University Of Basrah
Al-Zahraa College Of Medicine

Ministry Of Higher Education
And Scientific Research

Module: Molecule, Gene and Disease

Semester: 2
Session: 1, Lecture: 1
Duration: 1 hr

Lecture Title:

Introduction To the Cell and Biological Molecules

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This Lecture was loaded in blackboard and you can find the material in:
(Lippincott's Illustrated Reviews: Cell and Molecular Biology Chapter 5)
For more detailed instructions, any question, or you have a case you need help in, please post to the group of session

Learning Objectives (LO)

1. Identify the main organelles in a mammalian cell and list their functions. (LO 1.1)

2. List the principal differences between a prokaryotic and an eukaryotic cell. (LO 1.2)

3. Discuss the bonds important for macromolecular structure and interaction. (LO 1.3)

4. Explain the differences between hydrophobic and hydrophilic molecules in water. (LO 1.4)

5. Explain the concept of pH, pK and buffers. (LO 1.5)

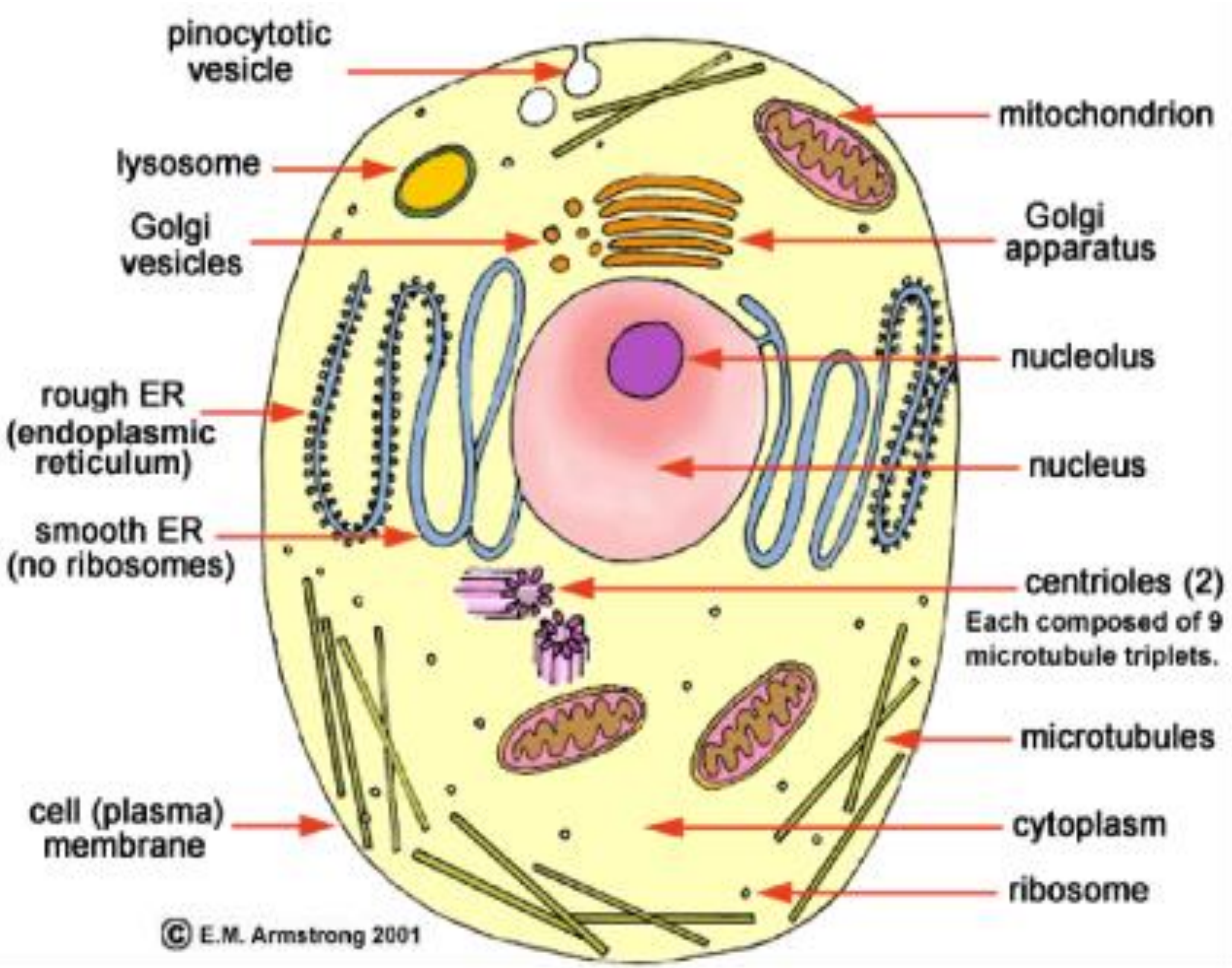
The Cell

LO. 1.1

- **The Cell:** is the basic structural, functional and biological units of all living organisms.
- Cells are small, membrane enclosed units, filled with a concentrated aqueous solution of chemicals.
- They are capable of carrying out all the activities necessary for life.
- They provides with the surprising ability to create copies of themselves by growing and dividing in two.

Cell components: The cell consists of three main parts: **LO.1.1**

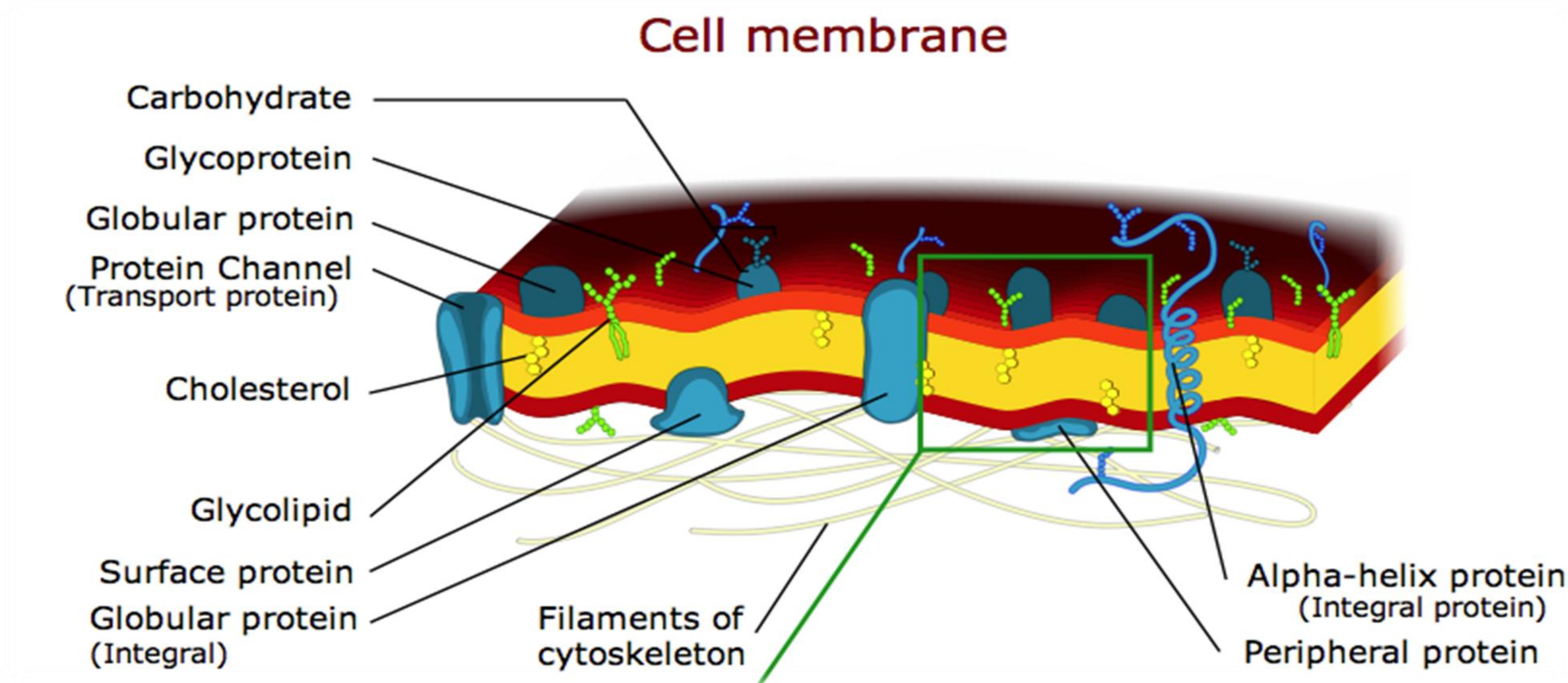
1. The membrane.
2. The nucleus.
3. The cytoplasm.



Cell Components:

LO. 1.1

- **Plasma membrane:** It is a phospholipid bilayer that responsible for the cell morphology, movement, and transport of ions and molecules.



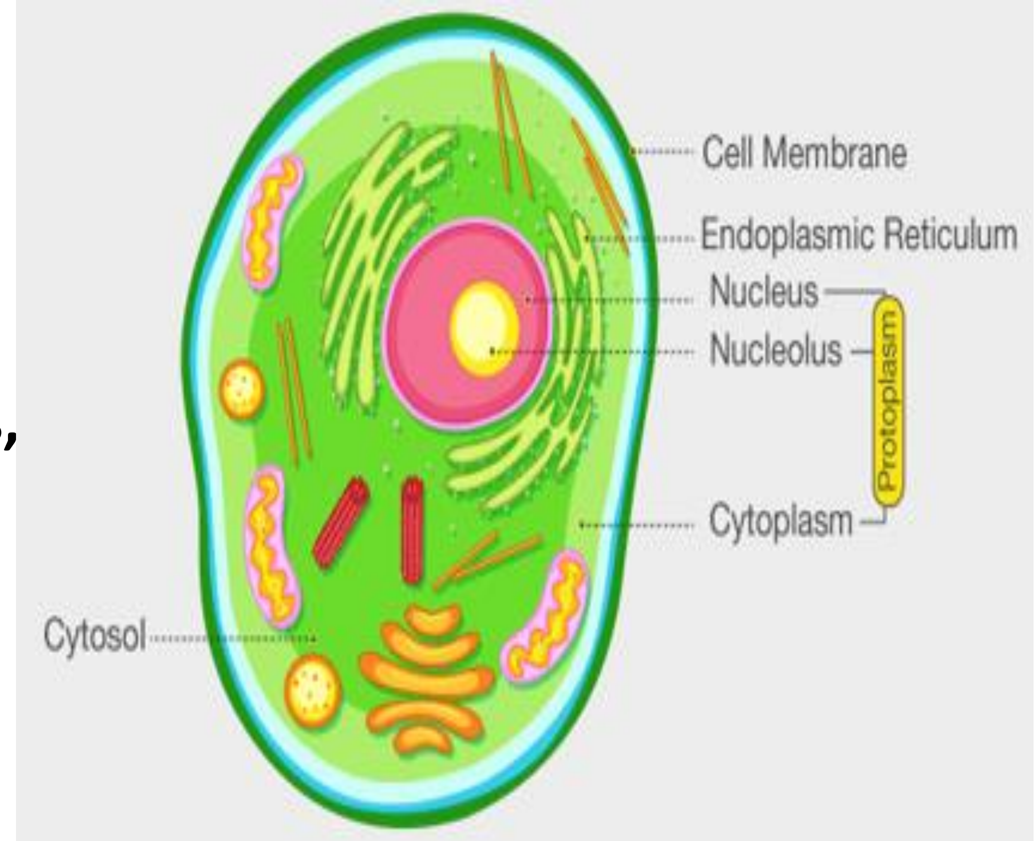
Cell Components:

LO. 1.1

➢ Cytoplasm vs. Cytosol:

✓ **Cytoplasm:** composed of all components contained within cytosol, excluding the nucleus.

✓ **Cytosol:** Liquid portion of cytoplasm.



✓ **Metabolism of carbohydrates, amino acids and nucleotides, and fatty acid synthesis are carried out in cytoplasm.**

LO. 1.1

Cytoplasm: internal contents of cell

Cytoplasm = cytosol + organelles + inclusions

Cytoplasm → Where most cellular activity occurs

cytosol →
-- Liquidy/syrupy-like
-- H_2O + dissolved molecules & ions

organelles →
-- specialized structures w/ specific functions
-- Division of labor and compartmentalization

inclusions →
--Masses/aggregations of molecules not surrounded by membranes

LO. 1.1

Cytoplasm vs Cytosol

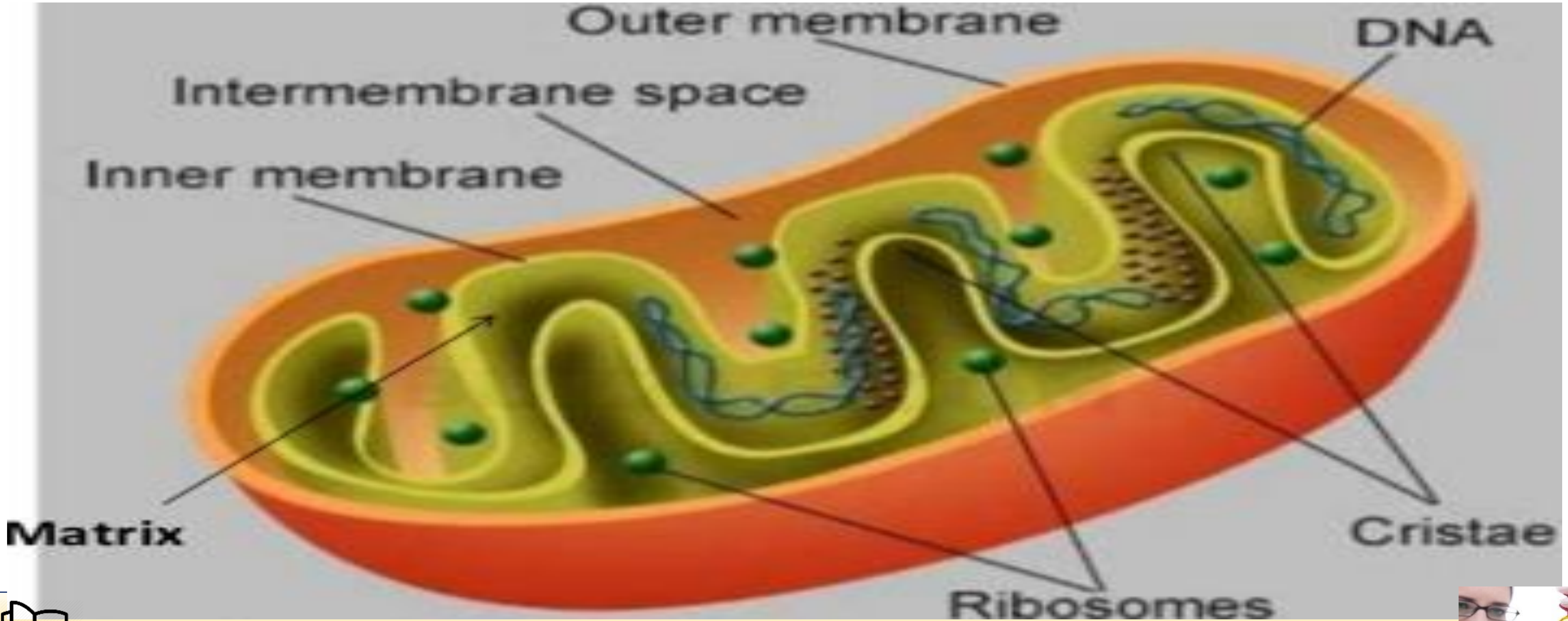
More Information Online WWW.DIFFERENCEBETWEEN.COM

	Cytoplasm	Cytosol
DEFINITION	Cytoplasm a transparent semisolid fluid, which is present in both prokaryotic and eukaryotic cells	Cytosol is the liquid part of the cytoplasm, and it accounts 70% of the cytoplasm
COMPOSITION	Has organelles, cytosol and cytoplasmic inclusions	Comprises organic molecules, cytoskeleton filaments, salt, and water
FUNCTIONS	Cell division, cell growth and expansion, glycolysis, many biochemical reactions, activities that occur at organelles such as protein synthesis at ribosome, cell respiration at mitochondria, etc.	Signal transduction, protein biosynthesis, gluconeogenesis, diffusion of water soluble molecules, transportation of hydrophobic molecules, and keeping cell shape and structure
DIVERSITY	High diversity	Comparatively less diversity

Cell Components:

LO. 1.1

- **Organelles:** is **specialized structure** within the cell that perform a specific functions (e.g. mitochondria, ribosomes, endoplasmic reticulum, ...).



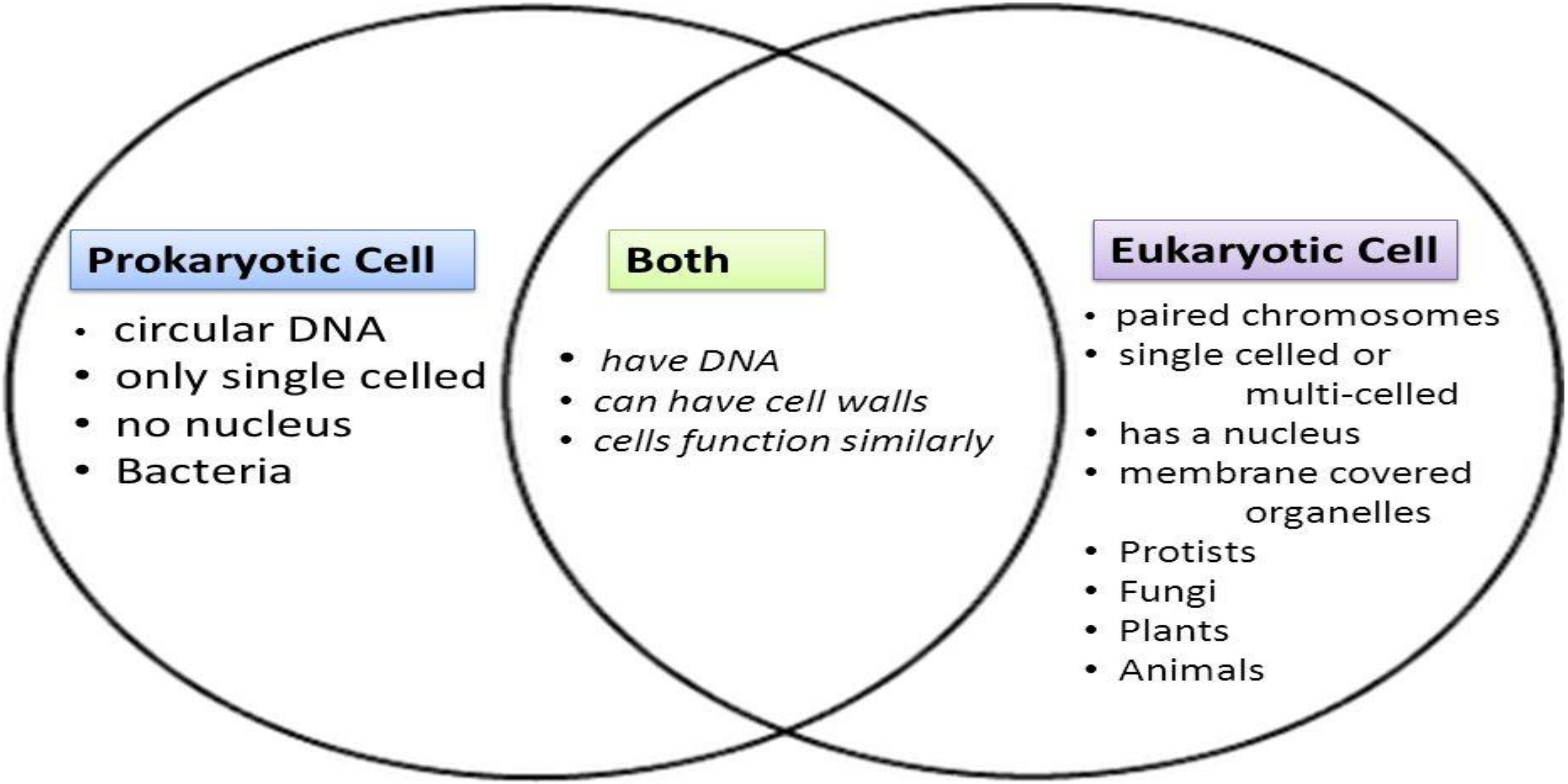
Mammalian Cell: Organelles Functions

LO. 1.1

Organelles	Functions
Nucleus/nucleolus	DNA synthesis and RNA synthesis (controls and regulates the activities of the cell)
Ribosome	Protein synthesis
Endoplasmic reticulum	Export of protein(Synthesis of proteins), Membrane synthesis, Lipid and steroid synthesis, Detoxification reactions
Golgi complex	Export of proteins
Mitochondrion	ATP synthesis
Lysosome	Cellular digestion
Peroxisomes	Fatty acids and purine brake down, Detoxification of hydrogen peroxide, and synthesis of cholesterol, bile acids and myelin

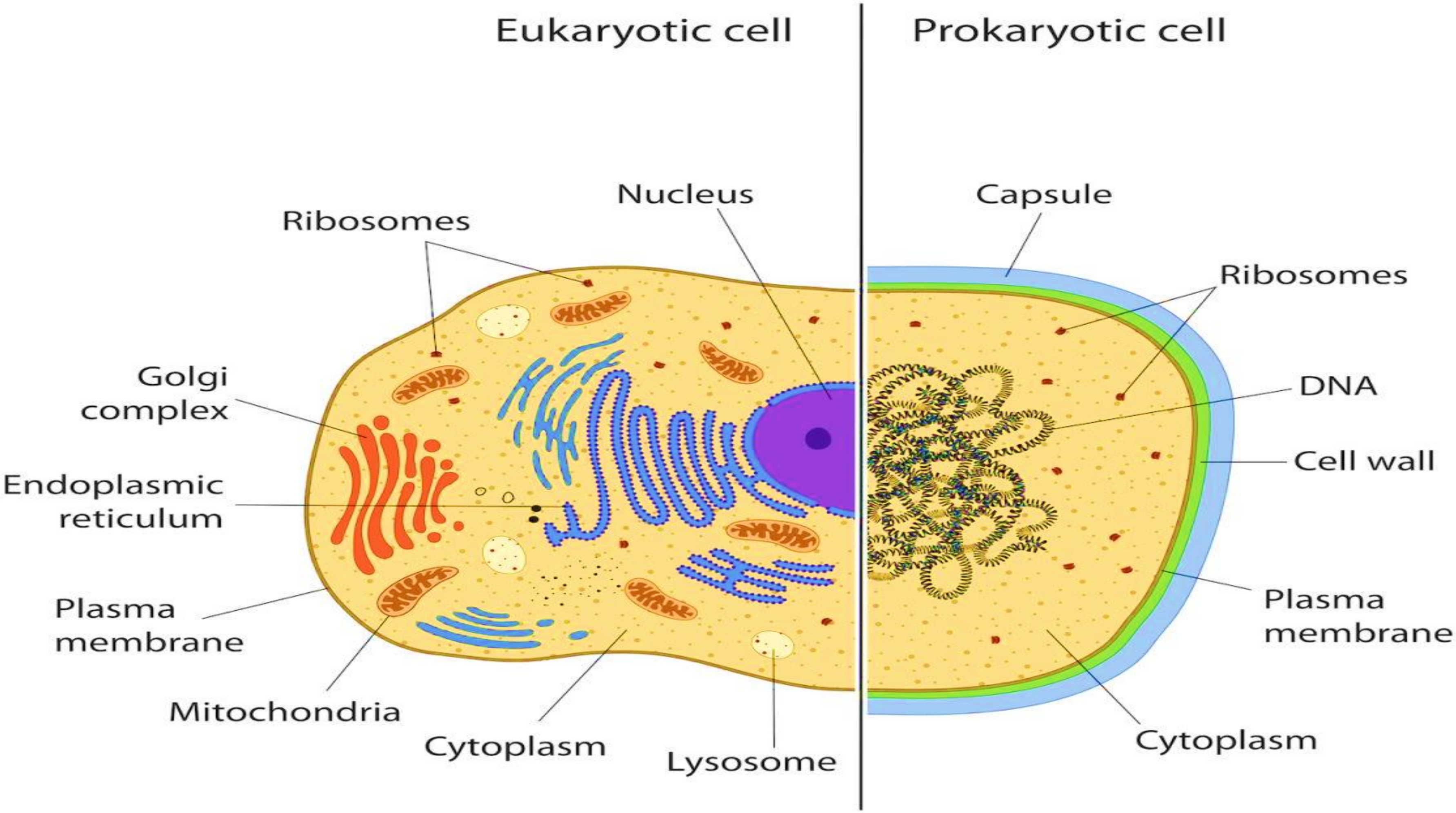
Prokaryotic cells vs. Eukaryotic cells

LO. 1.2



Prokaryotic cells vs. Eukaryotic cells

LO. 1.2



Macromolecules:

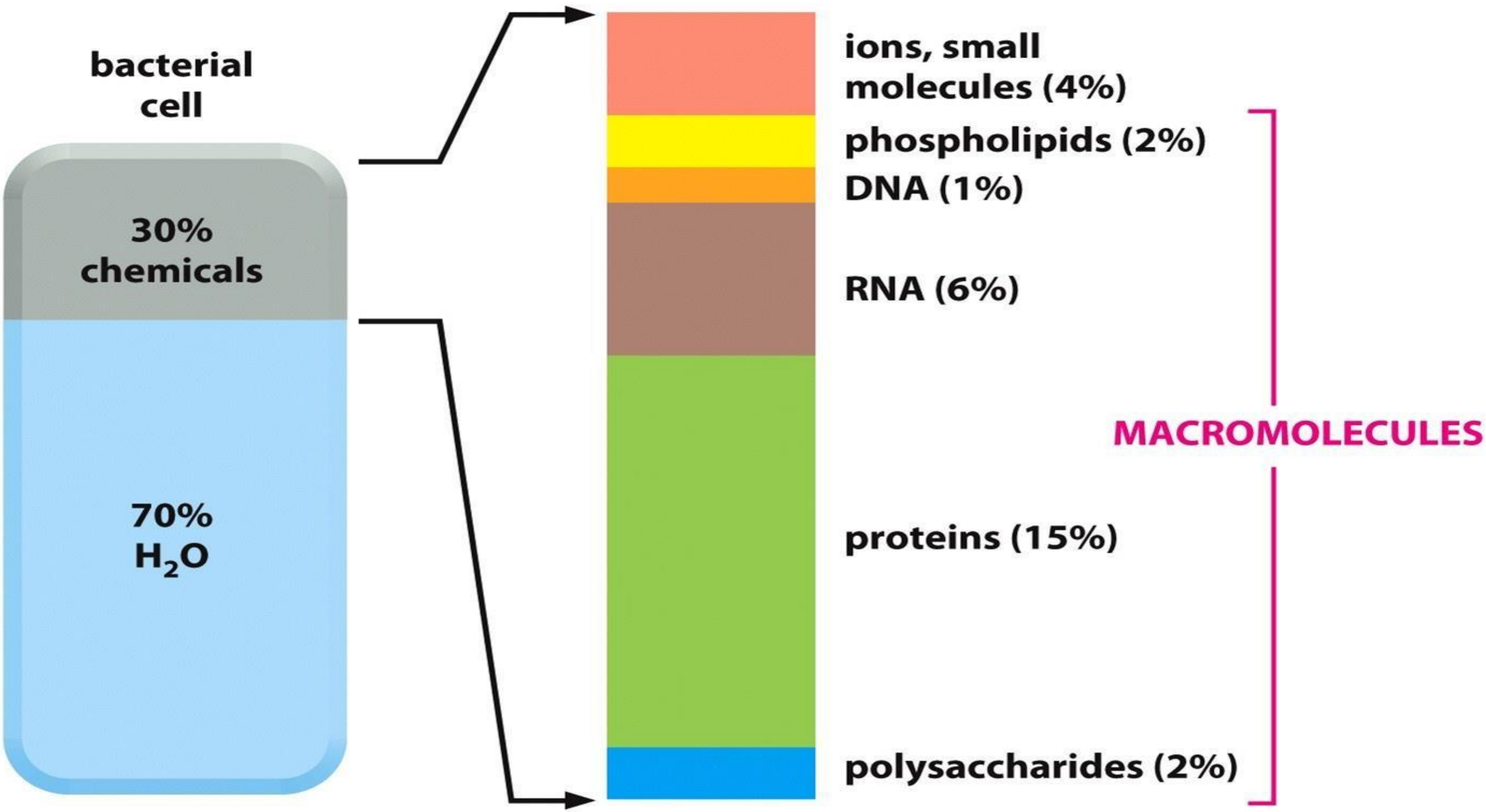
LO.1. 3

Are very large molecule, commonly composed of the polymerization of smaller subunits called monomers, such as carbohydrates, lipids, proteins, and nucleic acids.

Building blocks of the cell	Large units of the cell
Monosaccharides	Polysaccharides
Fatty Acids	Fats, Lipids, Membranes
Amino Acids	Proteins
Nucleotides	Nucleic Acids

Macromolecules: (LO 1.3)

Macromolecules amount in cells: Example:



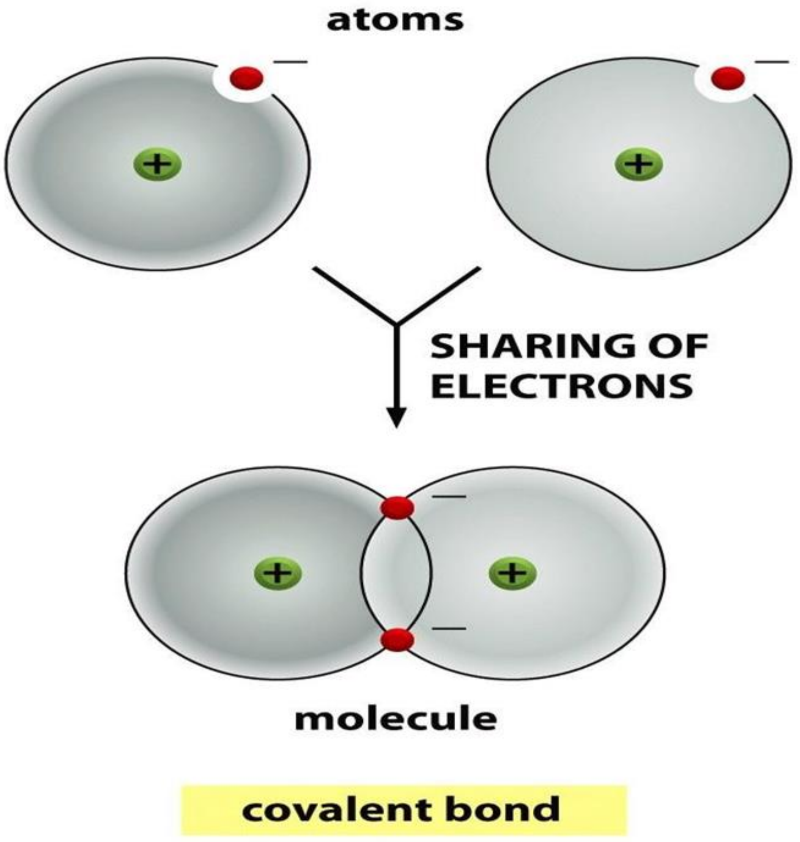
LO.1. 3

Chemical Bonds and Molecular forces:

Are forces that hold atoms together to make compounds or molecules.

➢ Covalent bond:

- ✓ **A covalent bond forms when two atoms, come very close together and share one or more of their electrons.**
- ✓ **Each atom forms a fixed numbe of covalent bonds.**

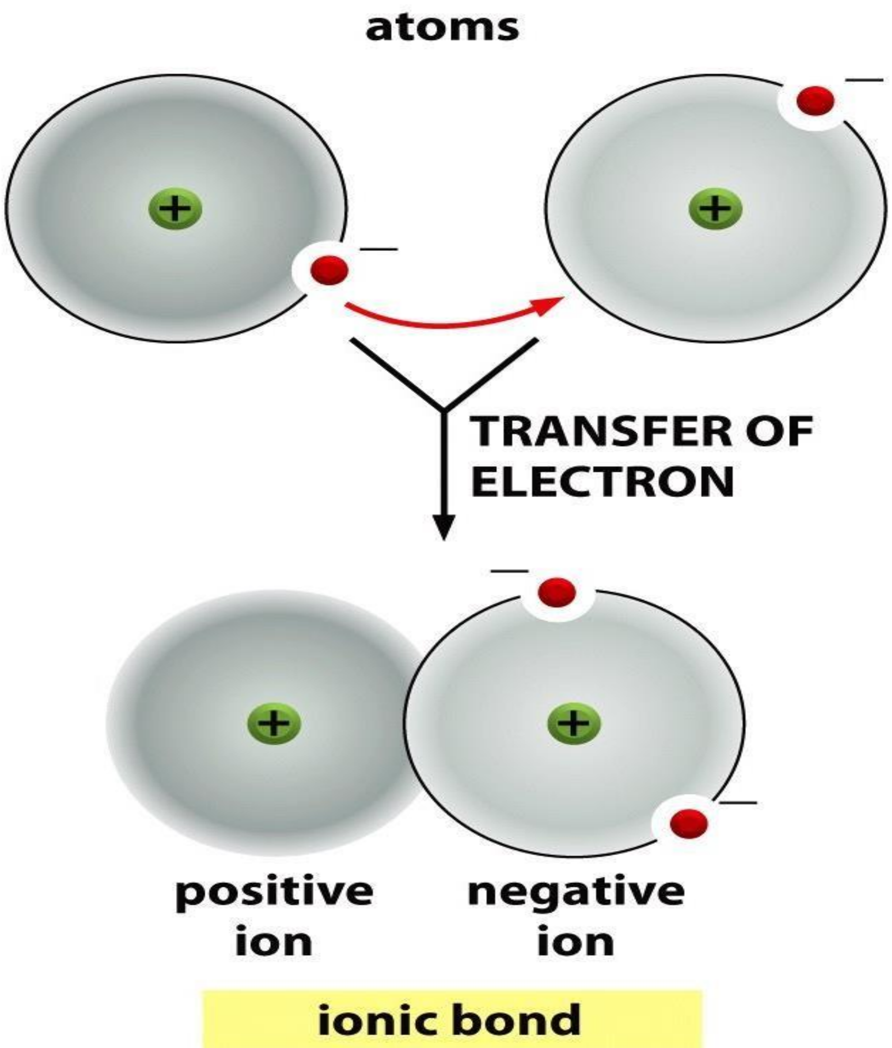


➢ Ionic bond:

LO. 1.3

✓ A bond formed between two atoms, where is a complete transfer of an electron resulting in the formation of two ions (One positive and one negative).

e.g. Na Cl

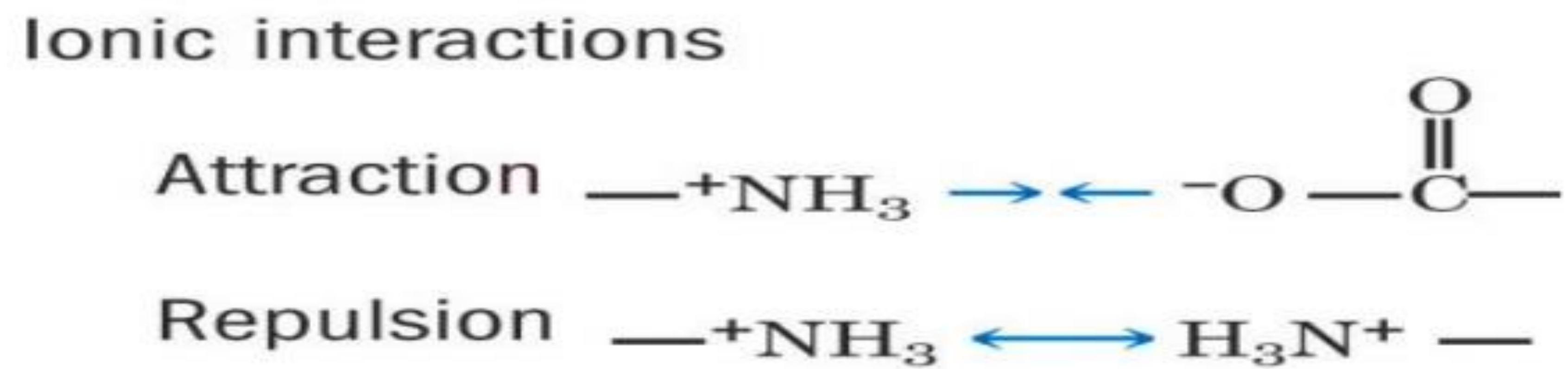


Bonds Important For Macromolecular Structure And Interaction

LO. 1.3

➢ Ionic bond:

✓ It should be differentiate between Ionic Bond and Ionic Interaction which may be attraction (between two groups with different charges), or Repulsion (between two groups with the same charges).

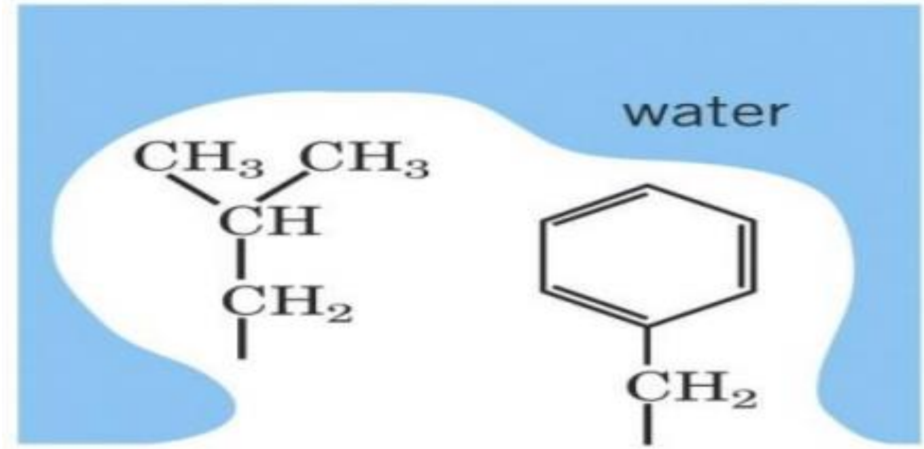


Bonds Important For Macromolecular Structure And Interaction

LO. 1.3

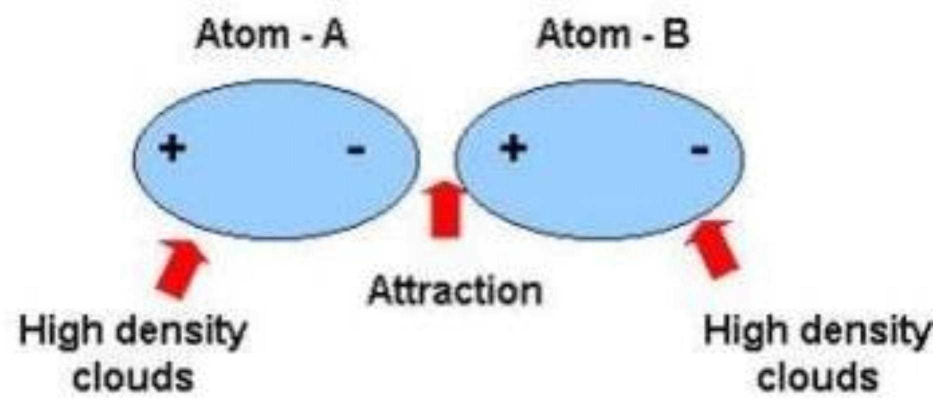
- ## Hydrophobic Interaction:

  A weak electrostatic interaction between two hydrophobic groups.



- ## Van der Waals Interaction:

  A weak interaction between any two atoms in close proximity.

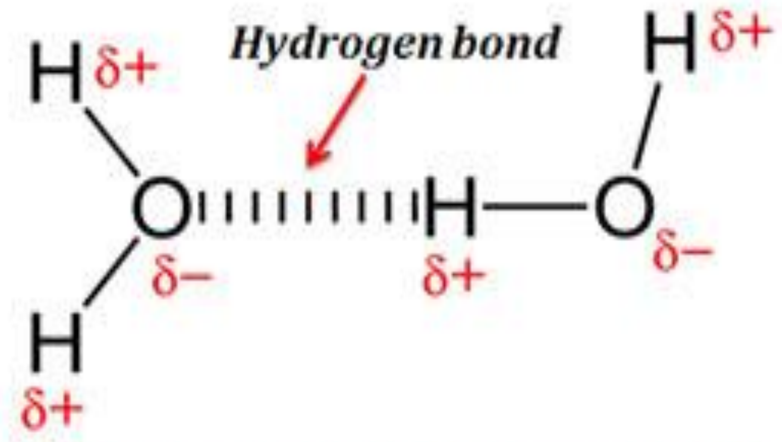


Van der Waals Bond

Hydrogen Bond:

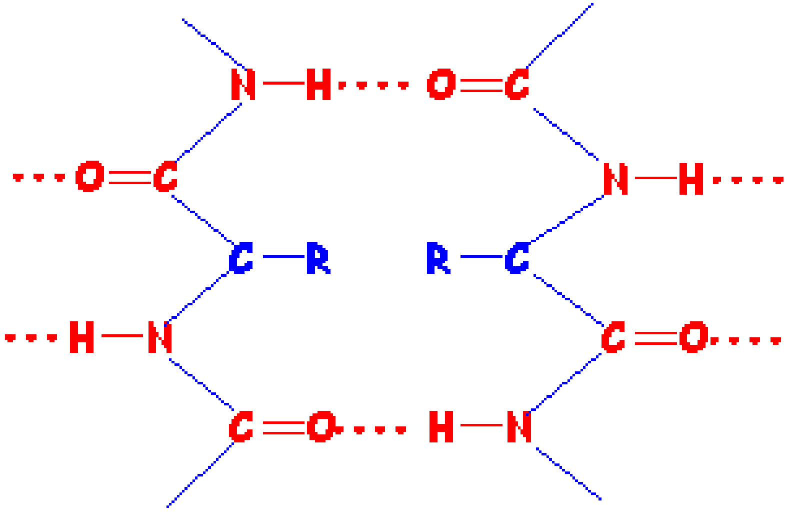
LO. 1.3

- ✓ A weak electrostatic interaction between a hydrogen atom bound to an electronegative atom (N, O) and another electronegative atom.



Hydrogen Bond Between H_2O

- ✓ Because they are polarized, two H_2O molecules can form a linkage known as Hydrogen bond.
- ✓ This type of bonds have only about 1/20 the strength of covalent bond.



Water Properties

LO.1.4

- Weak interactions are the key means by which molecules interact with one another.

- Two properties of water are biologically important:

  a. Water is polar molecule.

  b. Water is highly cohesive (hydrogen bonds between water molecules).

- Present in most cells, in a concentration of 70 to 85 per cent.

Water Functions:

LO. 1.4

1. Water is the principal fluid medium of the cell, Many cellular chemicals are dissolved in the water.
2. Water helps in regulation of temperature since it is able to absorb large amounts of heat.
3. It helps in regulation of intracellular pH since it is amphoteric solvent.
4. It used for transport – delivers nutrients and removes waste from cells.

Water As A Solvent:

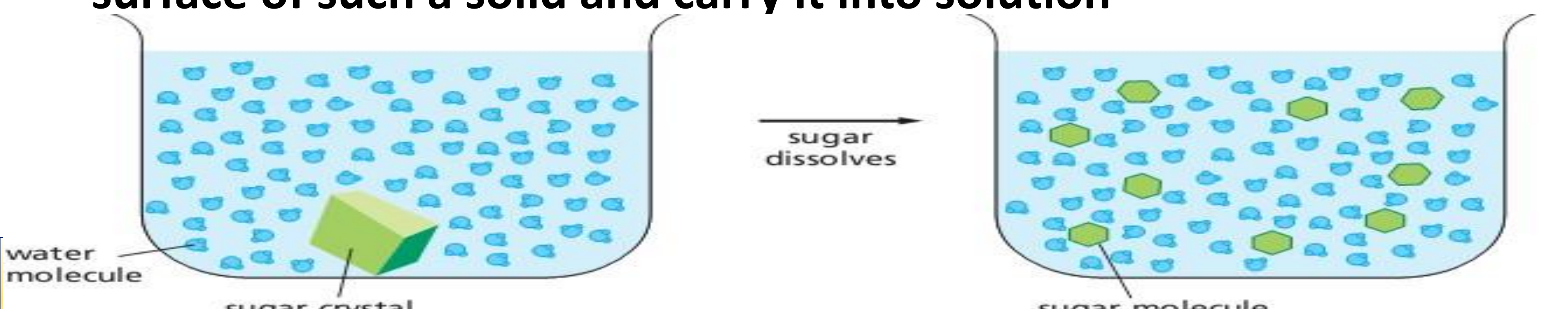
LO. 1.4

- According to the ability of water to dissolve the molecules, substances can be classified in to Hydrophilic, Hydrophobic, and Amphipathic.

- **Hydrophilic molecules:** substances that dissolve readily in water.

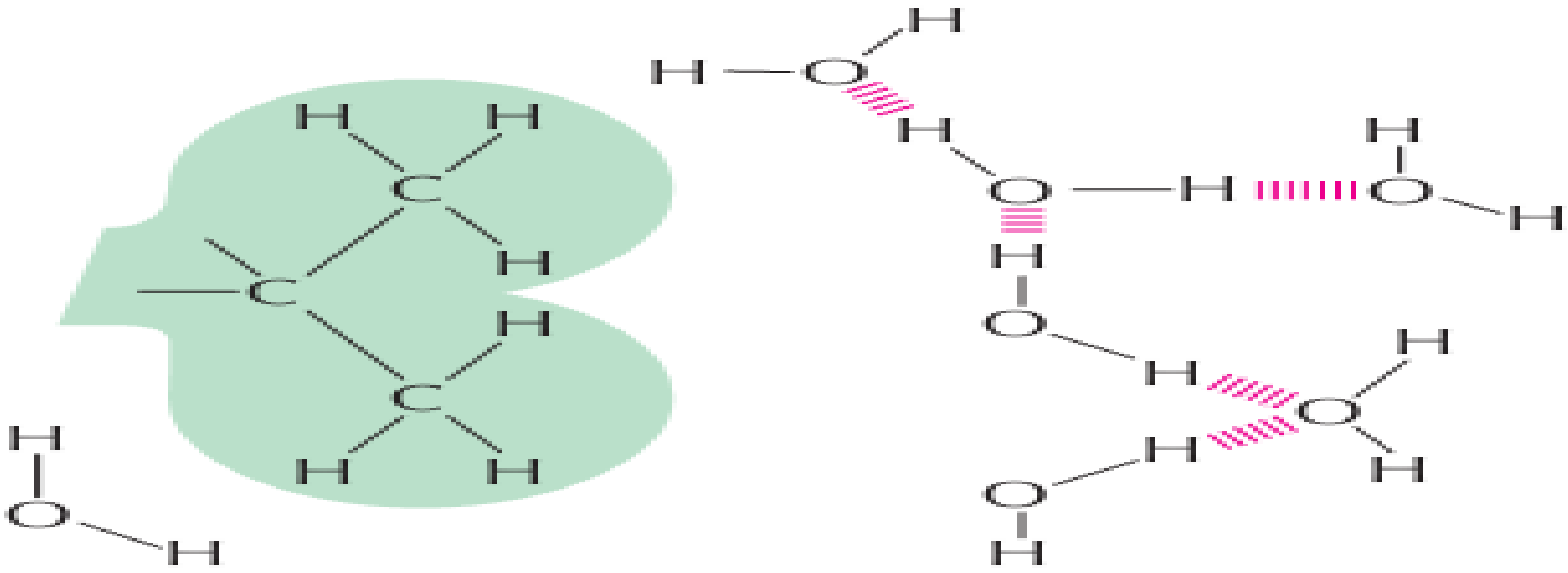
- ✓ They are composed of ions or polar molecules that attract water molecules through electrical charge effects.

- ✓ Water molecules surround each ion or polar molecule on the surface of such a solid and carry it into solution



❖ Hydrophobic Molecules: LO. 1.4

- ✓ Substances that contain nonpolar bonds and insoluble in water.
- ✓ Water molecules are not attracted to their molecules and so have little tendency to surround them and carry them into solution.

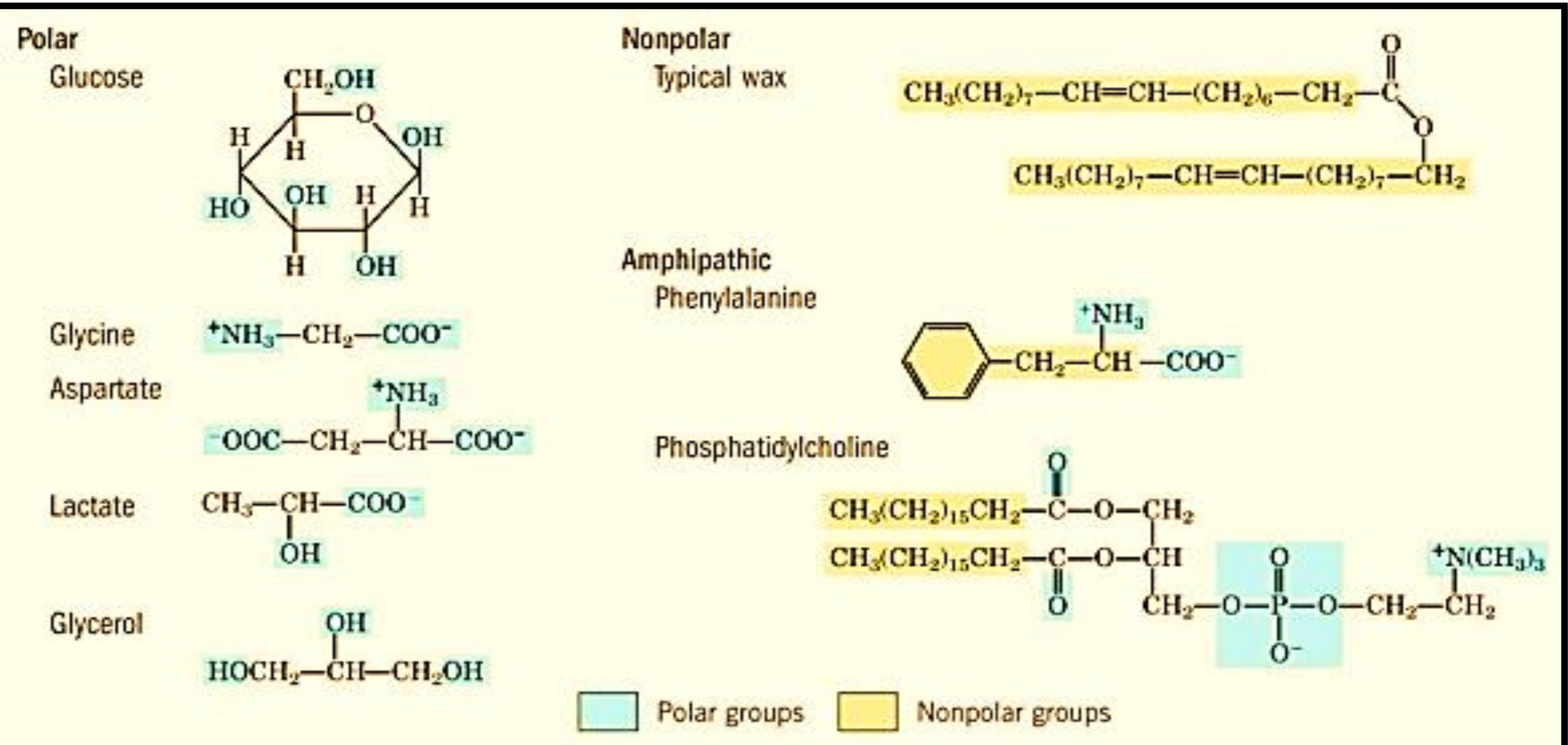


Hydrocarbons, which contain many C—H bonds, are especially hydrophobic.

❖ Amphipathic Molecules:

LO. 1.4

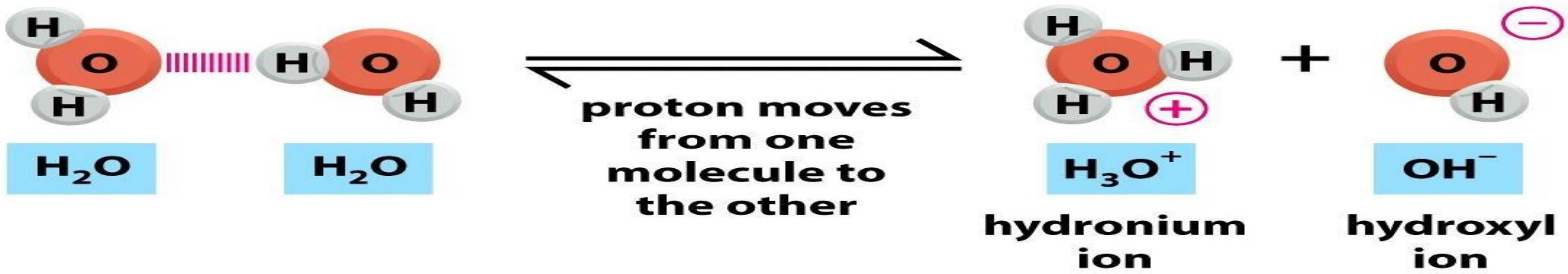
✓ Molecules that have both **hydrophilic** and **hydrophobic** properties are said to be **amphipathic.**



Ionization of Water

LO. 1.5

- Water dissociates into hydronium (H_3O^+) and hydroxyl (OH^-) ions



- For simplicity, the hydronium ion is refer to as a hydrogen ion (H^+) and write the equilibrium as: $H_2O \longleftrightarrow H^+ + OH^-$ $K_w = [H^+]\,[OH^-]$

Kw is the ion product of water. At 25°C, Kw is 1.0×10^{-14}.

- ✓ Note that the con. of H^+ and OH^- are reciprocally related.
- ✓ If the concentration of H^+ is high, then the concentration of OH^- must be low, and vice versa.
- ✓ For example, if $[H^+] = 10^{-2}$ M, then $[OH^-] = 10^{-12}$ M.

Acids and bases

LO. 1.5

- ACIDS: substances that release hydrogen ions into solution.

$$HCl \longrightarrow H^+ + Cl^-$$

- Note that HCl is completely dissociated
- Strong acids and bases: completely dissociate in solution.
- Many of the acids important in the cell are not completely dissociated, and they are therefore weak acids.
- For example the carboxyl group (COOH) which dissociate to give a hydrogen ion in solution.

$$COOH \longleftrightarrow COO^- + H^+$$

(Note: that this is a reversible reaction)

Bases:

LO. 1.5

- **BASES:** substances that reduce the number of hydrogen ions in solution.
- Some bases like ammonia combine directly with hydrogen ions.

$$NH_3 + H^+ \longrightarrow NH_4^+$$

- Other bases, such as NaOH reduce the number of H^+ ions indirectly, by making OH^- ions that then combine directly with H^+ ions to make H_2O.

$$NaOH \longrightarrow Na^+ + OH^-$$

- Many of the bases found in cells are partially associated with H^+ ions and are termed weak bases.

Bases

LO. 1.5

- This is true of compounds that contain an amino group ($^-NH_2$) which has a weak tendency to reversibly accept an H^+ ions from water, increasing the quantity of free OH^- ions.

$$NH_2 + H^+ \longleftrightarrow NH_3^+$$

- In biological system, when talk about NH_3^+ groups we consider it as weak acid (more weak than COOH groups) and talk about its tendency to release hydrogen ion rather than that of accepting hydrogen ion, as the above reaction can reverse.

Definition of pH and pK

LO. 1.5

- The pH of a solution is a measure of its concentration of H^+.
- The pH is defined as:

$$pH = \log_{10}(1/[H^+]) = -\log_{10}[H^+]$$

- ✓ **Note:** if a solutions differ in pH by one unit, it differs in [H^+] by a factor of 10.
- ✓ Example: a solution of pH=1 has [H^+]=0.1 M, while that of pH=2 has [H^+]=0.01 M

$$NH_2 + H^+ \longleftrightarrow NH_3^+$$

- The pH of a solution may be accurately and easily determined through electrochemical measurements with a device known as a pH meter.

- ✓ The ionization equilibrium of a weak acid is given by:

$$AH \leftrightarrow A^- + H^+$$

pH

LO. 1.5

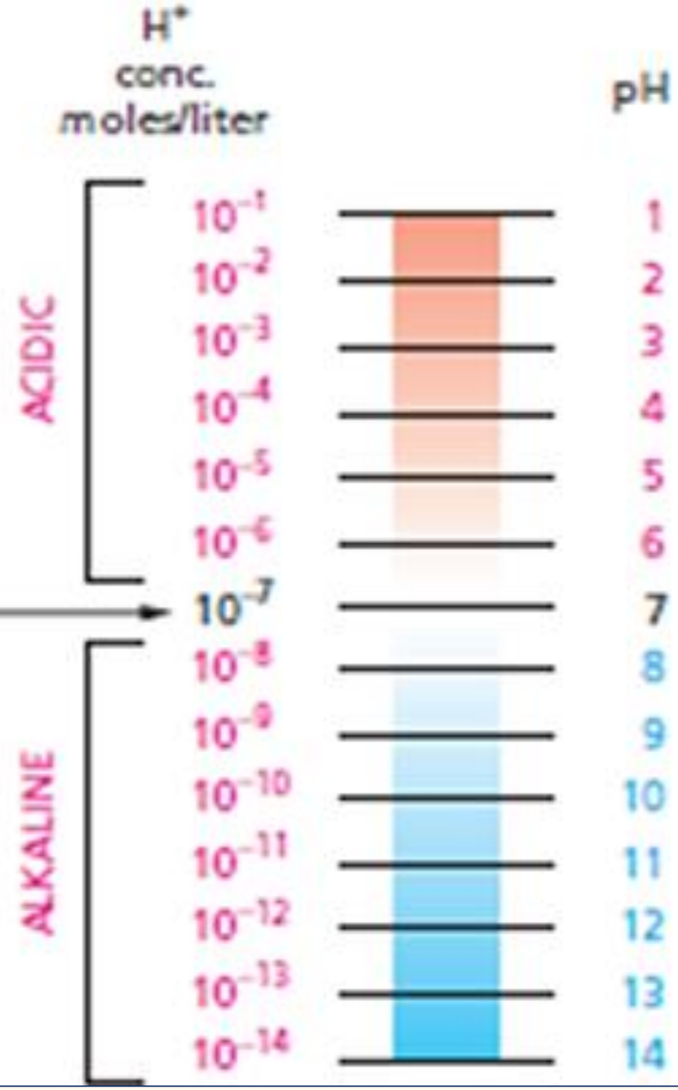
The acidity of a solution is defined by the concentration of hydronium ions it possesses, generally abbreviated as H^+. For convenience we use the pH scale, where

$$pH = -\log_{10}[H^+]$$

For pure water

$[H^+] = 10^{-7}$ moles/liter

$pH = 7.0$



Definition of pH and pK

LO. 1.5

- The apparent equilibrium constant (dissociation constant Ka) for this ionization is: $Ka = [H^+] [A^-] / [AH]$
- The pKa of an acid is defined as: $pKa = -\log Ka = \log (1/Ka)$
- The pKa of an acid is the pH at which it is half dissociated,
- when $[A^-]=[HA]$

Buffers:

LO. 1.5

- **Buffer** is a solution containing either a weak acid and its salt or a weak base and its salt, which is resistant to changes in pH.
- Since, the properties of biological substances vary significantly with small changes in pH.
- An conjugate pair (such as acetic acid and acetate ion) has an important property: it resists changes in the pH of a solution. In other words, it acts as a buffer.
- To understand how this is possible, let considered the titration of a weak acid with a strong base.
- addition of OH^- to a solution of acetic acid (HA):

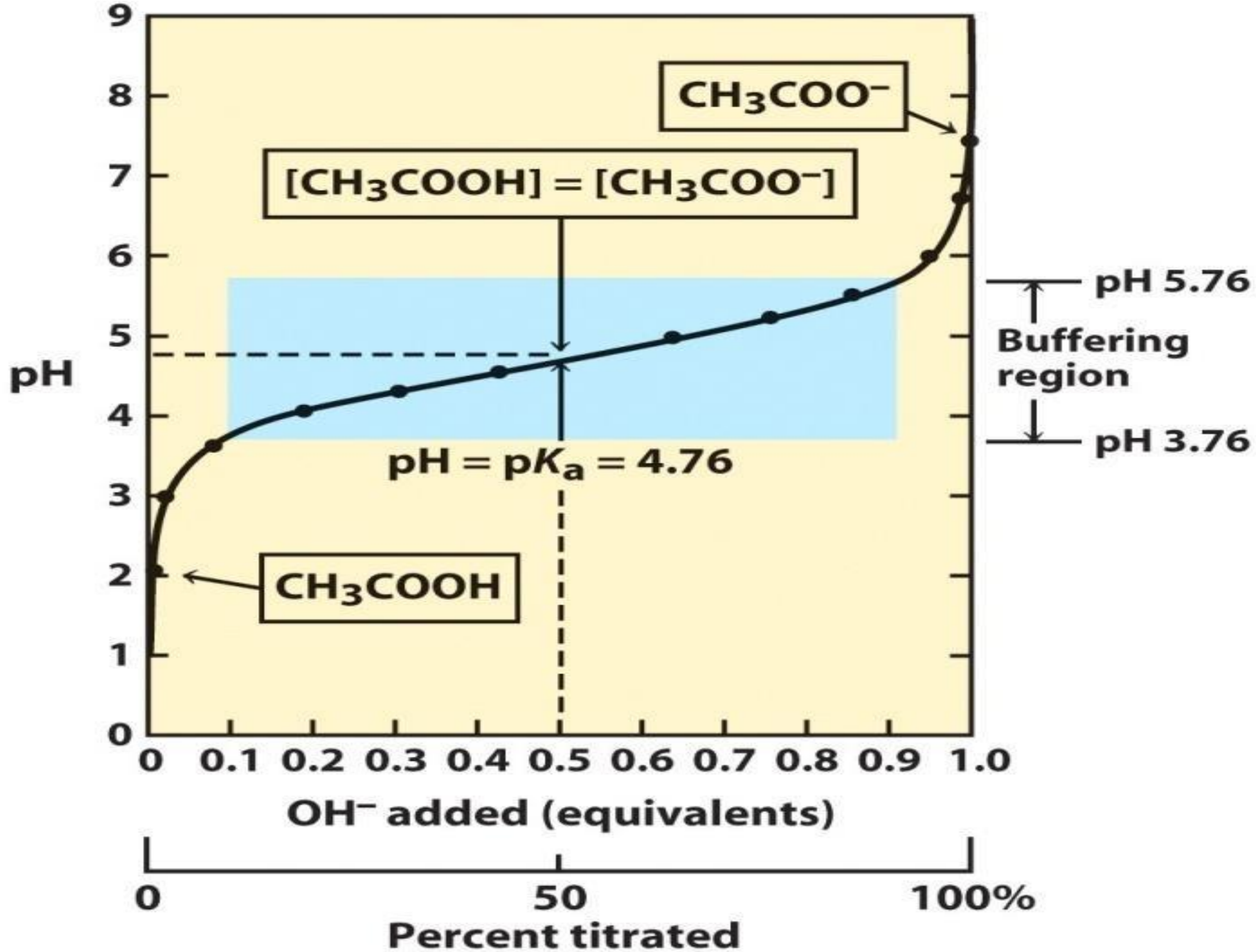
$$HA + OH^- \longleftrightarrow A^- + H_2O$$

Titration curve of acetic acid

LO. 1.5

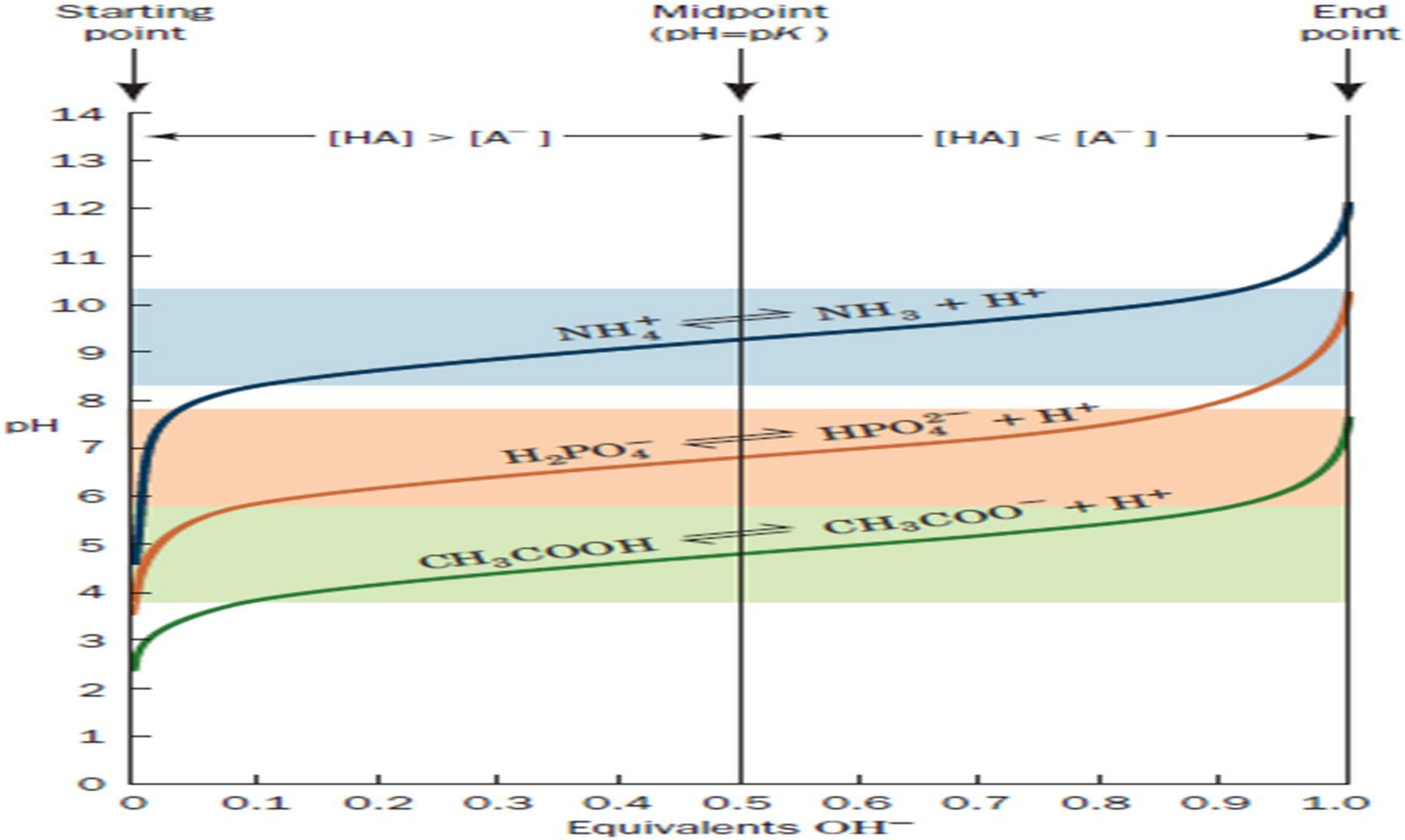
- A plot of the dependence of the pH of this solution on the amount of OH^- added is called a **titration Carve.**

- ✓ **There is an inflection point in the curve at pH 4.8, which is the pKa of acetic acid.**



Titration curves of acetic acid and another weak acids LO. 1.5

- ✓ **Acid–base titration curves of 1-L solutions of 1M acetic acid, H_2PO4^-, and NH^+ by a strong base.**



What is the relation between pH and the ratio of base to acid?

LO. 1.5

- **We know:**

1) $K_a = \frac{[H^+][A^-]}{[HA]}$

2) $[H^+] = K_a \frac{[HA]}{[A^-]}$

3) $-\log[H^+] = -\log K_a - \log \frac{[HA]}{[A^-]}$

4) $-\log[H^+] = -\log K_a + \log \frac{[A^-]}{[HA]}$

5) $pH = pK_a + \log \frac{[A^-]}{[HA]}$

HA = weak acid

A^- = Conjugate base

* H-H equation describes the relationship between pH, pKa and buffer concentration

- **This equation is commonly known as the Henderson-Hasselbalch equation.**

Application of Henderson Equation

LO. 1.5

- The pH of a solution can be calculated from this equation if the molar proportion of A^- / HA and the pKa of HA are known.

✓ **Example**: pH = 4.8+log (0.2/0.1)
= 4.8 + log 2.0
= 4.8 + 0.3
= 5.1

- **Conversely**, the pKa of an acid can be calculated, if the molar proportion of A^-/HA and the pH of the solution are known.

- The molar proportion of A^- to HA can be calculated, if the pH and pKa values are known.

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Application of Henderson Equation:

LO. 1.5

- A) Bicarbonate as a Buffer in blood

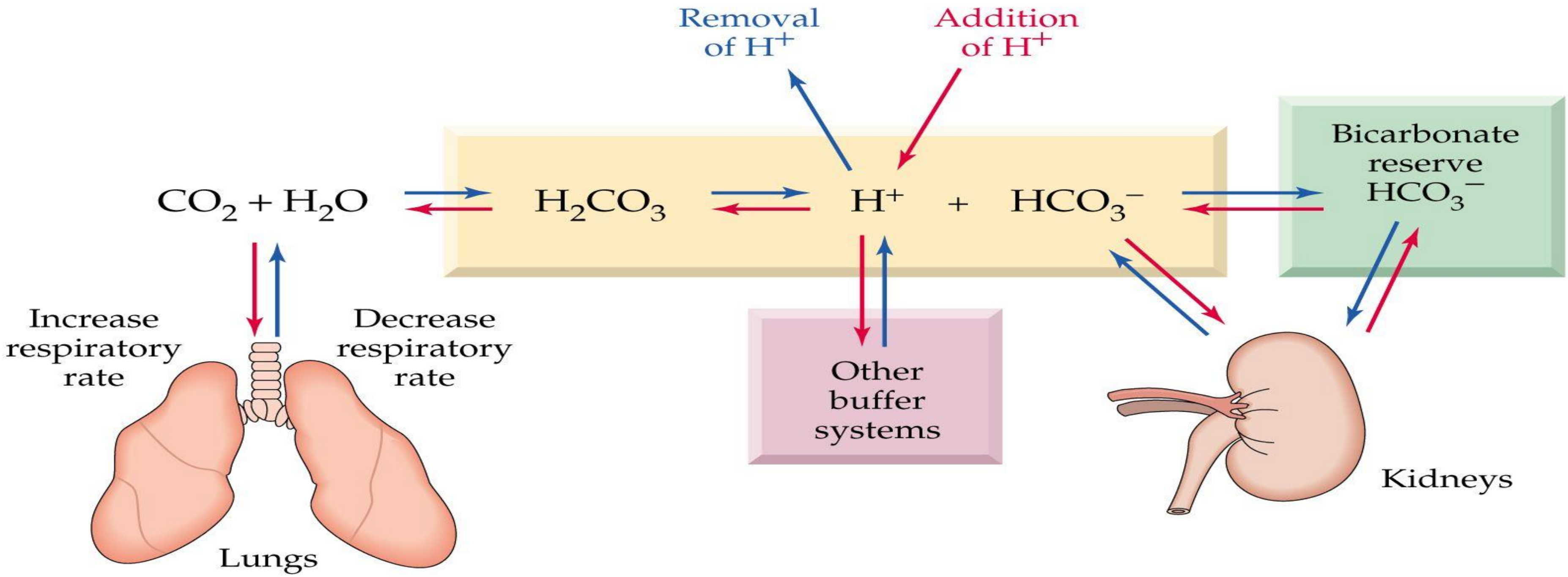
$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

- $pH = pKa + \log HCO_3^-/H_2CO_3$

- When bicarbonate ion increase due to any clinical cause, this will lead to increase the ratio HCO_3^-/H_2CO_3 and so, the pH will rise, and alkalosis may develop.

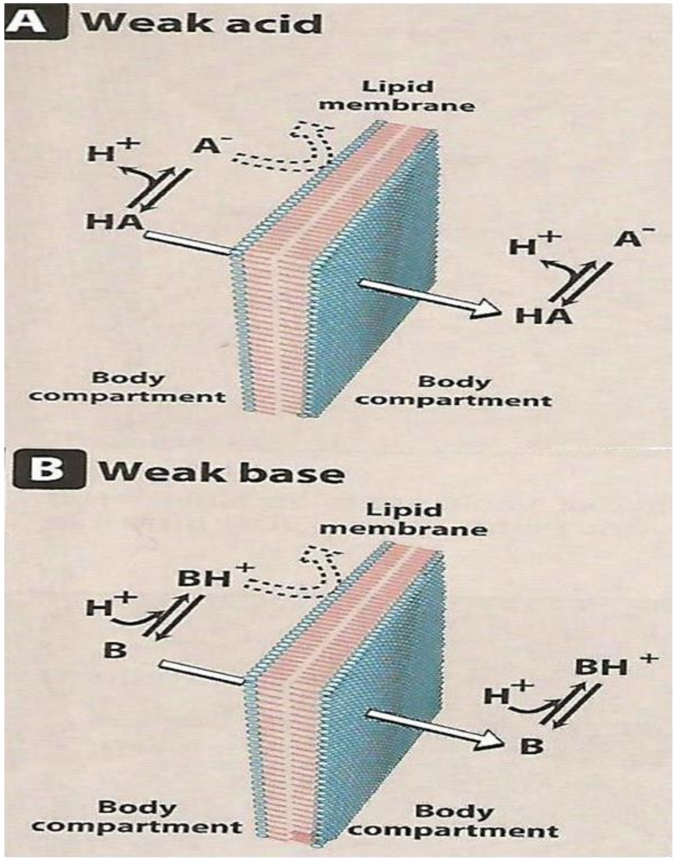
- When carbonic acid increase due to any clinical cause like pulmonary obstruction, this will lead to decrease the ratio HCO_3^-/H_2CO_3 and so, the pH will fall, and acidosis may develop.

LO. 1.5

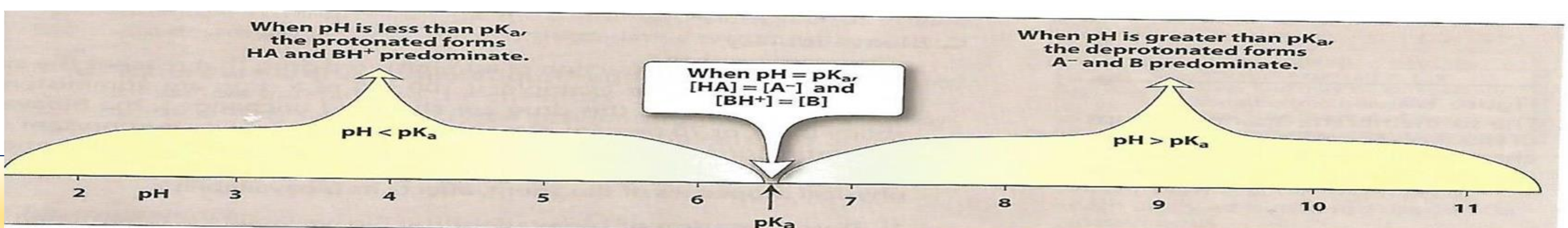

Removal of H^+
Addition of H^+
$CO_2 + H_2O$
H_2CO_3
H^+ + HCO_3^-
Bicarbonate reserve HCO_3^-
Increase respiratory rate
Decrease respiratory rate
Lungs
Other buffer systems
Kidneys

Application of Henderson Equation: Drug Absorption

LO. 1.5



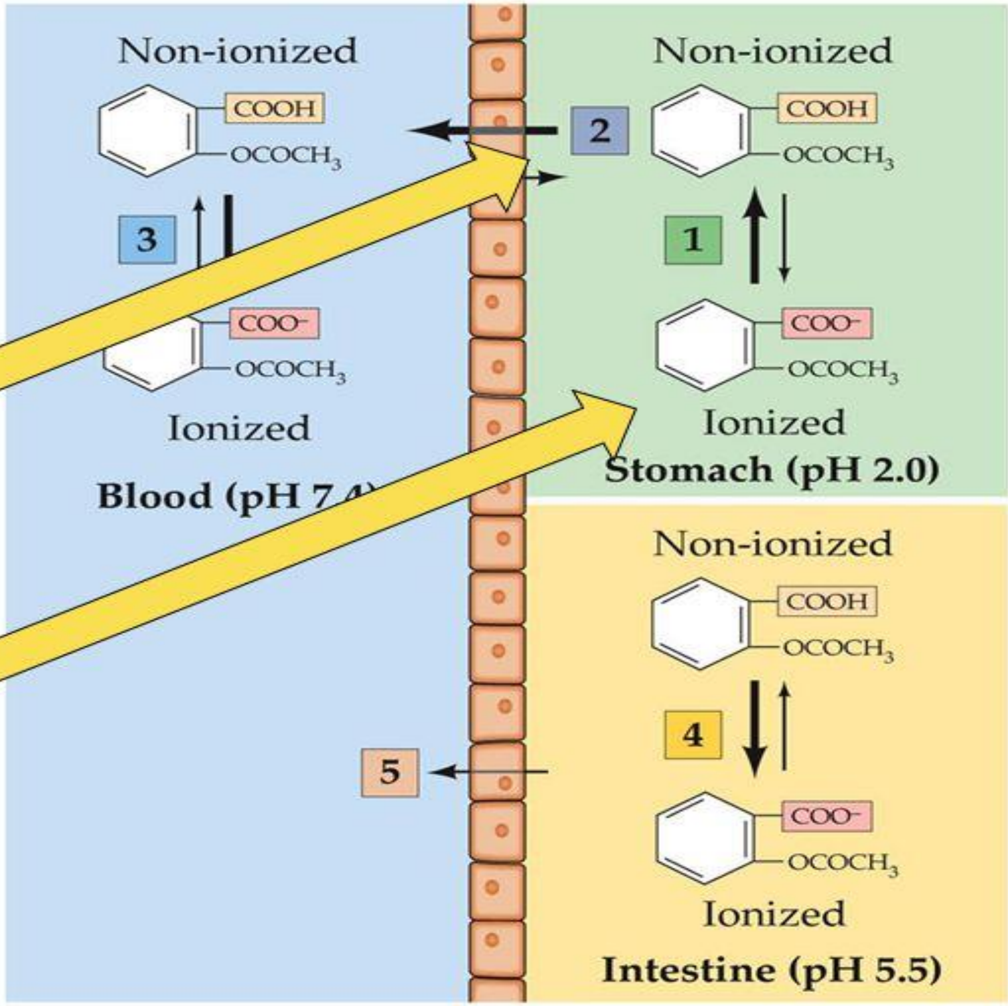
- pH = pKa + log [Drug⁻] / [Drug-H]
- at the pH of the stomach (1.5) a drug like aspirin (weak acid pK=3.5) will be largely protonated (COOH) and, thus, uncharged.
- Uncharged drug generally cross membranes (lipid bilayer) more rapidly than charged molecules.



Effect of ionization on drug absorption

Non-ionized drugs can easily pass through membranes

Ionized drugs **can not** easily pass through membranes



- **Q:** **What are other functions of mitochondria?**

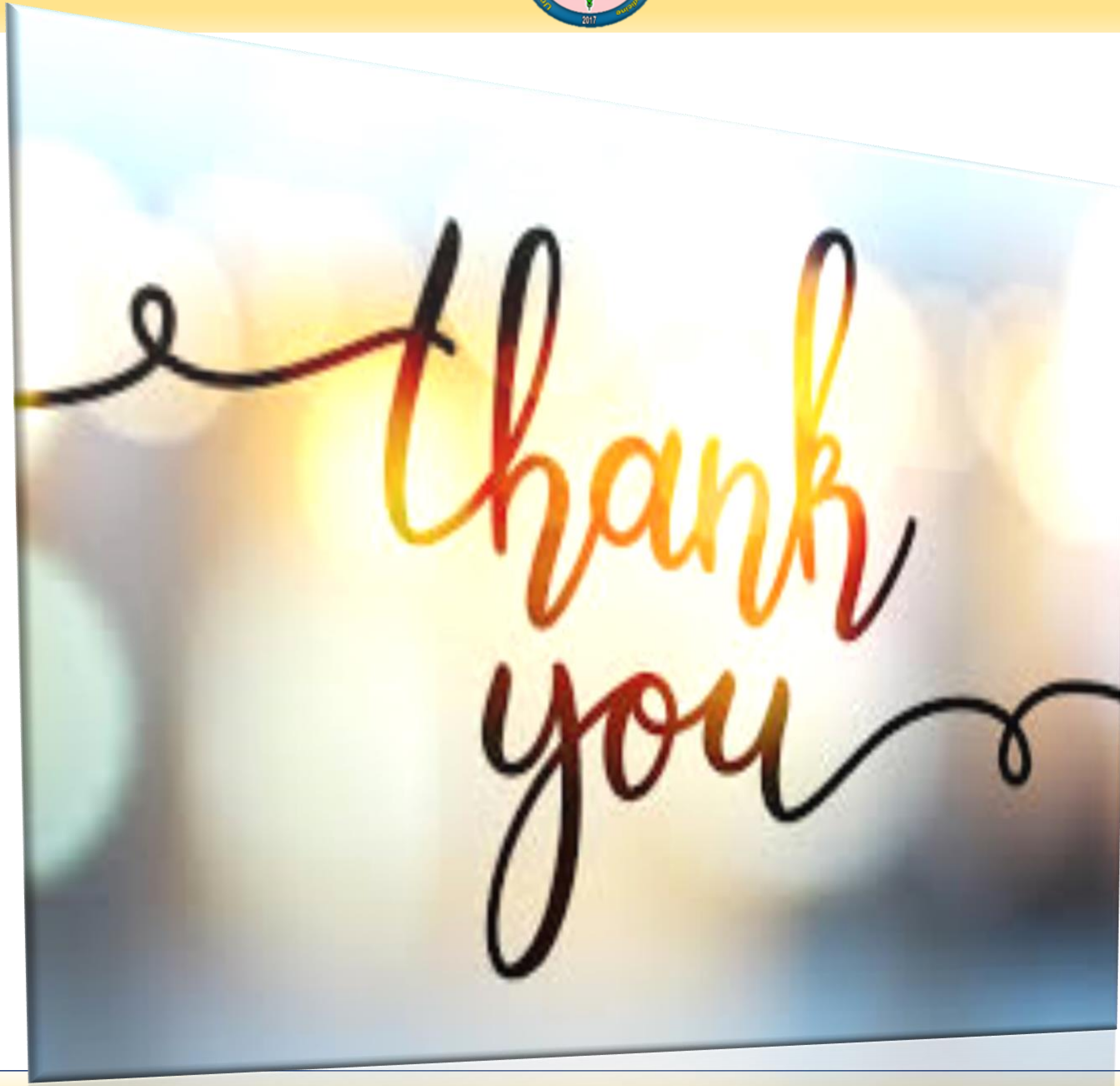
- **Q:** **Which bond is the strongest?**

- **Q:** **predict the change in the water's pH when a 0.01-mL droplet of 1M HCl is added to 1 L of pure water.**

- **Q:** **Estimate the change in H^+ ion concentration if pH is changed from:**

  7.4 to 7.1

  7.4 to 7.7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you