INTRODUCTION TO BIOCHEMISTRY

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BIOCHEMISTRY:-

- **The term Biochemistry was Coined by Neuberg in 1903 from Greek words bios = Life & Chymos = Juice .**
- **Biochemistry is the branch of chemistry . The subject explores the chemistry of living organisms & that of their biological process.**
- **Biochemistry deals with the chemical combinations & reactions that takes place because of the biological processes such as growth , reproduction , metabolism ,heredity , etc.**
- **Is a** Science Concerned with the Chemical basis of Life .
- Is the study of the chemistry of Cells & Organisms.

BIOCHEMISTRY:-

- Concerned with types of molecules found in biological systems , their structure & their chemical properties.
- Deals with the structure & function of the body at the molecular level.
- **Can also be described as the** Science concerned with the chemical constitutes of living cells , their reactions & the process they undergo.
- By the above definitions , Biochemistry encompasses large areas of cell biology, molecular biology & molecular genetics.
- **Has branches that includes molecular biology , immunology , Enzymology & Genetics** .

Milestones In History of Biochemistry

Scientists	Year	Landmark Discoveries
1. Rouel	1773	Isolated urea from urine
2. Lavoisier	1785	Oxidation of food stuffs
3. Wohler	1828	Synthesis of Urea
4. Berzelius	1835	Enzyme Catalysis theory
5. Louis Pasteur	1860	Fermentation process
6. Fiske & Subbarow	1926	Isolated ATP from muscle
7. Hans Krebs	1937	Citric acid cycle
8. Avery & Macleod	1944	DNA is genetic material
9. Watson & Crick	1953	Structure of DNA

Milestones In History of Biochemistry

Scientists	Year	Landmark Discoveries
10. Nirenberg	1961	Genetic code in mRNA
11. Holley	1963	Sequenced gene for tRNA
12. Khorana	1965	Synthesized the Gene
13. Paul Berg	1972	Recombinant DNA technology
14. Kary Mullis	1985	Polymerase Chain reaction

BIOCHEMISTRY PERSPECTIVE TO MEDICINE / HEALTH

- Biochemistry is the language of biology .
- Biochemistry is tool for all research in all branches of medical science.
- What is the molecular basis for immunological resistance against invading organisms? Answers for such basic questions can only be derived by a systematic study of medical Biochemistry.
- The demonstration of abnormal from normal constituents of the body is another aim of the study of Clinical biochemistry.

Biochemistry Perspective to Medicine/ Health

- Many aspects of health and disease

For example, a knowledge of protein structure and function was necessary to elucidate the single biochemical difference between normal hemoglobin and abnormal sickle cell hemoglobin.

THE AIM OF BIOCHEMISTRY

- To Describe & Explain ,

✓ Molecular terms, all chemical process of living organisms & their interactions with their environments both in health & disease conditions.

✓ **Biochemistry** as the science concerned with the chemical Composition of living cells and the reactions cells undergoes .

✓ **Biochemistry** as the study of biomolecules and the reactions they undergo

THE MAJOR OBJECTIVE OF BIOCHEMISTRY

- To describe the molecular level of all of the chemical processes associated with living cells.
- Explain numerous molecules found in cells , determine their structures ,& analyze how they function.
- To Explain the biochemistry of Nucleic acids lies at the heart of genetics .
- Explain the overlaps with Physiology, the study of body function .
- To describe Immunology employees , numerous biochemical techniques & many immunologic approaches have found wide use by biochemists.

Importance of Biochemistry

- Study of normal metabolism in biochemistry and helps us to understand the abnormal metabolism
- This is used to understand the molecular basis of diseases
- Example: Study of normal glucose metabolism in Biochemistry which help us to understand the abnormal glucose metabolism in Diabetes mellitus

SCOPE OF BIOCHEMISTRY

- Scope of biochemistry is as wide as life itself , where ever there is life , chemical processes are occurring .
- Biochemists study the chemical processes that occur in microorganisms , plants, insects , fish , birds , mammals & human beings.

BIOMOLECULES

(Macromolecules or Biopolymers)

Definition :

BIOMOLECULES :-

- Are molecules that occur naturally in living organisms.
- Include macromolecules like proteins, carbohydrates, lipids and nucleic acids.
- Includes small molecules like primary and secondary metabolites and natural products.
- Consists mainly of carbon and hydrogen with nitrogen, oxygen, sulphur, and phosphorus.
- Are very large molecules of many atoms, that are covalently bound together.

BIOMOLECULES

(Macromolecules or Biopolymers)

- More than 99% of the human body is composed of six (6) elements , i.e. Oxygen , Carbon , Hydrogen , Nitrogen , Calcium , & Phosphorous.
- Human body is composed of about 60 % water , 15% protein , 15 % Lipids , 2 % Carbohydrates & 8 % minerals.
- In living organisms the biomolecules are ordered in to a hierarchy of increasing molecular complexity . These biomolecules are covalently linked to each other to form macromolecules of the cell , example Glucose to Glycogen , Amino acids to

MAJOR CLASSES/TYPES OF BIOMOLECULES(Bioorganic Substance)

- There are four major classes of biomolecules:

1. Carbohydrates
(Polysaccharides)
2. Lipids
3. Proteins
4. Nucleic acids

1.CARBOHYDRATES

- Carbohydrates are -
- ✓ also called Saccharides .
- ✓ organic compounds containing carbon, hydrogen , & oxygen.
- ✓ Primarily produced by plants.
- ✓ the most abundant class of organic compounds found in living organisms .
- ✓ originate as product of photosynthesis, an endothermic reductive condensation of carbon dioxide requiring light energy and the pigment chlorophyll.

Cont. 1.CARBOHYDRATES

- Carbohydrates act as storehouse of chemical energy (glucose , starch , glycogen).
- Carbohydrates are components of supportive structures in plants (cellulose), crustacean shells (chitin), & connective tissues in animals & are essential components of nucleic acids.
- The formulas of many carbohydrates can be written as hydrates , Cn(H2O)n hence their name.
- The carbohydrates are a major source of metabolic energy , both for plants and for animals that depend on plants for food.

Cont. 1.CARBOHYDRATES

- Carbohydrates (polysaccharides) are long chains of SUGARS
- If we eat more carbohydrates than are needed for energy , the extra is stored in the liver or in the tissues as fat.
- Carbohydrates also serve as a structural material Cellulose , a component of the energy transport compound ATP , recognition site on cell surfaces ,& one of three essential components of DNA & RNA
- Example: glucose, fructose, sucrose, maltose, starch, cellulose etc.

2.PROTEINS

- The word protein is derived from Greek word 'Proteioś which means primary or of prime importance.
- All Proteins are polymers of α-amino acids.
- Proteins are required for growth & maintenance of the body.
- Amino acids are joined together by the peptide bond which is formed in between the carboxyl group and amino group of successive amino acids.

Cont. 2.PROTEINS

- All Proteins are polymers of α-amino acids.
- Amino acids are joined together by the peptide bond which is formed in between the carboxyl group and amino group of successive amino acids.
- Proteins are formed mainly from 20 different amino acids,.
- Example: Haemoglobin, insulin.
- Chief sources of proteins are Milk, cheese , peanuts, fish, meat , etc.

3.LIPIDS

- Lipids are -
- biological molecules that are insoluble in water(hydrophobic) but soluble in nonpolar solvents.
- Are primarily found in chloroplast membranes ,
- waxy , greasy , or oily compounds found in plants & animals.
- wax coating that protects plants
- used as energy storage
- structural components (cell membranes)
- insulation against cold
- composed of long hydrocarbon chains.

Cont. 3.LIPIDS

- The majority of plant lipids are act as energy stores.(e.g. triacylglycerols in seeds) or as plant membrane components (eg. Galactosylglycerides in chloroplast membranes & phosphoglycerides in non-chloroplast membrane)
- Surface lipids such as waxes & cutin provide an impervious barrier on the plant surface to reduce water loss & to provide protection against plant pathogens & toxins.

Cont.3.LIPIDS

❖ Lipids

- Are Present in every cell of the human body & are the main part of the cellular membrane.
- Can be found in many parts of a human cell membranes, cholesterol , blood cells , & in the brain
- Are important for cell membrane structure , regulating metabolism & reproduction

Cont. 3.LIPIDS

- Lipid molecules hold a large amount of energy and are energy storage molecules.
- Lack of lipids in the diet can lead to serious problems including blood clotting , bone structure , and eye sight
- Example of lipids: oils, waxes, fats, cholesterol etc.,

4.NUCLEIC ACIDS

- Nucleotides consists of nitrogenous base, a pentose sugar and a phosphate group.
- A nucleotide is made of nitrogenous base attached to a pentose sugar.
- The nitrogenous bases are adenine, guanine, thymine, cytosine and uracil.
- Example: DNA and RNA which are genetic material.

Functions of Biomolecules

- **Carbohydrates** provide the body with source of fuel and energy, it aids in proper functioning of our brain, heart and nervous, digestive and immune system.
- Deficiency of carbohydrates in the diet **causes** fatigue, poor mental function.

- **Proteins** are **the most abundant** biomolecules in the body
- Each protein in the body has specific functions, some proteins provide structural support, help in body movement, and also defence against germs and infections.
- **Proteins can be** antibodies, hormonal, enzymes and contractile proteins.

Functions of Biomolecules

Lipids: the primary purpose of lipids in body is energy storage.

Structural membranes are composed of lipids which forms a barrier and controls flow of material in and out of the cell.

Lipid hormones, like sterols, help in mediating communication between cells.

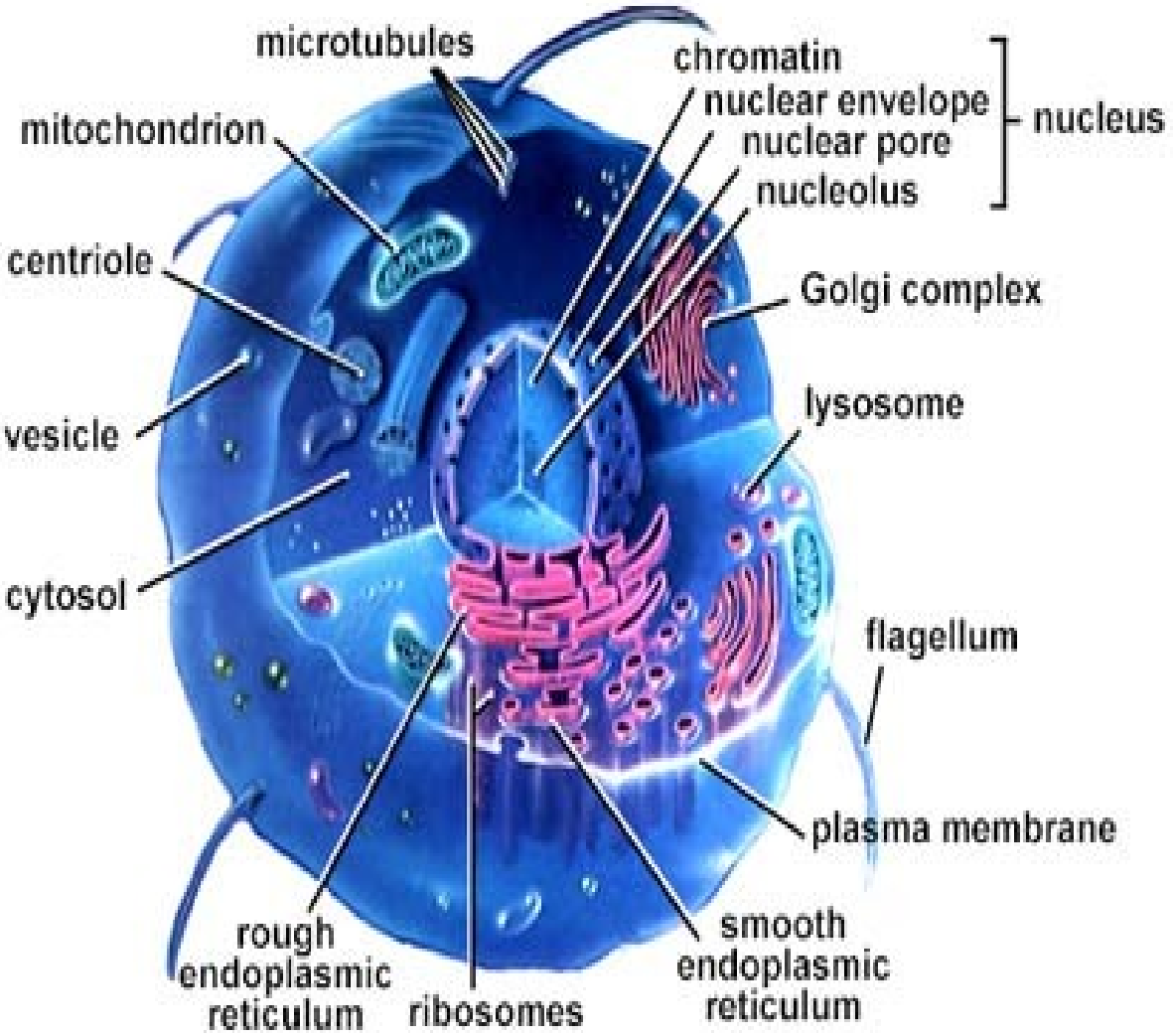
Nucleic Acids are the DNA and RNA, they carry genetic information in the cell.

They also help in synthesis of proteins, through the process of translation and transcription.

ANIMAL CELL

CELL

- The cell is the structural & functional unit of life
- It is regarded as the “basic unit of biological activity”
- Cells are composed of water , inorganic ions & organic molecules.
- Water is the most abundant molecule in cells , accounting for more than 70% of the total cell mass
- Prokaryotes – lack well defined nucleus, has simple structure
- Eukaryotes – possess a well defined nucleus, has complex structure


microtubules
mitochondrion
centriole
vesicle
cytosol
chromatin
nuclear envelope
nuclear pore
nucleolus
nucleus
Golgi complex
lysosome
flagellum
plasma membrane
rough endoplasmic reticulum
ribosomes
smooth endoplasmic reticulum

Eukaryotic cell

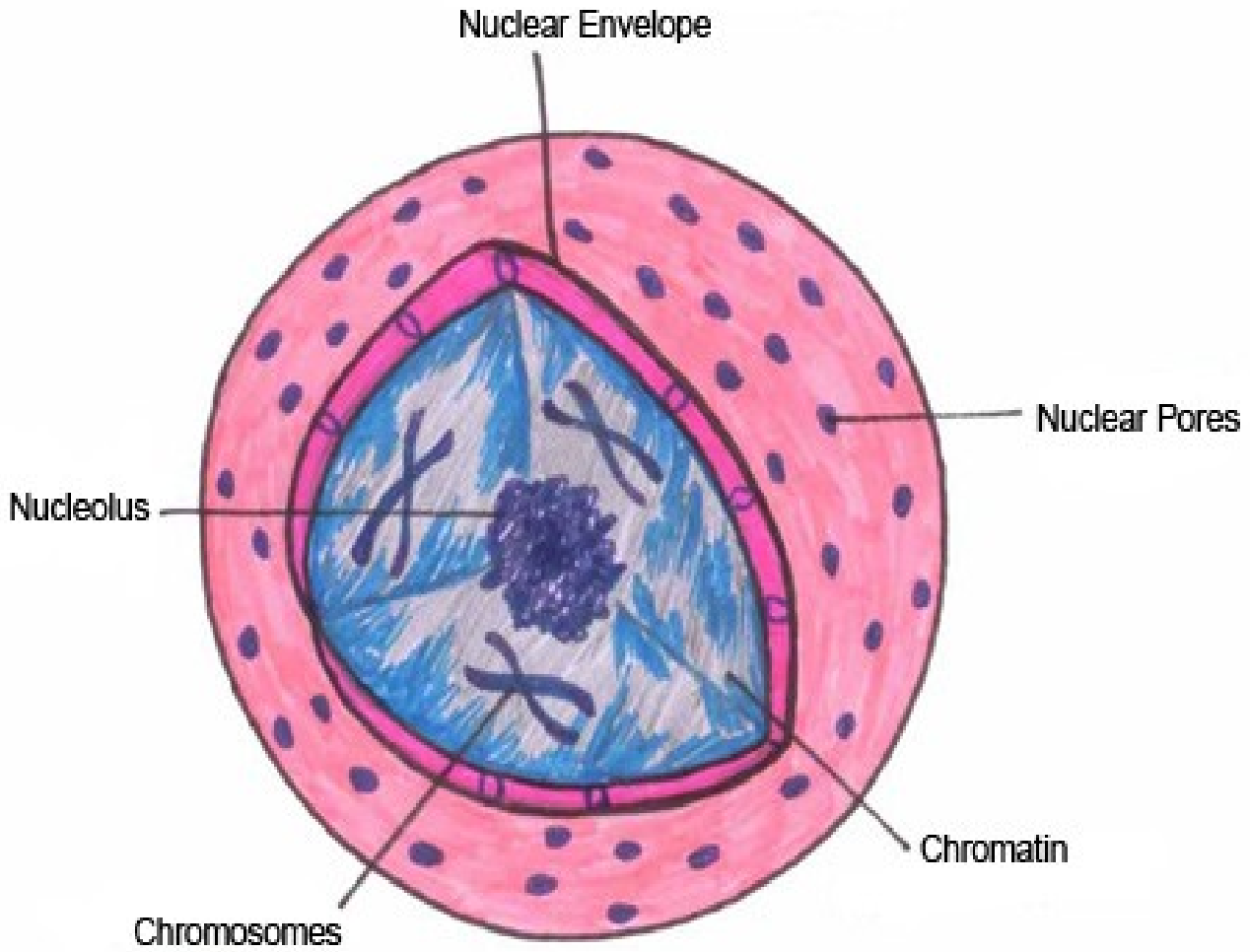
- It has well defined sub cellular organelles, enveloped by a plasma membrane
- The sub-cellular organelles are present in the cytoplasm.
- Cytoplasm is the internal volume bounded by the plasma membrane
- The clear fluid portion of the cytoplasm in which the particles/organelles are suspended is called **CYTOSOL**
- Cytosol also contains dissolved proteins, electrolytes & glucose

The major sub-cellular organelles are

1. Nucleus
2. Mitochondria
3. Endoplasmic reticulum
4. Golgi apparatus
5. Lysosomes
6. Peroxisomes

1. NUCLEUS

- It is the **largest** cell organelle.
- Is found in most Eukaryotic cells , Except RBC.
- Controls & regulates the activity of the cell (growth & metabolism)
- It controls the hereditary characteristics of an organism.
- It is responsible for protein synthesis ,cell division , growth & differentiation .
- Stores Hereditary materials in the form of Deoxyribonucleic acid (DNA) strands.



Cell Nucleus Diagram

CONT. 1. NUCLEUS

- Is the brain of the cell , controls most of cell function, thus w/t out a nucleus an animal cell or Eukaryotic cell will die.
- With out a nucleus , the cell will not know what to do & there would be no cell division.
- All cells in the body contain nucleus, except mature RBCs in circulation.

Cont. 2. NUCLEUS

- The primary functions of the nucleus are
  -store the cells DNA,
  -maintain its integrity &
  -facilitate DNA transcription & DNA replication. **(transcription is the synthesis of RNA from DNA. or Is the synthesis of single strand RNA from a double strand DNA templates. Or Transcription is the process in which a gene's DNA sequence is copied (transcribed) to make an RNA molecule). and**

Cont. 3. NUCLEUS

- DNA replication occurs during the synthesis phase of the cycle , before mitosis & cell division. DNA replication occurs when DNA is copied to form an identical molecule of DNA.)
- All the RNA‘S needed for the cell are synthesized in the nucleus.

Functions of nucleus

1. Nucleus contains the DNA, which is the hereditary material (condensed to chromosomes)
2. DNA replication and RNA synthesis are taking place inside the nucleus.

2. MITOCHONDRIA

STRUCTURE

1. It consists of

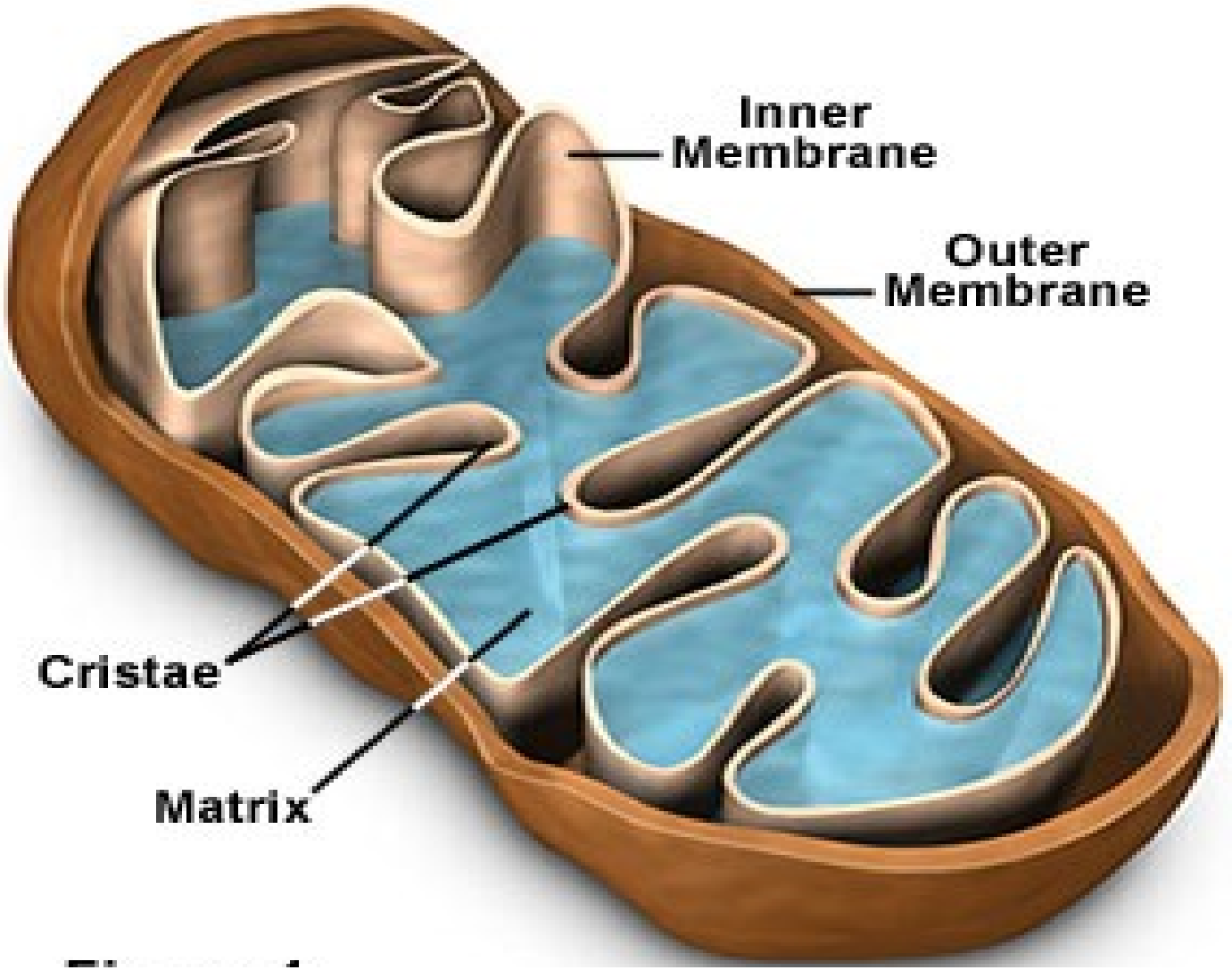
   a. Outer membrane – smooth, completely envelopes the organelle

   b. Inner membrane – is folded to form “cristae”

   c. Matrix – space within the inner membrane

   d. Intermembranal space-space between outer & inner membrane

Mitochondria Structural Features



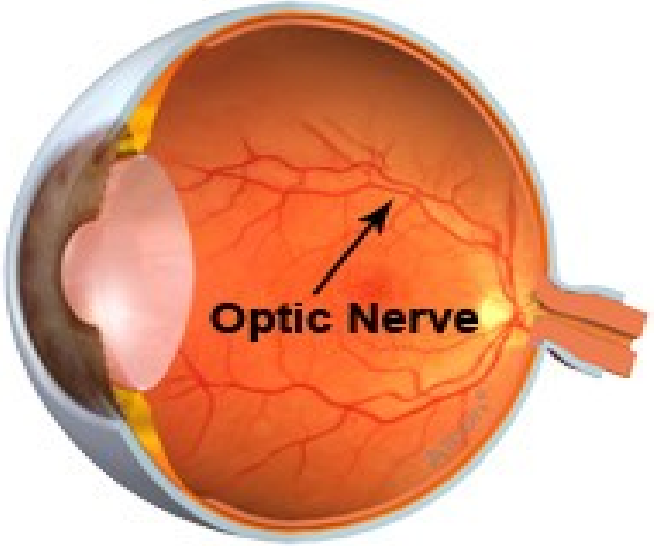
Functions of mitochondria

1. They are the power plants of the cell-synthesizing large amounts of ATP via aerobic respiration.
2. All eukaryotic cells possesses mitochondria.
   aerobic prokaryotes use the cell membrane to perform oxidative phosphorylation
3. They are involved in ATP production
4. Important metabolic pathways taking place in the mitochondria are TCA cycle, Urea cycle, Beta oxidation of fatty acids etc.,
5. Mitochondria also contains specific or their own DNA that encodes for mitochondrial proteins
6. Enzymes present in mitochondria-Inner membrane; matrix; intermembrane space

Clinical aspect

LEBER'S HEREDITARY OPTIC NEUROPATHY –

- Caused due to mutation in the mitochondrial DNA that codes for a protein/enzyme called NADH-Coenzyme Q reductase
- Due to this energy supply is affected & causes degeneration of optic nerves
- This may result in blindness



3. ENDOPLASMIC RETICULUM

STRUCTURE & FUNCTION

1. The network of membrane enclosed spaces that extends throughout the cytoplasm forms the endoplasmic reticulum.
2. Types of endoplasmic reticulum (ER)

   a. Rough ER – Attached to ribosomes

   - Helps in protein synthesis

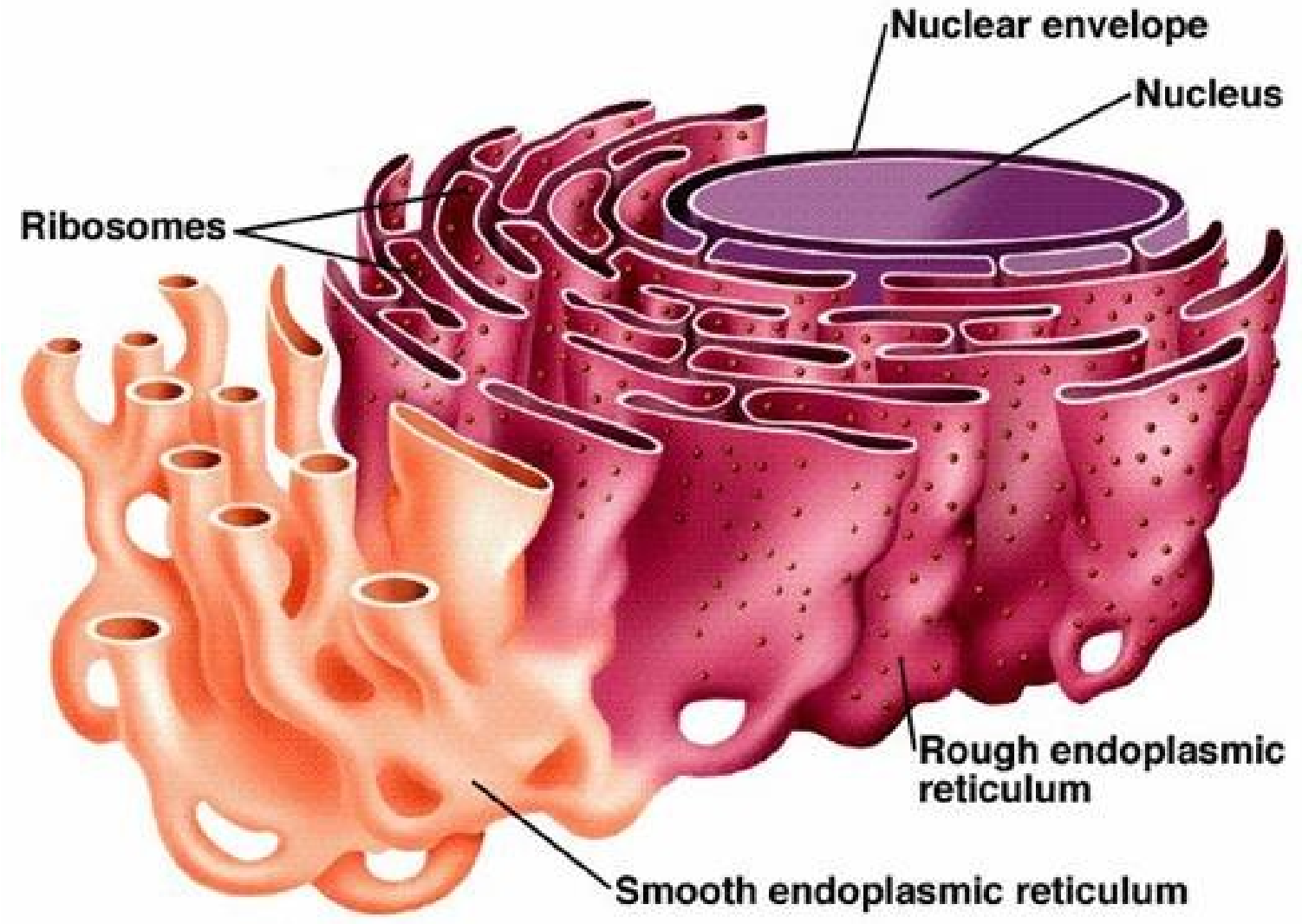
   b. Smooth ER – Not attached to ribosomes

   - Involved in the synthesis of steroid hormones.

   - Also involved in Detoxification of drugs

3. MARKER- a) Cholesterol desmolase (used in steroid hormone synthesis)

   b) NADPH cytochrome P450 reductase (used in detoxification of drugs)



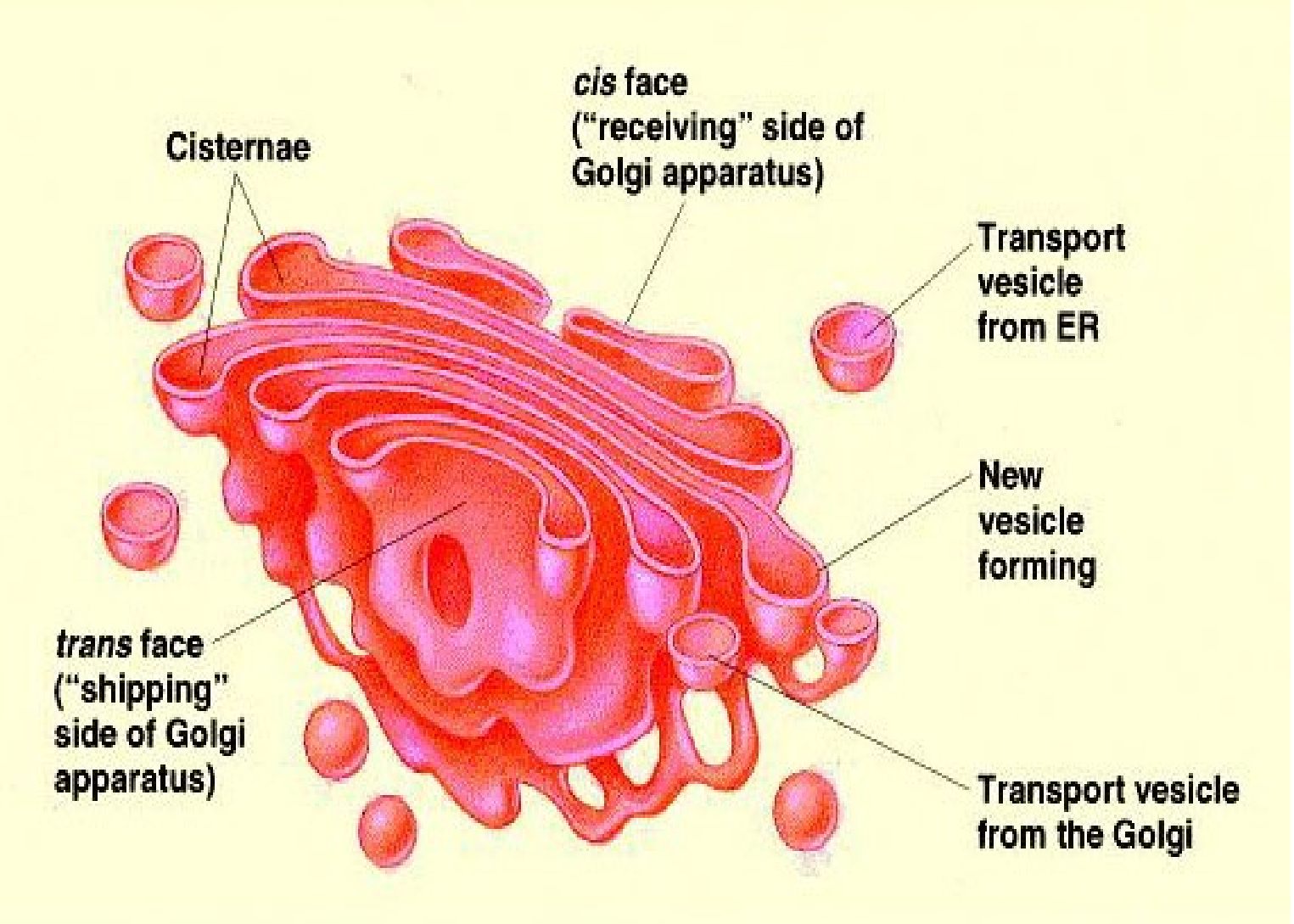
STRUCTURE OF ENDOPLASMIC RETICULUM

4. GOLGI APPARATUS

STRUCTURE & FUNCTION

1. It is the network of flattened smooth membranes & vesicles
2. It may be considered as the joining area of endoplasmic reticulum
3. It is composed of Cis, medial and trans cisternae
4. Functions – Protein sorting, packaging & secretion
5. Marker-Galactosyl transferase/Mannosidase

STRUCTURE OF GOLGI APPARATUS



5. LYSOSOMES

STRUCTURE & FUNCTION

1. They are spherical vesicles enveloped by a single membrane formed **from golgi apparatus**
2. Lysosomes are called as "suicidal bags of the cell", since they are actively involved in the digestion of cellular substances
3. The lysosomal enzymes have an optimum pH around **5**
4. Lysosomal enzymes are categorized as "**Hydrolases**" (hydrolytic enzymes) that act as markers for lysosomes

- Protein hydrolyzing enzymes like – CATHEPSINS
- Lipid hydrolyzing enzymes like – PHOSPHOLIPASES
- Nucleic acid hydrolyzing enzymes - RIBONUCLEASES

Clinical aspect

- GOUT – is a abnormal condition where muric acid crystals are digested by Lysosomes – that leads to inflammation and arthritis in joints
- Lysosomal proteins – Cathepsins are involved in detection of tumor/cancer
- Inclusion cell disease (I-cell disease) – Lack of lysosomal enzymes – protein targeting defect

Features of gout











6. PEROXISOMES

1. They are also known as "**microbodies**"
2. They are single membrane cellular organelles
3. Peroxisomes contain enzymes like
   a. Catalase
   b. Peroxidase

These enzymes are used for the removal of toxic peroxides from the cell

4. Peroxisomes also carry out beta oxidation of very long chain fatty acids

CLINICAL ASPECT

Zellweger syndrome: Genetic disease due to lack of peroxisomes in some tissues

STABILIZING FORCES IN BIOMOLECULES

Stabilizing forces in biomolecules

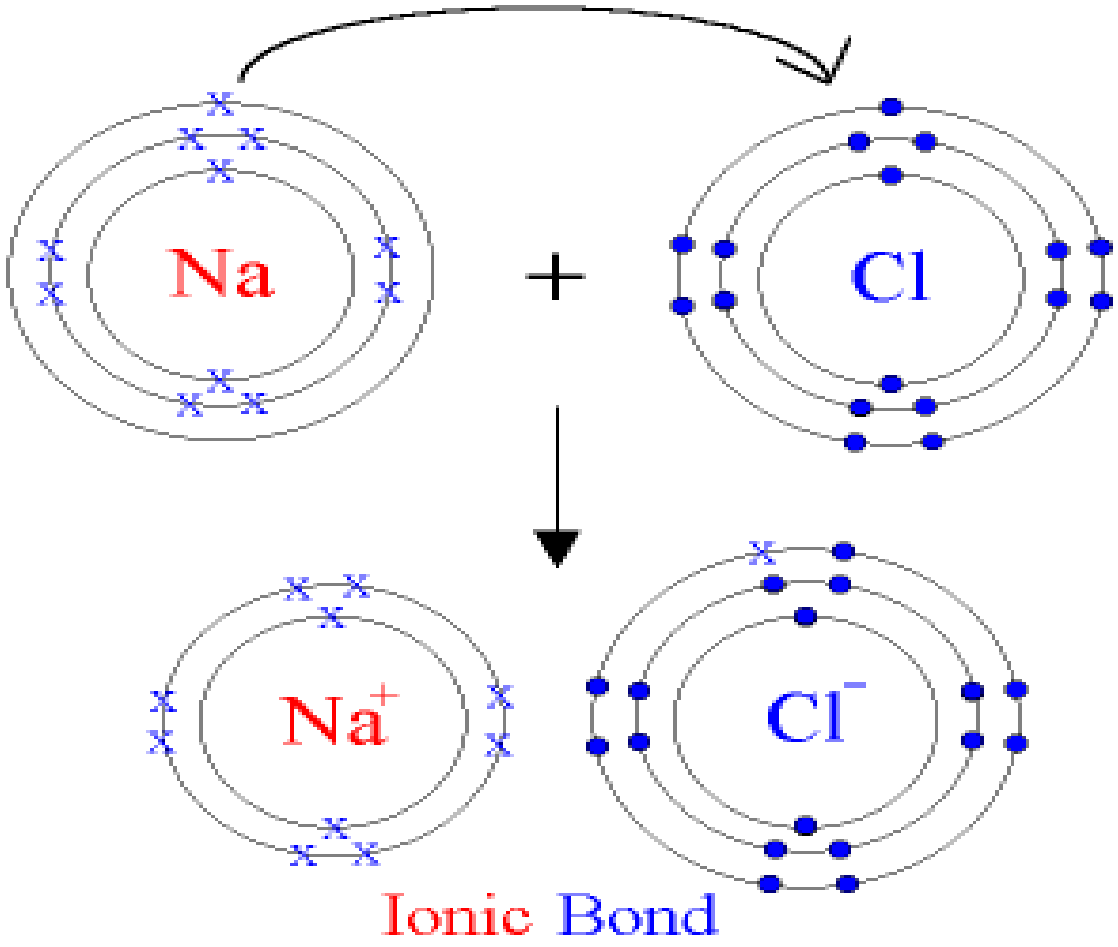
- Ionic bonds or electrostatic bonds
- Hydrogen bonds
- Hydrophobic interactions
- van der Waals forces

Ionic or electrostatic bonds

- **Formation**
- **Example**
- **Solubility**
- **Biological system: PROTEIN**

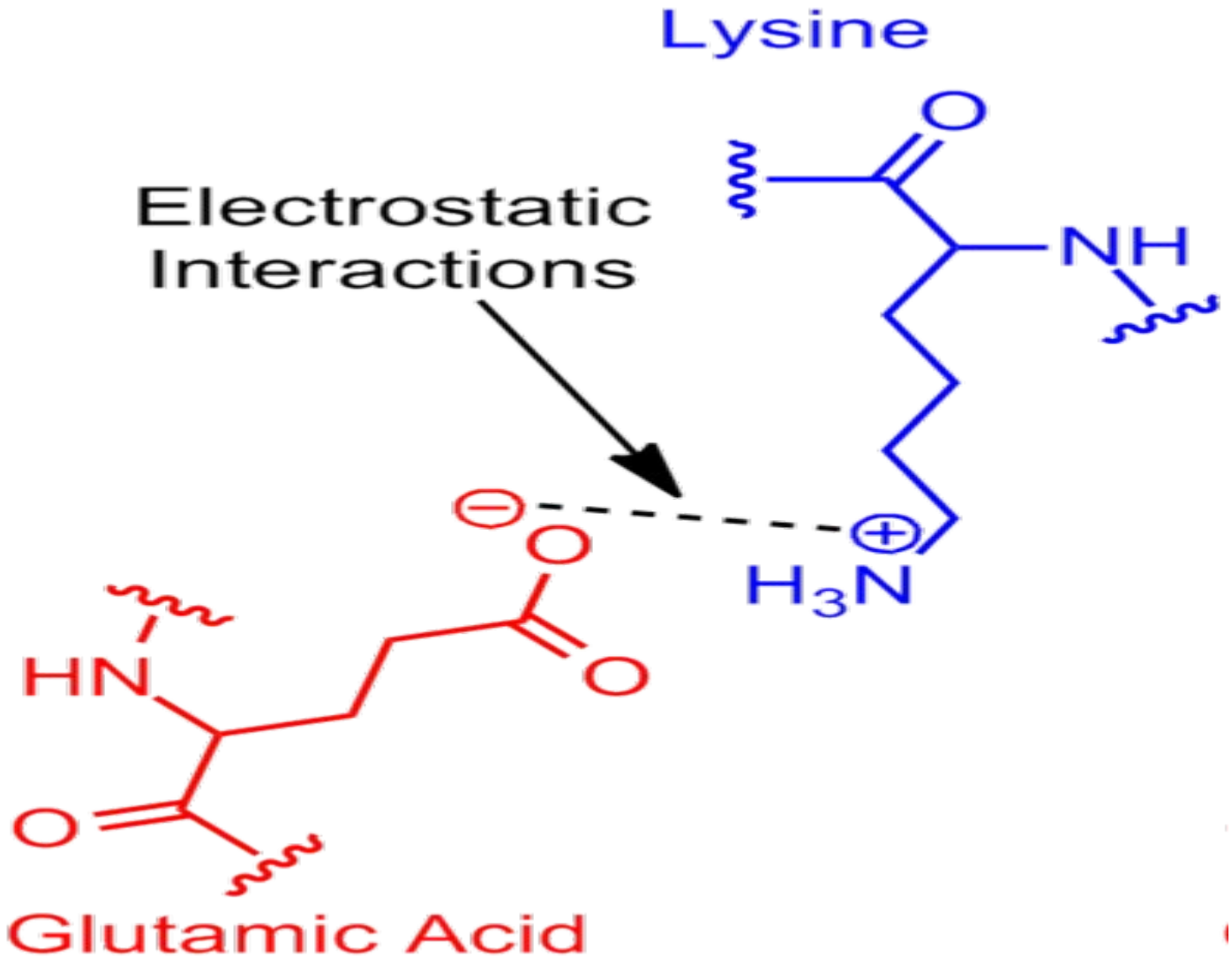
Ionic bond

- Attractive forces between two oppositely charged molecules
- Formed by the actual transfer of one or more valence electrons from outermost orbit of an electropositive atom to the outermost orbit of an electronegative atom
- This results in the formation of a “cation” and an “anion”, which get consequently bound by an ionic bond
- Common Examples: NaCl, KBr, NaF


Na
+
Cl
Na+
Cl−
Ionic Bond

Ionic bond

- Solubility of these compounds in polar solvents is much higher
- This is because a large amount of energy called "**energy of hydration**" is released when ions tightly bind water molecules
- In Biological system: Electrostatic interactions between oppositely charged groups within or between biomolecules are called "**Salt bridges**".


Lysine
Electrostatic
Interactions
O
NH
H3N
O
O
HN
O
Glutamic Acid

Ionic bond

- In Biological system (Eg.Proteins),

Positive charges produced by Amino group of lysine, guanidium group of arginine and imidazole group of histidine

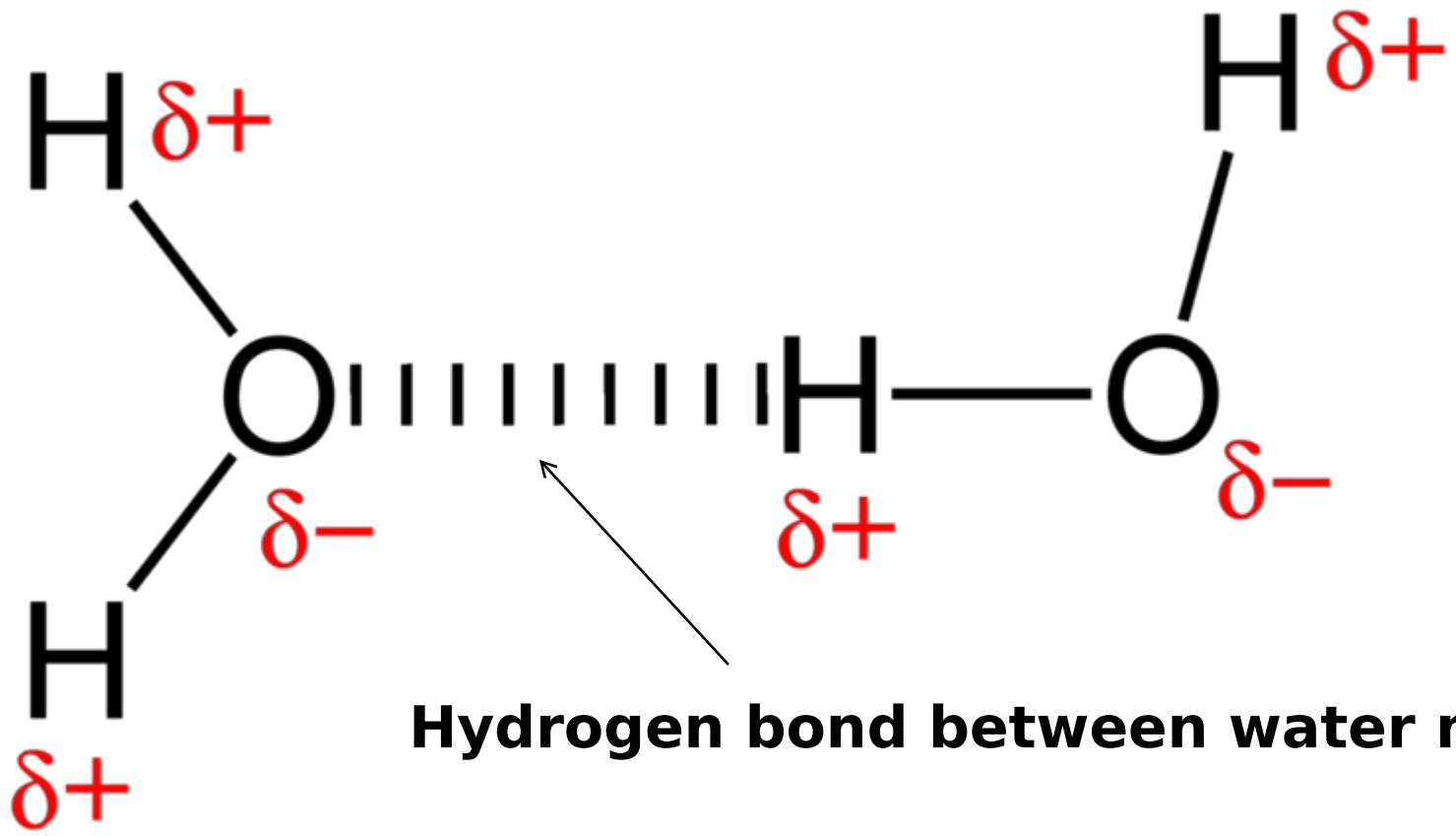
Negative charges produced by beta and gamma carboxyl groups of aspartic acid and glutamic acid

Hydrogen bond

- **Formation**
- **Example**
- **In Biological system, PROTEIN**

Hydrogen bond

- A hydrogen bond is the attractive interaction of a hydrogen atom with an electronegative atom such as nitrogen, oxygen or fluorine, that comes from another molecule or chemical group
- The hydrogen must be covalently bonded to another electronegative atom to create the bond
- Hydrogen bond is stronger than a van der Waals interaction but weaker than covalent or ionic bonds
- Example: Water molecule



Hydrogen bond between water molecu

Hydrogen bond

- In Biological system (Proteins)

  Hydrogen releasing groups – (-NH: imidazole group of histidine, indole group of tryptophan); (OH: group of serine and threonine); (NH_2 group of arginine and lysine)

  Hydrogen accepting groups: (COO- of aspartic acid and glutamic acid); (disulfide bond: S-S)

  Note: Secondary structure of protein and DNA structure are maintained by hydrogen bonding

Hydrophobic interactions

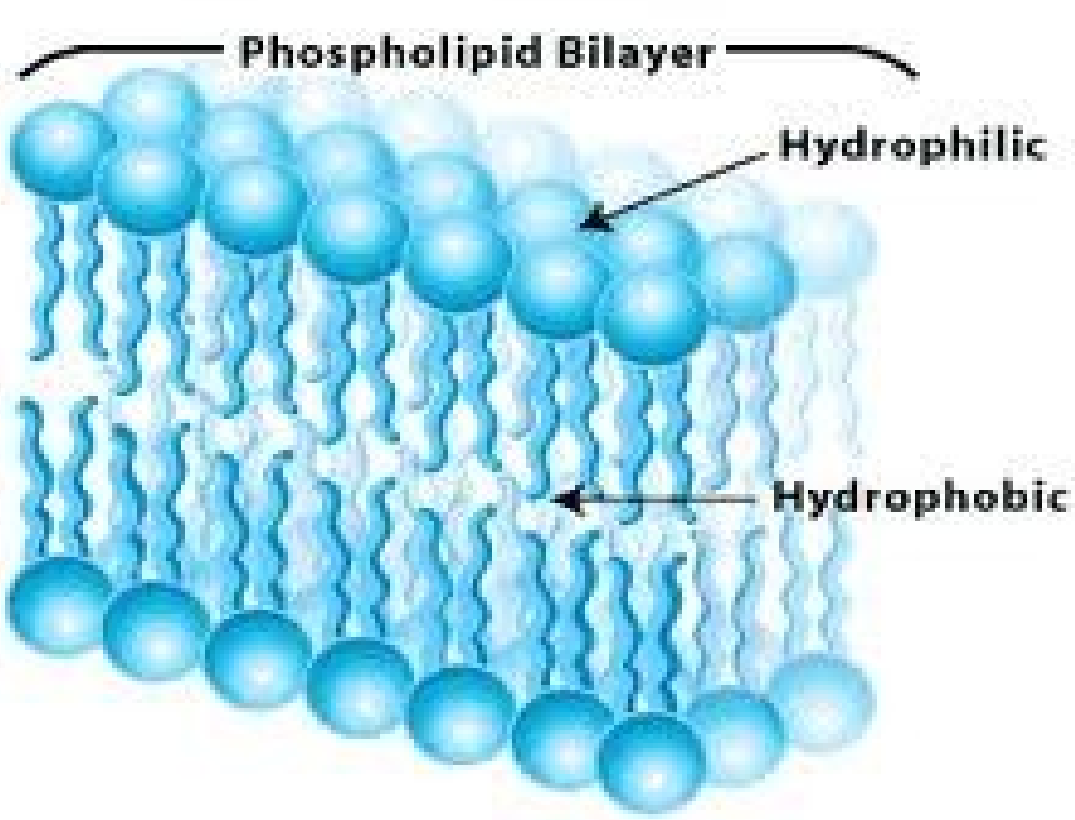
- **Formation**
- **Solubility**

Hydrophobic interactions

- It is the tendency of non-polar substances to aggregate in aqueous solution and exclude water molecules
- The force that causes hydrophobic molecules or non-polar portions of molecules to aggregate together rather than to dissolve in water is called HYDROPHOBIC BOND
- Hence they are insoluble in water

In Biological system

- Hydrophobic interactions are necessary for protein folding
- For the formation of lipid bilayers (in plasma membrane)


Phospholipid Bilayer
Hydrophilic
Hydrophobic

van der Waals forces

- **Formation**
- **In Biological system – protein structure**

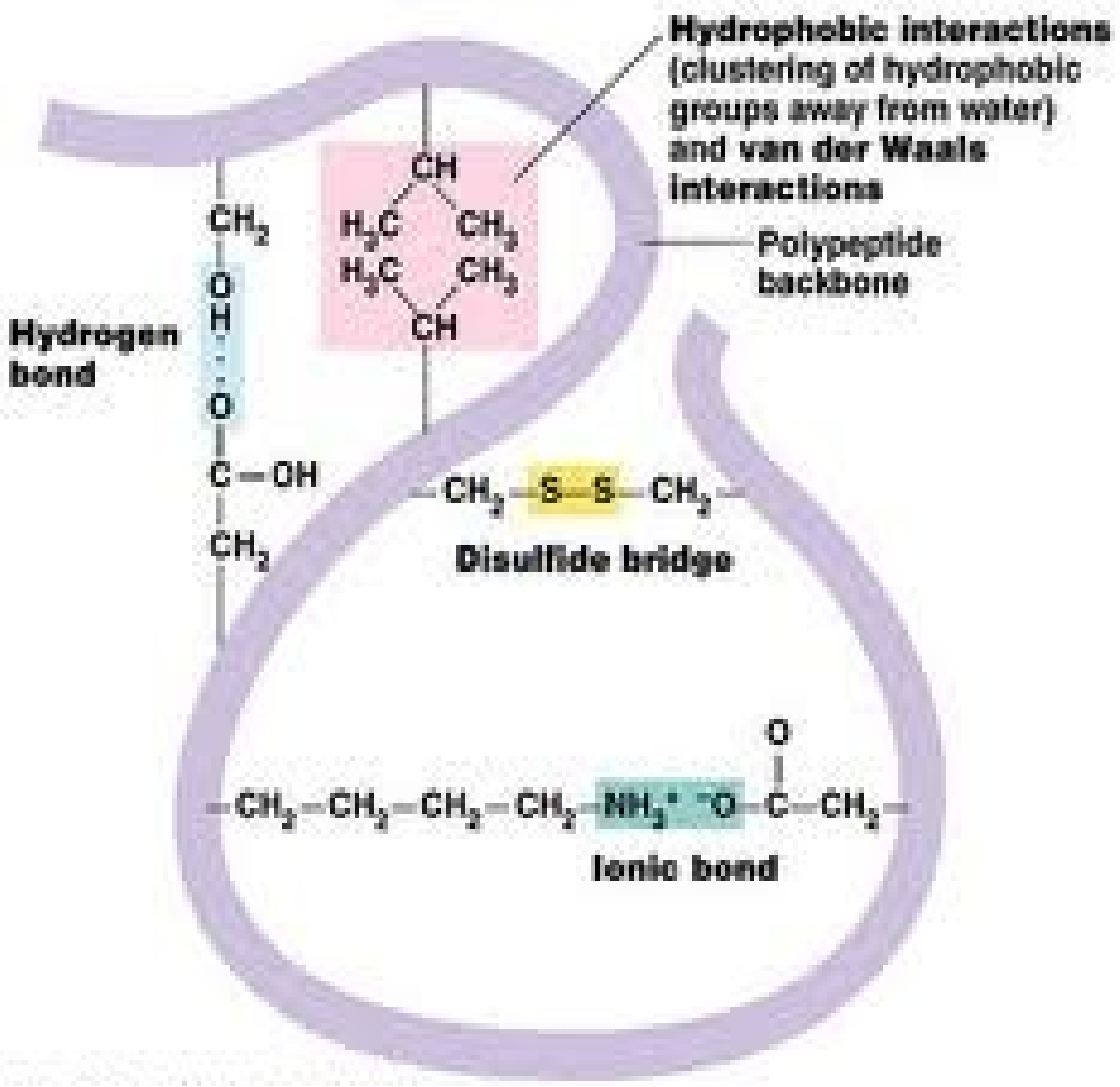
Van der Waals forces

- These are weak forces of attraction between polar and non-polar molecules
- Named after Dutch Physicist ‘Johannes Diderik van der Waals’
- They are weak forces compared to covalent bonds but play a major role in different branches of chemistry
- They define many properties of organic compounds including their solubility in polar and non polar

In Biological system

- Van der Waals forces collectively contribute maximum towards the stability of protein structure especially in preserving non polar structure of proteins

Example for different types of interactions in protein molecule



WATER – THE UNIVERSAL SOLVENT

WATER – THE UNIVERSAL SOLVENT

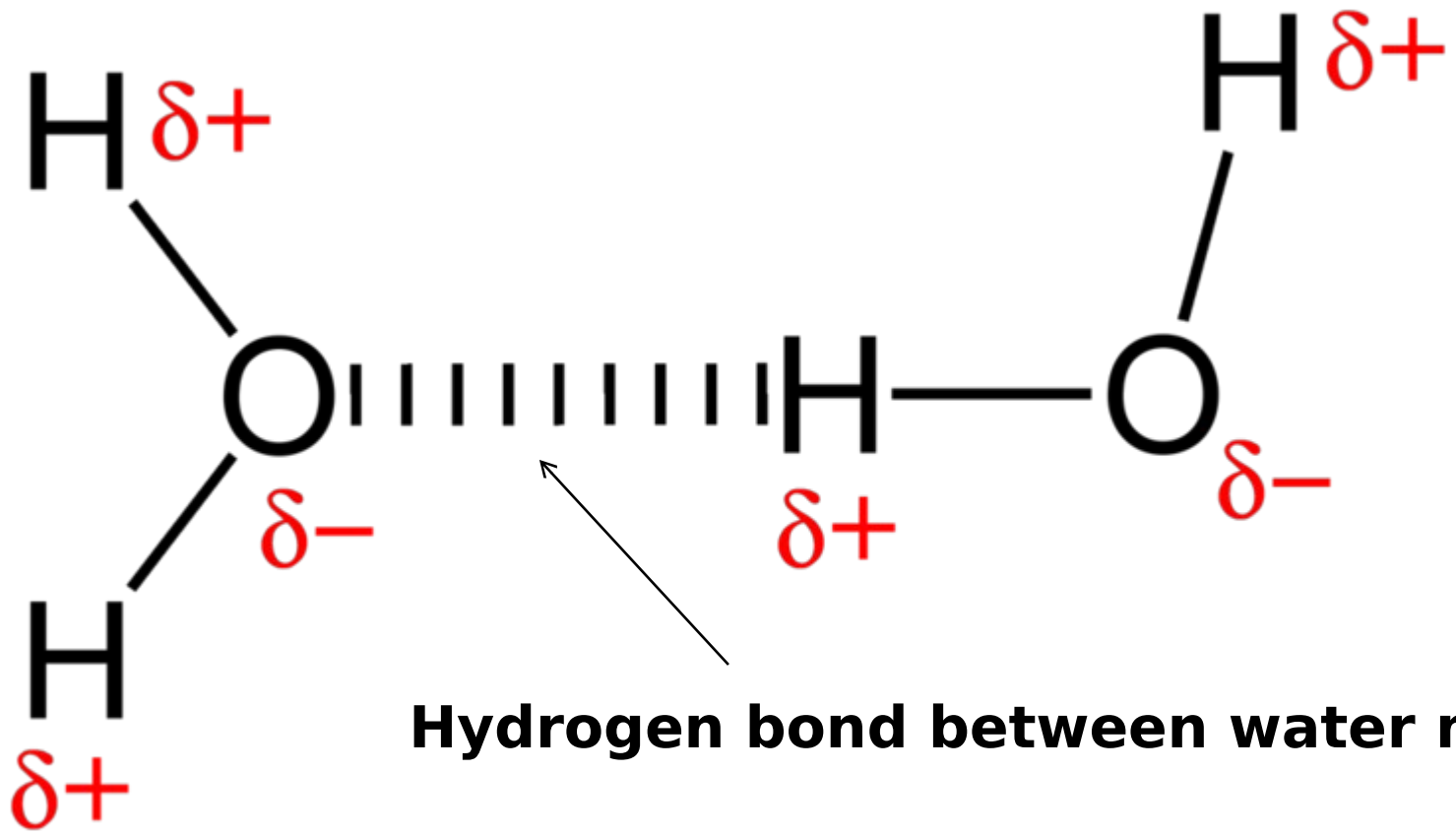
- Water is the predominant chemical component of living organisms
- Water is the mother liquor of all forms of life
- It is the vital essence, miracle of nature and the great sustainer of life
- The essentiality of water for living systems is quite evident as without water, there is NO LIFE

Structure of water

- Water molecules provide a classic example of hydrogen bonding
- The hydrogen atom in one water molecule is attracted to a pair of electrons in the outermost shell of oxygen atom in an adjacent molecule
- Water is a dipole, a molecule with electrical charge distributed asymmetrically about its structure

- The oxygen molecule attracts electrons more strongly than does the hydrogen nucleus (i.e the proton), oxygen is more electronegative
- The sharing of electrons between hydrogen and oxygen is therefore unequal; the electrons are more often in the vicinity of the oxygen atom than of the hydrogen
- This unequal electron sharing creates two electric dipoles in the water molecule, one along each of H-O bonds

- The oxygen atom bears a partial negative charge and each hydrogen bears a partial positive charge
- The resulting electrostatic attraction between oxygen atom of one water molecule and the hydrogen of another water molecule constitutes a HYDROGEN BOND



Hydrogen bond between water molecu

A few gifted properties of water make it the most preferred medium for all cellular reactions and interactions

a. Water is a polar molecule. Molecules with polar bonds that can easily form hydrogen bonds with water can dissolve in water & are termed “hydrophilic”
b. It has immense hydrogen bonding capacity both with other molecules & also the adjacent water molecules. This contributes to the cohesiveness of water
c. Water favors hydrophobic interactions & provides a basis for metabolism of insoluble substances

Water distribution in an adult male of 70 kg body weight

Compartment	Total body water (42 Litres)
ICF	30
ECF	
- Plasma	3
-Interstitial and lymph - Transcellular fluid	8.5 1

Water balance

- The maintenance of water balance i.e., the equilibrium between water intake and output, is a critical aspect of metabolism
- Besides the water obtained from foods and liquids, **metabolic water** is also made available through the oxidation of food in the body
- Water loss occur by perspiration, urine and faeces

Clinical aspect - Dehydration & Edema

- If the output of water significantly exceeds the intake, dehydration occurs (due to diarrhea, vomiting, fever etc.,)
- If water accumulates in tissues, then the condition is called EDEMA
- Edema is often observed in children suffering from KWASHIORKOR, a nutritional disease caused by inadequate intake of protein [Children appear plump (fatty/chubby)]

Features of kwashiorkor (protein-energy malnutrition)





Acid, Base & pH

- Bronsted & Lowry theory – Acids are substances that are capable of donating protons and bases are those that accept protons (OR)
- Acids are proton donors and bases are proton acceptors

Acids and bases dissociation

- $HCl \rightleftharpoons H^+ + Cl^-$
- $H_2CO_3 \rightleftharpoons H^+ + HCO3^-$

Bases

- $NH_3 + H^+ \rightleftharpoons NH_4$

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

Dissociation of acids and bases

- The extent of dissociation decides whether they are strong acids or weak acids
- Strong acids dissociate **completely** and weak acids **incompletely**
- Eg. HCl is a strong acid

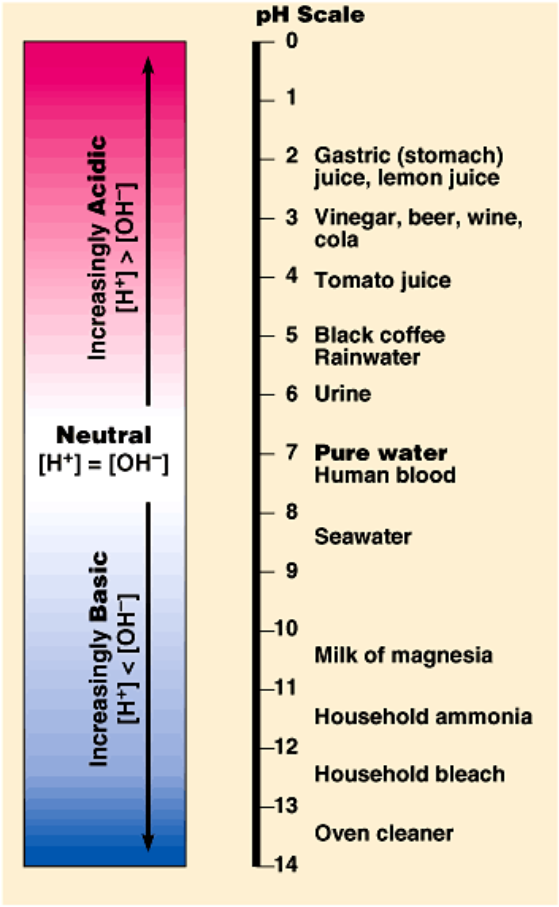
  H_2CO_3 is a weak acid

pH

- The term pH was introduced by Sorensen in 1909
- It is defined as the negative logarithm of hydrogen ion concentration
- $pH = -\log [H^+]$
- pH at which is the acid is **half ionized** is called pKa of an acid

pH scale

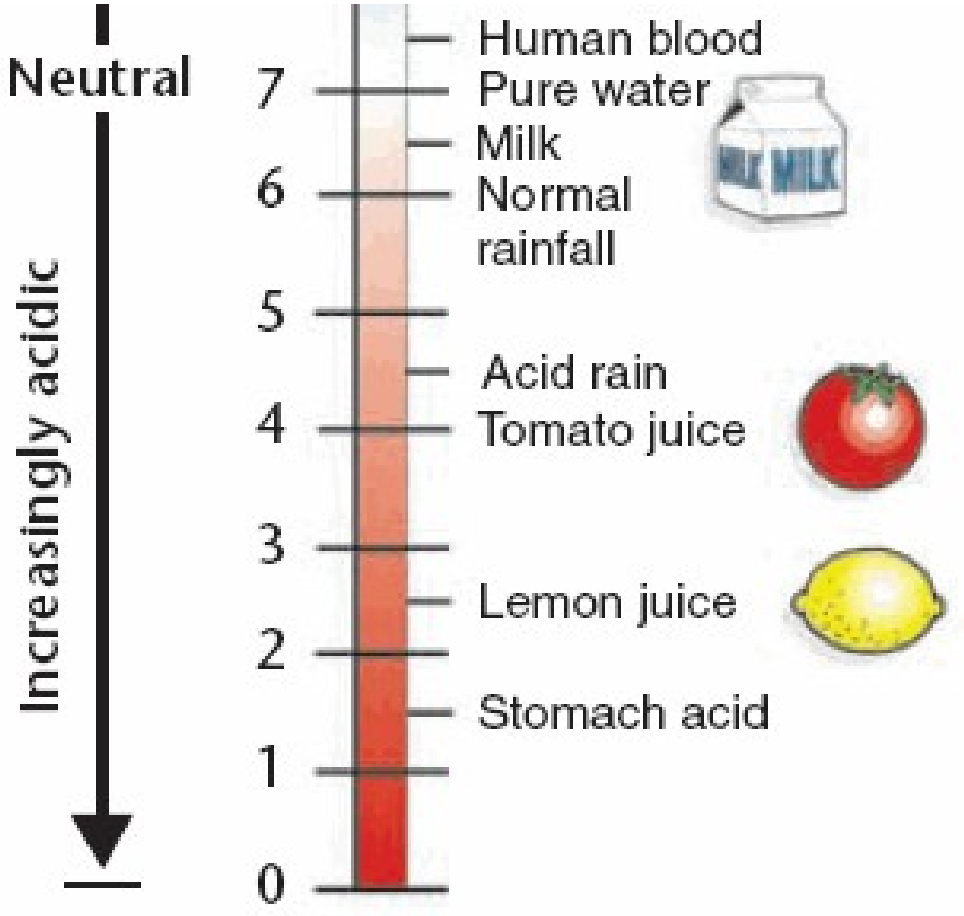
- Indicates the concentration of H^+ ions
- Ranges from 0 to 14
- pH of 7 is neutral
- pH of 0 to 7 ------ acidic (H^+)
- pH of 7 to 14 ----- basic (alkaline) (OH^-)



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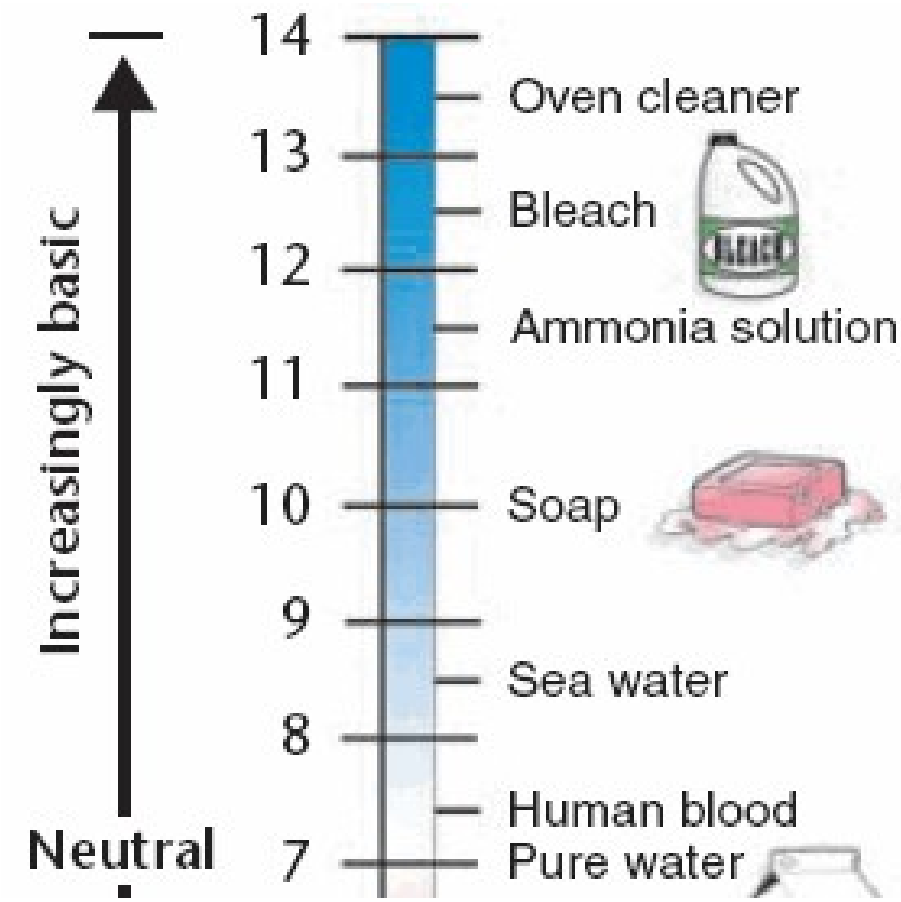
Acids

- **Strong Acids have a pH of 1-3**
- **Produce lots of H^+ ions**



Bases

- **Strong Bases have a pH of 11 to 14**
- **Contain lots of OH^- ions and fewer H+**



Henderson-Hasselbach equation

- The relationship between pH, pKa, concentration of acid and conjugate base (or salt) is expressed by Hen

$$pH = pK_a + \log \frac{[base]}{[acid]}$$

Buffers

- Buffers are solutions which can resist changes in pH when acid or alkali is added
- Examples:

1. Acetate buffer (acetic acid and sodium acetate)

2. Bicarbonate buffer (carbonic acid and sodium bicarbonate)

How do buffers act?

- Example: Addition of HCl to acetate buffer

  $CH_3COOH + CH_3COONa + HCl \rightarrow NaCl + 2CH_3COOH$

  Example: If NaOH is added to acetate buffer

  $CH_3COOH + CH_3COONa + NaOH \rightarrow 2CH_3COONa + H_2O$

- In either case, no free H+ or OH- ions are produced.
- Thus buffers resist the change in pH upon the addition of an acid or alkali.

Biological buffer system – Mechanisms of regulation of blood pH

- Normal blood pH is 7.4 (7.35-7.45)
- The acid base balance in the body is maintained by biological buffer system

Blood pH is regulated with the help of

- Buffers of the body fluids
- Respiratory system
- Renal system

Buffers of the body fluids

- ECF – Bicarbonate buffer
- ICF – Phosphate buffer
- Erythrocytes – Hemoglobin buffer

- Bicarbonate buffer: $H_2CO_3/NaHCO_3$ (Carbonic acid/Sodium bicarbonate)
- Phosphate buffer : Na_2HPO4/NaH_2PO4 (Disodium dihydrogen phosphate/Sodium dihydrogen phosphate)
- Hemoglobin acts as a buffer **due to** the presence of aminoacid histidine (imidazole group of histidine).
- Hemoglobin buffer is considered along with the respiratory regulation of pH.

Clinical aspect – Disturbances in acid-base balance

- ACIDOSIS (fall in pH) – when the blood pH falls below 7.35

  Two types – Respiratory acidosis and metabolic acidosis
- ALKALOSIS (rise in pH) – when the blood pH rises above 7.45

  Two types – Respiratory alkalosis and metabolic alkalosis