RU RMT 2
Anatomy and Physiology
Lecture 2
Cell Biochemical Level

Organization of Matter

Matter Exists in 3 states:

* Solids
* Liquids
* Gases

Solids

Solids

* They are compact and have a definite shape and volume
* For example: bones and teeth

Liquids

Liquids

* They have a definite volume but do not have a definite shape
* For example: blood

Gases

Gases

* They do not have a definite shape or volume
* For example: oxygen and carbon dioxide

Matter

* All matter is composed of chemical elements, and an element cannot be split into simpler substances by ordinary chemical means

* The different elements that are present in the body can be classified into three major groups

1. Major Elements

The major elements constitute ~96% of the body's mass and include:

* Oxygen (O)
* Carbon (C)
* Hydrogen (H)
* Nitrogen (N)

2. Lesser Elements

The 8 lesser elements account for ~3.8% of the body's mass and include:

* Calcium (Ca)
* Phosphorus (P)
* Potassium (K)
* Sulfur (S)
* Sodium (Na)
* Chlorine (Cl)
* Magnesium (Mg)
* Iron (Fe)

3. Trace Elements

The trace elements make up the remaining 0.2% of body mass and include:

* Iodine (I)
* Fluorine (F)
* Copper (Cu)
* Manganese (Mn)
* Zinc (Zn)

General Chemistry

Atoms:

* Atoms are the smallest units of an element
* Atoms retain the properties and characteristics of that element

Atoms

Atoms are extremely small and are made up of the following subatomic particles:

* **Protons** (p^+) which are positively charged
* **Neutrons** (n^o) which do not have any charge and hence are neutral
* **Electrons** $(e^-)^-$ which are negatively charged

Atoms

* At the center of an atom is the **nucleus** which contains the **protons and neutrons** of the atom

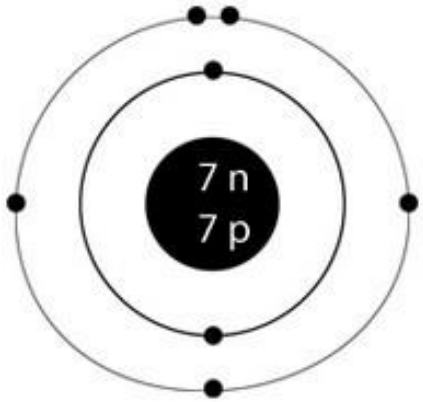
* The **electrons** are arranged in **concentric rings** (known as shells) around the nucleus

* The total number of electrons and protons in an atom are equal and so an atom is electrically neutral

Eg. Nitrogen Atom

Nitrogen

$^{14}_{7}N$



Atomic Number

* The **atomic number** is equal to the number of **protons** in the nucleus of that particular atom

* All atoms of a particular element have the same number of protons

* Different elements have different **atomic numbers** because they have different numbers of protons

* Since all atoms are electrically neutral, the atomic number also equals the number of **electrons** in each atom

Mass Number

* It is the sum of the total number of protons and neutrons in an atom

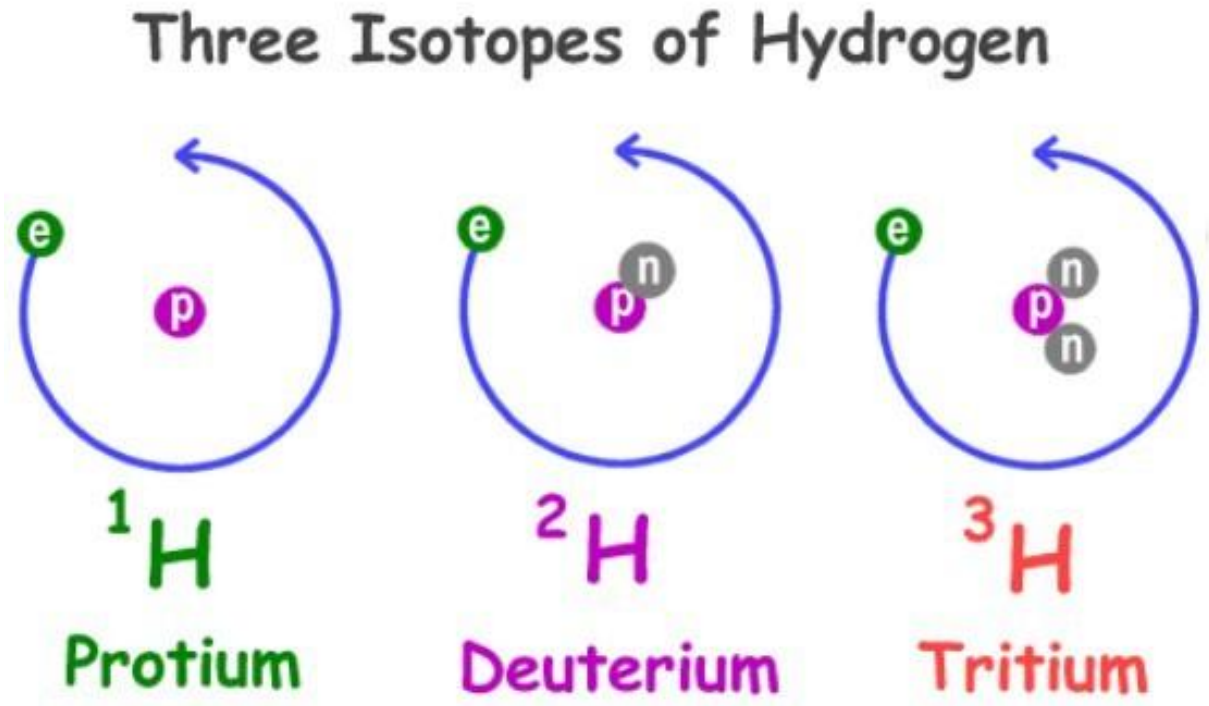
Atomic Mass

* It refers to the total mass of an atom and is equal to the total weight of protons and neutrons and electrons

Isotopes

* These are atoms of the same element that have the **same number of protons but different number of neutrons**
* Since the atomic number is equal to the number of protons and the atomic mass is the sum of protons and neutrons, we can also say that **isotopes** are elements with the same atomic number but different mass numbers

Eg. Hydrogen Isotopes



Stability of Atoms

* Atoms typically like to assume a stable structure and they do so by typically having eight electrons in their outermost shell

* They attain that stable state either by losing or gaining an electron or by sharing electrons with other atoms

Radioisotopes

* Radioisotopes are isotopes that are **unstable** and hence their nuclei decay (spontaneously change) into a stable configuration

* During this process of nuclear decay they emit radiation

* The decay of a radioisotope may be as fast as a fraction of a second, or as slow as millions of years

Harmful and Beneficial Effects of Radioisotopes

* Radioisotopes can either be beneficial or harmful

* The beneficial effects include their use in medical imaging procedures to diagnose and treat certain disorders. Other radioisotopes can be used as tracers to follow the movement of certain substance through the body.

* The harmful effects include tissue damage and the potential to cause cancers

Ions

* Atoms of each element can lose, gain, or share their electrons when interacting with other atoms to achieve stability

* Atoms that have either lost or gained electrons and therefore have either a positive charge or a negative charge respectively are known as ions

Ions

* Cations are positively charged ions that are formed when an atom loses an electron. For example: sodium ion=Na^{+}

* Anions are negatively charged ions that are formed when an atom gains an electron. For example: chloride ion= Cl^{--}

Ions

* Ions are symbolized by writing the chemical symbol followed by the number of its positive or negative charges. For example calcium ions=Ca^{2+}

* Ionization is the process by which an atom gains or loses an electron and thereby acquires a negative or a positive charge

* An ionic compound that breaks apart into positive and negative ions in solution is called an electrolyte

* Most ions in the body are dissolved in body fluids as electrolytes

Molecules

* Molecules are formed when two or more atoms join together

* Molecules may consist of:
  * two similar atoms joined together such as O_2
  * two or more different kinds of atoms joined together such as H_2O

Free Radicals

* A free radical is an electrically charged atom or group of atoms

* A free radical is unstable, highly reactive, and destructive to nearby molecules, and hence may break apart important body molecules

* Free radicals are often generated in the body from oxygen and antioxidants are substances that inactivate these oxygen--derived free radicals and thereby protect the molecules in the body

Chemical Bonds

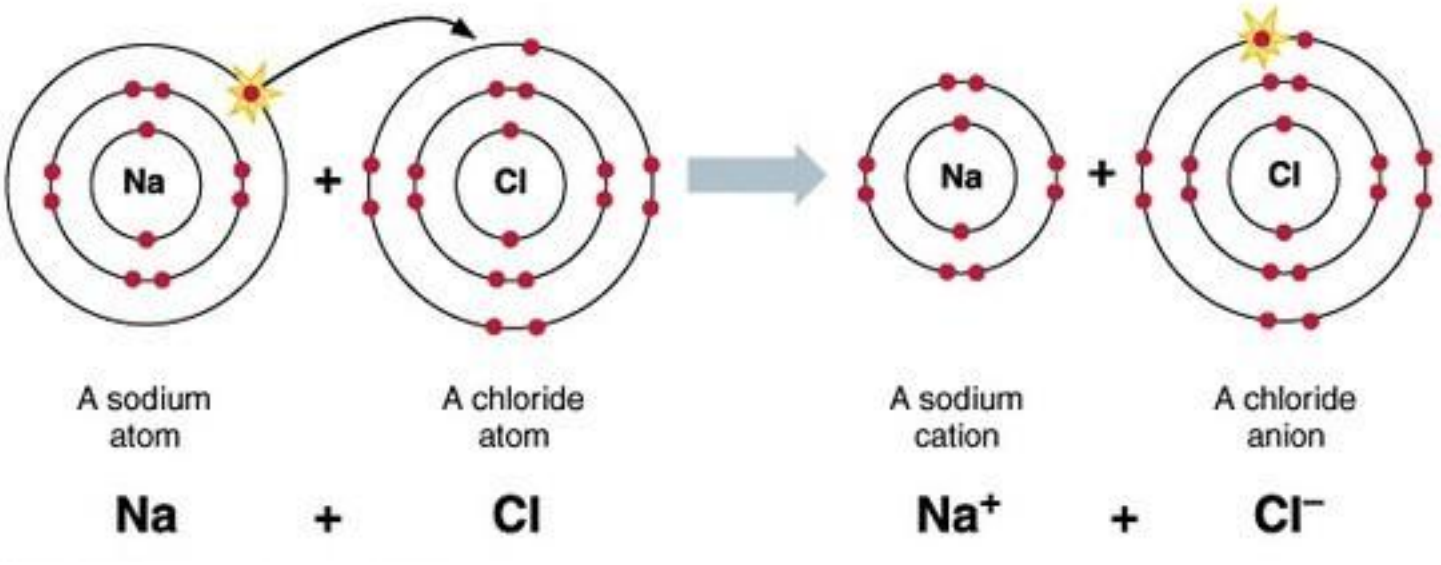
* Chemical bonds are the forces that hold atoms together to form a molecule or a compound

* There are three types of chemical bonds

Ionic Bonds*

Ionic Bonds

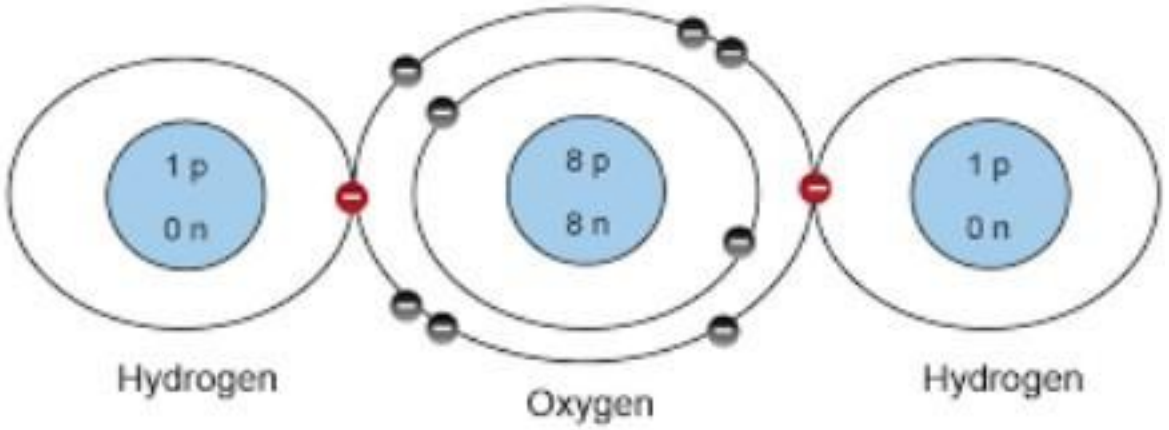
* Ionic bonds are bonds formed by the complete transfer of valence electrons between atoms
* Ionic bonds generate two oppositely charged ions



Covalent Bonds

Covalent Bonds

* Covalent bonds are formed when two or more atoms share electrons in order to achieve a stable state
* A compound can have single, double, or triple covalent bonds depending on the number of pairs of shared electrons



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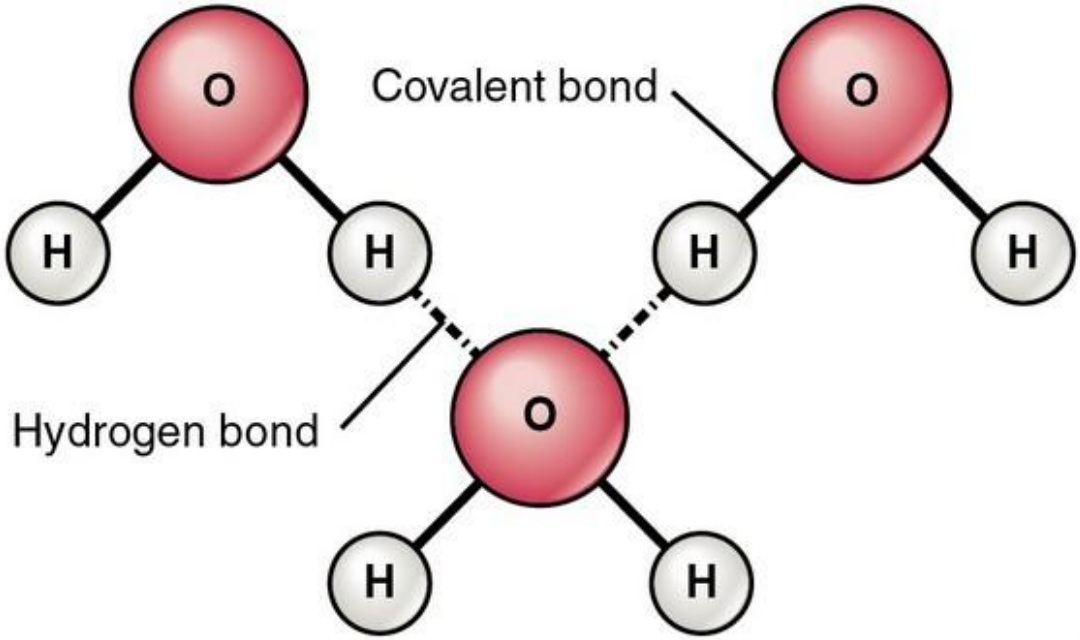
Hydrogen Bonds

Hydrogen Bonds

* These are bonds formed between hydrogen atoms and other atoms
* Since the hydrogen atom has a positive charge it is able to attract neighboring atoms that have a negative charge
* However, these bonds are weak compared to covalent and ionic bonds and cannot bind atoms into molecules, but rather establish links between molecules, or between different parts of a large molecule
* Acting collectively, hydrogen bonds provide strength and stability and help determine the three--dimensional shape of large molecules

Hydrogen Bonding in a Water Molecule



Chemical Reactions

* A chemical reaction occurs when bonds are formed or broken between atoms
* The starting substances in a chemical reaction are referred to as the **reactants** of a chemical reaction
* The ending substances in a chemical reaction are referred to as the **products** of a chemical reaction
* Since atoms are rearranged in chemical reactions the reactants and products have different chemical properties

Chemical Reactions

- The law of conservation of mass:
- In chemical reactions:
  - total mass of the reactants = total mass of the products
  - number of atoms of each element is the same before and after the reaction

Energy and Chemical Reactions

* Energy is the capacity to do work and each chemical reaction involves energy changes

* Law of conservation of energy:
  * The law of conservation of energy states that energy can neither be created nor destroyed; it may be converted from one form to another

  * The conversion of energy releases heat, some of which is used to maintain body temperature

Energy Transfer in Chemical Reactions

* Chemical bonds represent stored chemical energy, and hence breaking chemical bonds releases energy, while forming new bonds requires energy

There are two types of chemical reactions, namely:

Exergonic reactions:

Exergonic reactions release more energy than they absorb, such as by the catabolism of food

The energy that is released is used for bodily activities and also as heat

Endergonic reactions:

* Endergonic reactions absorb more energy than they release and are used to produce new molecules
* The energy that is required is usually obtained from an ATP molecule

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Catalysts

* A catalyst is a compound that speeds up chemical reactions but itself remains unchanged after the reaction occurs

* Enzymes are the most important catalysts in the body

Types of Chemical Reactions

* Following a chemical reaction, the atoms of the reactants are rearranged to yield products with new chemical properties.

* Four types of chemical reactions are common to all living cells:
  * Synthesis Reactions: also known as anabolic reactions
  * Decomposition Reactions: also known as catabolic reactions
  * Exchange Reactions
  * Reversible Reactions

Synthesis Reactions

- Synthesis Reactions
  - Synthesis reactions are also known as anabolism reactions
  - They involve the joining of two or more particles (atoms, ions, or molecules) to form new and larger molecules
  - Hence new chemical bonds are formed in the process

Decomposition Reactions

Decomposition reactions

* Decomposition reactions are also known as catabolism reactions
* They involve splitting up large molecules into smaller particles (atoms, ions, or molecules)
* Hence, new chemical bonds are broken in the process

Exchange Reactions

Exchange Reactions

* Consist of both synthesis and decomposition reactions

Reversible Reactions

Reversible Reactions

* These are reactions where the reactants can form products, and products can revert back to the original reactants
* Reversible reactions are indicated by two half arrows pointing in opposite directions
* Many reactions in the body are reversible and need enzymes