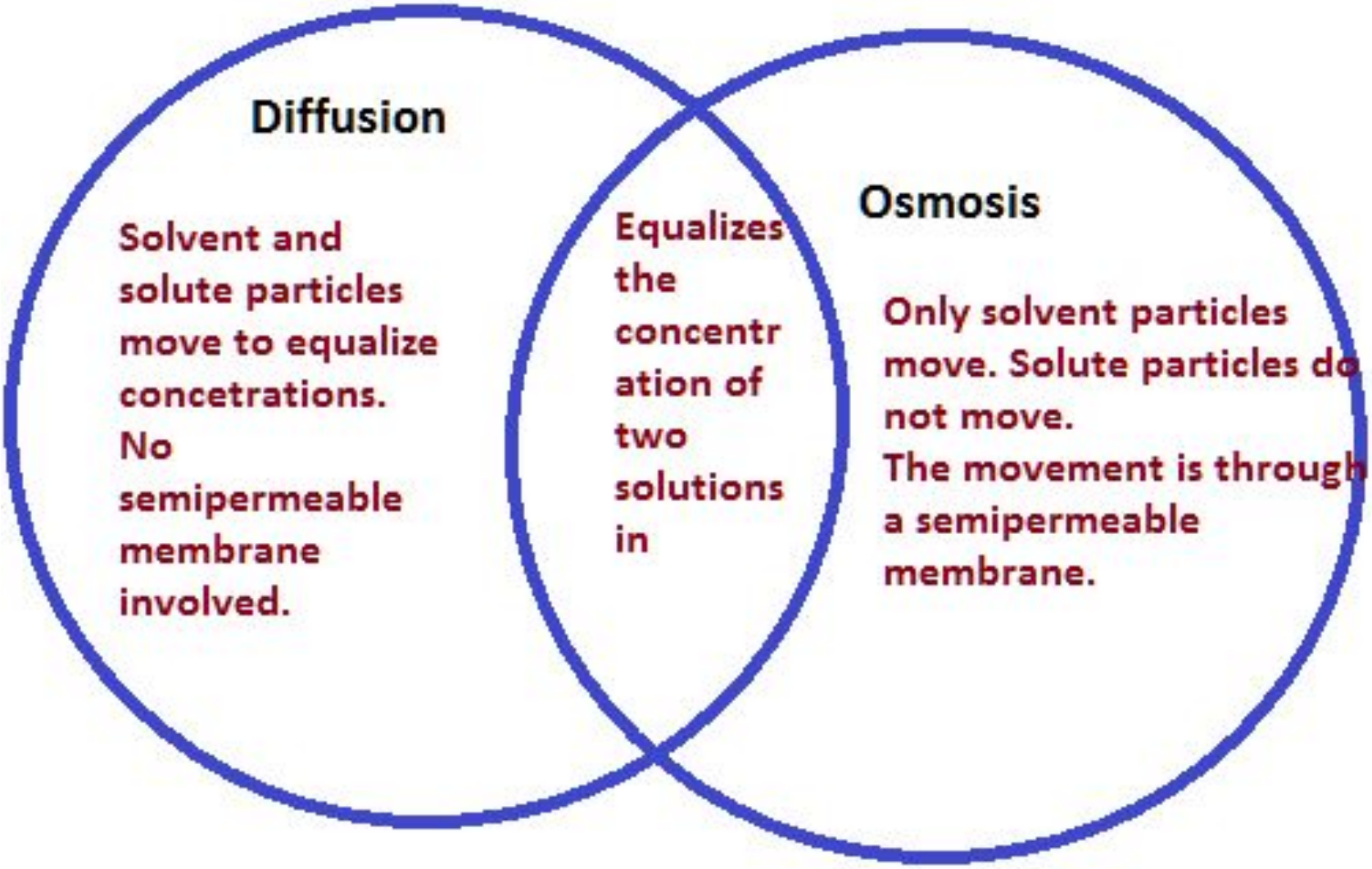

If a substance can permeate the membrane:
Membrane
If the membrane is impermeable to a substance:
(a) Diffusion occurs
(b) No diffusion occurs
KEY
= Penetrating solute
= Nonpenetrating solute

OSMOSIS

- The diffusion of water (across a membrane). Water will move in the direction where there is a high concentration of solute (and hence a lower concentration of water).



Diffusion vs. Osmosis



Tonicity

- The effect of a solution on the osmotic movement of H_20.
- The tonicity of a solution has no units
- Reflection of its concentration of non-penetrating solutes relative to the cell's concentration of non-penetrating solutes

- **Isotonic**

  If the concentration of solute (salt) is equal on both sides, the water will move back and forth but it won't have any result on the overall amount of water on either side

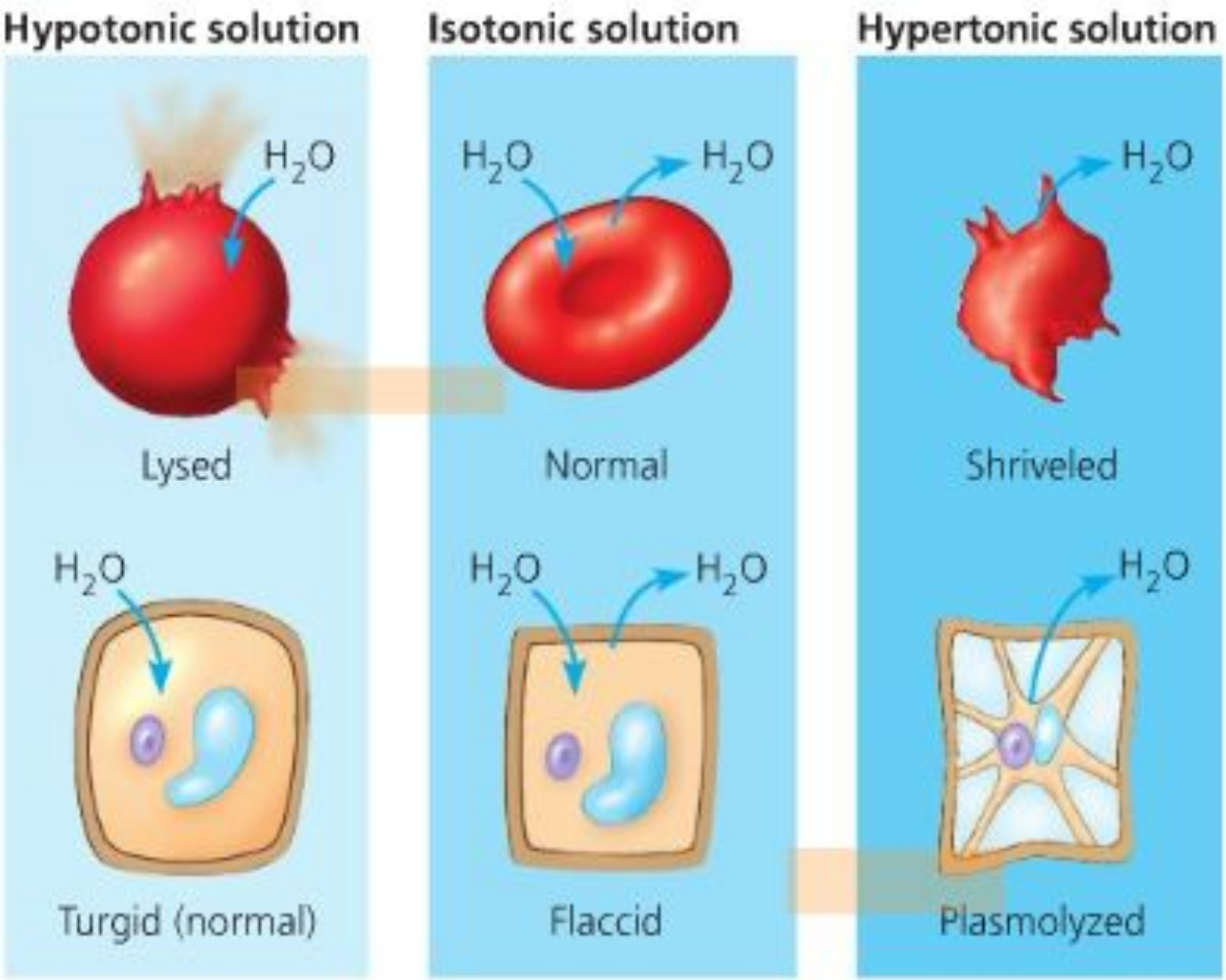
- **Hypotonic**

  The word "**HYPO**" means less, in this case there are less solute (salt) molecules outside the cell, since salt sucks, water will move into the cell

- **Hypertonic**

  The word "**HYPER**" means more, in this case there are more solute (salt) molecules outside the cell, which causes the water to be sucked in that direction.

Tonicity and living cells

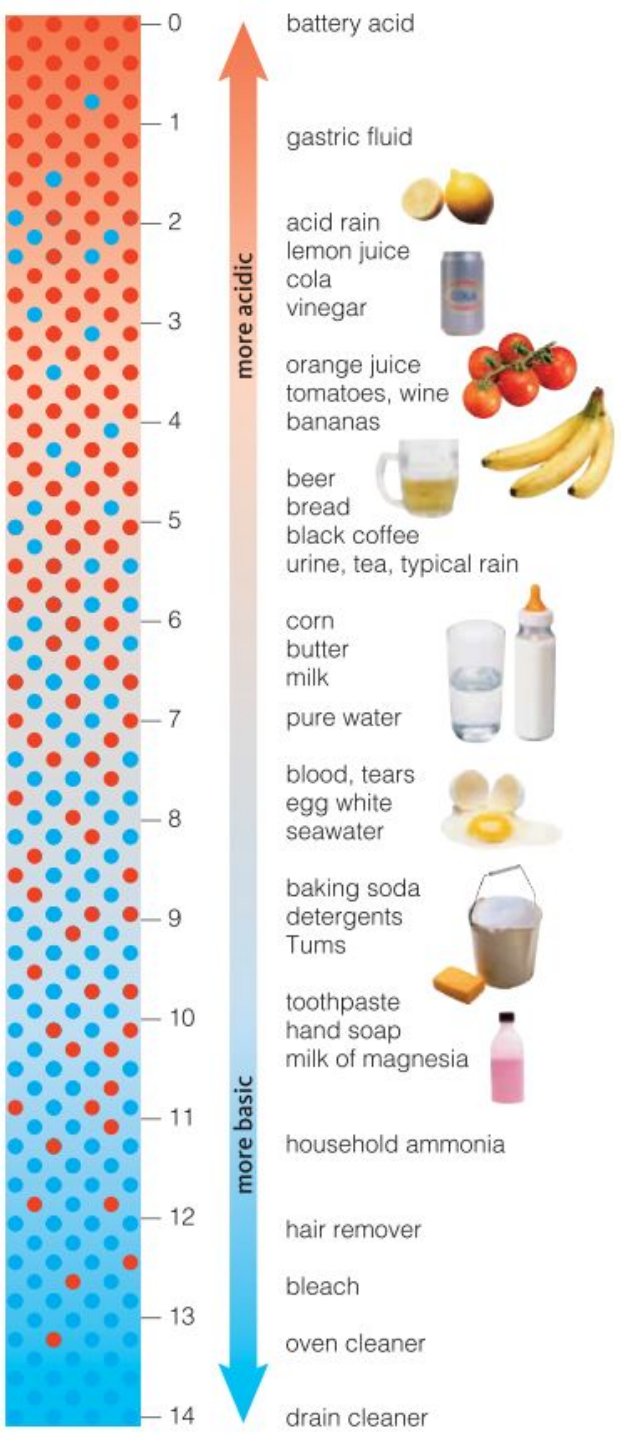


Acids and Bases

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

water — hydrogen ions — hydroxide ions — water

- **Acids:** Fossil fuel, N_2 containing fertilizers, Acid rain
- **Bases**
- Hydrogen ions contribute to pH. Acids release hydrogen ions in water; bases accept them. Salts release ions other than H^+ and OH^-.
- What is pH
- A figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid, and higher values more alkaline.
- The pH is equal to $-\log_{10} c$, where c is the hydrogen ion concentration in moles per liter.
- Buffers
- A solution that resists changes in pH when acid or alkali is added to it. Buffers typically involve a weak acid or alkali together with one of its salts.
- Buffers keep the pH of body fluids stable. They are part of homeostasis.



Thank you.
Any Questions?