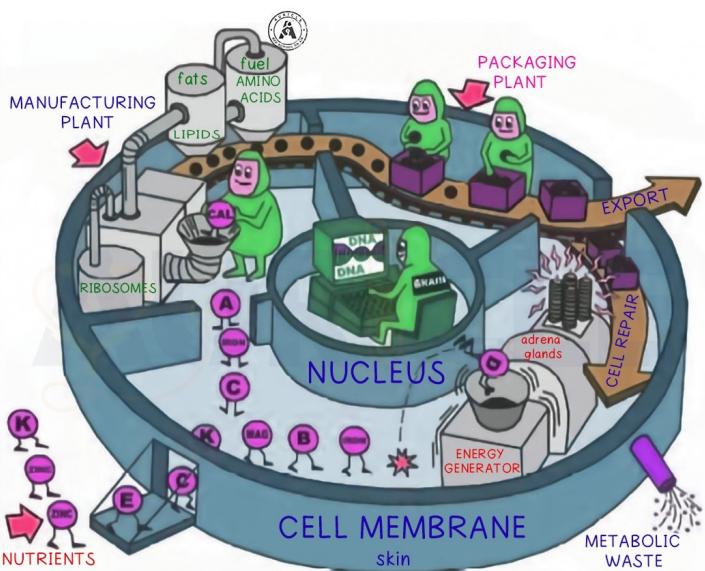




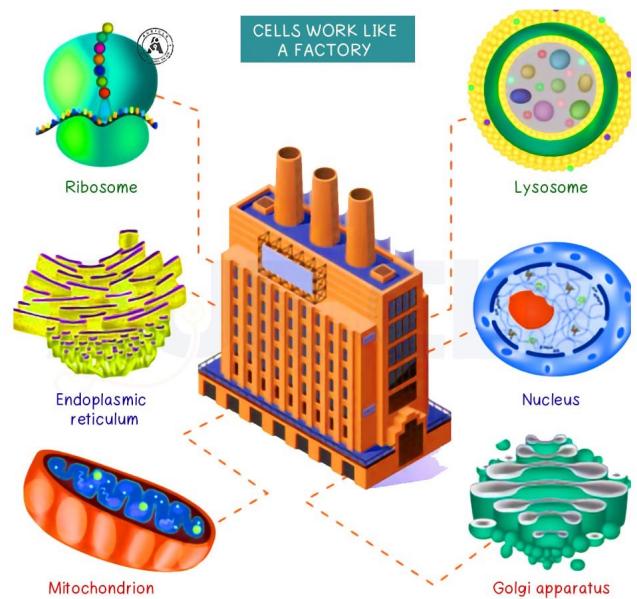
INTRODUCTION

Think of a cell as a tiny, bustling city inside your body. Each cell is like a worker, busy doing important jobs to keep you alive. Cells have walls called membranes, which are like city borders, deciding what goes in and out.

Inside a cell, there are little factories called organelles, each with a special role. The nucleus is like the city's control center, holding the important instructions (DNA) for everything about you. Mitochondria act as power plants, giving you energy for daily activities.



As an MBBS student, this is your secret code to understanding diseases and helping people. Learning about cells and their chemistry is your path to making a real difference in people's lives. It's like being a detective in the body, solving health mysteries and making the world a healthier place. So, let's dive into this amazing world of cells and biochemistry - your key to unlocking the secrets of life and medicine.



Now, here's where it gets exciting. The way these cells work is all about chemistry. It's like a dance of tiny molecules and reactions. This is where you'll see how your body functions and what happens when things go wrong.



Biomolecules and cell

Introduction

- Life is composed of lifeless chemical molecule
- living matter is mainly composed of carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur.
- Several other functionally important elements are Ca, K, Na, Cl, Mg, Fe, Cu, Co, I, Zn, F, Mo and Se.
- Carbon, it possesses a unique property to form an infinite number of compounds.
- It is estimated that about 90% of compounds found in living system invariably contain carbon.

What are Complex biomolecules??

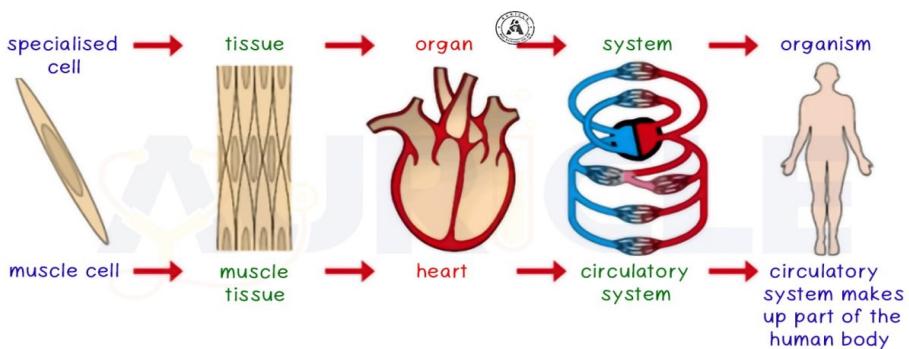
- this complex molecule is formed by lot of single molecules (i.e monomeric units)
- example of monomeric units which forms the complex molecule are aminoacids, nucleotides & monosaccharide
- This monomeric unit Serve building blocks of complex biomolecules Like proteins, nucleic acids(DNA and RNA) and polysaccharides, respectively.

- The important complex biomolecules their respective building blocks and functions are given below

TABLE 1.1 The major complex biomolecules of cells		
Biomolecule	Building block (repeating unit)	Major functions
1. Protein	Amino acids	Fundamental basis of structure and function of cell (static and dynamic functions).
2. Deoxyribonucleic acid (DNA)	Deoxyribonucleotides	Repository of hereditary information.
3. Ribonucleic acid (RNA)	Ribonucleotides	Essentially required for protein biosynthesis.
4. Polysaccharide (glycogen)	Monosaccharides (glucose)	Storage form of energy to meet short term demands.
5. Lipid	Fatty acids, glycerol	Storage form of energy to meet long term demands; structural components of membranes.

- The macromolecules (protein, lipids ,nuclei acids and polysaccharides)form supramolecular eg.membranes
- which in turn organize into organelles, cells, tissues,organs and finally the whole organism

- * Cell
- * : Cell is defined as the structural and functional unit of the living body.
 - it has two major parts:
 - Nucleus
 - Cytoplasm
- * Tissue is defined as the group of cells having similar function.
e.g.: muscle tissue, nervous tissue, epithelial tissue.
- * organ is defined as the structure that is made up of two or more primary types of tissues.
- * organ system is defined as group of organs that work together to carry out specific functions.
e.g. : Digestive system, respiratory system, Circulatory system



Example of general organization of circulatory system.

What is a cell membrane?

Cell membrane / plasma membrane

- It is a protective sheath.
- It is an elastic structure
- It envelops the cell body.
- This membrane separates extracellular fluid from intracellular fluid.
- It is semi-permeable membrane.
- So, there is free exchange of certain substances between ECF and ICF.
- It is composed of proteins; lipids; carbohydrates.

What are the functions of cell membrane?

Ans: Functions

protection: Cell membrane protects the cytoplasm; organelles present in the cytoplasm.

Selective permeability: Cell membrane allows only some specific substances to pass through it.

Nutrients are absorbed into the cell through the cell membrane

excretory function: waste products & metabolites are excreted out from cell through the cell membrane.

Exchange of gases like Oxygen and carbon dioxide occurs through the cell membrane.

cell membrane Maintains shape and size of the cell.

What are the functions of cell membrane?

ANS :- cytoplasm

- cytoplasm is a gelatinous material bound by the cell membrane
- It contains many organelles
- 5 important organelles present in cytoplasm are
 - endoplasmic reticulum
 - Golgi apparatus
 - mitochondria
 - lysosomes
 - peroxisome.

Q. What is endoplasmic reticulum (ER)? What are the types of endoplasmic reticulum?

The endoplasmic reticulum (ER) is a system of channels that is continuous with the nuclear membrane (or “envelope”) covering the nucleus and composed of the same lipid bilayer material.

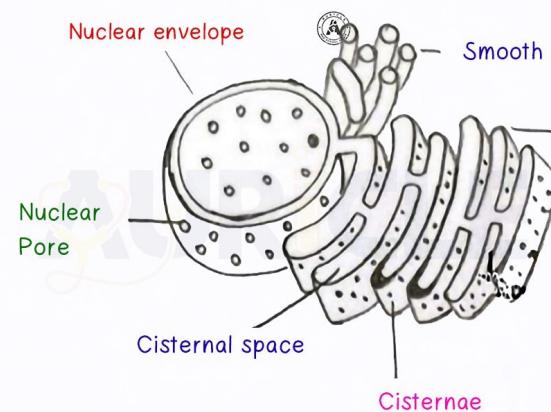
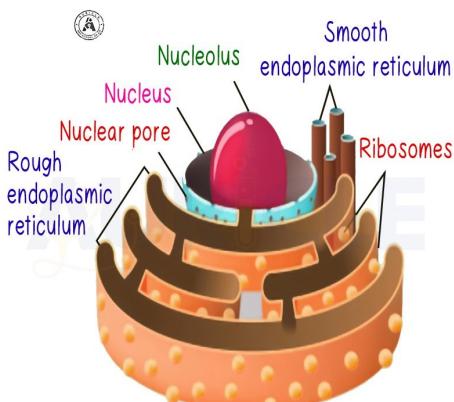
- It is made up of network of tubular and flat vesicular structures
- It processes and transport molecules that are made by the cell.
- It's of two types I) rough endoplasmic reticulum
ii) smooth endoplasmic reticulum

Rough Endoplasmic Reticulum

- it appears rough due to the attachment of granular ribosomes.
- it helps in protein synthesis
- It helps in removing worn-out organelles

Smooth endoplasmic reticulum

- It appears smooth and is called agranular endoplasmic reticulum.
- It helps in synthesis of lipid substances



Q.What is Golgi apparatus ? What are the Functions of it?

Golgi apparatus is responsible for sorting, modifying, and shipping off the products that come from the rough ER

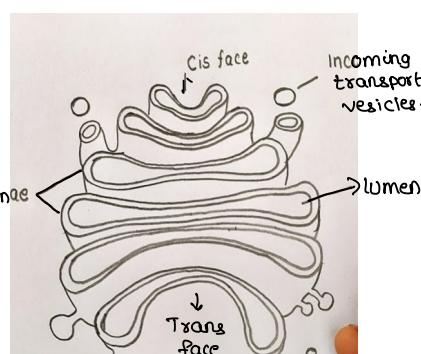
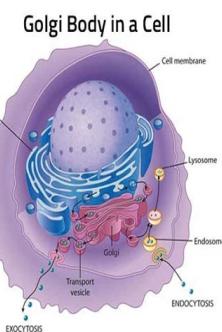
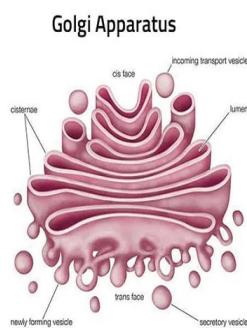
Golgi apparatus / Golgi complex is a membrane-bound organelle.

- They process the proteins
- They are absent in red blood cells.
- It has 5 to 8 flattened membranous sacs called the cisternae.

Functions

The Golgi apparatus has two distinct sides, each with a different role. One side of the apparatus receives products in vesicles.

- i) processing of material: vesicles containing lipids and glycoproteins are transported to Golgi apparatus from ER ; here they are modified and processed
- ii) Packaging of materials: The processed material is packed in the form of secretory vesicles and lysosome
- iii) Then delivers the packed material from the opposite side



What is lysosome?

A lysosome is an organelle that contains enzymes that break down and digest unneeded cellular components, such as a damaged organelle.

- * Lysosomes are formed by breaking off from Golgi apparatus
- * Lysosomes act as intracellular digestive system.
- * it digests:
 - damaged cellular structures.
 - products of protein digestion intracellularly.
 - bacteria.

* **Hydrolytic enzymes** are present in the lysosomes.

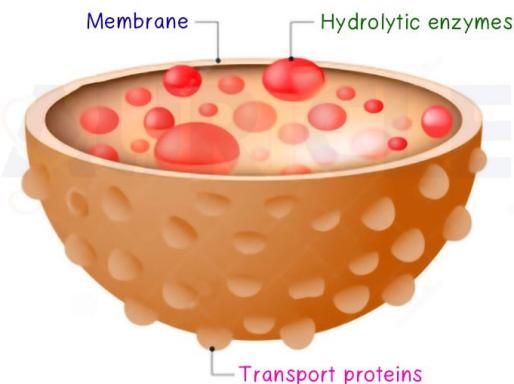
- * these hydrolytic enzymes can split an organic compound into many parts
- * important lysosomal enzymes are
 - Proteases : it hydrolyzes the proteins into amino acids
 - Lipases: it hydrolyzes the lipids into fatty acids and glycerides
 - Amylases: it hydrolyzes the polysaccharides into glucose
 - Nucleases: it hydrolyses the nucleic acids into mononucleotides.

Specific Functions of lysosome

- It degrades macromolecules
- It degrades worn-out molecules
- It Removes excess secretory products in the cells.



LYSOSOME



Q. What is mitochondria?

- Mitochondrial is the “powerhouses” of the cell.
- It is rod shaped.
- It is a bilayered organelle containing an outer membrane and inner membrane.
- The inner membrane is folded in the form of shelf-like inward projections called cristae
- Cristae contains many enzymes which are involved in respiratory chain and synthesis of ATP
 - i. Succinic dehydrogenase
 - ii. Dihydronicotinamide adenine dinucleotide dehydrogenase
 - iii. Cytochrome oxidase
 - iv. Cytochrome C
 - v. ATP synthase.

Functions of mitochondria

i) Production of energy

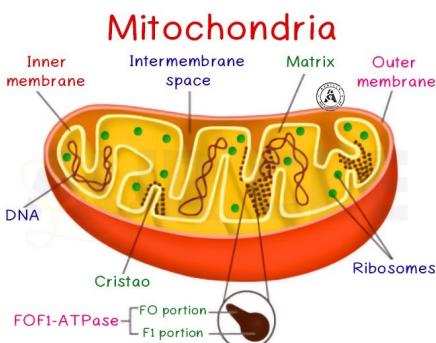
- It produces the energy required for cellular functions.
- Energy is produced by oxidation of digested food particles like proteins, lipids etc.
- Released energy is stored in mitochondria and used later for synthesis of ATP.

ii) Synthesis of ATP

- Components of respiratory chain in mitochondria are responsible for the synthesis of ATP

iii) Apoptosis

- Cytochrome C and second mitochondria-derived activator of caspases are secreted in mitochondria
- They are involved in apoptosis.



what are peroxisomes? What are the functions of peroxisomes?

- Peroxisomes are the membrane limited vesicles like the lysosomes.
- They are pinched off from endoplasmic reticulum.
- Peroxisomes contain some oxidative enzymes such as catalase, urate oxidase and D-amino acid oxidase
- they are also called as microbodies

Functions of peroxisomes

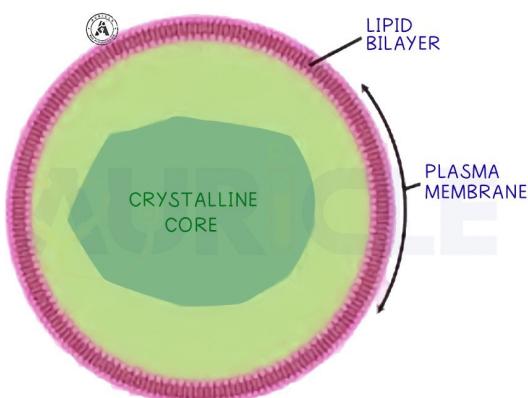
Peroxisomes:

- i. Breakdown the fatty acids by beta-oxidation
- ii. Degrades the toxic substances such as hydrogen peroxide and other metabolic products by detoxification.

Example:

Whenever hydrogen peroxide is produced in the cell, the peroxisomes are ruptured, and the oxidative enzymes are released; These oxidases destroy hydrogen peroxide

- iii. Accelerate gluconeogenesis from fats
- iv. Degrades purine to uric acid
- v. Participate in the formation of myelin
- vi. Play a role in the formation of bile acids.



Zellweger syndrome

- a condition characterized by the absence of functional peroxisome due to defect in peroxisome biogenesis
- Peroxisome biogenesis disorders (PBDs), are a Group of rare diseases involving the defective enzyme activities of peroxisomes
- zellweger syndrome is one of it and it is severe form
- The victims of this disease may die within one year after birth
- The biochemical abnormalities associated with PBDs include increased levels of very long chain fatty acids and decreased concentrations of plasmalogens

Mcq

1. What is the enzyme present in peroxisome?

- a) Enolase
- b) Catalase
- c) Zymase
- d) Granzyme

2.what is the function of lysosome?

- E. degradation
- F. Blood supply
- G. Helps in migration
- H. Kills wbc

3.protein is a macromolecule it is made up of?

- I. carbon
- J. magnesium
- K. aminoacids
- L. sucrose

4.polysaccharides is made up of ?

- m) monosaccharides
- n) Aminoacid
- o) Nitrogen
- p) Potassium

5.example of prokaryote cell

Q. bacteria

R. Rat cell

s. Human cell

T. Plant cell

Answers

1.b

2.a

3.c

4.a

5.a

MEMBRANE TRANSPORT

Explain the structure of the plasma membrane.

Fluid mosaic model of Membrane

Passive Transport Mechanisms

Classify membrane transport mechanisms.

Add a note on active transport.

- . Classify transport mechanisms across the cell membrane. Define uniport, symport, antiport with examples.**

Explain the structure of the plasma membrane.

Fluid mosaic model of Membrane

Plasma Membrane :- It is a protective sheath.

- It is an elastic structure
- It envelops the cell body.
- This membrane separates extracellular fluid from intracellular fluid.

The plasma membrane consists of:

1) lipid layer

lipid bilayer is composed of three main types of lipids:

- phospholipids
- sphingolipids
- cholesterol.

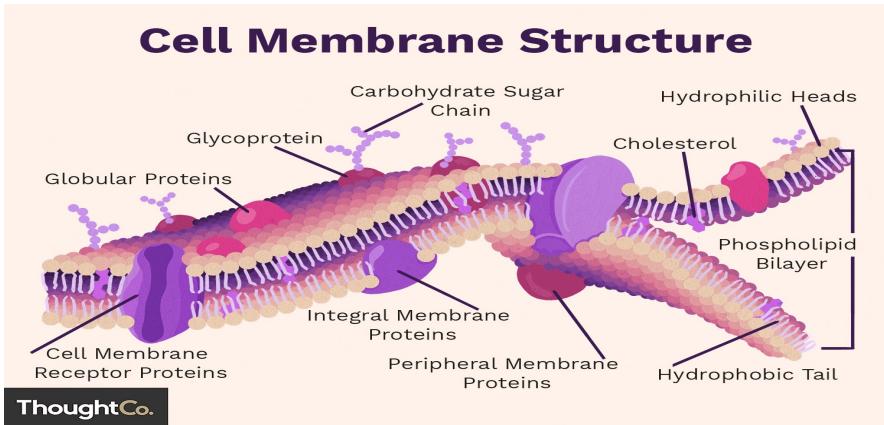
3. Membrane Proteins

The protein substances present in protein layer is classified into two categories:

1. Integral proteins.
2. Peripheral Proteins.

4. Carbohydrate Groups

These are present only on outer side and attached to lipids (glycolipids) or proteins (glycoproteins), aiding in cell recognition and communication.



The Fluid mosaic model, proposed by Singer and Nicolson, provides a comprehensive understanding of the structure of biological membranes. This model is widely accepted due to its accuracy in describing the complex composition and behavior of cell membranes.

Membrane Thickness and Composition

Biological membranes are remarkably thin, typically ranging from 5 to 8 nanometers in thickness.

These membranes are primarily composed of a lipid bilayer, which is a double layer of lipid molecules.

This bilayer serves as the fundamental structural component of the membrane.

Lipid Bilayer Arrangement

The hydrophobic (nonpolar) regions of the lipid molecules face each other at the core of the bilayer, creating a hydrophobic interior.

The hydrophilic (polar) regions face outward, interacting with the aqueous environment both inside and outside of the cell.

Extrinsic (Peripheral) Membrane Proteins

- These proteins are loosely associated with the surface of the membrane.

- They can be easily separated from the membrane.

- An example of an extrinsic protein is cytochrome c found in mitochondria.

Intrinsic (Integral) Membrane Proteins

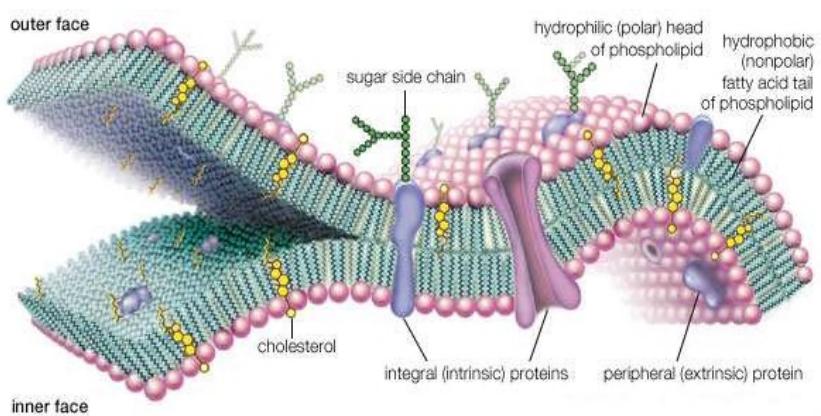
- Intrinsic proteins are tightly integrated into the lipid bilayer.

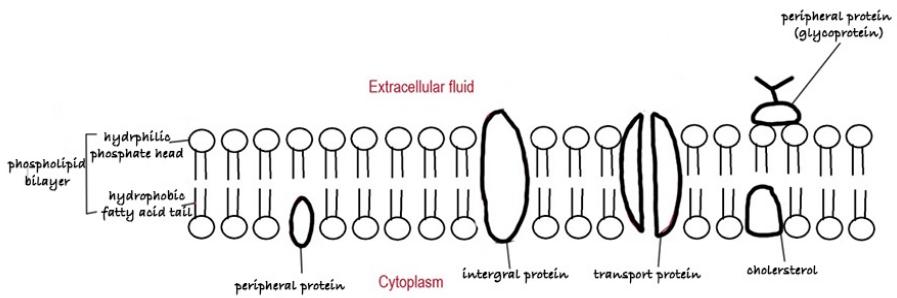
- They can only be separated from the membrane through the use of detergents or organic solvents.

- Examples of intrinsic proteins include hormone receptors and cytochrome P450.

Asymmetry and Mosaic Appearance

One of the critical observations of the fluid mosaic model is that membranes exhibit asymmetry. This is due to the irregular distribution of proteins across the membrane's surface, resulting in a mosaic-like appearance. The combination of lipid and protein subunits in the membrane creates a mosaic.



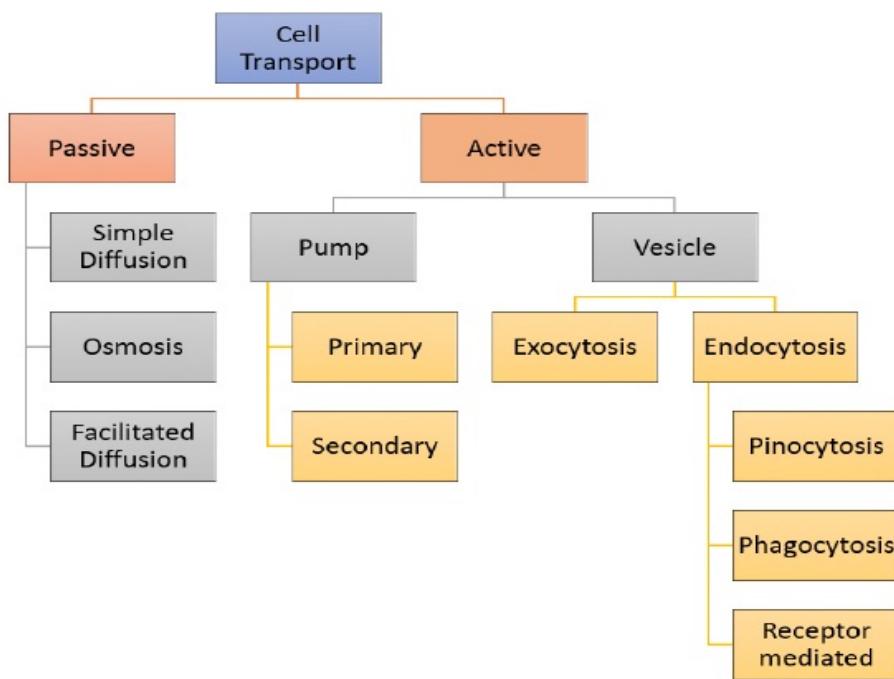


Classify membrane transport mechanisms. Add a note on passive and active transport

Transport mechanism across the cell membrane helps in transport of essential substances like nutrients, water, electrolytes to the cell

- It also helps the Cells to get rid of unwanted substances like waste materials, CO₂.

Classification :-



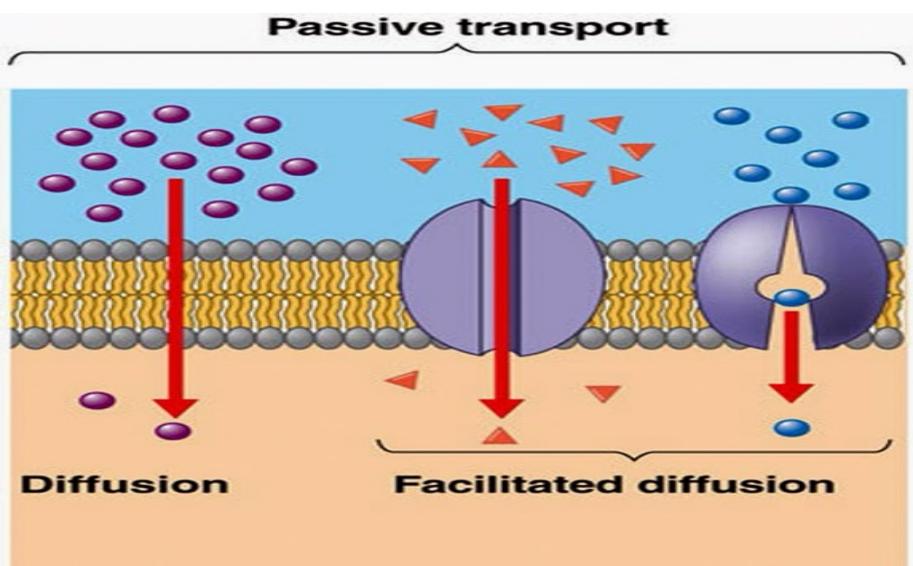
PASSIVE TRANSPORT

Simple diffusion :

- simple process depends on concentration gradient of a particular substance across the membrane.
- Passage of water and gases through membrane occurs by passive diffusion.
- This process does not require energy.

2. Facilitated diffusion :

- Solute moves along the concentration gradient (from higher to lower concentration) and no energy is needed.
- distinguishing feature is facilitated diffusion occurs through mediation of carrier or transport proteins.
- Specific carrier proteins for the transport of
1. glucose
2. galactose
3. leucine
4. phenylalanine have been isolated



Mechanism of Facilitated diffusion :

- transport(carrier)protein exists in two conformations.
- pong conformation-exposed to side with high solute concentration
- This allows binding of solute to specific sites on carrier protein.
- Protein undergoes a conformational change (ping state) to expose to the side with low solute concentration
- solute molecule is released.
- Hormones regulate facilitated diffusion.

EXAMPLE:

- 1.insulin- increases glucose transport in muscle and adipose tissue
- 2.amino acid -transport in liver and other tissues.

Active transport

Active transport is the movement of substances against the chemical or electrical or electrochemical gradient.

- It is also called uphill transport.
- It requires energy
- Energy is obtained by breaking down adenosine triphosphate (ATP).

Carrier proteins involved in active transport are of two types:

1. Uniport : carries a substance only in single direction
2. Symport/antiport: this type of carrier protein can transports two substances at a time.

Active transport is of two types
i) primary active transport
ii)Secondary active transport

Primary active transport

It is the type of transport mechanism in which the energy is liberated directly from the breakdown of ATP.

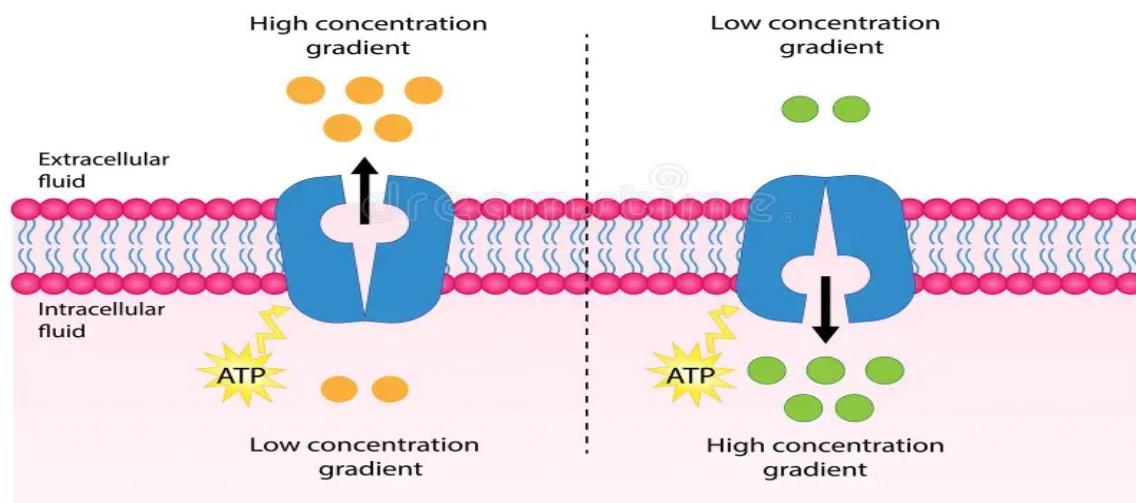
sodium, potassium, calcium, hydrogen and chloride are transported by this method.

Example :- sodium potassium (Na⁺-K⁺) pump

This pump transports sodium from inside to outside the cell and potassium is transported from outside to inside the cell

This pump is responsible for the distribution of sodium and potassium ions across the cell membrane

Active Transport



Secondary active transport

It is the transport of a substance with sodium ion, by means of a common carrier protein. i.e. When sodium is transported by a carrier protein, another substance is also transported by the same protein simultaneously.

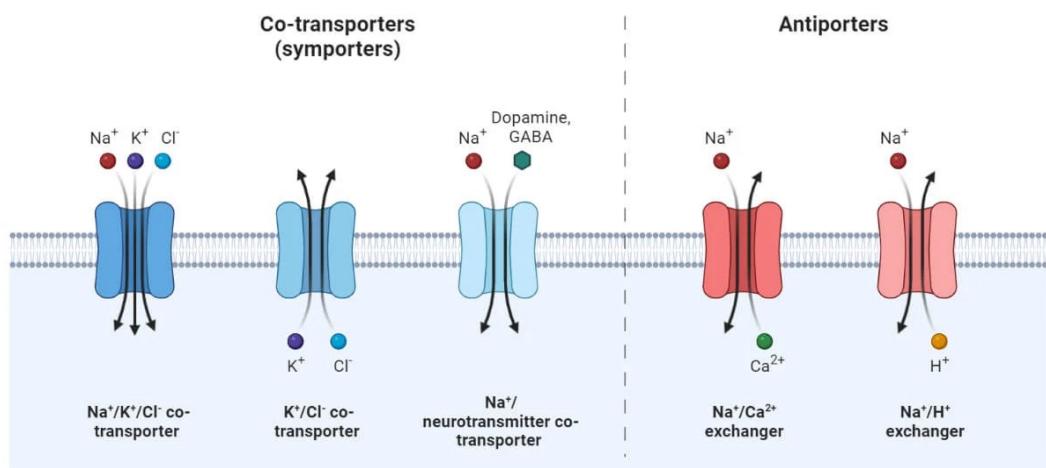
- It may be in the same direction of sodium movement or in the opposite direction.

It may be in the **same** direction of sodium movement or in the **opposite** direction.

Secondary active transport is of two types:

1. Cotransport (same direction)
2. Counter transport.(opposite direction)

Examples of Secondary Active Transporters



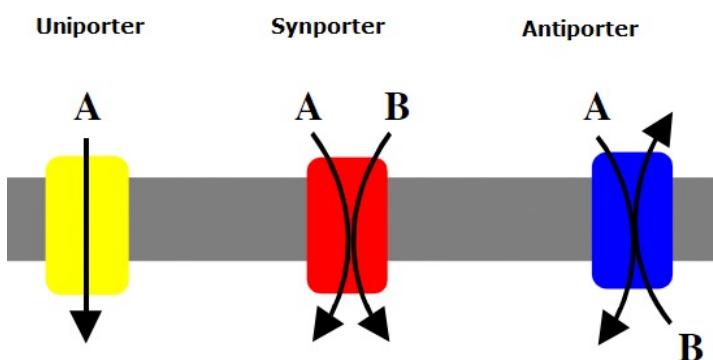
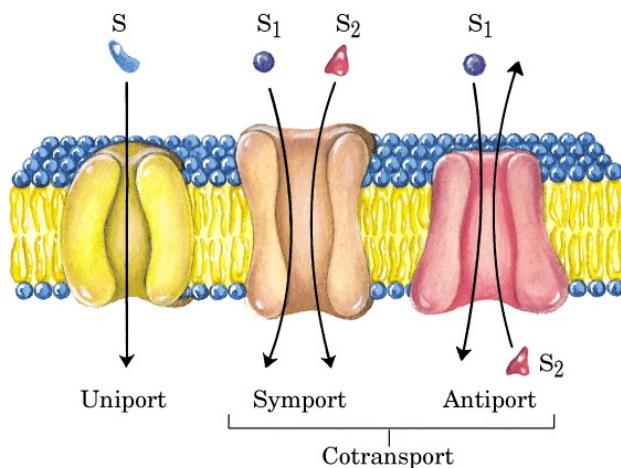
. Classify transport mechanisms across the cell membrane. Define uniport, symport, antiport with examples.

**Classification discussed in another answer **

Uniport system : This involves the movement of a single molecule through the membrane e.g. transport of glucose to the erythrocytes.

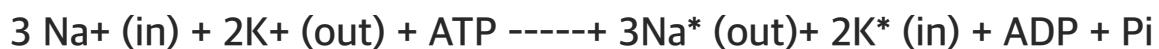
2. **Symport system** : The simultaneous transport of two different molecules in the same direction
e.g. transport of Na^+ and glucose to the intestinal mucosal cells from the gut.

3. **Antiport system** : The simultaneous trans- port of two different molecules in the opposite direction
e.g exchange of Cl^- and HCO_3^- in the erythrocytes. Uniport, symport and antiport systems are considered as secondary active transport systems.



Na⁺-K⁺ pump :

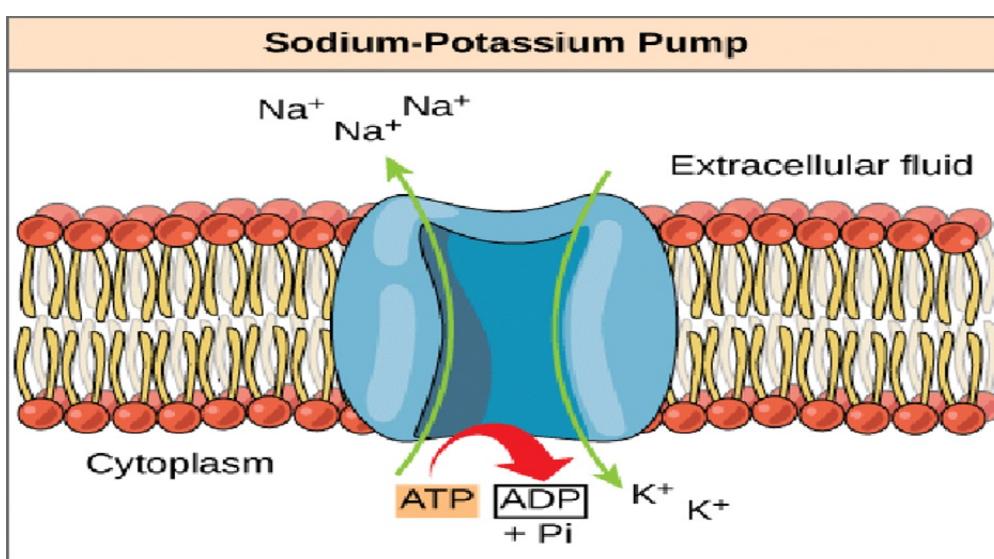
- cells have a high intracellular K⁺ concentration and a low Na⁺ concentration.
- Na⁺-K⁺ pump Consists of two alpha and two beta subunits
- Na⁺-K⁺ ATPase pumps 3Na⁺ ions from inside cell to outside and brings 2K⁺ ions from the outside to inside with a concomitant hydrolysis of intracellular ATP.



- major portion of cellular ATP utilized by Na⁺-K⁺ pump to maintain requisite cytosolic Na⁺ and K⁺ levels.
- Ouabain inhibits Na⁺-K⁺ ATPase.

Na⁺-cotransport system :

- amino acids and sugars are transported into cells by Na⁺-cotransport system
- consists of passage of glucose(or amino acid)into cell with a simultaneous movement of Na⁺.
- ATP is required to pump out intracellular Na⁺ through mediation of Na⁺-K⁺ ATPase.



TRANSPORT OF MACROMOLECULES:

- transport of macromolecules such as proteins, polysaccharides and polynucleotides across the membranes is equally important.

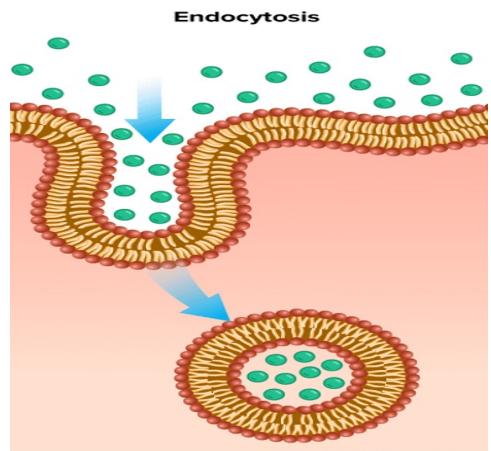
- two independent mechanisms namely

1. endocytosis-intake of macromolecules by the cells

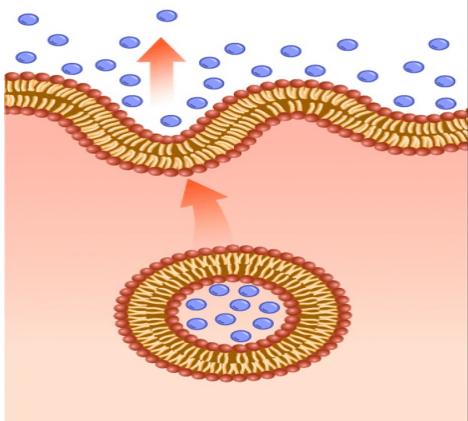
2. exocytosis -release of macromolecules from cells to outside

Endocytosis :

- estimated approximately of exterior surface of plasma membrane possesses characteristic coated pits.
- pits can be internalized to form coated vesicles which contain an unusual protein called clathrin.
- Uptake of low density lipoprotein (LDL) molecules by cells is a good example of endocytosis.



Exocytosis



Exocytosis:

- Release of macromolecules to outside of the cells mostly occurs via Golgi apparatus.
- macromolecules are transported to the plasma membrane in vesicles
- secretion of hormones (e.g) insulin, parathyroid hormone) usually occurs by exocytosis.

MCQ'S

Q1) WHICH OF THE FOLLOWING IS NOT AN PRIMARY ACTIVE TRANSPORT?

- a) Na-k atpase
- b) h-k atpase
- c) h atpase
- d) cl-hc03 exchange

ANS:D)CL-HC03 EXHANGE

Q2) WHICH OF THE FOLLOWING IS NOT AN TRANSPORT SYSTEM?

- A)uniport
- B)symport
- c)antiport
- d)biport

ANS:D)BIPORT

Q3) MOVEMENT OF IONS IN NA-K ATPASE?

- A)3na and 2k
- b)2na and 3 k
- c)3 na and 1 k
- d)2na and 2 k

ANS:A)3NA AND 2K

A horizontal line for a signature, ending with a small icon of a pen nib pointing upwards and to the right.

- Classification of carbohydrates with suitable examples.
- Monosaccharides.
- What are Mucopolysaccharides? Mention Describe their biomedical importance with suitable examples.
 - Compare and contrast the structural differences between starch and glycogen.
 - Epimerism and anomerism.
 - Mutarotation.
 - Why is sucrose a non-reducing sugar?
 - Composition of sucrose, maltose and lactose.

Describe polysaccharides.

Describe disaccharides.

mucopolysaccharides, location, and its function.

Carbohydrates

INTRODUCTION OF CARBOHYDRATES

They are the major source of energy from our diet.

. They composed of the elements C, H and O.

. They are also called saccharides, which means "sugars." are produced by photosynthesis in plants .

. Such as glucose which are synthesised in plants from CO₂, H₂O, and energy from the sun.

. (CH₂O)_n : Molecular/Chemical formula

n-> no. of total carbons

. Isomers - 2N

n -> no. of asymmetrical/chimeric carbons

. Carbohydrates are compounds of biological importance , includes :

- . provide energy through oxidation
- . supply carbon for the synthesis of cell components
- . serve as a form of stored chemical energy
- . Form part of the structures of some cells and tissues

major carbohydrates include

1 . D-Glucose

👉 . Blood sugar. Main source of energy in body.

2 . D-Fructose

Constituent of sucrose, the common sugar.

3 . D-Galactose

Constituent of lactose, glycolipids and glycoproteins.

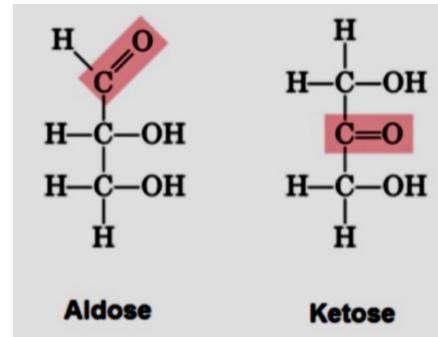
4 . D-Mannose

Constituent of globulins, mucoproteins and glycoproteins.

BASICS OF CARBOHYDRATE CHEMISTRY

Carbohydrates defined as Poly hydroxy group with Aldehyde or Ketones

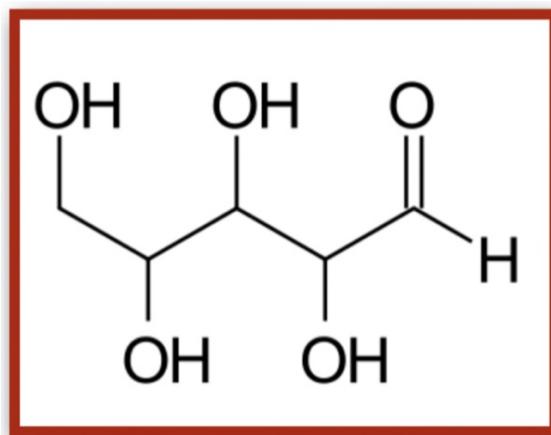
- 👉 . POLYHYDROXY means many OH groups
- 👉 . OH GROUP group makes the carbohydrate
- 1 . Polar
- 2 . Has tendency to bind phosphate
- 3 . Suffix - 'ol' (Eg. Glycerol)
- 4 . No.ofOHgroupsareless than 1 the no. of carbon atoms



- 👉 . CHOLESTEROL - Amphipathic (polar & non-polar components)
- 👉 . ALDEHYDE OR KETONE - Functional Groups
- 👉 . Aldehyde group is always present at C1
- 👉 . Keto group is always present at C2
- 👉 . Functional carbon is symmetric but only in linear configuration 👉 .
SYMMETRIC CARBON - Any 2/3/4 valencies are occupied by same group-of atoms

👉 . ASYMMETRIC CARBON

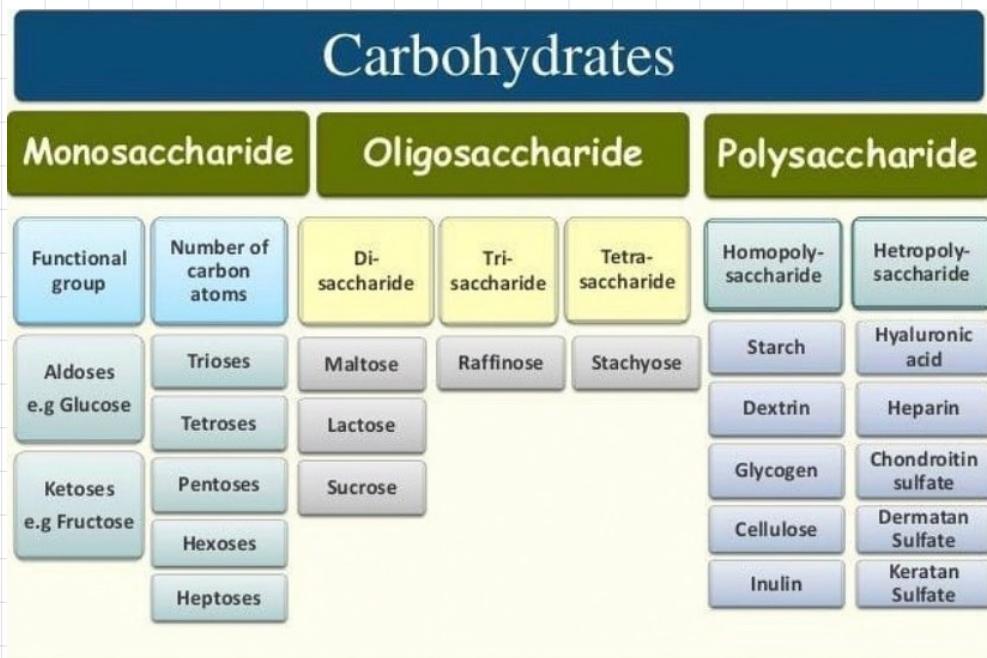
- ➡ . An asymmetric carbon atom (chiral carbon) is a carbon atom that is attached to four different types of atoms or groups of atoms
- ➡ . Whenever a compound has asymmetric carbon, that compound will show both structural & optical isomerism
- ➡ . Central carbon is asymmetric & shows both Structural & Optical isomerism
- ➡ . Knowing the number of asymmetric carbon atoms, one can calculate the maximum possible number of stereoisomers for any given molecule as follows:
- ➡ . If n is the number of asymmetric carbon atoms then the maximum number of isomers = 2^n (Le Bel-van't Hoff rule).
- ➡ . An aldopentose with 3 asymmetric carbon atoms has $2^3 = 8$ stereoisomers:



CLASSIFICATION OF CARBOHYDRATES

Question: what is the classification of carbohydrates ?

CLASSIFICATION OF CARBOHYDRATES



Question : what are different types of monosaccharides and their biological importance

monosaccharides contain 2-9 carbon molecule

- Monosaccharides, often called simple sugars, are the simplest group of carbohydrates.
- They have the general formula $C_n(H_2O)_n$ and cannot be further hydrolyzed.
- Monosaccharides are categorized based on the functional group and the number of carbon atoms.
- Aldoses are monosaccharides with an aldehyde functional group (e.g., glyceraldehyde, glucose).
- Ketoses are monosaccharides with a keto functional group (e.g., dihydroxyacetone, fructose).
- Monosaccharides are further classified as trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C), and heptoses (7C) based on the number of carbon atoms.
- These classifications, along with functional groups, are used in the naming of monosaccharides. For example, glucose is an aldohexose, while fructose is a ketohexose.

Monosaccharides	Occurrence	Biochemical importance
Trioses		
Glyceraldehyde	Found in cells as phosphate	Glyceraldehyde 3-phosphate is an intermediate in glycolysis
Dihydroxyacetone	Found in cells as phosphate	Its 1-phosphate is an intermediate in glycolysis
Tetroses		
D-Erythrose	Widespread	Its 4-phosphate is an intermediate in carbohydrate metabolism
Pentoses		
D-Ribose	Widespread as a constituent of RNA and nucleotides	For the structure of RNA and nucleotide coenzymes (ATP, NAD ⁺ , NADP ⁺)
D-Deoxyribose	As a constituent of DNA	For the structure of DNA
D-Ribulose	Produced during metabolism	It is an important metabolite in hexose monophosphate shunt
D-Xylose	As a constituent of glycoproteins and gums	Involved in the function of glycoproteins
L-Xylulose	As an intermediate in uronic acid pathway	Excreted in urine in essential pentosuria
D-Lyxose	Heart muscle	As a constituent of lyxoflavin of heart muscle
Hexoses		
D-Glucose	As a constituent of polysaccharides (starch, glycogen, cellulose) and disaccharides (maltose, lactose, sucrose). Also found in fruits	The 'sugar fuel' of life; excreted in urine in diabetes. Structural unit of cellulose in plants
D-Galactose	As a constituent of lactose (milk sugar)	Converted to glucose, failure leads to galactosemia
D-Mannose	Found in plant polysaccharides and animal glycoproteins	For the structure of polysaccharides
D-Fructose	Fruits and honey, as a constituent of sucrose and inulin	Its phosphates are intermediates of glycolysis
Heptoses		
D-Sedoheptulose	Found in plants	Its 7-phosphate is an intermediate in hexose monophosphate shunt, and in photosynthesis

Describe disaccharides.

Composition of sucrose, maltose and lactose.

DISACCHARIDES - 2 monosaccharides bound by glycosidic bond

Maltose	Glu + Glu	alpha (1 - 4)	Reducing sugar
Isomaltose	Glu + Glu	alpha (1-6)	Reducing sugar
Trehalose	Glu + Glu	alpha (1-1)	Non - Reducing sugar
Sucrose	Glu + Fruc	alpha. (1. - 2)	Non - Reducing sugar
Lactose	Gal+ Glu	B (1 - 4)	Reducing sugar

- 👉 . When two monosaccharide are combined by glycosidic linkage, a disaccharide is formed.
- 👉 . Therefore they yield two molecules of same or different monosaccharide on hydrolysis.
- 👉 . General formula of Disaccharides : $C_n(H_2O)_{n-1}$
- 👉 . They are formed when two monosaccharides combine in a dehydration reaction
- 👉 . Monosaccharides - Disaccharide
 - glucose + glucose - maltose + H₂O
 - glucose + galactose- lactose
 - glucose + fructose - sucrose

Sucrose

- Sucrose (cane sugar) is a common commercial sugar produced primarily from sugar cane and sugar beets.
- Sucrose consists of two monosaccharides: α-D-glucose and β-D-fructose.
- These two monosaccharides are connected by a glycosidic bond (α-1,2 linkage), specifically between C1 of α-glucose and C2 of β-fructose.
- Because the reducing groups of glucose and fructose are involved in the glycosidic bond, sucrose is a non-reducing sugar and cannot form osazones.
- Sucrose is a significant source of dietary carbohydrates and is employed as a sweetening agent in the food industry.
- It is sweeter than most common sugars, such as glucose, lactose, and maltose (except for fructose).
- In the intestine, the enzyme sucrase hydrolyzes sucrose into glucose and fructose, which are then absorbed into the body.

MALTOSE

- 👉 Maltose, is a disaccharide formed from two units of glucose.
- 👉 . Maltose is commonly called Malt Sugar.
- 👉 It is produced commercially and used as an energy
- 👉 source for growing embryo in seed
- 👉 Used in alcohol production.

LACTOSE

- 👉 Lactose is a disaccharide derived from the condensation of Galactose and glucose
- 👉 Lactose is commonly called Milk Sugar
- 👉 It is Dextrorotatory
- 👉 Lactose requires you have an enzyme called lactase to digest
- 👉 Widely used in food industry.
- 👉 Also used as filler in tablets.

EXTRA EDGE

What is inversion of sucrose ??

- Sucrose is naturally dextrorotatory ($+66.5^\circ$).
- When sucrose is hydrolyzed, it becomes levorotatory (-28.2°), and this change in optical rotation is called inversion.
- The hydrolyzed mixture of sucrose, containing glucose and fructose, is known as invert sugar.
- The process of inversion occurs during the hydrolysis of sucrose, which can be catalyzed by the enzyme sucrase (invertase) or dilute acid.
- During this process, sucrose is first split into α -D-glucopyranose ($+52.5^\circ$) and β -D-Fructofuranose, both of which are dextrorotatory.
- However, β -D-Fructofuranose is less stable and quickly converts to β -D-Fructopyranose, which is strongly levorotatory (-92°).
- As a result, the overall effect is that dextrorotatory sucrose ($+66.5^\circ$) is converted to the levorotatory form (-28.2°) after inversion.

Its revision time

Carbohydrates

Monosaccharide		Oligosaccharide			Polysaccharide	
Functional group	Number of carbon atoms	Di-saccharide	Tri-saccharide	Tetra-saccharide	Homopolysaccharide	Heteropolysaccharide
Aldoses e.g Glucose	Trioses	Maltose	Raffinose	Stachyose	Starch	Hyaluronic acid
Ketoses e.g Fructose	Tetroses	Lactose			Dextrin	Heparin
	Pentoses	Sucrose			Glycogen	Chondroitin sulfate
	Hexoses				Cellulose	Dermatan Sulfate
	Heptoses				Inulin	Keratan Sulfate

POLYSACCHARIDES

Question: what are different types of polysaccharides ?

POLYSACCHARIDES are two types

1. HOMO POLYSACCHARIDES

- 👉 Made up of same carbohydrate units
- 👉 Mostly Branched

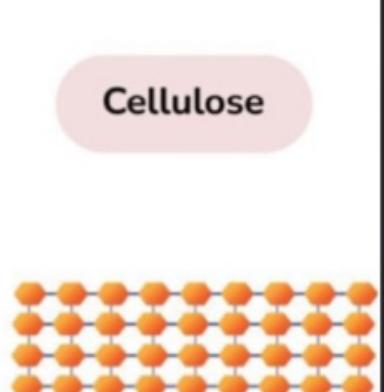
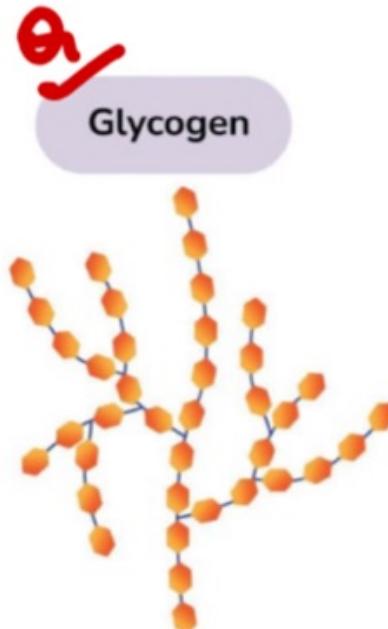
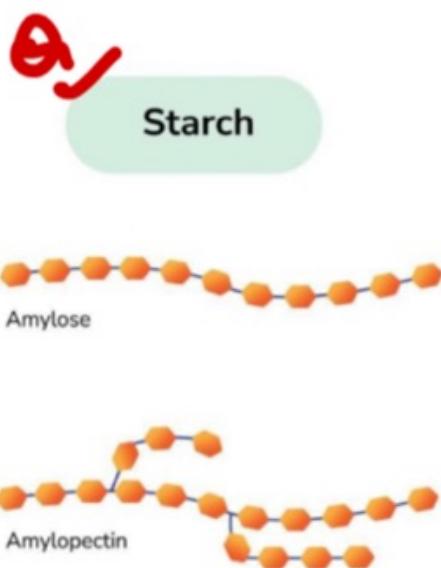
2. HETERO POLYSACCHARIDES

- 👉 Made up of different carbohydrates units
- 👉 Mostly unbranched

HOMOPOLYSACCHARIDES

👉 different types of HOMO POLYSACCHARIDES

1. STARCH
2. GLYCOGEN
3. DEXTRAN
4. CELLULOSE
5. INULIN
6. DEXTRIN
7. CHITIN



Question : what are different and similarities Btw starch and glycogen?

Similarities

1. Both starch and glycogen are polysaccharides, composed of multiple sugar (glucose) units linked together.
2. Glucose is the basic repeating unit in both starch and glycogen, connected by glycosidic bonds.
3. They serve as storage forms of carbohydrates in their respective organisms, providing a readily available energy source.
4. Both starch and glycogen contain α -glycosidic bonds in their structures, which contribute to their branching patterns.

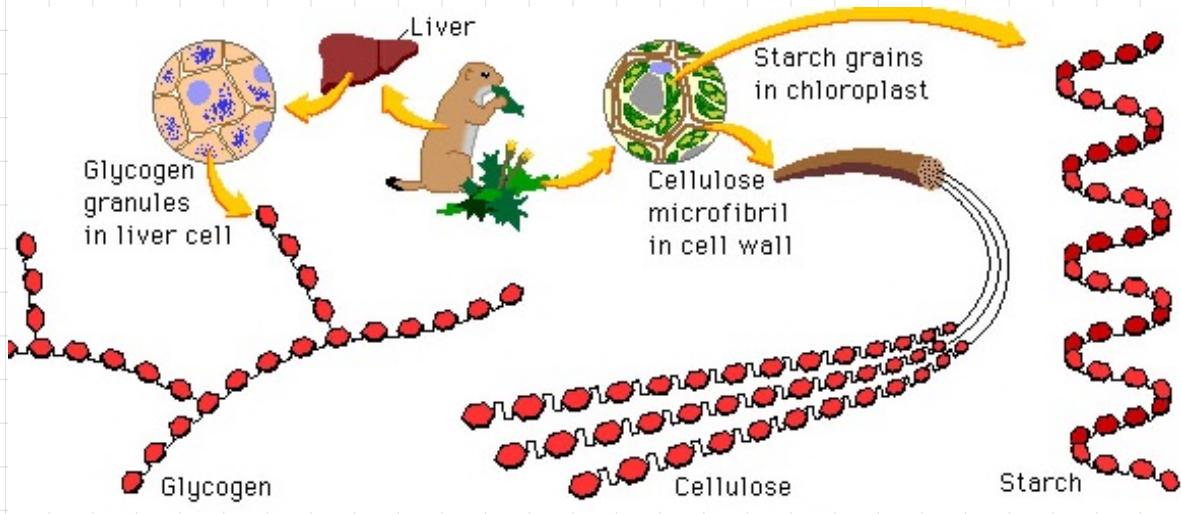
Differences between Starch and Glycogen: [Table]

Starch:

1. Starch is primarily found in plants and serves as their carbohydrate reserve.
2. It consists of two main components, amylose (water-soluble) and amylopectin (water-insoluble), each with distinct structural characteristics.
3. Amylopectin is branched with $\alpha(1 \rightarrow 6)$ glycosidic bonds at the branching points, creating a more complex structure.
4. Starch is an essential dietary component for humans and plays a significant role in nutrition.

Glycogen:

1. Glycogen is the primary carbohydrate storage molecule in animals, including humans.
2. It is highly concentrated in the liver, muscles, and other tissues of animals.
3. Glycogen has more numerous branches than starch, with $\alpha(1 \rightarrow 6)$ glycosidic bonds at branching points.
4. Glycogen primarily functions as a short-term energy reserve in the human body, particularly in muscles and the liver.



Question: what is dextran and use of it ?

DEXTRAN

- 👉 Made up of alpha - glucose
- 👉 Has $\alpha(1\rightarrow4), \alpha(1\rightarrow6), \alpha(1\rightarrow2), \alpha(1\rightarrow3)$ bonds
- 👉 High molecular weight structure
- 👉 Highly branched structure
- 👉 i/v (intravenously) Dextran is used as Plasma volume expander in hypovolemic shock
- 👉 In Gel Filtration chromatography, Gel is dextran

CELLULOSE

- Cellulose is exclusively found in plants and is the most abundant organic substance in the plant kingdom.
- It is a major component of plant cell walls, providing structural support.
- Cellulose is completely absent in the bodies of animals.
- Cellulose is composed of β-D-glucose units linked by $\beta(1\rightarrow4)$ glycosidic bonds.
- Mammals, including humans, lack the enzyme needed to break β -glycosidic bonds, so they cannot digest cellulose (α -amylase breaks α -bonds only).
- Some ruminants and herbivorous animals have gut microorganisms that produce enzymes capable of cleaving β -glycosidic bonds.
- Hydrolysis of cellulose results in the formation of the disaccharide cellobiose, followed by β -D-glucose.

Donot get confused

"Dextrins result from starch breakdown, while dextrans are glucose polymers in microbes "

DextRAN - runs in blood '(plasma volume expander)

Extra edge

Question: what are different types of Fibers ?

FIBRES - TYPES

1. INSOLUBLE

- Cellulose
- Hemicellulose
- 👉 Excreted unchanged

2. SOLUBLE

- .- Pectins
- 👉 Absorbs water & converted to Gel form, which is excreted
- 👉 Better in preventing Constipation

Question: what is inulin and use of it ?

INULIN

Made up of B Fructose

USES

- 👉 Ideal for measuring GFR
- 👉 PREBIOTIC (Food for Bacteria)

HETEROPOLYSACCHARIDES

Question: What are heteropolysaccharides and features ?

Mucopolysaccharides are heteroglycans made up of repeating units of sugar derivatives, namely amino sugars and uronic acids. These are more commonly known as glycosaminoglycans (GAG).

- 👉 . Defined as Tandem Repeat AS- UA
- 👉 . Present in mucus secretions (lubricant)
- 👉 . All GAGS combine with proteins to form PROTEOGLYCANs
- 👉 . Highly SULFATED
- 👉 . Contains more negative charge
- 👉 . Slimy & Slippery

EXAMPLES

Mucopolysaccharides or glycosamino glycans (GAG) are heteropolysaccharides, containing uronic acid and amino sugars.

Acetylated amino groups, sulfate and carboxyl groups are also generally present. They attract water molecules and so they produce viscous solutions.

Mucopolysaccharides in combination with proteins form mucoproteins. Examples of mucopolysaccharides are..

1. Hyaluronic Acid

It is present in connective tissues, tendons, synovial fluid and vitreous humor.

It serves as a lubricant in joint cavities.

It is composed of repeating units of N-Acetyl-glucosamine → Glucuronic acid

2. Heparin

It is an anticoagulant widely used when taking blood in vitro for clinical studies.

It is also used in vivo to prevent intravascular coagulation.

It activates antithrombin III, which in turn inactivates thrombin, Factor X and Factor IX.

Heparin is present in liver, lungs, spleen and monocytes.

3. Chondroitin Sulphate

It is present in ground substance of connective tissues

Widely distributed in cartilage, bone, tendons, cornea-and skin.

4. Keratan Sulphate

It is the only GAG which does not contain any uronic acid.

The repeating units are galactose and N-acetyl glucosamine in beta linkage.

It is found in cornea and tendons.

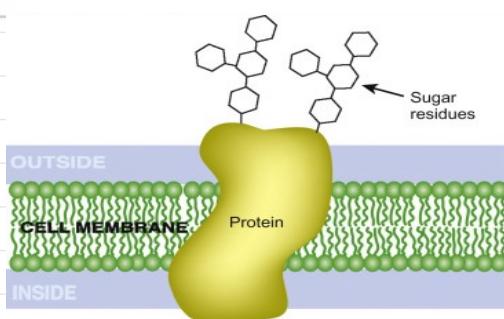
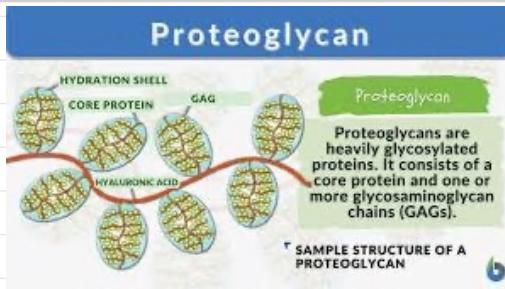
5. Dermatan Sulphate:

It is found in skin, blood vessels and heart valves.

It is helpful in maintaining shape and structure of tissue.

Question: what are differences btw proteoglycans and glycoproteins ?

PROTEO GLYCANS	GLYCO PROTEIN
Carbohydrate >> Protein	Protein >> Carbohydrate
Ex: GAGS	Ex: Collagen
Carbohydrate is always Heteropolysaccharide	ALL plasma proteins > EXCEPT ALBUMIN (only protein)



ISOMERISM

Question : What are isomerism for carbohydrate ?

Isomerism

👉 The existence of two or more molecules having the same molecular formula, but with different bonding arrangements of atoms, or different orientation of their atoms in space

(1) STRUCTURAL / STEREO ISOMERISM

Functional

Enantiomerism

Epimerism

Anomerism

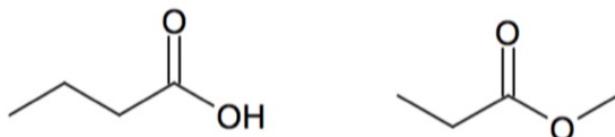
2) OPTICAL ISOMERISM

Question : What are types of structural isomersim ?

STRUCTURAL / STERIO ISOMERS - compounds with the same molecular formula, but which differ in the spatial arrangement of their atoms.

(1)FUNCTIONAL ISOMERS

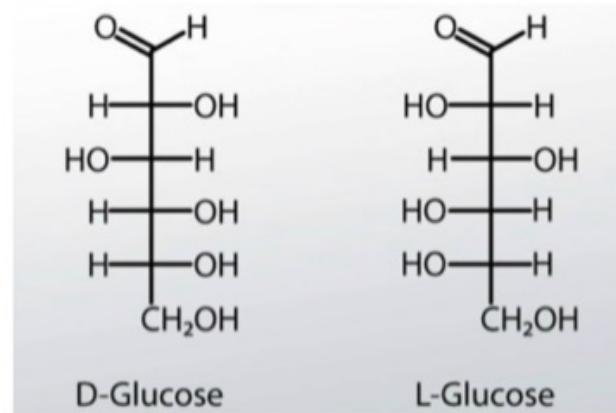
👉 . Two or more compounds having the same molecular formula but different functional groups are functional group isomerism.



2 . ENANTIOMERISM | D/ L ISOMERISM / mirror images

👉 . Different H & OH orientation around the penultimate carbon Reference 2nd last carbon

👉 ABUNDANT FORMS IN Carbohydrates are D forms , Amino Acids are L forms



3. EPIMERISM

👉 . Always Exogenous

👉 . Different H & OH orientation around only one carbon other than penultimate carbon

👉 . Mannose is epimer of glucose at C2

👉 . Galactose is epimer of glucose at C4

👉 . Mannose & Galactose are not epimers of each other

Question : What are different anomersims for carbohydrate ?

4. ANOMERISM

- 👉 . Linear Structures To Cyclic Structure's
- 👉 . The combining carbons are Functional carbons; Always combine with 2nd last carbon

CYCLIC STRUCTURE

1) PYRANOSE

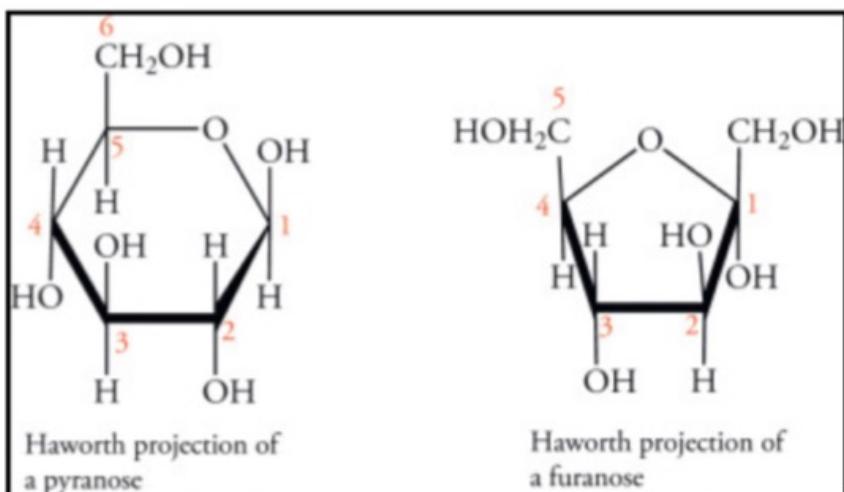
- 👉 . 6 Membered Ring

- 👉 . No. of carbons -5

2) FURANOSE

- 👉 . 5 Membered Ring

- 👉 . No. of carbons -4

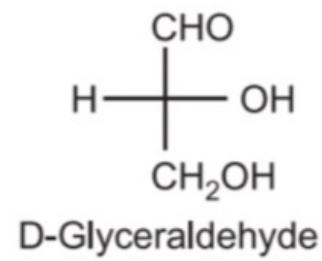
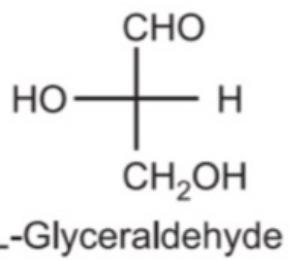


- 👉 . Glucose includes 99% Pyranose, 1% Furanose mainly Pyranose
- 👉 . Fructose includes 1.99% Furanose g% pyranose mainly Furanose
- 👉 . In Hexoses (6C) Both Pyranose & Furanose exists
- 👉 . In Pentoses (5C) Only Furanose exists

Question : What are types of optical isomersim ?

OPTICAL ISOMERISM

- 👉 . Same molecular formula but different optical properties
- 👉 . right - dextro rotatory (d) (+)
- 👉 . Left - levo rotatory Cl) (-)
- 👉 . Glucose is always d (+)
- 👉 . Fructose is always I (-)
- 👉 . Levo rotatory power of Fructose more than Dextro rotatory power of Glucose
- 👉 RACEMIC MIXTURE - Equal d + I, Optically inactive
- 👉 RACEMASE - Interconvert 2 isomers



Question : What are test for carbohydrate ?

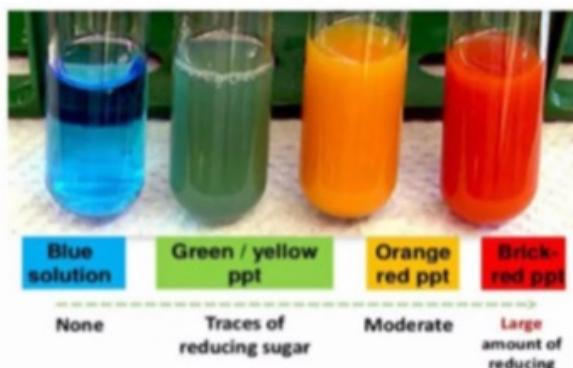
TESTS

1. MOLISCH TEST

- 👉 . General test given by all
- 👉 . No. of carbons $> \geq 5$

2. BENEDICT'S TEST

- 👉 . Given by reducing sugars to detect the presence of glucose in urine (gluco- suria).
- 👉 . It is a standard laboratory test employed to diagnose diabetes mellitus.
- 👉 . Benedict's reagent contains sodium carbonate, copper sulphate and sodium citrate.
- 👉 . Any sugar with free aldehyde/ keto group will reduce the Benedict's reagent
- 👉 . Therefore, this is not specific for glucose



3. SELIWANOFF TEST

- 👉 . Distinguish b/w keto & Aldehyde sugar
- 👉 . Positive in keto sugar

4. BARFOED'S TEST

- 👉 . Positive in monosaccharides
- 👉 . Distinguishes b/w mono & Disaccharides

5. GOD - POD TEST (Glucose Peroxidase Oxidase Enzymatic test)

- 👉 Measures blood glucose
- GLUCOSE under action of GOD form Gluconic Acid + H₂O₂ under action POD coloured Compound formed
- 👉 . Accurate

6. Osazone Formation

- 👉 . All reducing sugars will form osazones with excess of phenylhydrazine when kept at boiling temperature
- 👉 Osazones are insoluble.
- 👉 Each sugar will have characteristic crystal form of osazones



Introduction

This chapter uncovers the central role of proteins in our lives. Enzymes drive chemical reactions, hormones regulate our bodies, and immunoglobulins protect us from infections, all hinging on proteins. Understanding denaturation, where proteins unravel due to factors like heat, sheds light on why some injections require refrigeration.

But this journey isn't confined to textbooks; it's practical. In today's fitness-conscious world, proteins are key to sculpting the body you desire. You'll grasp the significance of amino acids, the building blocks of life, and their essential role in nutrition. You'll differentiate between proteins that align with your fitness goals and those to avoid. These insights will guide your daily dietary choices and fitness routines.

Through this exploration, you'll realize that proteins are the foundation of life, shaping not only your health but also your understanding of the world within and around you.

Amino acids and proteins

Amino Acids:

- Compounds with both amino group (NH_2) and carboxyl (COOH) groups.
- Building blocks (monomeric units) of peptides and proteins bonded by peptide bonds.

Peptides and Proteins:

- Polymers of amino acids bonded by peptide bonds.

Peptide Bonds:

- Formed between two amino acids.
- Created between a carboxyl group of the first amino acid and an amino group of the next.
- Number of peptide bonds is one less than the amino acid residues in the chain (e.g., dipeptides have 2 amino acids and 1 peptide bond).

Amino Acids / Amino Acid Residues:

- Once included in a peptide or protein chain, they are called amino acid residues or amino acid moieties.

Difference between Peptides and Proteins:

- Peptides: 2-50 amino acids in the chain.
 - Oligopeptide: 2-10 amino acids.
 - Polypeptide: 11-50 amino acids.
- Proteins: More than 50 amino acids.
 - Note: Some authors consider chains with over 100 amino acids as proteins.
 - Example: Insulin (51 amino acids) can be labeled as a protein or polypeptide.

Proteins are organic compounds with a high molecular weight formed of carbon, oxygen, hydrogen and nitrogen and may also contain sulphur, phosphorus and non-protein organic groups and metal ions.

They are polymers formed of subunits called amino acids linked together by peptide linkage.

INTRODUCTION

👉 Functional groups of Amino Acids

1. Amino group is always on left side
2. Acid group is always on right side

👉 Central carbon atom is Asymmetric

👉 Can show both Optical & Structural Isomerism

👉 ALL AA HAVE 1 ASYMMETRIC CARBON , EXCEPTIONS

No asymmetrical carbon - Glycine

2 asymmetrical carbons - Isoleucine , Threonine

Classification of amino acids based on nutritional requirement with suitable examples.

Classification of amino acids based on chemical structure with suitable examples.

Classification of amino acids

The 20 primary protein amino acids can be classified on several basis. These are,

I. Based on the Chemical structure:

Amino acids are classified into 7 structural groups.

1) Aliphatic amino acids:

- a) Non-branched chain amino acids: Glycine, Alanine.
- b) Branched chain amino acids: Valine, Leucine and Isoleucine.

2) Aromatic amino acids: Tryptophan, Phenylalanine, Tyrosine, Histidine

3) Sulphur containing amino acids: Cysteine and Methionine.

4) Hydroxy amino acids: Serine, Threonine and Tyrosine

5) Amino acids with amide group (CONH₂): Asparagine, Glutamine

6) Charged amino acids: Include Acidic amino acids, basic amino acids.

a) Acidic amino acids: Aspartic acid, Glutamic acid

b) Basic amino acids: Lysine, Arginine, Histidine.

7) Imino acids (contain an imino group): Proline (Pro)

II. Based on the Charge:

Amino acids are classified into 3 groups based on the charge on their R - group.

a) Acidic Amino Acids (Monoamino dicarboxylic acids): These have acidic R groups. E.g.: Glutamic Acid, Aspartic Acid

b) Basic Amino Acids (Diamino monocarboxylic acids): These have basic R groups. E.g.: Lysine, Arginine, and Histidine

c) Neutral Amino Acids (Monoamino monocarboxylic acids):

They have neutral R groups. E.g.: Glycine, Alanine etc

III. Based on the polarity

1. Polar amino acids: They are hydrophilic in nature

E.g.:Glycine, serine, cysteine, threonine, glutamine, lysine, arginine, glutamic acid etc.

2. Non-polar amino acids: They are hydrophobic in nature.

E.g.:Alanine, Phenylalanine, tryptophan, valine, leucine, isoleucine, methionine etc.

IV. Based on the Nutritional requirement:

Based on the nutritional requirement, the amino acids can be classified into two groups-

Essential amino acids - examples given in essential amino acid question (MATT VIL PHLY)

Non-essential amino acids.(Glycine, alanine, serine, cysteine, tyrosine, aspartic acid, glutamic acid, asparagine, glutamine, proline.)

Classification based on metabolic status:

Glucogenic :- Can be converted to glucose in the body after the removal of the amino group.

Ex:-Glycine, Alanine, Serine, Threonine, Glutamic acid, Glutamine,

Ketogenic :- Can be converted to ketone bodies, acetyl CoA, or fat after the removal of the amino group.

- Example: Leucine.

Both glucogenic and ketogenic :- Can split into two parts after the removal of the amino group; one part can be converted to glucose, and the other can be converted to ketone bodies or fat. Examples: Lysine, Isoleucine, Tyrosine, Phenylalanine, Tryptophan.

Essential amino acids.

Essential amino acids (Indispensable amino acids):

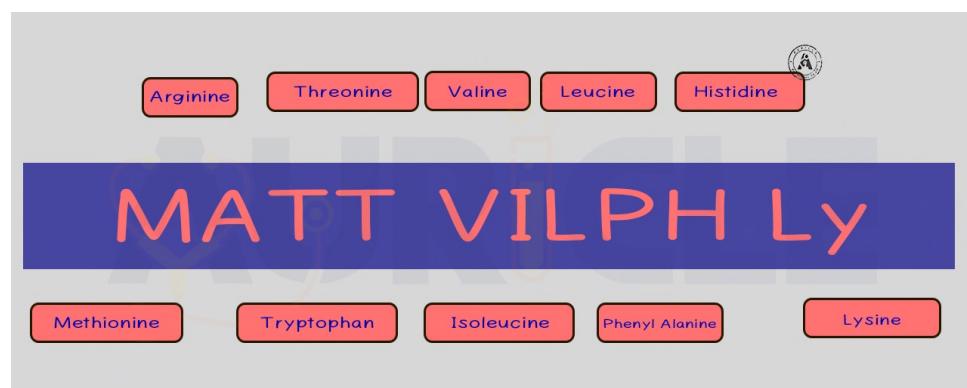
Amino acids, which are not synthesized in the body and therefore have to be supplied through the diet, are called essential amino acids. These are:

1. Methionine
2. Arginine*
3. Threonine
4. Tryptophan
5. Valine
6. Isoleucine
7. Leucine
8. Phenylalanine
9. Histidine
10. Lysine

Importance of essential amino acids:

Twenty amino acids needed for protein synthesis, with the body capable of producing non-essential amino acids.

- Essential amino acids must come from dietary proteins as the body cannot synthesize them.
- Dietary proteins are the sole source of essential amino acids for the body.
- Lack of essential amino acids in the diet hinders protein synthesis and results in negative nitrogen balance.
- Proteins lacking one or more essential amino acids fail to support proper growth and body tissue maintenance.



Matt vil phly

Semi-essential amino acids: Among the essential amino acids, **arginine** and **histidine** are called semi-essential amino acids as they are essential in the diet of children, pregnant & lactating women (Semi-essential amino acids are not synthesized in sufficient quantities in these physiological groups) & are not essential in the diet of normal adults.

Extra edge

Amphoteric nature of amino acids (Ampholytes):

Amino acids are ampholytes, because they behave both as an Acid and as a Base.

a) Behavior as an Acid: In the presence of a base, amino acids can donate a proton and thus acts as an acid.

b) Behavior as a Base: In the presence of an acid, amino acid can accept a proton thus acts as base

Since amino acids can act both as an acid (i.e. proton donor) and a base (i.e. proton acceptor), they are said to have amphoteric nature (ampholytes).

Isoelectric pH (pl) of amino acids

What is zwitter ion and their properties ?

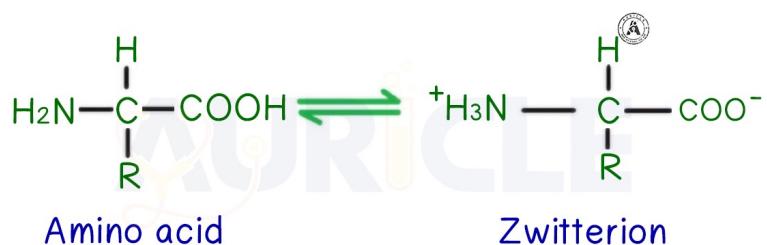
Isoelectric pH (pl) of an amino acid is defined as the pH at which amino acids exist as neutral zwitterions (dipo]ar ion).

E.g.: pl of aspartic acid is 2.9; pl of glycine is 6.1; pl of histidine is 7.6

At Isoelectric pH, amino acids possess equal number of positive and negative charges, hence bear no net charge, do not move in an electric field.

A zwitter ion is an ion that contains two functional groups. In simple terms,

it is an ion possessing both positive and negative electrical charges. Therefore, zwitterions are mostly electrically neutral (the net formal charge is usually zero).



EXTRA EDGE

Define limiting amino acids.

The term "limiting amino acid" is used to describe the essential amino acid present in the lowest quantity in a food protein relative to a reference food protein like egg whites. The term "limiting amino acid" may also refer to an essential amino acid that does not meet the minimal requirements for humans.

Examples :- lysine, threonine, methionine, and tryptophan

Explain disorders of sulfur-containing amino acids.

1. Cystinuria:

- Cystinuria is a genetic disorder where the renal tubules fail to reabsorb cystine efficiently. This results in the accumulation of cystine in the urine, leading to the formation of cystine stones in the kidneys and urinary tract.

2. Homocystinuria:

- Homocystinuria is an inherited metabolic disorder characterized by the accumulation of homocysteine in the blood and urine. It can result from deficiencies in enzymes involved in homocysteine metabolism. This condition can lead to various health problems, including eye, skeletal, and cardiovascular issues.

3. Methionine Malabsorption:

- In methionine malabsorption disorders, the body has difficulty absorbing and utilizing methionine. This can lead to various symptoms and issues related to methionine deficiency.

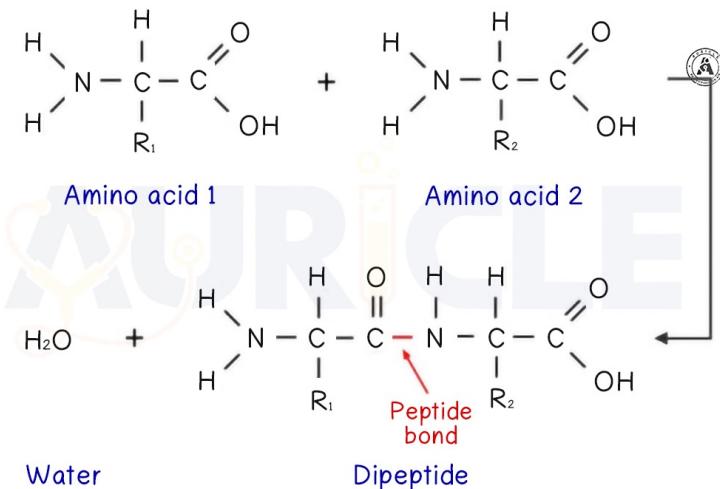
4. Cystathioninuria:

- Cystathioninuria is a metabolic disorder in which there is an elevated excretion of cystathione in the urine due to an enzyme deficiency. It is typically considered a benign condition with no associated clinical symptoms.

Peptide bonds

Definition :

Peptide bonds are anhydride, covalent bonds formed between a carboxyl group of an amino acid and an amino group of succeeding amino acid.



Salient features of peptide bonds:

- 1) Peptide bond is a strong covalent bond.
- 2) Peptide bond is an anhydride bond (i.e. Formed by the loss of a water molecule).
- 3) Peptide bonds are amide linkages.
- 4) Peptide bond generally exists in -trans configuration (exception is peptide bond formed by proline, a imino acid, which has -cis configuration).
- 5) Peptide bonds are partial double bond in nature.
- 6) Peptide bonds are semi-rigid in nature.
- 7) All atoms - C, N, O and H are coplanar.
- 8) During denaturation, peptide bonds are not affected, because peptide bonds are strong covalent bonds.

Importance of peptide bonds:

Peptide bonds are responsible for the polymerization of amino acids to form peptides (oligopeptides and polypeptides) and proteins.

Biologically important peptides (biological importance of peptides).

Physiologically (Biologically) important peptides:

Body contains many important peptides (containing 2-50 amino acids) that have diverse physiological functions.

These are,

1) Carnosine and Anserine: Both are dipeptides. Carnosine is made up of ~-alanine & histidine; anserine is a derivative of carnosine. These peptides are present in muscles.

2) Glutathione (-γ-glutamyl cysteinyl glycine): It is a tripeptide made up of γ-glutamic acid, cysteine and glycine.

Present in erythrocytes in large amounts. It is a powerful reducing agent and involved in various reduction reactions in the body. (**further information given in glutathione question**)

Glutathione functions are discussed in detail in next page.

3) Thyrotropin releasing hormone (TRH): A tripeptide secreted by hypothalamus, stimulates the pituitary gland to release thyrotropin stimulating hormone (TSH).

4) Enkephalins: Pentapeptide neurotransmitters. Enkephalins inhibit pain sensation.

5) Oxytocin: Nonapeptide hormone secreted by posterior pituitary. It causes uterine contraction.

6) Vasopressin (ADH): A nonapeptide hormone secreted by posterior pituitary. It is required for smooth muscle contraction and water reabsorption.

7) Bradykinin: Nonapeptide. It is a vasodilator.

8) Kallidin: Decapeptide. It is a vasodilator.

9) Angiotensins: Angiotensin II (octapeptide) is derived from Angiotensin I (decapeptide). Angiotensin II is a hypertensive peptide, stimulates the release of aldosterone from adrenal glands.

10) Glucagon :It is a hyperglycemic hormone.

11) Gramicidin, Actinomycin (Antibiotics) are peptides in nature.

12) Gastrin, Secretin (Gastrointestinal hormones) are also peptides.

13) Insulin (51 amino acids): Secreted from ~-cells of islet of Langerhans. It is a hypoglycemic hormone, lowers blood glucose level.

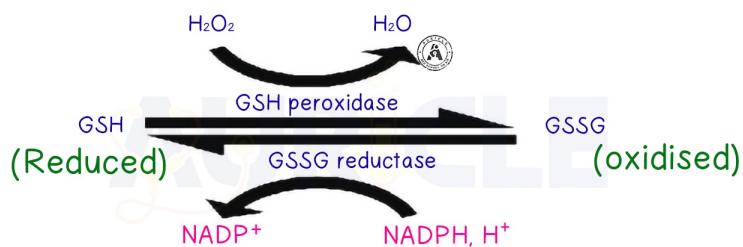
Glutathione

Glutathione (Abbreviated as GSH):

Glutathione (or γ - glutamyl cysteinyl glycine) is tripeptide made up of γ -glutamic acid, cysteine and glycine. Glutathione is abbreviated as GSH, because sulphydryl group (SH) of cysteine is the active group of glutathione.

Structure of GSH : γ Glutamic acid - Cystein - Glycine

It exists in 2 forms, reduced glutathione (GSH) and oxidized glutathione (GS-SG).



Reduced form of glutathione is biologically active and it is a powerful reducing agent, required for many reduction reactions.

Functions:

1. GSH is involved in the anti-oxidation of toxic oxidants like hydrogen peroxide, and superoxides by its peroxidase activity. This reaction is catalyzed by glutathione peroxidase, a selenium containing enzyme. In this reaction, reduced glutathione (GSH) will be converted to oxidized glutathione (GS-SG).

Glutathione's antioxidant properties are utilized in skin whitening treatments



2. GSH required for the intestinal absorption of iron by convering Fe•3 to Fe•2
3. GSH required for the recoverision of methemoglobin (Fe•3) to Hemoglobin (Fe•2).
4. Glutathione also has a coenzyme role (E.g. Maleyl acetoacetate isomerase etc.)
5. GSH protects the sulphydryl (SH) group of several enzymes I proteins.
6. Meister cycle: Glutathione is also involved in the transport of amino acids in the kidney tubules via Meister cycle or γ - glutamyl cycle.
7. GSH is involved in the detoxification of bromobenzene to mercapturic acid.

Proteins

Structure of protein

The structure of proteins is rather complex which can be divided into 4 levels of organisation

1. Primary structure: The linear sequence of amino acids forming the backbone of proteins (polypeptides).

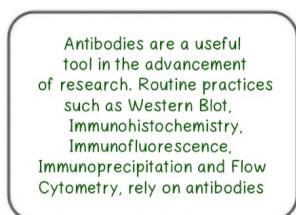
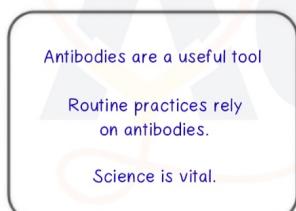
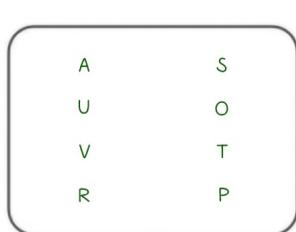
2. Secondary structure: The spatial arrangement of protein by twisting of the polypeptide chain.

3. Tertiary structure: The three dimensional structure of a functional protein.

4. Quaternary structure: Some of the proteins are composed of two or more polypeptide chains referred to as subunits.

The spatial arrangement of these subunits is known as quaternary structure.

For your understanding

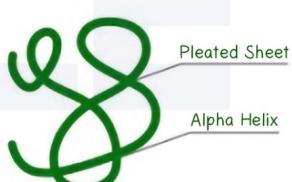
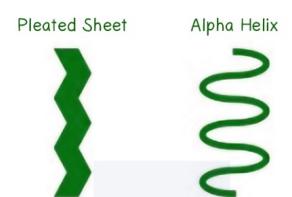
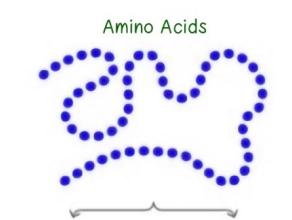


Alphabets \longleftrightarrow Primary Structure

Words \longleftrightarrow Secondary Structure

Sentences \longleftrightarrow Tertiary Structure

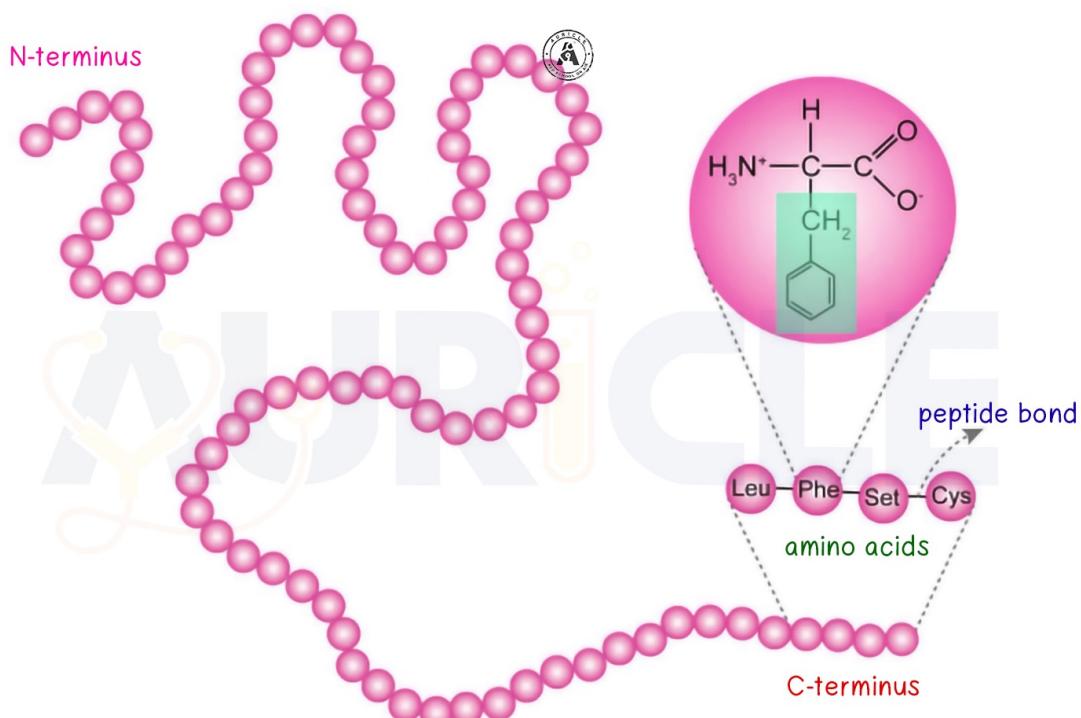
Paragraphs \longleftrightarrow Quaternary Structure



Structural organisation of proteins (primary, secondary, tertiary and quaternary structure).

PRIMARY STRUCTURE OF PROTEIN

1. Each protein has a unique sequence of amino acids which is determined by the genes contained in DNA.
2. The primary structure of a protein is largely responsible for its function Lead to many genetic diseases.
3. The amino acids are held together in a protein by covalent peptide bonds or linkages.
4. These bonds are rather strong.
5. Formation of a peptide bond: When the amino group of an amino acid combines with the carboxyl group of another amino acid, a peptide bond
6. dipeptide will have two amino acids and one peptide bond
7. The peptide bond is rigid and planar with partial double bond in character.



Secondary structure of proteins

SECONDARY STRUCTURE OF PROTEIN

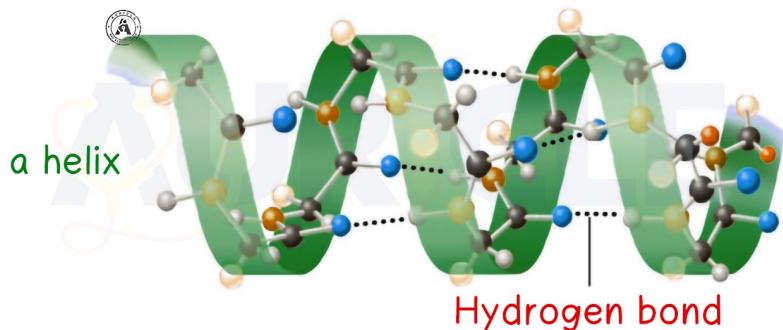
1. The conformation of polypeptide chain by twisting or folding is referred to as secondary structure.
2. The amino acids are located close to each other in their sequence.
3. Two types of secondary structures, α -helix and β -sheet

alpha - Helix

it is most common spiral structure of protein.

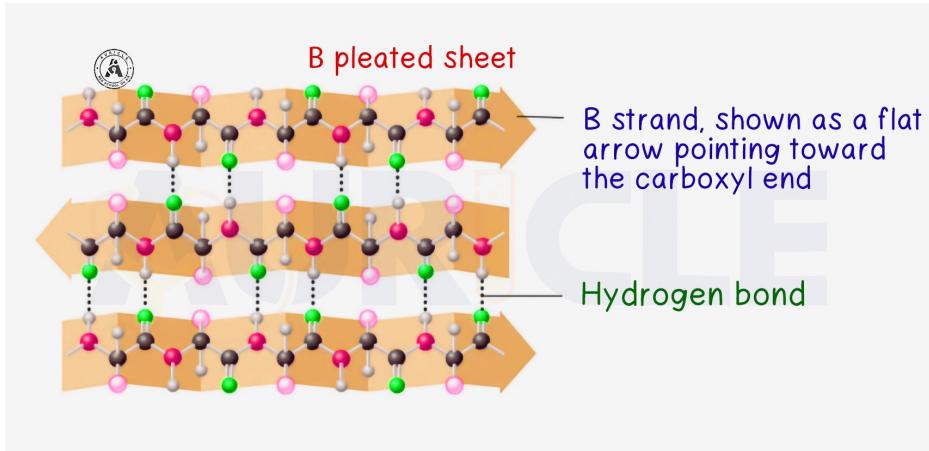
- . It has a rigid arrangement of polypeptide chain.
- . The α -helix is a tightly packed coiled structure with amino acid side chains extending outward from the central axis.
- . The α -helix is stabilised by extensive hydrogen bonding. It is formed between H atom attached to peptide N, and O atom attached to peptide C.
- . The hydrogen bonds are individually weak but collectively, they are strong enough to stabilise the helix.
- . All the peptide bonds, except the first and last in a polypeptide chain, participate in hydrogen bonding.
- . Each turn of α -helix contains 3.6 amino acids and travels a distance of 0.54 nm.
- . The spacing of each amino acid is 0.15 nm.
- . α -Helix is a stable conformation formed spontaneously with the lowest energy.

Secondary structure



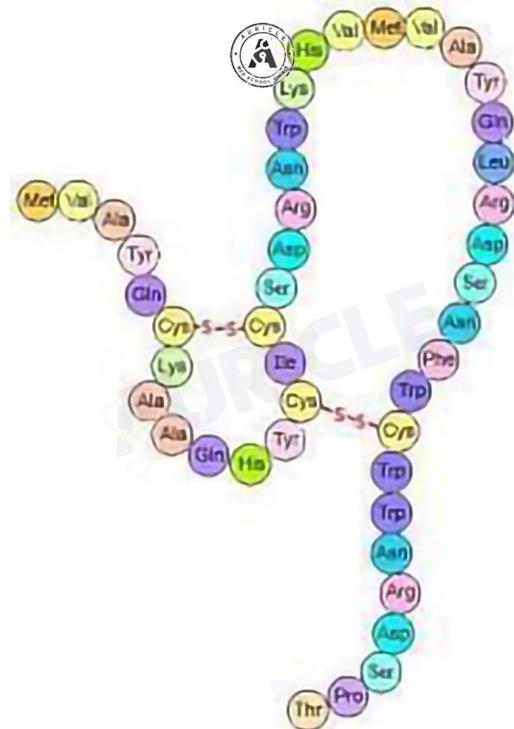
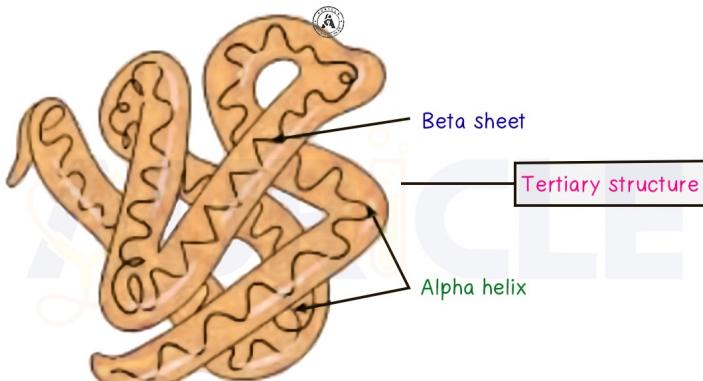
β -Pleated sheet

- . This is the second type of structure . β -sheets are composed of two or more segments of fully extended peptide chains.
- . In the β -sheets, the hydrogen bonds are formed between the neighbouring segments
- Parallel and anti-parallel -sheets



TERTIARY STRUCTURE OF PROTEIN

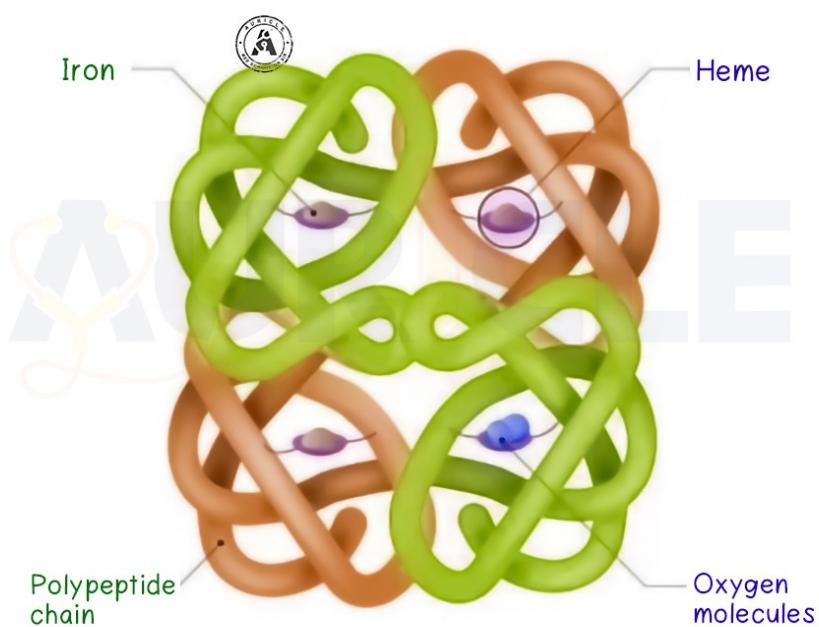
1. The three-dimensional arrangement of protein structure is referred to as tertiary structure.
2. It is a compact structure with hydrophobic side chains held interior while the hydrophilic groups are on the surface of the protein molecule.
3. This type of arrangement ensures stability of the molecule.
4. Bonds of tertiary structure: Besides the hydrogen bonds, disulfide bonds (-S-S), ionic interactions (electrostatic bonds) and hydrophobic interactions also contribute to the tertiary structure of proteins.



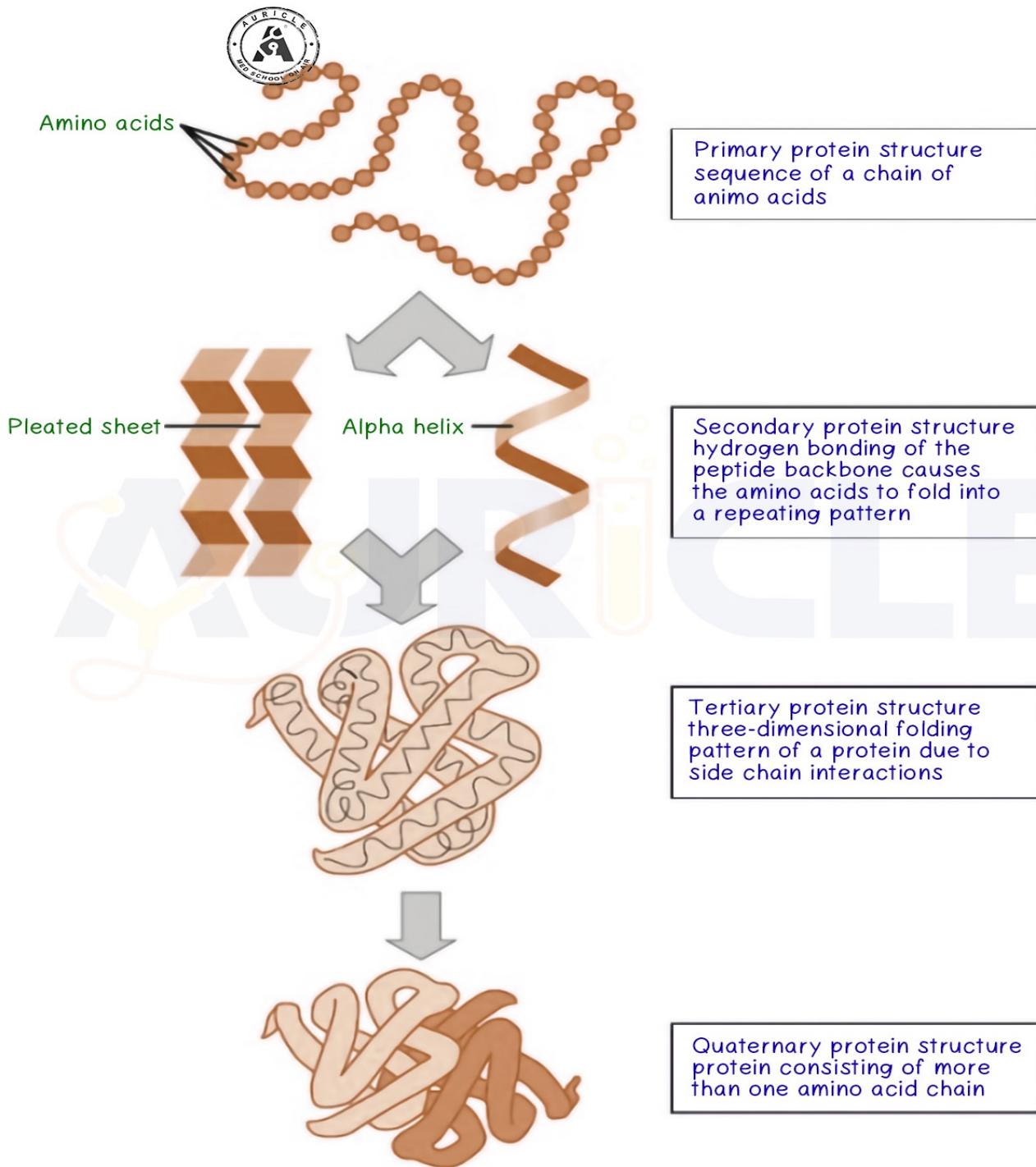
QUATERNARY STRUCTURE OF PROTEIN

1. Some of the proteins, however, consist of two or more polypeptides which may be identical or unrelated.
2. Such proteins are termed as oligomers and possess quaternary structure.
3. A dimer consists of two polypeptides while a tetramer has four Bonds in quaternary structure
4. The monomeric subunits are held together by non-covalent bonds namely hydrogen bonds, hydrophobic interactions and ionic bonds.
5. These proteins play a significant role in the regulation of metabolism and cellular function.
6. Examples of oligomeric proteins: Hemo-globin, aspartate transcarbamoylase, lactate

HEMOGLOBIN



Summary



Extra edge

Chaperones (Heat shock proteins):

Some proteins can spontaneously undergo folding to attain the active conformation. But, some proteins require a specialized group of proteins known as chaperones (or heat shock proteins) that assist in protein folding. Chaperones reversibly bind with unfolded proteins to cause the proteins to fold and attain the compact and biologically active conformations.

Bonds responsible for protein structure Protein structure

-**Covalent Bonds:** These are strong bonds in protein structure.

- **Peptide Bonds:** Formed between amino acids, creating the protein's backbone.

- **Disulfide Bonds:** Created by the sulfur groups (SH) of cysteine residues, contributing to structural stability. They can form within a single polypeptide chain or between different chains.

- **Non-Covalent Bonds:** These are weaker, but collectively crucial for protein structure.

- **Hydrogen Bonds:** Formed by sharing hydrogen atoms between the nitrogen and carbonyl oxygen of different peptide bonds.

- **Hydrophobic Bonds:** Non-polar amino acid side chains tend to associate with each other.

- **Electrostatic Bonds:** Occur between negatively charged (COO^-) and positively charged (NH_3^+) groups in amino acids.

- **Van der Waals Forces:** Non-covalent associations between electrically neutral molecules, resulting from electrostatic interactions due to dipoles.

Protein Characteristics:

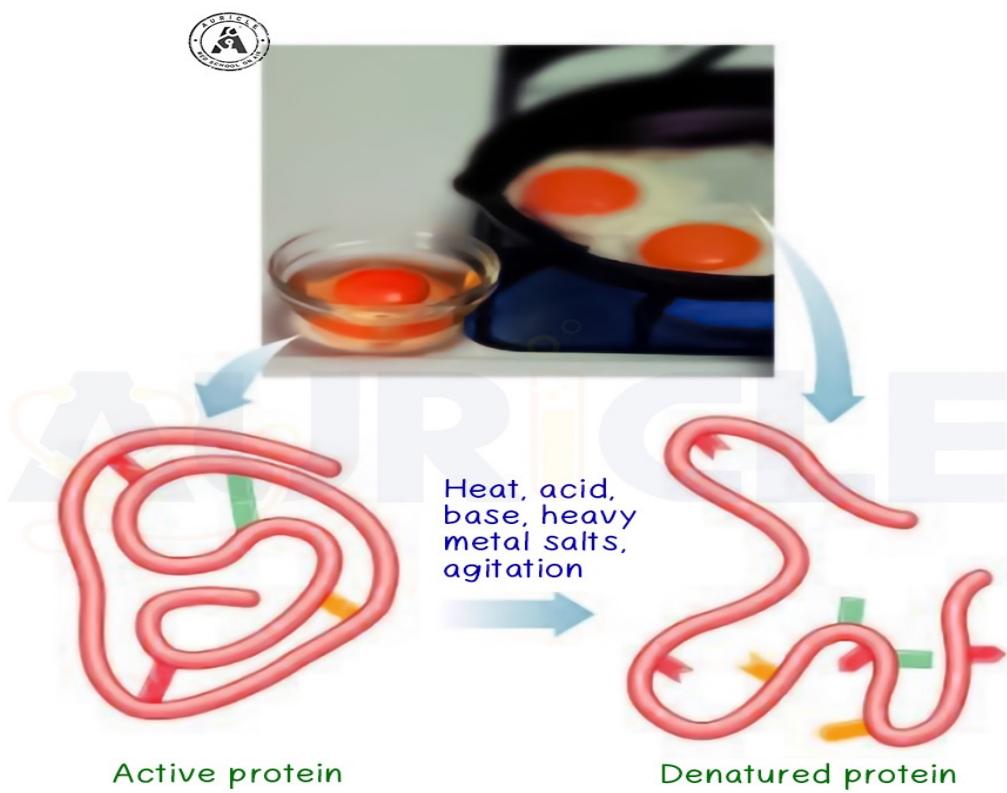
1. Solubility: Proteins form colloidal solutions in water due to their large size.
2. Molecular Weight - Protein molecular weights vary based on the number of amino acid residues. They range from 4,000 to 440,000.
 - Examples: Insulin (5,700), Myoglobin (17,000), Hemoglobin (64,450), Serum albumin (69,000).
3. Shape:- Proteins exhibit a wide variety of shapes, including globular (insulin), oval (albumin), and fibrous (fibrinogen).
4. Isoelectric pH (pl):- The isoelectric pH (pl) is determined by the nature of amino acids. At pl, proteins are electrically neutral.
 - Examples: Pepsin (1.1), Casein (4.6), Human albumin (4.7), Urease (5.0), Hemoglobin (6.7), Lysozyme (11.0)
5. Acidic and Basic Proteins:- Basic proteins have a higher ratio of (Lys + Arg) to (Glu + Asp), while acidic proteins have a lower ratio.
6. Precipitation of Proteins:-
 - Precipitation at pl: Proteins are least soluble at their isoelectric pH and can be precipitated.
 - Precipitation by Salting Out:- Neutral salts like ammonium sulfate cause protein precipitation, with the amount required depending on molecular weight.
 - Salting In: Small salt quantities increase protein solubility.
 - Precipitation by Heavy Metal Salts:- Heavy metal ions like Pb²⁺ cause protein precipitation.
 - Precipitation by Anionic Reagents:- Anionic acids like tannic acid can precipitate proteins.
 - Precipitation by Organic Solvents:- Organic solvents like alcohol dehydrate proteins, causing precipitation.
7. Color Reactions:- Proteins give various color reactions useful for identifying amino acids present in them.

Denaturation of proteins and agents causing denaturation.

Definition: The process of disorganization of native protein structure is called Denaturation. Denaturation involves the loss of secondary, tertiary and quaternary structures without breaking the primary structure.

Denaturation causes the unfolding of native 3-dimensional form of proteins.

Reason: Higher structures of proteins (3-D conformation) are maintained by weak non-covalent bonds, which can be easily disrupted by a variety of physical and chemical agents, whereas the primary structure of proteins are not easily broken because they are maintained by strong covalent peptide bonds.



Agents causing denaturation:

Denaturation can be caused by various physical and chemical agents.

- i) Physical agents: Pressure, heat, X-ray, UV radiation, ultrasound etc.
- ii) Chemical agents: Acids, alkali, organic solvents (ether, alcohol etc.), high concentration of urea, salicylates and heavy metals (lead, mercury, silver etc).

Characteristics of Protein Denaturation:

1. Native helical structure of the protein is lost.
2. The primary structure remains intact; peptide bonds are not hydrolyzed.
3. Denatured protein loses its biological activity.
4. It becomes insoluble in the solvent where it was originally soluble.
5. Denatured protein's solution becomes more viscous with reduced surface tension.
6. Denaturation increases the presence of ionizable and sulphydryl groups due to the loss of hydrogen and disulfide bonds.
7. Denatured protein is more easily digested due to increased exposure of peptide bonds to enzymes.
8. Denaturation is typically irreversible.
9. Some careful denaturation can be reversible, known as renaturation (e.g., hemoglobin in the presence of salicylate).
10. Denatured protein cannot be crystallized.

EXTRA EDGE

Denaturation vs Coagulation



DEFINITION

Denaturation

Denaturation is the process of changing properties of a molecule from its native state

Coagulation

Coagulation is the process of clumping small molecules together and form aggregates.

IMPORTANCE

Important in sterilization and killing of microorganisms.

Important in blood coagulation and water treatment

DISADVANTAGES

Denaturation abolishes the properties of a molecule

Coagulation changes the liquid state of the molecules

CAUSES

Denaturants such as strong acids, bases, heat, radiation, etc

Coagulants such as alum sulfate, clotting factors, etc.

Classification of proteins based on the biological function:

Proteins have diverse biological functions, based on which they can be classified as,

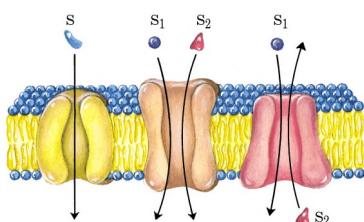
1) Catalytic proteins:
All enzymes are protein in nature (exception is ribozymes, which are RNA in nature). E.g.: Hexokinase, Amylase etc.

2) Defence proteins:
E.g.: Immunoglobulins as antibodies

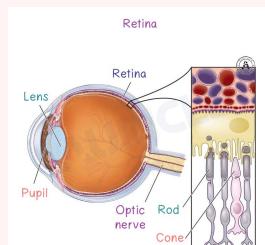


10) Haemostatic proteins:
E.g.: Fibrinogen, Prothrombin etc.

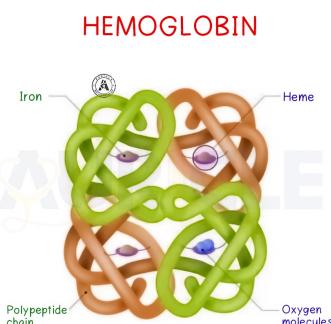
9) Membrane proteins:
E.g.: Sodium potassium pump or Sodium potassium ATPase.



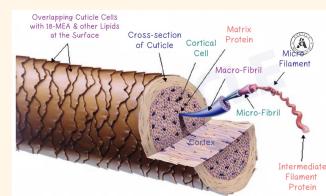
8) Visual proteins:
E.g.: Rhodopsin and Iodopsin present in the retina of eye.



12) Respiratory proteins:
E.g.: Hemoglobin, Myoglobin

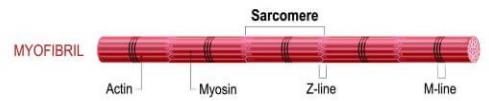


3) Structural proteins:
E.g.: Keratin present in hair and nail; Collagen is present in muscles.



4) Hormonal proteins:
Some hormones are protein in nature. E.g.: Growth hormone, Insulin etc.

5) Contractile proteins:
E.g.: Actin, Myosin and Tropomyosin present in muscle



7) Storage proteins:
E.g.: Ferritin storage of iron in liver and bone marrow.

6) Transport proteins:
E.g.: Serum albumin carries bilirubin, fatty acids etc. Transferrin transports Iron.

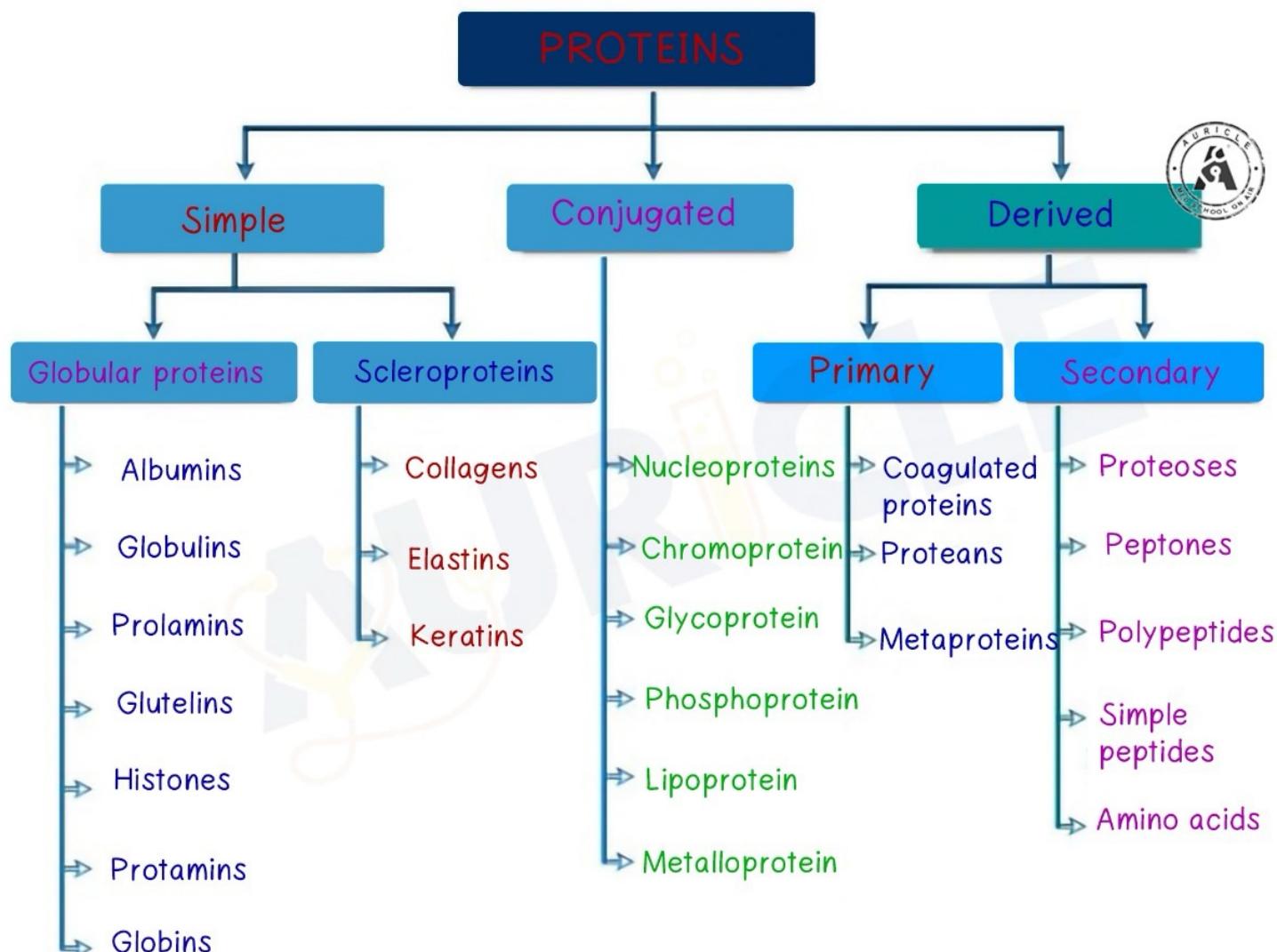
13) Receptor proteins:
E.g.: Insulin receptors, Glucagon receptor, steroid hormone receptors etc.

11) Buffer proteins:
E.g.: Plasma proteins, Hemoglobin

14) Genetic proteins:
E.g.: Histones, various transcription and translation factors.

Extra edge

Classification of proteins based on their chemical composition



Classification of proteins based on shape (conformation)

- : Based on shape, proteins are classified into 2 groups.
- 1) Globular proteins: These are spherical or oval in shape. E.g.: Hemoglobin, Albumin and Enzymes.
 - 2) Fibrous proteins: These are elongated and fiber-like structures. E.g.: Keratin, collagen, elastin etc.

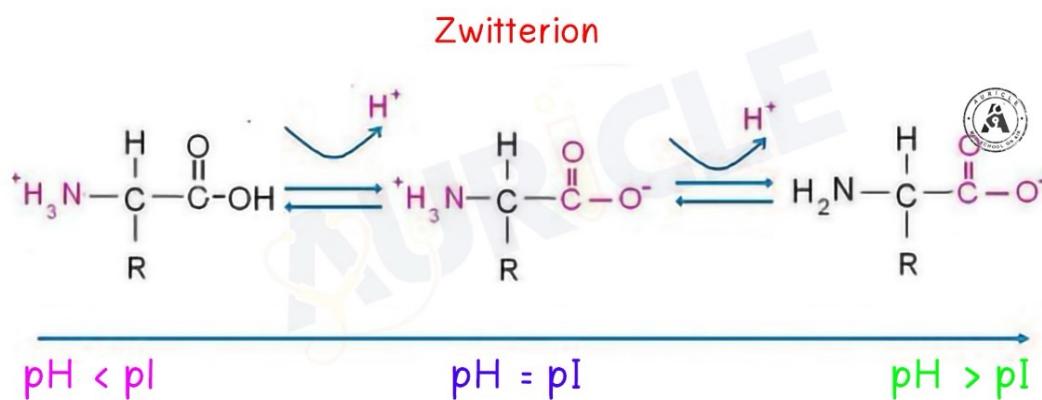
Isoelectric pH and isoelectric precipitation of proteins.

Isoelectric pH (pl) of Proteins:

- Definition: The pH at which proteins exist as zwitterions, with an equal number of positive and negative charges.
- Examples: Pepsin (pl 1.1), Casein (pl 4.6), Albumin (pl 4.7), Human Hemoglobin (pl 6.7), etc.
- Properties:
 1. At pl, the net charge is zero; the protein doesn't move in an electric field.
 2. Proteins have minimal buffering capacity and viscosity at their isoelectric pH.
 3. Proteins are least soluble and most precipitable at their isoelectric pH, as they tend to aggregate and precipitate.

Isoelectric Point (pl):

- Definition: The pH at which a molecule carries no net electrical charge, especially for amino acids.
- Proteins have their own isoelectric pH (pl) values based on their amino acid composition.
- pl is important in various biological and chemical processes, such as electrophoresis and isoelectric precipitation.



Isoelectric Precipitation of Proteins:

- Definition: Precipitation of proteins at their isoelectric pH.
- Some proteins, like casein, precipitate immediately when adjusted to their isoelectric pH.
- Explanation: Proteins are least soluble at their isoelectric pH, where they exist as zwitterions with minimal electrostatic repulsion. This leads to easy aggregation and precipitation.
- Example: Casein precipitates readily when pH is adjusted to 4.6 (the isoelectric pH of casein).

Which of the following is not an aromatic amino acid?

- A. Phenylalanine
- B. Tyrosine
- C. Tryptophan
- D. Arginine

Which of the following amino acids has an imino ring?

- A. Proline
- B. Tyrosine
- C. Tryptophan
- D. Histidine

Which of the following is not a basic amino acid?

- A. Histidine
- B. Arginine
- C. Lysine
- D. Glycine

Which of the following amino acids is polar in nature?

- A. Aspartic acid
- B. Alanine
- C. Proline
- D. Methionine

Which of the following contain a phenol group?

- A. Arginine
- B. Phenylalanine
- C. Tyrosine
- D. Proline

Answers

- 1.D
- 2.A
- 3.D
- 4.A
- 5.C

a. Deamination is _____ of amino group.

- (A) Removal
- (B) Addition
- (C) Supplementation
- (D) None of these

Answer:

The removal of amino group from the amino acids as ammonia is deamination. It may be oxidative or non-oxidative in nature. The NH₃ so liberated is used for synthesis of urea.

. The amino acids required for creatine formation:

- (A) Glycine
- (C) Methionine
- (B) Arginine
- (D) All of these

Answer:

The three amino acids glycine, arginine and methionine are required for creatine formation. Glycine combines

Biuret test is specific for

- (A) Two peptide linkage
- (B) Phenolic group
- (C) Imidazole ring
- (D) None of these

Answer:

Biuret test is answered by compounds containing two or more C=O—NH groups i.e., peptide bonds. All protein and peptides possessing at least two peptide linkages i.e., tripeptide (with 3 amino acids) give positive biuret test. The principle of biuret test is conveniently used to detect the presence of proteins in biological fluids. The mechanism of biuret test is not clearly known. It is believed that the colour is due to the formation of a copper co-ordinated complex.

1 The basic amino acids are

- (A) Lysine
- (B) Bile acids
- (C) Glycine
- (D) Alanine

Answer:

Lysine, arginine, histidine. These are dibasic monocarboxylic acids.

Non-Protein amino acids are

- (A) Ornithine
- (B) β -alanine
- (C) γ -amino butyric acid
- (D) All of these

Answer:

The amino acids which are never found in protein structure are collectively referred to as non-protein amino acids. However, the non-protein amino acids perform several biological functions. e.g., ornithine, citrulline, thyroxine.

In metabolic point of view, amino acids are classified as

- (A) Glycogenic
- (B) Ketogenic
- (C) Glycogenic or Ketogenic
- (D) All of these

Answer:

Amino acids are divided into 3 groups based on their metabolic fates.

a. Glycogenic: These amino acids can serve as precursors for the synthesis of glucose (or glycogen) e.g., alanine, aspartate, glycine.

b. Ketogenic: Fat can be synthesized from these amino acids e.g., leucine, lysine.

c. Glycogenic or ketogenic: The amino acids that can form glucose as well as fat e.g., isoleucine, phenylalanine, lysine.

A Zwitterion is

- (A) Positive ion
- (B) Negative ion
- (C) Both (A) and (C)
- (D) None of these

Answer:

Zwitterion (dipolar ion) is a hybrid molecule containing positive and negative ionic groups. Each amino acid has a characteristic pH (e.g., leucine pH 6.0), at which it exists as zwitterions.



What are Essential Fattyacids? Name them.

Enumerate the functions of essential fatty acids.

Name three essential fatty acids

What are the advantages and disadvantages of the intake of polyunsaturated fatty acids?

Classification of lipids with suitable examples.

Essential fatty acids – definition, examples and important functions.

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Phospholipids – definition, types and functions.

Rancidity and lipid peroxidation.

Lung surfactant and Respiratory Distress Syndrome.

Cholesterol - structure and biological importance.

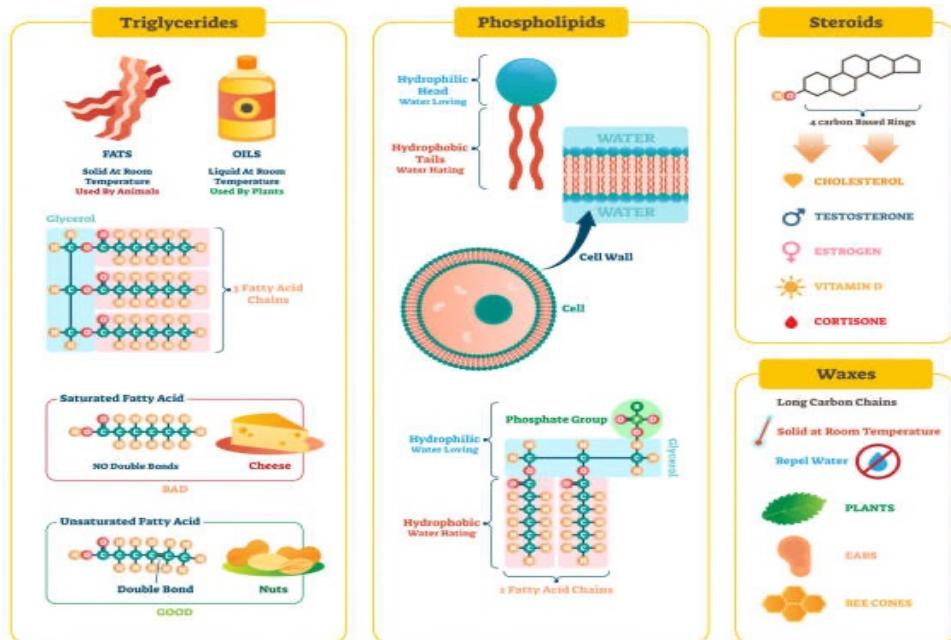
Name four functions of phospholipids in the body.

Name any Two Phospholipids. Write their Significance.

INTRODUCTION

Understanding lipid biochemistry is crucial not only for biochemists but also for everyone, as it unravels the intricate mechanisms of how lipids, in our body, function. From a day-to-day perspective, this knowledge empowers individuals to make informed dietary choices and grasp the significance of essential and non-essential fatty acids. Knowing this can lead to healthier eating habits and better nutrition, which are fundamental for overall health and well-being. It sheds light on the role of lipids in energy storage, cellular structure, and their impact on various health aspects, promoting a more holistic approach to personal health management and nutrition.

LIPIDS

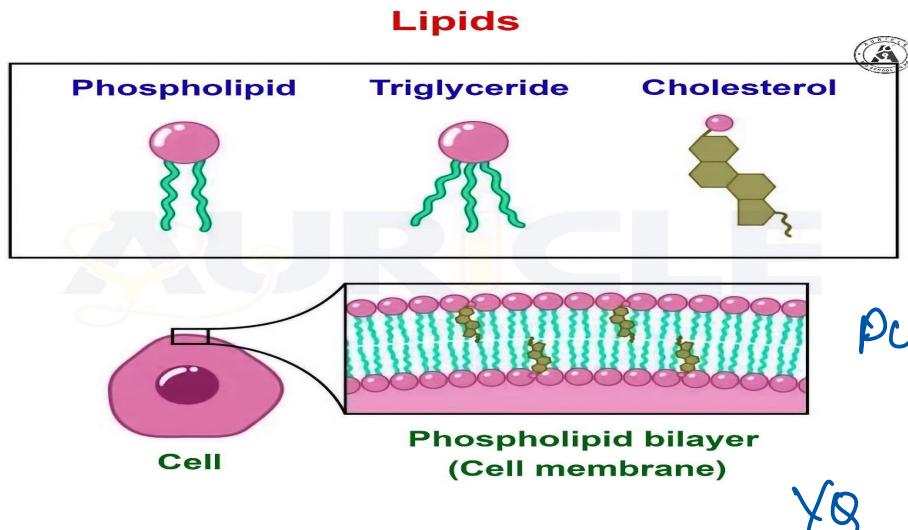


Lipids

Introduction to lipid biochemistry

Any compound that is insoluble in water & soluble in non-polar organic solvent

Soluble in organic solvents (alcohol, ether etc.) actually potentially related to fatty acids.



FATTY ACID / Acyl group

- . Polar compounds
- . FA + alcohol = Non polar fat

$R:COOC(H + HO) R = R.COOR:$ (non-polar fat) (Ester bond)

✓ highly
with

Functions of Lipids

- . Storage form of energy (triglycerides)
- . formation of membranes (phospholipids and cholesterol)
- . Metabolic regulators (steroid hormones and prostaglandins)
- . Act as surfactants
- . Act as detergents

✓ next
side
diy
Colour
Underline

- . Act as emulsifying agents (amphipathic lipids)
- . Act as electric insulators in neuron's
- . Provide insulation against changes in external temperature (subcutaneous fat)
- . Give shape and contour to the body
- . Protect internal organs by providing a cushioning effect (pads of fat)
- . Help in absorption of fat soluble vitamins (A, D, E and K)
- . Improve taste and palatability of food

Q: What are the clinical applications of lipids

Clinical Applications

- . Excessive fat deposits cause obesity.
- . Truncal obesity is a risk factor for heart attack
 - . Abnormality in cholesterol and lipoprotein metabolism leads to atherosclerosis and cardiovascular diseases
- . In diabetes mellitus, the metabolisms of fatty acids and lipoproteins are deranged, leading to ketosis

What is Classification of lipids ?

Classification of lipids

1 . Simple lipids

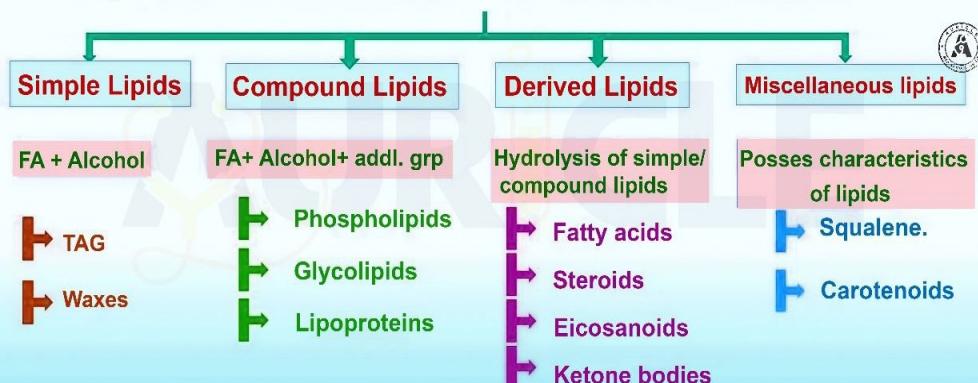
2 . Compound lipids

- . They are fatty acids esterified with alcohol; but in addition they contain other groups.
- . Phospholipids, containing phosphoric acid. Non-phosphorylated lipids

3 . Derived lipids

- . They are compounds which are derived from precursors of lipids, fatty acids, steroids. 4 . Lipids complexed to other compounds.

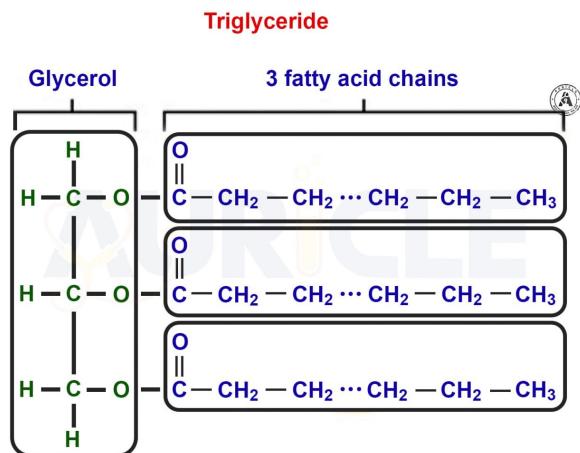
Lipids: Definition & Classification



Simple lipids. They are esters of fatty acids with glycerol

Mono Acyl Glycerol	DiAcyl Glycerol	Triacyglycerol
Ester bond.		
One FA + Glycerol.	2 FA + Glycerol.	3 FA + Glycerol.+TG
Amphipathic	Amphipathic	Neutral Fats (Non polar)

Example of Structure of simple Lipids



QUESTION : what are the PROPERTIES OF TRIACYLGLYCEROLS ?

Rancidity and lipid peroxidation

PROPERTIES OF TRIACYLGLYCEROLS

A few important properties of triacylglycerols, which have biochemical relevance, discussed below

1. Hydrolysis:

- . Triacylglycerols undergo stepwise enzymatic hydrolysis to finally liberate free fatty acids and glycerol .
- . The process of hydrolysis, catalysed by lipases

2. Saponification:

- . The hydrolysis of triacyl-glycerols by alkali to produce glycerol and soaps is known as saponification



3. Rancidity:

- . Rancidity is the term used to represent the deterioration of fats and oils resulting in an unpleasant taste.

- . Fats containing unsaturated are more susceptible to rancidity.

- . Hydrolytic rancidity occurs due to partial hydrolysis of triacylglycerols by bacterial enzymes.

- . Oxidative rancidity is due to oxidation of unsaturated fatty acids.

4. Antioxidants:

- . The substances which can prevent the occurrence of oxidative rancidity are known antioxidants.

- . antioxidants such as tocopherols (vitamin E, hydroquinone, gallic acid and α-naphthol)

Forensic correlation :-

Saponification (adipocere)

late-stage postmortem

decomposition product consisting of a mixture of free fatty acids (FFAs) formed under favorable conditions due to the hydrolysis of triglycerides in adipose tissue.



Critical thinking ??



How is low calcium levels in blood in pancreatitis related to process of saponification ??

5. **Lipid peroxidation/ oxidative rancidity** is the chain of reactions of oxidative degradation of lipids. It is the process in which free radicals "steal" electrons from the lipids in cell membranes, resulting in cell damage. This process proceeds by a free radical chain reaction mechanism. It most often affects polyunsaturated fatty acids, because they contain multiple double bonds in between which lie methylene bridges (-CH₂-) that possess especially reactive hydrogen atoms.



Pathology correlation:-
Lipid peroxidation, driven by oxidative stress, is linked to cell damage, atherosclerosis, cancer, and inflammation

Topic : COMPLEX lipids

Complex lipids has
FA + ALCOHOL + OTHER COMPONENTS

If the other compound is **Phosphate** Then Phospholipids form which has

Polar phosphate NP lipid forms

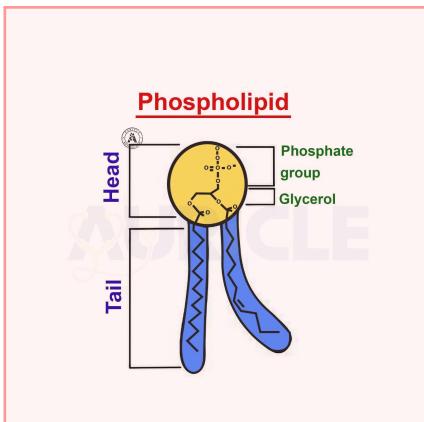
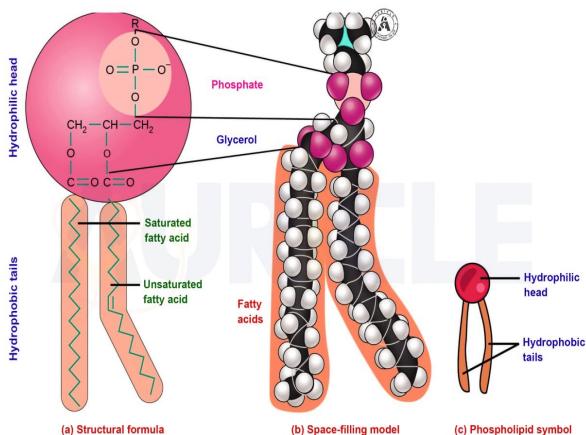
. If the other compound is **Carbohydrate** Then Glycolipids form which has Polar carbohydrate NP lipid forms

Phospholipids

Name four functions of phospholipids in the body.

Structure of phospholipid

- A phospholipid is characterized by its amphipathic nature, signifying the presence of both hydrophobic and hydrophilic components.
- At the molecular level, a phospholipid consists of a phosphate group, known as the "head," on one end and two parallel fatty acid chains, often referred to as the "tails."
- The phosphate group's negative charge imparts polarity to the head, rendering it hydrophilic, or "water-loving."
- In contrast, the lipid tails are nonpolar, uncharged, and hydrophobic, indicating their "water-fearing" nature, as they repel and are repelled by water.
- The tails may consist of both saturated and unsaturated fatty acids, and this combination significantly influences the fluidity of these tails.
- The dynamic interplay between the polar head and hydrophobic tails plays a fundamental role in the structure and function of phospholipids.



Name any Two Phospholipids. Write their Significance.

Phospholipids are structural components of biological membrane and helps in selective permeability of membrane

There are two classes of phospholipids

1Glycerophospholipids (or phosphoglyceroles)
that contain glycerol as the alcohol.

2Sphingophospholipids (or sphingomyelins)
that contain sphingosine as the alcohol.

Glycerol phospholipids are the major lipids that occur in biological membranes.

Phosphatidic acid

This is the simplest phospholipid

It is an intermediate in the synthesis of triacylglycerols and phospholipids.

The other glycerol phospholipids containing different nitrogenous bases or other groups may be regarded as their derivatives.

Point to remember :-

In sphingophospholipid
Alcohol glycerol is
never present
.*Phosphate & base is
never present

Lecithins (phosphatidylcholine)

These are the most abundant group of phospholipids
Chemically, lecithin is a phosphatidic acid with choline as the base.

see lung surfactant answer to know more about lecithin

Cardiolipin :-

It is so named as it was first isolated from heart muscle. Structurally, a cardiolipin consists of two molecules of phosphatidic acid held by an additional glycerol through phosphate groups.

It is an important component of inner mitochondrial membrane and essential for mitochondrial function.

Decreased cardiolipin levels may result in mitochondrial dysfunction, aging, hypo-thyroidism, cardioskeletal myopathy (Barth syndrome). Cardiolipin is the only phospho-glyceride that possesses antigenic properties.

Others :- Cephalins , Phosphatidylinositol, Phosphatidylserine, Plasmalogens.



Correlation :-

You encounter this cardiolipin

In microbiology as anti cardiolipin antibody
in detection of syphilis
And in medicine in anti phospholipid antibody syndrome

Sphingophospholipids

. Glucosyl ceramide / Glucocerebroside

1

- . Always found in extra neural tissues
- . Never found in CNS

. Galactosyl Ceramide Galacto cerebroside

1

Always found in CNS

Funtions of phospholipids

Phospholipids constitute an important group of compound lipids that perform a wide variety of functions

1. In association with proteins, phospholipids form the structural components of membranes and regulate membrane permeability.
2. Phospholipids (lecithin, cephalin and cardiolipin) in the mitochondria maintain the conformation of electron transport chain components, and thus cellular respiration.
3. Phospholipids participate in the absorption of fat from the intestine.
4. Phospholipids are essential for the synthesis of different lipoproteins, and thus participate in the transport of lipids.
5. Accumulation of fat in liver (fatty liver) can be prevented by phospholipids, hence they are regarded as lipotropic factors.
6. Arachidonic acid, an unsaturated fatty acid liberated from phospholipids, serves as a precursor for the synthesis of eicosanoids (prosta- glandins, prostacyclins, thromboxanes etc.).
7. Phospholipids participate in the reverse cholesterol transport and thus help in the removal of cholesterol from the body.



for Antiphospholipid
Antibody Syndrome :-
An autoimmune disorder
where the immune
system produces
antibodies against
phospholipids

8. Phospholipids act as surfactants (agents lowering surface tension). For instance, dipalmitoyl phosphatidylcholine is an important lung surfactant. Respiratory distress syndrome in infants is associated with insufficient production of this surfactant.
9. Cephalins, an important group of phospho-lipids participate in blood clotting.
10. Phosphatidylinositol is the source of second messengers—inositol triphosphate and diacylglycole, that are involved in the action of some hormones.

Lung surfactant and Respiratory Distress Syndrome.

- **Dipalmitoyl lecithin** is an important phosphatidylcholine found in lungs.

It is a surface active agent and prevents the adherence of inner surface of the lungs due to surface tension.

Respiratory distress syndrome in infants is a disorder characterized by the absence of dipalmitoyl lecithin.

Respiratory Distress Syndrome (RDS) in children, also known as infant respiratory distress syndrome (IRDS), is a condition primarily affecting premature infants. It's caused by a deficiency of surfactant in the lungs, leading to breathing difficulties.

Symptoms :-

- Rapid and labored breathing
- Grunting during exhalation
- Visible retractions (chest wall pulling in)
- Cyanosis (bluish skin and mucous membranes)
- Flaring of the nostrils
- Difficulty feeding

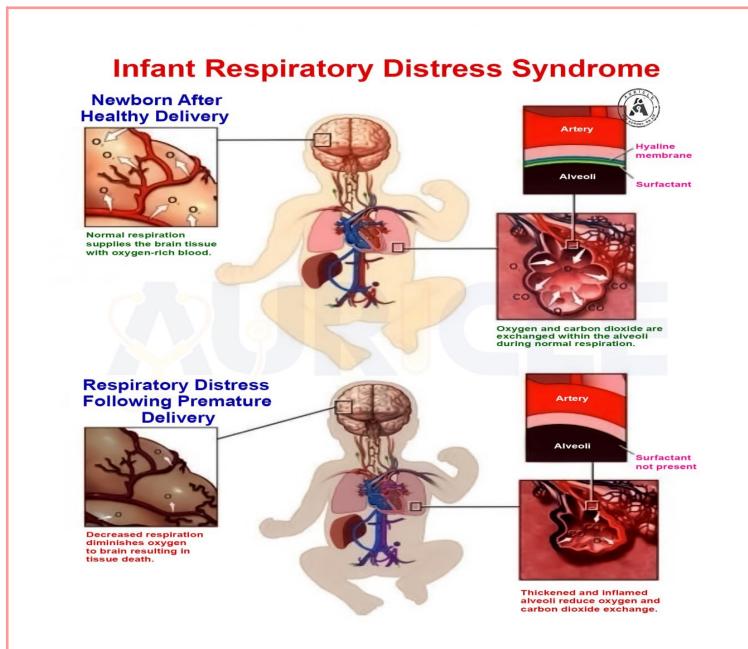
L/S RATIO :-

Lecithin- Sphingomyelin ratio (L/ Sratio) in amniotic fluid is an indicator frequently used to evaluate fetal lung maturity.

Prior to 34 weeks of gestation, the concentrations of lecithin and sphingomyelin in amniotic fluid are almost equal.

Later, the concentration of lecithin rises markedly and the L Sratio becomes 5 at term.

In preterm infants, the L/ Sratio is 1 or < 1 , resulting in respiratory distress.



Extra edge

Glycolipids (Glycosphingolipids):

- Important components of cell membranes and nervous tissues, especially in the brain.
- Simplest form is cerebrosides, containing a ceramide (sphingosine attached to a fatty acid) and one or more sugars.
- Key glycolipids include galactocerebroside and glucocerebroside.
- Galactocerebroside contains cerebronic acid as its fatty acid component.
- Sulfagalactosylceramide is the sulfatide derived from galactosylceramide.

Gangliosides:

- Predominantly found in ganglia and are the most complex glycosphingolipids.
- Derivatives of cerebrosides and contain one or more molecules of N-acetylneurameric acid (NANA), an important sialic acid.
- Key brain gangliosides: GM1, GM2, GD, and GT (G represents ganglioside, M/D/T indicate sialic acid residues, and the number denotes the carbohydrate sequence).
- GM2 accumulates in Tay-Sachs disease.

- Lipoproteins:

Complexes of lipids and proteins, transport lipids in circulation.

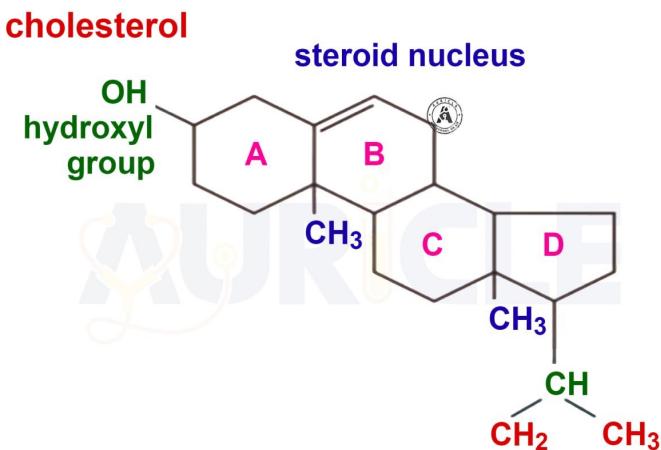
- Types: Chylomicrons, VLDL, LDL, HDL, and free fatty acid-albumin complexes.
- Structure: Lipid core (cholesterol esters, triglycerides) surrounded by a phospholipid monolayer with apolipoproteins.
- Separation: Done by density (ultracentrifugation, electrophoresis, immunoassays).
- Metabolism: Includes synthesis, transport, utilization; key sites are liver and intestines.
- Diseases: Imbalances linked to atherosclerosis, cardiovascular disease, hyperlipidemia, familial hypercholesterolemia.

Steroids

Steroids are the compounds containing a cyclic steroid nucleus (or ring) namely cyclopentanoperhydrophenanthrene (CPPP). It consists of a phenanthrene nucleus (rings A, B and C) to which a cyclopentane ring (D) is attached.

There are several steroids in the biological system. These include cholesterol, bile acids, vitamin D, sex hormones, adrenocortical hormones, sitosterols, cardiac glycosides and alkaloids. If the steroid contains one or more hydroxyl groups it is commonly known as sterol (means solid alcohol).

CHOLESTEROL STRUCTURE AND BIOLOGICAL IMPORTANCE



Functions

1. Cholesterol is an integral **component of cell membranes** and hence influences membrane permeability.
2. A number of biologically important substances are synthesised from cholesterol (e.g. **vitamin D, bile acids, mineralocorticoids, glucocorticoids and sex hormones**).
3. Cholesterol acts as an **electrical insulator** and helps in the propagation of nerve impulses.

Fatty acids are transported to liver as cholesteryl esters for oxidation

It is an essential ingredient in the structure of lipoproteins

It help in Membrane Fluidity

Topic : FATTY ACIDS

Question : what are the uses of fatty acids ?

- Fatty acids can exist both free and as part of complex lipids
- They play a number of key roles in metabolism
- Functions of fatty acids are
 - 1. major metabolic fuel
 - 2. storage and transport of energy
 - 3. as essential components of all membranes
 - 4. gene regulators

Question: what is the classification of fatty acids ?

- On the basis of various characteristics, fatty acids are classified into different categories, i.e.

According to the chain length

According to the body requirement

- According to the degree of unsaturation
- According to the position of H-atoms

CLASSIFICATION BASED ON THEIR CHAIN LENGTH

Short chain FA = 2-4C

Medium chain FA = 6-12C

Long chain FA = 14-20C

Very long chain (VLCFA) = >20C (usually required in brain)

classification based on the body requirement

Man can not synthesis some fatty acids in his body and these must be included in diet is called as **essential fatty acids**.

The examples are linoleic acid, linolenic acid and arachidonic acid.

..Certain fatty acids can be synthesized in the tissue from other fatty acids. These fatty acids are need not be included in diet and called as **nonessential fatty acids**.

The examples are Palmitoleic acid and Oleic acid.

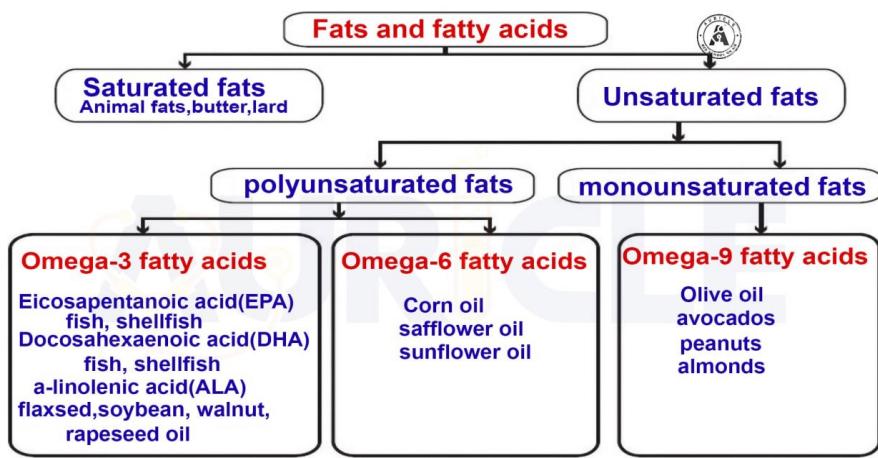
CLASSIFICATION DEPENDING ON THE DEGREE OF SATURATION

1 Saturated fatty acids

- . Saturated fatty acids are 'filled' (saturated) with hydrogen no double bonds
- . Most saturated fatty acids are straight hydrocarbon chains with an even number of carbon atoms.
- . The most common fatty acids contain 12–22 carbon atoms.

2 Unsaturated fatty acids are the fatty acids that contain one or more double bond in their aliphatic chain.

- . These may either be Monounsaturated fatty acids (MUFA) or Polyunsaturated fatty acids (PUFA).
 - . They are liquid at room temperature.
- Abundant in fish and reduce the risk of coronary heart diseases.



Classification of fats based on fatty acids

QUESTION :- Essential fatty acids – definition, examples and important functions.

PUFA

The fatty acids that cannot be synthesized by the body and, therefore, should be supplied in the diet are known as essential fatty acids (EFA).

Chemically, they are polyunsaturated fatty acids, namely linoleic acid and linolenic acid .

Arachidonic acid becomes essential, if its precursor linoleic acid is not provided in the diet in sufficient amounts.

Biochemical basis for essentiality :

Linoleic acid and linolenic acid are essential since humans lack the enzymes that can introduce double bonds beyond carbons 9 to 10.

Functions of EFA :

Essential fatty acids are required for the membrane structure and function, transport of cholesterol, formation of lipoproteins, prevention of fatty liver etc.

They are also needed for the synthesis of another important group of compounds, namely eicosanoids .

Deficiency of EFA :

The deficiency of EFA results in phrynoderma or toad skin, characterized by the presence of horny eruptions



Question: What are the omega 3 fatty acids ?

OMEGA 3 CATEGORY

1

22 carbons & 6 double bonds present

Health drinks are fortified with DHA

Requires for brain development of first 2-3 yrs of Life

Breast milk contains DHA

218 carbons & 3 double bonds Essential FA

Precursor of omega 3 category 3

. 20 carbons & 5 double bonds

Question: What are the omega 6 fatty acids ?

OMEGA 6 CATEGORY

1. GAMMA - LINOLENIC

2 LINOLEIC ACID

. 18 carbons & 2 double bonds

. Most essential FA

. Precursor of Omega - 6 category

3. ARACHIDONIC ACID

. 20 carbons & 4 double bonds

. Important for the Synthesis of PGs & Leukotrienes

Question : what are difference btw omega 3 and omega 6 fatty acids ?

Omega 3	Omega 6
<ul style="list-style-type: none">• Anti-inflammatory• Polyunsaturated fatty acids• Role in the body: control blood clotting, build cell membranes in the brain, normal growth and development• Research indicates roles in blood pressure, rheumatoid arthritis, and depression	<ul style="list-style-type: none">• Pro-inflammatory• Polyunsaturated fatty acids• Role in the body: brain function, normal growth and development

PROSTAGLANDINS

TOPIC: PROSTAGLANDINS AND RELATED COMPOUNDS

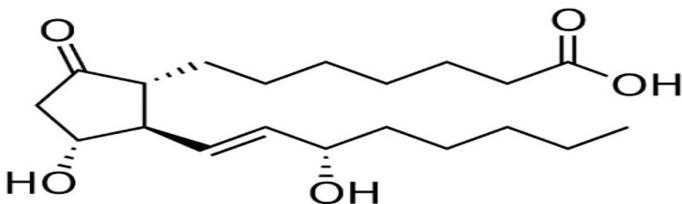
prostaglandins and their related compounds

1. prostacyclins (PGI)
2. thromboxanes (TXA)
3. leukotrienes (LT)
4. ipoxins are collectively known as eicosanoids

- they all contain 20 carbons
- Eicosanoids are locally acting hormones with a wide range of biochemical functions.

STRUCTURE OF PROSTAGLANDIN:

- Prostaglandins are derivatives of 20-carbon fatty acid namely prostanic acid hence known as prostanoids.
- a cyclopentane ring (formed by carbon atoms 8 to 12) and two side chain with carboxyl group on one side.
- Differ in structure due to substituent group and double bond on cyclopentane ring.



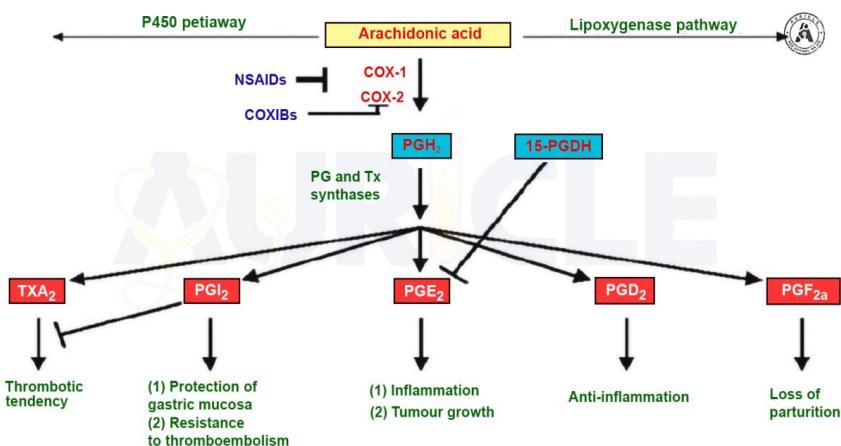
PROSTAGLANDINS

SYNTHESIS OF PROSTAGLANDINS:

- Arachidonic acid (5,8,11,14 -eicosatetraenoic acid) is the precursor for prostaglandinins .
- occurs in endoplasmic reticulum as:
 1. Release of arachidonic acid from membrane bound phospholipids by phospholipaseA
 - 2-occurs due to hormones such as epinephrine or bradykinin.
- 2. Oxidation and cyclization of arachidonic acid to PGG2 converted to PGH2 by a reduced glutathione dependent peroxidase.
- 3. PGH2 serves as the immediate precursor for synthesis of a numbero f prostaglandins, including prostacyclins and thromboxanes.
- known as cyclic pathway of arachidonic acid.
- In the linear pathway of arachidonic acid, leukotrienes and lipoxins are synthesize

Cyclooxygenase:

- prostaglandin synthesis partly controlled by enzyme cyclooxygenase.
- Capable of undergoing self-catalysed destruction to switch off PG synthesis.



Actions

- Prostaglandins act as local hormones
- produced in tissues in contrast to hormonal synthesis which occurs in specialized glands.
- not stored and degraded to inactive products at site of production.
- actions of PGs differ in different tissues.
- Sometimes PGs bring about opposing actions in the same tissue.
- They mediate :

1. Regulation of blood pressure :

- prostaglandins (PGE, PGA and PGI₂) are vasodilator
- results in increased blood flow and decreased peripheral resistarrce to lower blood pressure.
- PGs serve as agents in treatment of hypertension.

2. Inflammation :

- prostaglandins PGE₁ and PG_{E2} induce the symptoms of inflammation (redness, swelling, edema etc.)
- natural mediators of inflammatory reactions of
1.rheumatoid arthritis (involving joints)
2.psoriasis (skin)
3.conjunctivitis (eyes)
- Corticosteroids are used to treat inflammatory reactions as they inhibit prostaglandin synthesis.

3. Reproduction:

- PGE₂ and PGF₂ are used for medical termination of pregnancy and induction of Iabor.

4. Pain and fever :

- pyrogens (fever producing agents) promote prostaglandin biosynthesis leading to the formation of PGE2 in hypothalamus
- PGE2 along with histamine and bradykinin cause pain.
- Migraine is also due to PGE2.
- Aspirin and other non-steroidal Drugs inhibit PG synthesis and thus control fever and relieve pain.

PAIN MNEMONIC - BEE (B - bradykinin ; EE - PGE2).



FEVER



5. Regulation of gastric secretion :

- prostaglandins(PGE) inhibit gastric secretion used for treatment of gastric ulcers.
- Stimulate pancreatic secretion and increase motility of intestine causes diarrhea.

6. Influence on immune system :

- Macrophages secrete PGE which decreases immunological functions of B-andT -lymphocytes.

7. Effects on respiratory function :

- PGE – bronchodilator
- PGF- constrictor of bronchial smooth muscles.
- PGFI and PGF2 are used in the treatment of asthma.



Correlation with physiology :-
Prostaglandins constrict the efferent arteriole in the kidney, helping to maintain glomerular filtration rate (GFR) and regulate renal blood flow.

10. Platelet aggregation and thrombosis :

- prostacyclins (PGI₂) inhibit platelet aggregation.
- thromboxanes (TXA₂) and prostaglandin E₂ promote platelet aggregation and blood clotting lead to thrombosis.
- PGI₂-endothelial cells lining the blood vessels prevents adherence of platelets to blood vessels.
- TXA₂ -released by platelets and spontaneous aggregation when the platelets contact with collagen or thrombin.
- PGI₂-vasodilator
TXA₂-vasoconstrictor.

8. Influence on renal functions :

- PGE increases glomerular filtration rate (GFR) and promotes urine output.
- Excretion of Na⁺ and K⁺ is also increased by PGE.

9. Effects on metabolism :

- Prostaglandins influence certain metabolic reactions by mediation of cAMP.
- PGE decreases lipolysis, increases glycogen formation and promotes calcium mobilization from bone.

USES OF PROSTAGLANDINS:

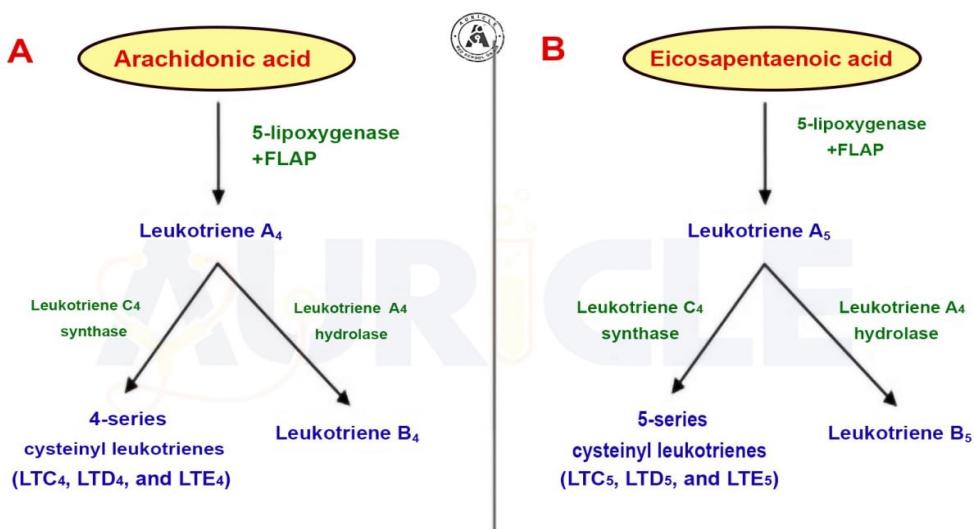
- used in treatment of
- 1. gastric ulcers
- 2. hypertension
- 3. Thrombosis
- 4. asthma
- 5. medical termination of pregnancy,
- 6. prevention of conception
- 7. induction of labor
- Inhibitors of prostaglandin synthesis in controlling fever, pain, migraine, inflammation etc.



Correlation to pharmacology :-
(Nonsteroidal Anti-Inflammatory Drugs):
NSAIDs work by inhibiting prostaglandin production, reducing inflammation, pain, and fever, decreases renal blood flow

WHAT IS LEUKOTRINES?

- Leukotrienes are synthesized by
 - 1.leucocytes
 - 2.mast cells
 - 3.lung
 - 4.heart
 - 5. spleen by lipoxygenase pathway of arachidonic acid.
- synthesis of different leukotrienes (A₄, 8₄, C₄, D₄ and E₄) through intermediate, 5-hydroperoxyeicosatetraenoic acid (5-HPETE)
- Anaphylaxis is a violent and fatal allergic reaction.
- leukotrienes(C₄, D₄ and E₄) are slow-reacting substances of anaphylaxis (SRS-A), released after immunological challenge.
- Leukotrienes are implicated in asthma, inflammatory reactions, hypersensitivity (allergy) and heart attacks.
- cause contraction of smooth muscles, bronchoconstriction, vasoconstriction, adhesion of white blood cells and release of lysosomal enzymes.
- lipoxins act as counter regulatory compounds of immune response.



DIETRY AND OTHER RELATIONS OF PGS:

- high intake of marine lipids containing unsaturated fatty acids (UFA).
- most predominant UFA in the fish foods consumed by Eskimos is 5, 8, 11, 14, '17-eicosapentaenoic acid (EPA).
- EPA is the precursor for leukotrienes
- eicosapentaenoic acid inhibits the formation of thromboxanes (TXA) promotes platelet aggregation and thrombosis.
- diet rich in marine lipids (with EPA) decreases plasma cholesterol and triacylglycerols.
- Reduced synthesis of TXA₂ responsible for low incidence of heart attacks in Eskimos.

Q1) WHICH OF THE FOLLOWING IS A SUCIDE ENZYME?

- a)cyclooxygenase
- b)lipooxygenase
- c)histamine
- d)leukotrienes

ANS:A) CYCLOOXYGENASE

Q2) DIET OF FISH FOOD CONTAINS?

- a)unsaturated fatty acid
- b)saturated fatty acid
- c)sodium
- d)glucose

ANS:A) UNSATURATED FATTY ACID

Q3) WHICH OF THE FOLLOWING IS NOT EICOSANOIDS?

- A)prostaglandins
- b)leukotrienes
- c)thromboxanes
- d)histamine

ANS:D) HISTAMINE

Eicosanoids (including prostaglandins):

Eicosanoids are compounds derived from eicoso (20 -carbon) polyenoic fatty acids (C20 polyunsaturated fatty acids). There are three different eicosanoids,

- Prostanoids: (includes Prostaglandins, Prostacyclins and Thromboxanes).
- Leucotriens
- Lipoxins



Definition:

Nucleotides are building blocks of nucleic acids (DNA and RNA).

Components:

Each nucleotide is made up of 3 components

- i) Nitrogenous base ii) Pentose sugar iii) Phosphate group

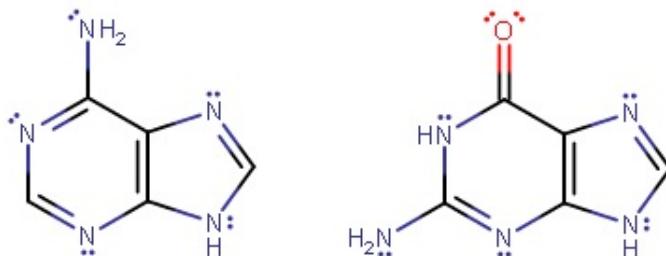
i) Nitrogenous base:

May be either purine bases or pyrimidine bases.

a) Purine bases:

Adenine and guanine are major purine bases

- Adenine (6-aminopurine)
- Guanine (2-amino 6-oxopurine)



b) Pyrimidine bases:

Adenine (A)

Guanine (G)

Cytosine, Thymine and Uracil are pyrimidine bases.

- Cytosine (2-oxy 4-aminopyrimidine)
- Thymine (2,4-dioxy 5-methylpyrimidine)
- Uracil (2,4-dioxypyrimidine)

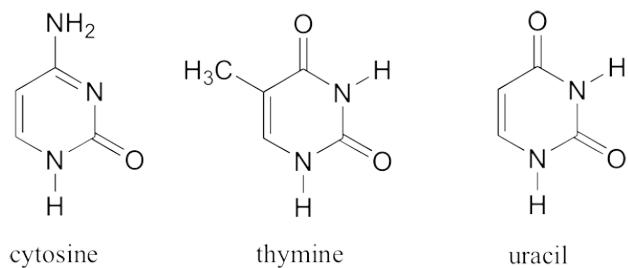
ii) Pentose sugar:

Pentose sugar can be either ribose or deoxyribose sugar. DNA has deoxyribose sugar and RNA has ribose sugar.

iii) Phosphate molecules:

Nucleotides can have one, two or three phosphate molecules; consequently Nucleotides are called mono, di and tri nucleotide phosphates.

E.g.: AMP, ADP, ATP have one, two and three phosphate molecules respectively.



Nucleoside: Nitrogenous base + Pentose sugar

- Nucleotide: Nitrogenous base + Pentose sugar + Phosphate(s)
[i.e. Nucleotide = Nucleoside + Phosphate(s)]

Similarly, Deoxy nucleotide: Nitrogenous base + deoxy pentose sugar + Phosphate(s)

Functions of free nucleotides:

Nucleotides are the building blocks of nucleic acid. In addition to this, free nucleotides in the body perform various functions like energy metabolism, protein synthesis, regulation of enzyme activities, signal transduction and variety of metabolic activities.

I) Functions of adenosine nucleotides:

1) ATP:

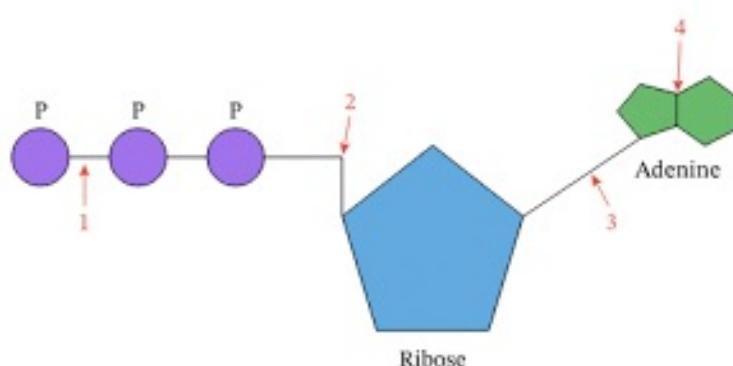
- ATP is the energy currency of the cell. It is the universal carrier of energy within the body. ATP is required for the provision of energy for muscle contraction, transmission of nerve impulses and transport of nutrients across the membrane.
- ATP is required for the ligase type of enzymatic reactions. Energy is released when

ATP is hydrolyzed to ADP and Pi. E.g. Pyruvate carboxylase.

- ATP is also required for energy transfer when ATP is hydrolyzed to AMP and PPi.

E.g. Acyl CoA synthase

- ATP is involved in phosphate transfer reactions. E.g. Glucokinase reaction.
- ATP is involved in pyrophosphate transfer reactions. E.g. PRPP synthetase.
- ATP is involved in adenosyl transfer reactions. E.g. SAM synthesis.
- Cyclic AMP a secondary messenger is formed from ATP (by adenylate cyclase).



2) Coenzymes:

Few coenzymes have adenosine nucleotides. E.g. NAO, NADP, FMN, FAD

3) PAPS (Phosphoadenosine phosphosulphate) or Active sulfate:

PAPS act as a sulfate donor for many sulfation reactions.

E.g.: PAPS is required for the synthesis of sulfated glycosaminoglycans. PAPS is also required for certain detoxification process.

4) SAM (S-Adenosylmethionine):

SAM functions as a methyl donor in methylation reaction.

E.g.: SAM is required for the synthesis of epinephrine from nor-epinephrine.

II) Functions of guanosine nucleotides:

1) GTP is required for provision of energy during protein synthesis.

2) Cyclic GMP is a secondary messenger formed from GTP by guanylate cyclase.

III) Functions of cytidine nucleotides :

1) CDP choline is required for the synthesis of lecithin (Phosphatidyl choline).

2) CDP ethanolamine is required for synthesis of cephalin (Phosphatidyl ethanolamine).

IV) Functions of uridine nucleotides:

1) UDP glucose:(Uracil-ribose-(P)-(P)-Glucose)

UDPG is carrier of glucose in the synthesis of glycogen, glycoproteins and proteoglycans.

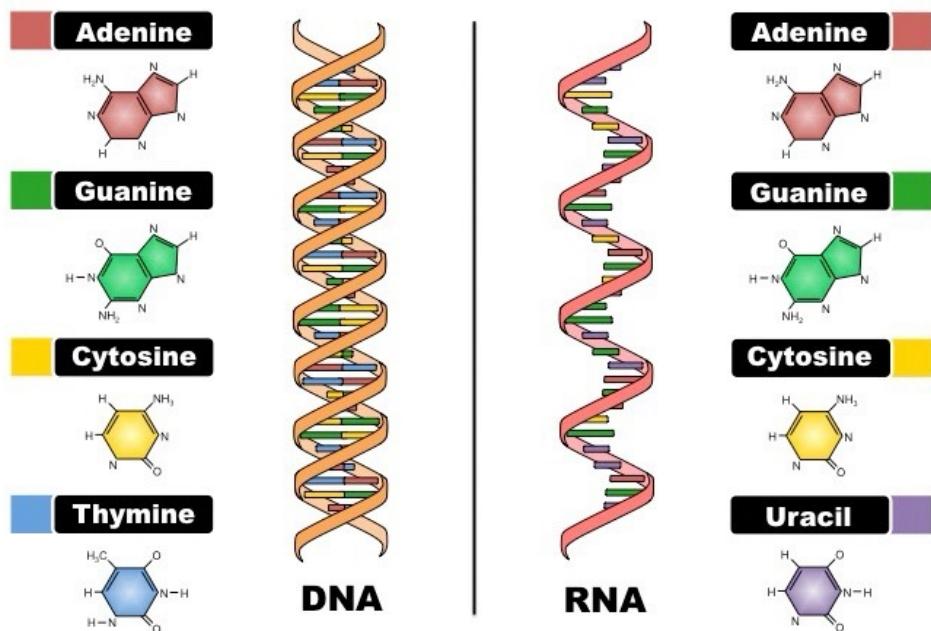
2) UDP-glucuronic acid: (Uracil-ribose-(P) - (P) - glucuronic acid) UDP glucuronic acid is required for detoxification of bilirubin.

Nucleic acid Chemistry

Definition: Nucleic acids are polynucleotides.

There are 2 types of nucleic acid:

- 1) Deoxyribonucleic acid (DNA):
- 2) Ribonucleic acid (RNA)



Structure and function of DNA.

Watson and Crick model of DNA.

Name 2 differences of B form and A form DNA

Structure of DNA:

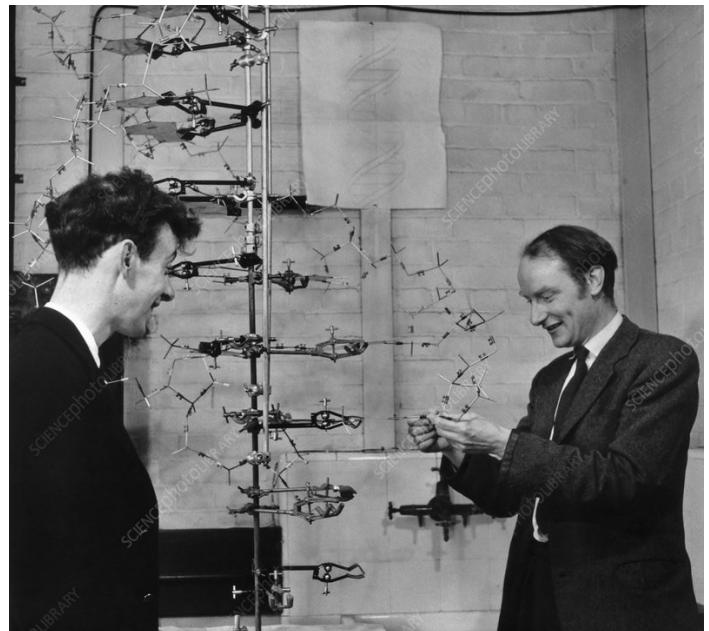
DNA is a polymer of deoxy-ribonucleotides. Bases present are adenine, guanine, cytosine & thymine. Sugar present in DNA is deoxy ribose. The monomeric deoxyribonucleotides are held together by 3'-5' phosphodiesterase linkage .

There are many different forms of DNA. Among these, B, A and Z forms are important.

- Bform: Right handed double helix, has 10 base pairs per turn.
- A form: Right handed double helix, has 11 base pairs per turn.
- Z form: Left handed double helix, has 12 base pairs per tum.

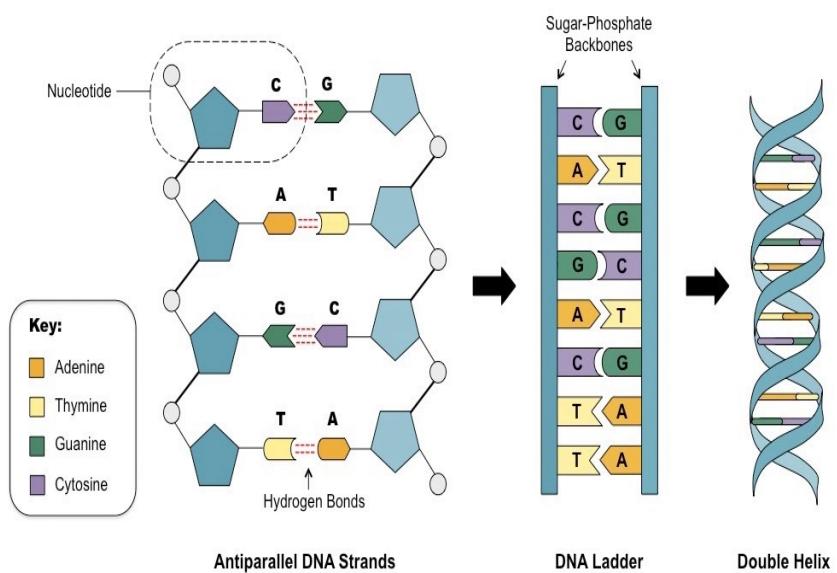
In physiological conditions, B-form of DNA is predominant.

Watson & Crick proposed the double helix model to explain the structure of B-DNA.



1. DNA is a right-handed double helix consisting of two twisted polydeoxyribonucleotide strands.
2. These strands are antiparallel, like two roads with opposite traffic directions.
3. The double helix has a width of 20 \AA and a turn (pitch) of 34 \AA with 10 pairs of nucleotides.
4. Hydrophilic deoxyribose phosphate backbones are on the outside, and hydrophobic bases are on the inside.
5. Complementary base pairing holds the two strands together, with A-T having 2 hydrogen bonds and G-C having 3.
6. Chargaff's rule is proven as A equals T and G equals C.
7. Genetic information is on the template (sense) strand, while the other is the antisense strand.
8. The double helix features major and minor grooves for protein interactions without disrupting base pairs.

This concise summary should help you memorize the key points for your examination.



Base pairing rule: The base adenine of one chain is always paired with thymine of another chain with two hydrogen bonds. Similarly cytosine of one chain is bonded with guanine of another chain with three hydrogen bonds. This is called base pairing rule. Thus 2 strands are complementary to each other.

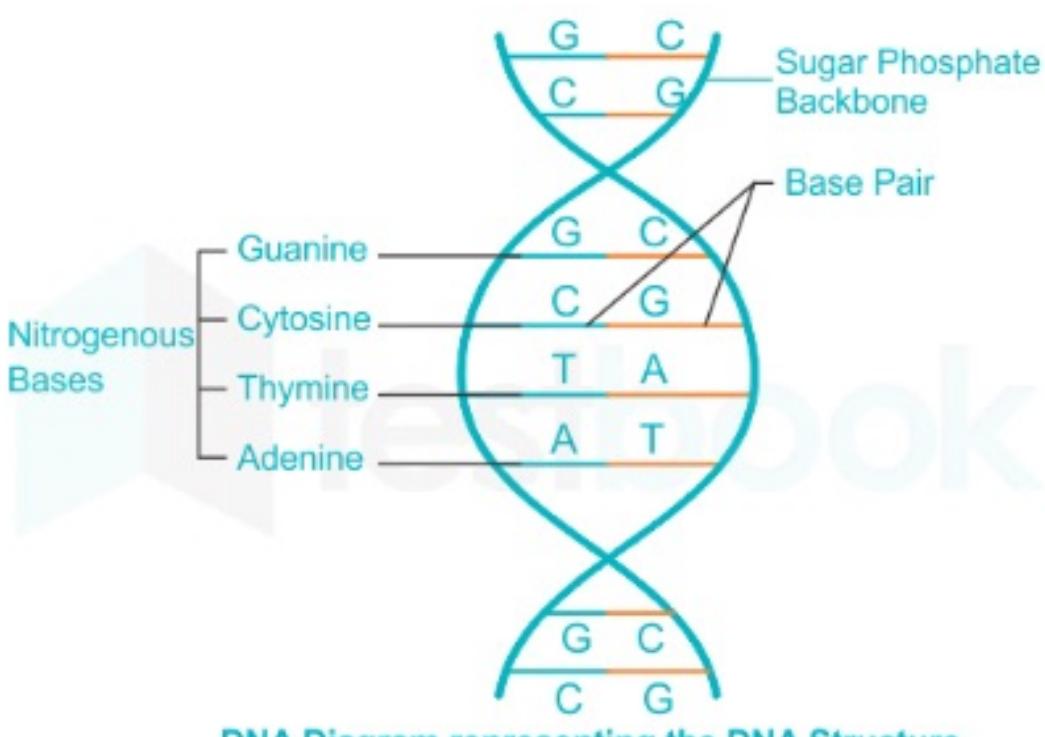
This is explained by

chargaff's rule. Chargaff's Rule: It states that the sum of purine nucleotides ($A+G$) is equal to sum of pyrimidine nucleotides ($C+T$). [$A+G = C+T$]. This is because of base pairing rule.

Functions of DNA

DNA is the fundamental unit of genetic information. The genetic information stored in the DNA serves two functions:

1. DNA is the chemical basis of expression of characters: DNA contains the information for the synthesis of all the protein molecules of the body. The information contained in the DNA is first copied into RNA molecules (by transcription), which then directs the synthesis of proteins (by translation).
2. DNA is the chemical basis of heredity: It provides the template for the transferring the genetic information from the parent cell to daughter cell (by replication). This maintains the genotype in offspring.



Extra edge

Other types of DNA

- DNA is not limited to the double helical structure and can adopt unusual forms.
- These unique DNA structures play a crucial role in molecular recognition by proteins and enzymes, essential for DNA to function correctly.

Bent DNA:

- DNA typically follows a straight path with adenine-containing tracts.
- Bent DNA arises when A-tracts are substituted with other bases or when the helix collapses into the minor groove of an A-tract.
- Bending can also result from factors like photochemical damage or mispairing of bases.

G-Quartets and G-Triplexes:

- G-quartets are planar structures connected by Hoogsteen hydrogen bonds.
- G-triplexes, antiparallel four-stranded DNA structures, have been observed.
- Telomeres at the ends of eukaryotic chromosomes, rich in guanine, form G-triplexes.
- G-triplexes are targeted for anticancer treatments.
- They play roles in processes such as immunoglobulin gene recombination and HIV double-stranded RNA dimerization.

These unusual DNA structures have far-reaching implications for the functioning of DNA and its interactions with proteins and enzymes.

Different types of RNA and their functions.

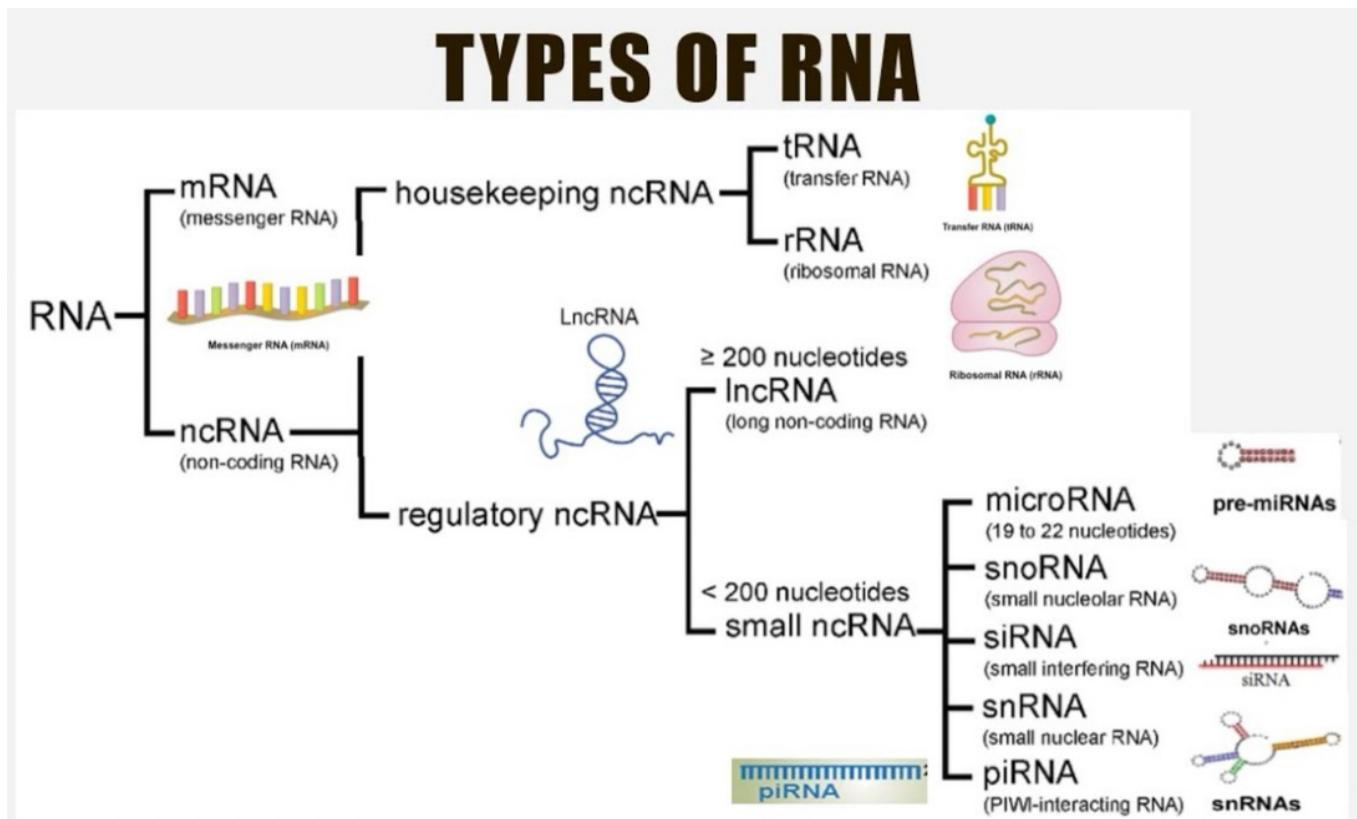
RNA (Ribonucleic acid):

RNA is the polymer of ribonucleotides. Sugar is ribose. Bases present are Adenine, Guanine, Cytosine, Uracil. RNA is generally single stranded. There are 3 major types of RNA

- 1) Transfer RNA (tRNA)
- 2) Messenger RNA (mRNA)
- 3) Ribosomal RNA (rRNA)

Besides these, two minor forms of RNA

- 1) Heterogeneous nuclear RNA (hnRNA): These are precursors of mRNA
- 2) Small nuclear RNA (snRNA): These aid in the conversion of hnRNA to mRNA.



Structure and function of tRNA.

Transfer RNA Structure

- Transfer RNA (tRNA) typically contains 71-80 nucleotides, often around 75, with a molecular weight of approximately 25,000.
- There are at least 20 types of tRNAs, corresponding to the 20 amino acids found in proteins.
- The first elucidation of tRNA's structure was performed for alanine by Holley.

Cloverleaf Structure:

- The overall structure of tRNA resembles a clover leaf with four arms, each featuring a base-paired stem.

The Arms:

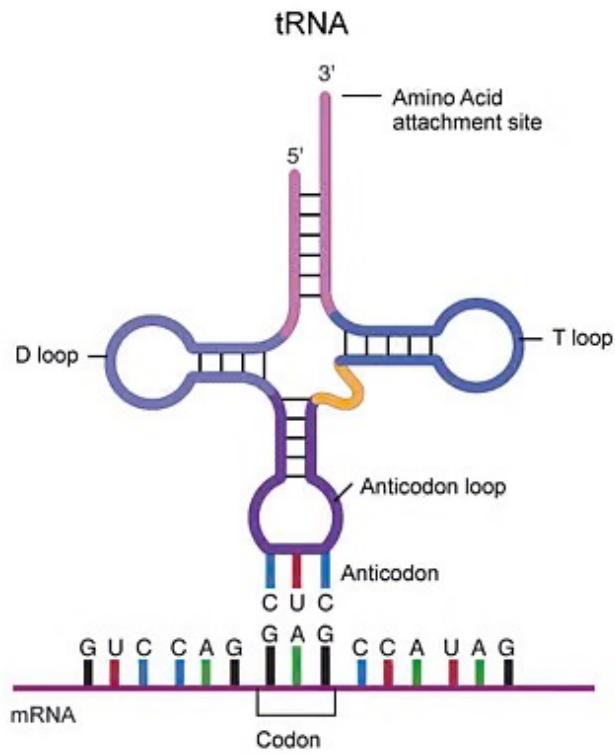
1. **Acceptor Arm (CCA Arm):** It has a CCA sequence (5' to 3') at its end where the amino acid binds.
2. **Anticodon Arm:** This arm holds a three-base sequence (anticodon) crucial for recognizing mRNA's triplet codon. The codon and anticodon are complementary.
3. **D Arm:** Named due to dihydrouridine presence.
4. **T Ψ C Arm:** Contains a sequence of T, pseudouridine (Ψ), and C.
5. **Variable Arm:** The most variable part of tRNA. This variability leads to two tRNA categories:
 - Class I tRNAs: The most common form, with 3-5 base pairs in length (about 75% of tRNAs).
 - Class II tRNAs: Contain longer arms with 13-20 base pairs.

Base Pairs:

- The structure of tRNA is maintained by complementary base pairing in its arms.
- Base pairs in the arms: Acceptor arm (7 bp), T Ψ C arm (5 bp), Anticodon arm (5 bp), D arm (4 bp).

Functions of tRNA:

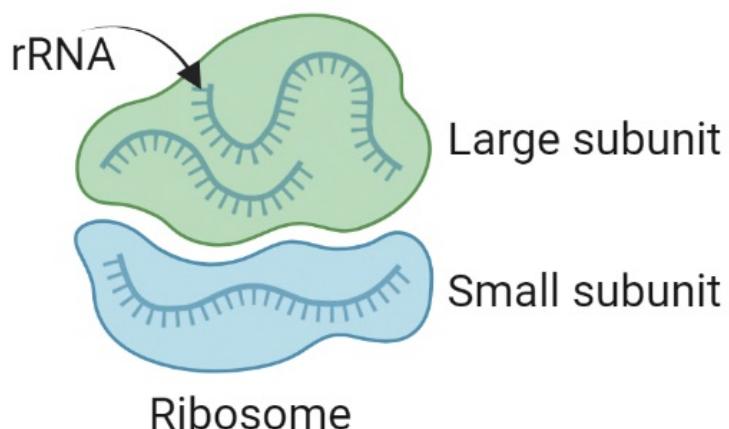
tRNA carries amino acids to the ribosomes during protein synthesis. Each tRNA is specific for an amino acid, but some amino acids are carried by more than one tRNA.



rRNA (Ribosomal RNA):

- rRNA constitutes 60 to 70% of total RNA's of the cell.
- Most of the rRNA combines with protein and exist as ribosomes. Thus ribosome is nucleoprotein particle.
- Ribosomes have 2 sub unit a large subunit and small subunit. The prokaryotic ribosomes are 70 S ribosomes, made up of larger 50 S and smaller 30 S subunits. The eukaryotic ribosomes are 80 S ribosomes, made up of larger 60 S and smaller 40 S subunits. Each subunit (larger and smaller) exists in dissociated form. Association of these subunits takes place during protein synthesis. The complete ribosome has 2 sites. (A site is amino acyl site and P site is peptidyl site).

Function of rRNA: Ribosomes are factory of protein synthesis. On ribosomes, mRNA, tRNA interacts to translate the codons present in mRNA to the specific sequence of amino acids in the polypeptide chain.



Structure and function of mRNA

mRNA (Messenger RNA):

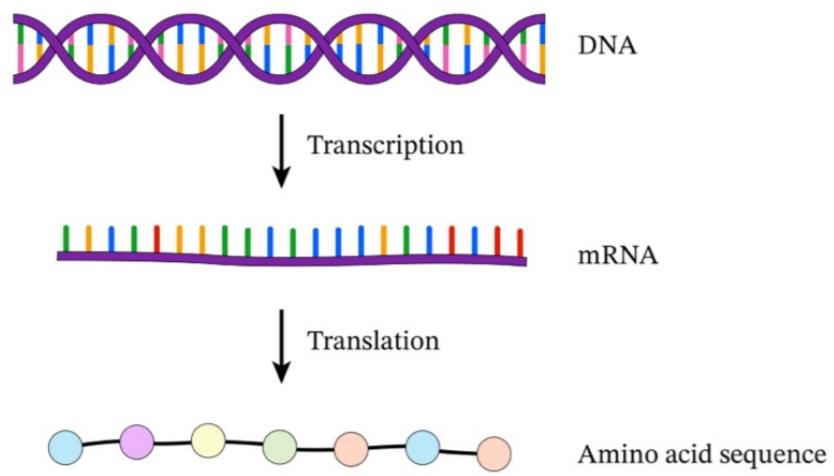
- mRNA is synthesized from the template strand of DNA. Thus mRNA synthesized will be complementary to the template strand (or similar to the non-template strand).
- The genetic message encoded in DNA is transcribed to mRNA. But the site of synthesis of protein is ribosomes present in the cytosol. So mRNA from the nucleus is transported to the cytoplasm. Since mRNA carries the message from DNA present in the nucleus to ribosomes present in the cytosol for protein synthesis, it is called the messenger RNA. mRNA acts as template for protein synthesis.

Structure:

- 5'end of mRNA start with 7 methyl GTP (hence called 7 methyl GTP cap), which protects mRNA from 5' exonuclease action.
- 3' end of mRNA has a polyadenylate tail of 22 - 250 AMP residues (hence called Poly A tail), which provides stability and protects from 3' exonuclease action.
- Between the 5' and 3' ends, there are number of codons.

Functions

- mRNA (messenger RNA) serves as a critical intermediary in protein synthesis.
- The genetic code, in mRNA, is comprised of codons, which are sequences of 3 bases (triplet codons).
- Using four types of nucleotides (A, G, C, and U), there are 64 possible triplet codons.
- Out of these 64 codons, 61 are responsible for coding amino acids.
- The remaining 3 codons are referred to as "nonsense codons" or "chain termination codons."
- Since these codons code for amino acids, there are instances where some amino acids are coded by more than one codon.
- The codon **AUG** acts as the "chain initiation codon," and it codes for methionine, signaling the start of protein synthesis.
- On the other hand, the codons **UAA, UGA, and UAG** are the "nonsense codons" or "chain termination codons." When any of these codons occurs in the mRNA sequence, the protein synthesis process stops or reaches its end point.



Extra edge

Genetic code:

Definition:

The genetic code is defined as the specific nucleotides sequence present in mRNA. Genetic code directs the synthesis of proteins with specific amino acid sequences.

Characteristic of genetic code:

a) Triplet codon:

The genetic code is present as codons. Each codon consists of three bases (Triplets) on rRNA. Using 4 bases (A, G, C, and U), 64 codons are possible. Out of these 64 codons, 3 codons (UAA, UAG, UGA) are called nonsense codons or chain termination codons because they do not code for any amino acids and the protein synthesis stops or ends whenever these codons occurs on mRNA. Other 61 codons code for 20 different amino acids. In these, AUG (present in 5' end of mRNA), which codes for amino acid methionine is called Initiator codon. (Some of examples of codons are UCU = Serine, UUU = Phenylalanine, AGU = Serine, GUU = Valine, GGU = Glycine etc.).

b) Unambiguous (Specific):

A codon always codes for a single specific amino acid.

c) Degenerative:

Most amino acids are coded by more than one codon.

E.g.: Serine has 6 codons, Glycine has 4 codons.

(Only methionine and tryptophan are coded by single codon)

d) Universal:

Same codon codes for same amino acids in all the organisms.

e) Non overlapping and comma less:

The codons are read from 5' to 3' direction continuously from AUG without any punctuation.

Base pairing rule and Wobble hypothesis.

- Wobbling refers to the loose pairing between the base at the 3' end of the codon and the complementary base at the 5' end of the anticodon.
- In the genetic code, the first two bases of the codon on mRNA always have a strong complementary base pairing with the anticodon on tRNA.
- However, the complementary pairing of codon and anticodon can wobble at the third base (3' base).
- The third base (3' base) in the codon sometimes fails to recognize its complementary base in the anticodon (Sf base).
- This phenomenon allows some tRNAs to recognize more than one codon.
- For example, the two codons for arginine, AGA and AGG, can bind to the same anticodon UCU.
- The Wobble hypothesis explains the degeneracy of the genetic code, where multiple codons can code for the same amino acid.
- The degeneracy and wobbling phenomenon together reduce the occurrence of mutations in the genetic code.

***Base pair rule given in DNA STRUCTURE answer **

Difference dna vs rna

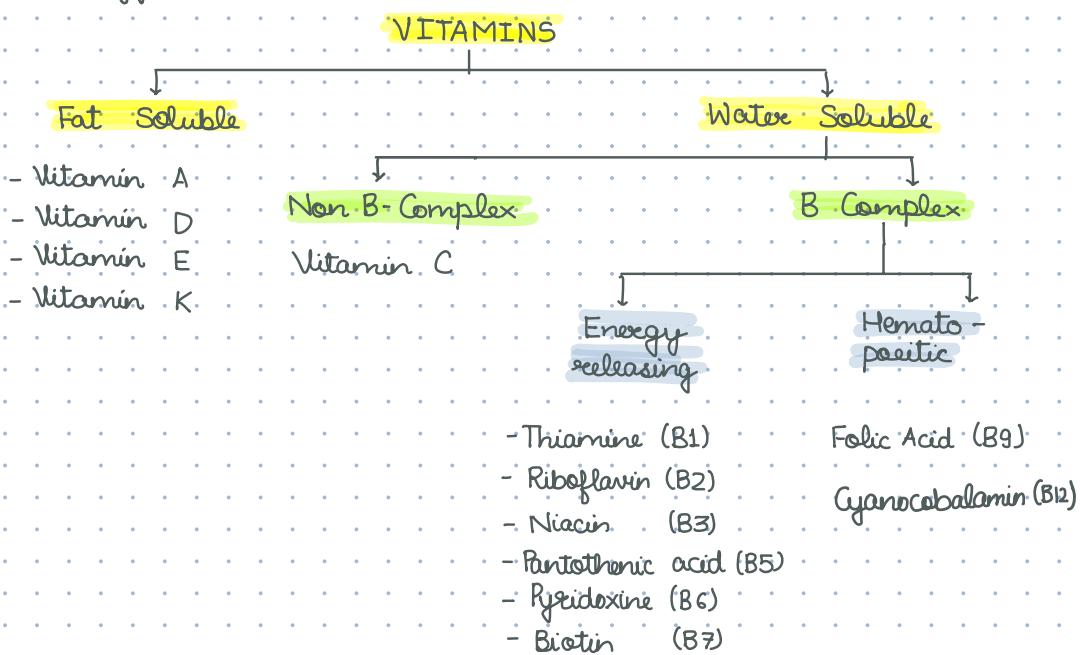
VITAMINS

Q) What are Vitamins ?

A) Vitamins are organic compounds required in diet in small amounts to perform specific biological functions for normal maintenance of optimum growth and health of organism.

Q) Classify Vitamins

A



Q) What are Vitamin like compounds? Name some examples.

- A)
- Compounds which are present in foods as accessory factors but their essential nature & requirements in humans have not been established are Vitamin like compounds.
 - The various Vitamin like compounds are -
 - ① Choline
 - ② Inositol
 - ③ Lipoic Acid
 - ④ Para Aminobenzoic Acid (PABA)
 - ⑤ Bioflavonoids

Summary - Chemistry, Dietary sources, RDA of Fat Soluble Vitamins

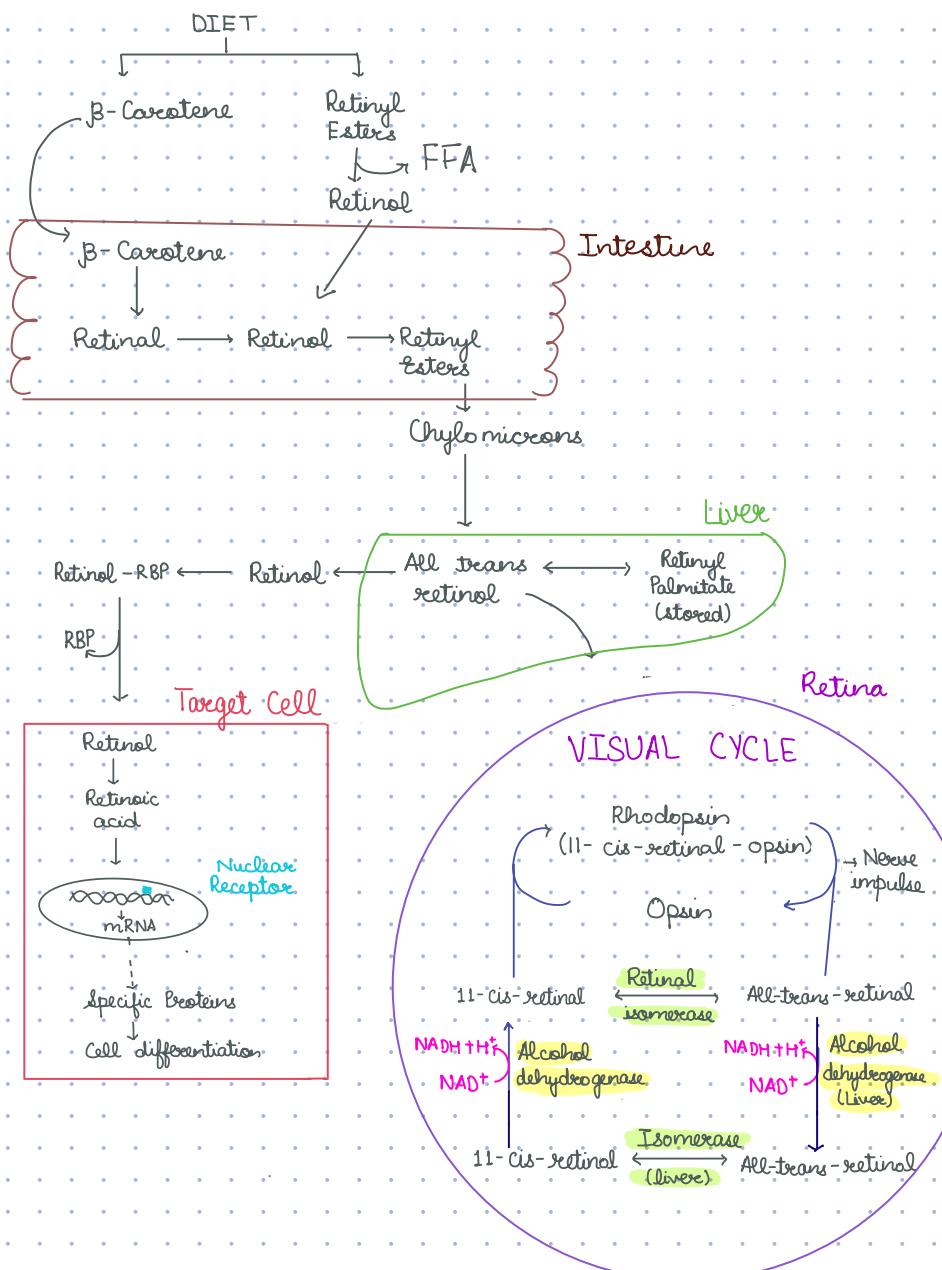
VITAMIN	CHEMISTRY	DIETARY SOURCES	MALE	FEMALE	RDA CHILD
Vitamin A	1. Retinol (alcohol) 2. Retinal (aldehyde) 3. Retinoic acid (acid) 4. β -Carotene (Provitamin A)	Animal Sources → Liver, Kidney, Egg yolk, Milk, cheese, butter Fish liver oil Vegetable source → Yellow & dark green vegetables, fruits	1000 mcg	840 mcg	1-9 years 400-700 mcg 10-18 years 800-1000 mcg
Vitamin D	1. Ergocalciferol (D2) 2. Cholecalciferol (D3)	1. Exposure of skin to sunlight 2. Fatty fish, fish liver oil 3. Food fortification	600 IU	600 IU	<1 year 400 IU >1 year 600 IU
Vitamin E	Tocopherols (Vitamin E Vitamins) ↴ ↴ ↴ ↴ α β γ δ	Vegetable oils ↓ ↓ ↓ ↓ Wheat germ Cotton seed Peanut, Corn flour	10 mg	8 mg	5-8 mg
Vitamin K	1. K1 - Phylloquinone 2. K2 - Menaquinone 3. K3 - Menadiolone	Vegetable sources → Cabbage, cauliflower, tomato, alfa alfa, spinach Animal sources → Egg Yolk, Meat, Liver, Cheese	55 µg	55 µg	<1 year 2-3 µg Child 30-50 µg

Summary - Functions, Deficiency & Excess of Fat Soluble Vitamins

VITAMIN	FUNCTION	DEFICIENCY	EXCESS
Vitamin A	<ol style="list-style-type: none"> 1. Anti-oxidant 2. Visual Cycle 3. Epithelial growth 4. Reproduction 5. Anti-Cancer 6. Anti-infective 	<ol style="list-style-type: none"> 1. Night blindness, ↓ Bitot spots ↓ Xerophthalmia ↓ Keratomalacia 2. Acne, Psoriasis 3. Impaired immunity 4. Sterility 	<p>Hypervitaminosis A</p> <p>↓ Acute Chronic</p> <ul style="list-style-type: none"> - Nausea - Vomiting - Vertigo - Blurred vision <ul style="list-style-type: none"> - Alopecia - Arthralgia → Pseudotumour cerebri - Hepatotoxic - Teratogenic
Vitamin D	<ol style="list-style-type: none"> 1. ↑ intestinal absorption of Calcium 2. ↑ Bone mineralisation 3. Calcitropic hormone 	<p>Vitamin D deficiency</p> <p>↓ Children Adults</p> <ul style="list-style-type: none"> - Rickets - Osteomalacia <p>Renal Rickets → Renal osteodystrophy.</p>	<p>Most toxic in overdoses</p> <ul style="list-style-type: none"> - Bone Resorption - Hypercalcemia/ hypercalciuria/renal calculi - Loss of appetite - Also seen in granulomatous disease
Vitamin E	<ol style="list-style-type: none"> 1. Anti-oxidant 2. Membrane structure & integrity of cells 3. Prevents RBC from hemolysis 4. Reproductive function 5. Heme synthesis 6. Prevention of chronic disease 7. Glutathione peroxidase 	<ol style="list-style-type: none"> 1. Sterility 2. Hemolytic anaemia 3. Muscle weakness 4. Demyelination of Posterior column. 	Least toxic
Vitamin K	<ol style="list-style-type: none"> 1. Co-factor for γ-carboxylation of glutamic acid 2. Maturation of <ul style="list-style-type: none"> - Clotting factors II, VII, IX, X; - Protein C & S 	<p>Neonatal hemorrhage with ↑PT, ↑aPTT & ↓BT</p>	<p>Administration of large doses of Vitamin K</p> <p>↓ breakdown of RBCs</p> <p>Hemolytic anaemia } Infants Jaundice</p>

Summary of Vitamin A -

Absorption, Transport and Biochemical functions

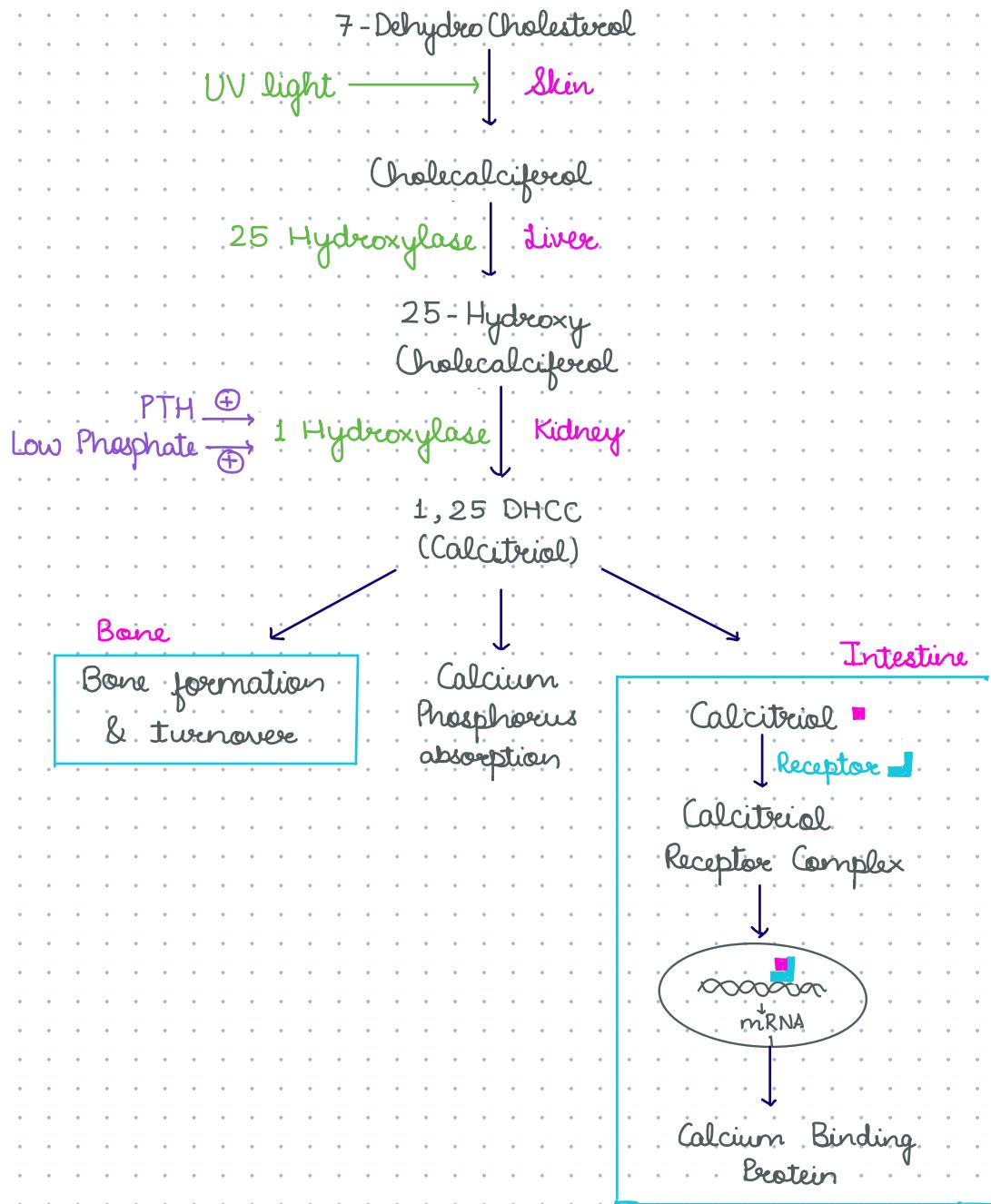


Vitamin A — Mention

1. Dietary source \rightarrow _____
2. Chemical Forms \rightarrow _____
3. Storage Form \rightarrow _____

Summary of Vitamin D -

Absorption, Transport and Biochemical functions



Vitamin D - Mention

1. Dietary source → _____
2. Chemical Forms → _____
3. Enzymes & Sources → _____

Summary - Chemistry, Dietary sources, RDA of Water Soluble Vitamins

VITAMIN	CHEMISTRY Coenzyme	Function	DIETARY SOURCES	RDA
Vitamin B1 (Thiamine)	Thiamine Pyrophosphate (TPP)	1. Decarboxylation 2. Transketolase reaction	Cereals, Pulses, Seeds Outer layer (bran) of cereals Polishing removes 80% B1	1-1.5 mg/day
Vitamin B2 (Riboflavin)	Flaavin adenine dinucleotide (FAD)	Hydrogen transfer	Milk & milk products, meat, eggs, liver, kidney, Cereals	1-1.5 mg/day
Vitamin B3 (Niacin)	Nicotinamide adenine dinucleotide (NAD^+)	Hydrogen transfer	Liver, yeast, whole grains, cereals, pulses	15-20 mg/day
Vitamin B5 (Pantethenate)	Coenzyme A	Transfer of acyl group	Egg, Liver, meat, yeast, milk	5-10 mg/day
Vitamin B6 (Pyridoxine)	Pyridoxal Phosphate (PLP)	1. Transamination 2. Decarboxylation	Egg yolk, fish, milk, meat Wheat, corn, cabbage, tubers	1-2 mg/day
Vitamin B7 (Biotin/ Vitamin H)	Biotin	Carboxylation	Liver, kidney, egg yolk, milk	100-300 $\mu\text{g}/\text{day}$
Vitamin B9 (Folic Acid)	Tetrahydro Folic Acid (THFA)	Donor of methyl/ formyl group	Green leafy vegetables, Poor source → Milk	300-400 $\mu\text{g}/\text{day}$
Vitamin B12 (Cobalamin)	Methyl-cobalamin Adenosyl-cobalamin	Cofactor of 1. Methionine synthase 2. Methyl malonyl CoA mutase	Only animal sources → Liver, kidney, milk, curd, eggs, pork, fish, chicken	1.5-2.5 $\mu\text{g}/\text{day}$
Vitamin C (Ascorbic acid)	Ascorbic acid Dehydroascorbic acid	Oxidation-reduction	Citrus fruits - gooseberry, guava Vegetables - cabbage, spinach, tomatoes Milk - poor source	60-70 mg/day

VITAMIN	DEFICIENCY
Vitamin B1	<p>Wernicke Korsakoff Syndrome</p> <p>Ophthalmoplegia</p>
	<p>Beri - Beri</p> <pre> graph TD Beri[Beri - Beri] --> Wet[Wet] Beri --> Dry[Dry] Wet --- NP["- NeuroPathy - Polynuropathy"] Dry --- CF["- Cardiac failure - Muscle wasting"] Dry --- E[Edema] </pre> <ul style="list-style-type: none"> - NeuroPathy - Polynuropathy - Cardiac failure - Muscle wasting - Edema
Vitamin B2	<ol style="list-style-type: none"> 1. Cheilosis 2. Corneal vascularisation
Vitamin B3	<p>Ds →</p> <ol style="list-style-type: none"> 1. Diarrhoea 2. Dementia 3. Dermatitis 4. Death <p>Pellagra</p> <p>Facial flushing (Casals necklace)</p> <p>Hyperglycemia</p> <p>Hyperacidaemia</p>
Vitamin B5	<ol style="list-style-type: none"> 1. Alopecia 2. Adrenal insufficiency 3. Dermatitis 4. Enteritis 5. Burning Feet syndrome → pain, numbness in toes
Vitamin B6	<ol style="list-style-type: none"> 1. Hyper excitability 2. Convulsions 3. Peripheral neuropathy 4. Sideroblastic anaemia <p>Drug induced B6 deficiency</p> <ul style="list-style-type: none"> - Penicillamine - Isoniazid
Vitamin B7	<ol style="list-style-type: none"> 1. Alopecia 2. Fasting hypoglycemia 3. Dermatitis 4. Enteritis 5. Muscle pain <p>Deficiency Causes</p> <ol style="list-style-type: none"> 1. Prolonged use of anti-biotics 2. High consumption of raw eggs (contains Avidin)
Vitamin B9 (MC)	<p>Vitamin deficiency</p> <p>Macrocytic megaloblastic anaemia</p> <p>Nerve tube defects in fetus</p>
Vitamin B12	Macrocytic megaloblastic anaemia
Vitamin C	<ol style="list-style-type: none"> 1. Scurvy 2. Decreased immunity

Vitamin B₂ (Riboflavin)

- FAD and FMN dependent enzymes and respective reactions

Enzyme	Reaction
FAD dependent	
I. <i>Carbohydrate metabolism</i>	
(a) Pyruvate dehydrogenase complex *	Pyruvate → Acetyl CoA
(b) α -Ketoglutarate dehydrogenase complex *	α -Ketoglutarate → Succinyl CoA
(c) Succinate dehydrogenase	Succinate → Fumarate
II. <i>Lipid metabolism</i>	
(d) Acyl CoA dehydrogenase	Acyl CoA → α , β -Unsaturated acyl CoA
III. <i>Protein metabolism</i>	
(e) Glycine oxidase	Glycine → Glyoxylate + NH ₃
(f) D-Amino acid oxidase	D-Amino acid → α -Keto acid + NH ₃
IV. <i>Purine metabolism</i>	
(g) Xanthine oxidase	Xanthine → Uric acid
FMN dependent	
L-Amino acid oxidase	L-Amino acid → α -Keto acid + NH ₃

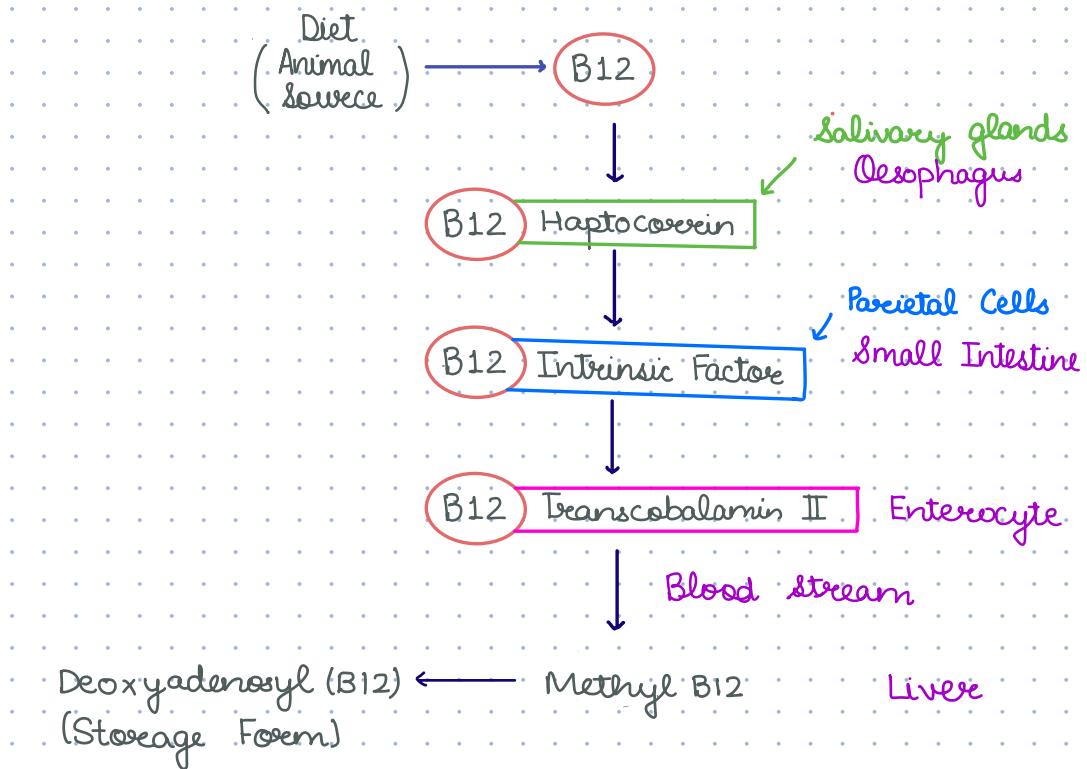
* Dihydrolipooyl dehydrogenase component requires FAD

Vitamin B3 (Riboflavin)

- NAD⁺ and NADP⁺ dependent enzymes and respective reaction

Enzyme	Reaction
NAD⁺ dependent	
I. Carbohydrate metabolism	
(a) Glyceraldehyde 3-phosphate dehydrogenase	Glyceraldehyde 3-phosphate → 1, 3-Bisphosphoglycerate
(b) Lactate dehydrogenase	Pyruvate → Lactate
(c) Pyruvate dehydrogenase complex	Pyruvate → Acetyl CoA
(d) α -Ketoglutarate dehydrogenase complex	α -Ketoglutarate → Succinyl CoA
II. Lipid metabolism	
(e) β -Hydroxy acyl CoA dehydrogenase	β -Hydroxy acyl CoA → β -Keto acyl CoA
(f) β -Hydroxybutyrate dehydrogenase	β -Hydroxybutyrate → Acetoacetate
(g) Alcohol dehydrogenase	Alcohol → Acetaldehyde
III. Protein metabolism	
(h) Branched chain α -keto acid dehydrogenase	α -Keto acids of branched chain amino acids (Leu, Ile, Val) → Corresponding acyl CoA thioesters
(i) Tyramine dehydrogenase	Tyramine → p-Hydroxyphenyl acetate
NAD⁺ or NADP⁺ dependent	
(a) Glutamate dehydrogenase	Glutamate → α -Ketoglutarate + NH ₃
(b) Isocitrate dehydrogenase	Isocitrate → Oxaloacetate
NADP⁺ dependent	
(a) Glucose 6-phosphate dehydrogenase	Glucose 6-phosphate → 6-Phosphogluconolactone
(b) Malic enzyme	Malate → Pyruvate
NADPH dependent	
(a) 3-Ketoacyl reductase	3-Ketoacyl enzyme → 3-Hydroxy acyl enzyme
(b) HMG CoA reductase	HMG CoA → Mevalonate
(c) Squalene epoxidase	Squalene → Squalene oxide
(d) Cholesterol 7 α -hydroxylase	Cholesterol → 7 α -Hydroxy cholesterol
(e) Phenylalanine hydroxylase	Phenylalanine → Tyrosine
(f) Dihydrofolate reductase	Folic acid → Tetrahydrofolic acid

Summary of Vitamin B12 → Absorption and Transport



Vitamin B12 – Mention

1. Dietary Source → _____
2. Chemical Forms → _____
3. Pernicious anaemia → _____
4. Treatment of deficiency → _____

Q) What are the causes of deficiency of Vitamin B12?

A) The causes of deficiency of Vitamin B12 include -

1. Nutritional deficiency → strict vegetarians
2. Malabsorption → Auto-immune gastritis (IF destruction),
 - Pernicious anaemia
 - Fish tap worm infection (*D. latum*)
3. Intestinal causes → Ileal resection, Crohn's disease

ANTIVITAMINS

Q) What are anti-vitamins?

- A) Antivitamins are antagonistic to the action of vitamins
- They have structural similarities with vitamins
 - Administration of antivitamins causes Vitamin deficiencies.

Examples of Anti-vitamins are -

Antivitamin/vitamin antagonists	Vitamin
Dicumarol	Vitamin K
Warfarin	
Thiaminase	Thiamine
Pyrithiamine	
Oxythiamine	
Galactoflavin	Riboflavin
Isoniazid	Niacin
Deoxypyridoxine	
Avidin	Biotin
Desthiobiotin	
Aminopterin	Folic acid
Methotrexate	
Trimethoprim	
Sulfonilamide	Para-aminobenzoic acid



Introduction

Enzymes are biocatalyst that speeds up digestion and metabolism. They are located in the cells, cytoplasm, mitochondria, tissues and body fluids.

2 types:

Endoenzymes-

Enzymes that function within the cells. Most of the enzymes are these types. Eg. metabolic enzymes (cytochrome oxidase)

Exoenzymes-

Enzymes that are liberated by cells and catalyse reactions outside the cell. Eg. digestive enzymes (amylase, lipase, protease)

PROPERTIES OF ENZYMES

- . it doesn't involve in the reaction
- . it is used for rate of reaction
- . Decrease the time of reaction
- . Provide activation energy
- . Do not change the equilibrium of reaction
- . Do not change the free energy of Substrate / product
- . Heat liable

TOPIC : ENZYME CLASSIFICATION

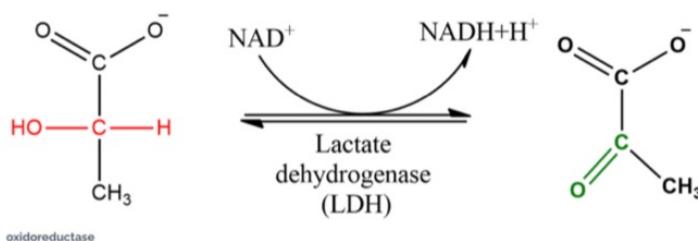
Question: . Write in detail about the classification of enzymes and give suitable examples.(IUBNB CLASSIFICATION)

EC No.	ENZYME
1	Oxidoreductase
2	Transferase
3	Hydrolase
4	Lyase
5	Isomerase
6	Ligase

OXIDOREDUCTASE:

- They are defined as a enzyme that is used to transfer's electrons or hydrogen atoms

Reaction:

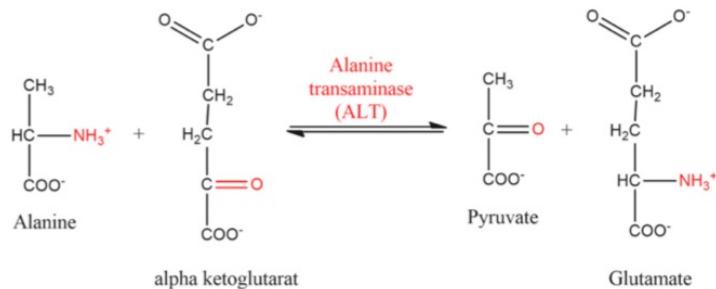


EXAMPLE	FEATURES
Dehydrogenase	Use O ₂ as an electron acceptor
Oxidases	Use molecules other than O ₂ as electron acceptor (NAD, FAD, NADP) - Oxidative decarboxylases
Peroxidases	Use H ₂ O ₂ as an electron acceptor
Oxygenases	Incorporate O ₂ into the substrate

TRANSFERASES:

- Transferases are defined as enzymes that used to transfer any molecules so that the molecular formula is changed

Example:



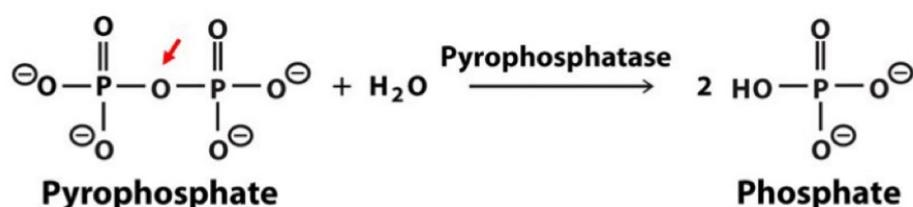
ENZYME	FEATURES
Methyl transferase	Transfer 1 carbon units
Kinases	Transfer phosphate from ATP
Phosphorylase	Transfer phosphate from pi
Amino transferase	Transfer amino groups

HYDROLASES:

- They are defined as enzymes that used to break the chemical structure with Use of H₂O.

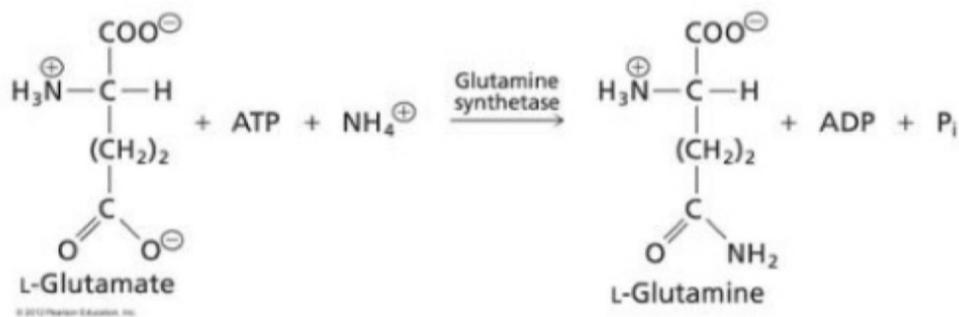
Examples:

- Phosphatase - Remove phosphate from a substrate
- All digestive enzymes



LYASES:

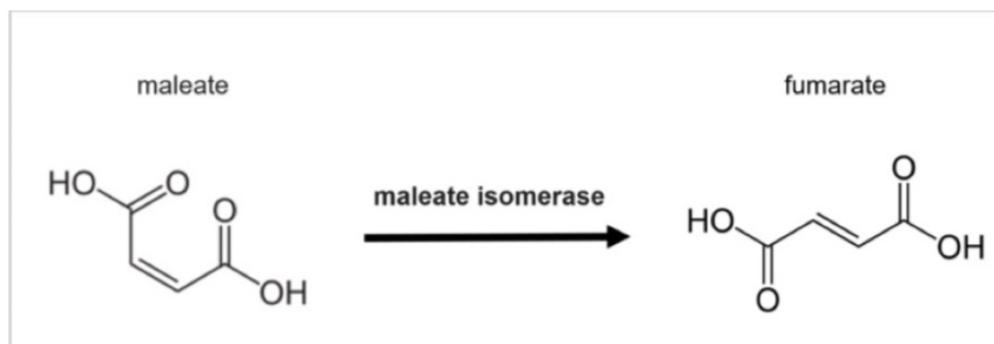
- They are defined as enzymes that can make/ break [do not require H₂O / ATP]



EXAMPLES	FEATURES
Synthetases	Link 2 molecules without using ATP
Aldolase	Produce aldehydes via elimination reactions
Decarboxylase	Produce CO_2 by eliminating reactions (simple only)
Hydratase	Add or remove water (do not break bond)

ISOMERASES:

- They are defined as enzymes that used to make different compounds but the molecular formula do not change .

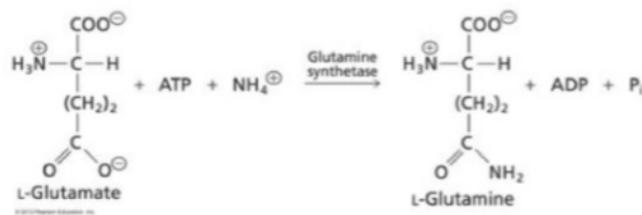


EXAMPLES	FEATURES
Racemase	Interconvert L&D stereoisomers
Mutase	Transfer groups between atoms within a molecule
Epimerase	Interconvert epimers

LIGASES:

- They are defined as enzymes that used to make different compound use of ATP to make them

EXAMPLES	FEATURES
Synthetase	Link 2 molecules via an ATP-dependent reaction.
Carboxylase	Use CO ₂ as a substrate



TOPIC: CO ENZYMES

Question: what are CO ENZYMES and their examples ?

DEFINITION:

- Coenzyme is a substance that enhances the action of an enzyme .
- The catalytic activity of enzymes mostly depends on the presence of non-protein compounds called coenzymes.

1. Lipoic acids

- Lipoic acid is a coenzyme but not a vitamin

2. Vitamins

- All water -soluble vitamins act as coenzymes (B-complex & VIT C)
- Only fat soluble vitamin acting as coenzyme - VIT K (carboxylation)

3. Nucleotides

- NAD
- NADP
- FAD FMN

4. Mg requires as a coenzyme for

- Kinases
- Phosphorylases
- Carboxylases

5. Cu REQUIRED FOR

- Oxidases
- Cyt c Oxidase
- Tyrosinase
- Ascorbic Acid Oxidase
- Amino Acid Oxidase
- Lysyl Oxidase
- Cytoplasmic SOD [Super Oxide dismutase]
- Mitochondrial SOD requires Manganese

6. Molybdenum

- Xanthine Oxidase
- Sulfite Oxidase

Question: what are types of enzymes inhibitors ?

There are 6 types of enzymes inhibitors:

1. Competitive
2. Non-competitive
3. Uncompetitive
4. Allosteric
5. Feedback inhibition
6. Suicidal inhibition

COMPETITIVE INHIBITION -

Inhibitor resembles substrate in structure. Inhibitor binds at active site.

Features:

- . K_m (Michaelis constant) does not depend upon change in enzyme and substrate concentration.
- . K_m defines affinity between a particular enzyme substrate pair.
- . But in competitive inhibition the affinity b/w enzyme and substrate decreases because now enzyme has affinity for both substrate and inhibitor.
- . Affinity decreases so K_m increases
- . Inhibitor resembles substrate
- . V_{max} remains same but K_m increases.

Competitive Inhibitors examples

1. Arsenate = Glyceraldehyde-3 -PDH
2. Oxamate ->Lactate DH
3. Malonate (3C) -> Succinate DH
4. Fluorocitrate -> Aconitase

NON - COMPETITIVE INHIBITION -

Substrate do not resemble inhibitor in structure. Inhibitor binds at regulatory or allosteric site. When inhibitor binds at regulatory site, it changes the shape of active site, so that substrate cannot bind .

Features

- . V_{max} is lowered
- . K_m is same
- . Affinity is same
- . Inhibitor can bind with ES complex, and does not change the substrate affinity for the enzyme.
- . This inhibition is mostly irreversible.

Examples

- 1.Iodoacetate -> Glyceraldehyde - 3 - PDH
- 2.NaF -> Enolase
3. Fluoroacetate -> Aconitase

UN-COMPETITIVE INHIBITION (ANTI-COMPETITIVE)

- Substrate binding exposes the inhibitor binding site away from the catalytic/substrate binding site.
- Increasing substrate concentration does not reverse the inhibition. The inhibited reaction rate parallel the normal one as reflected on decreased both v_{max} and K_m .

Uncompetitive Inhibitor examples:

- Acetylcholine inhibits Placental ALP (Alkaline Phosphatase)

FEED BACK INHIBITION / END PRODUCT INHIBITION

- End product itself inhibits the reaction

Example

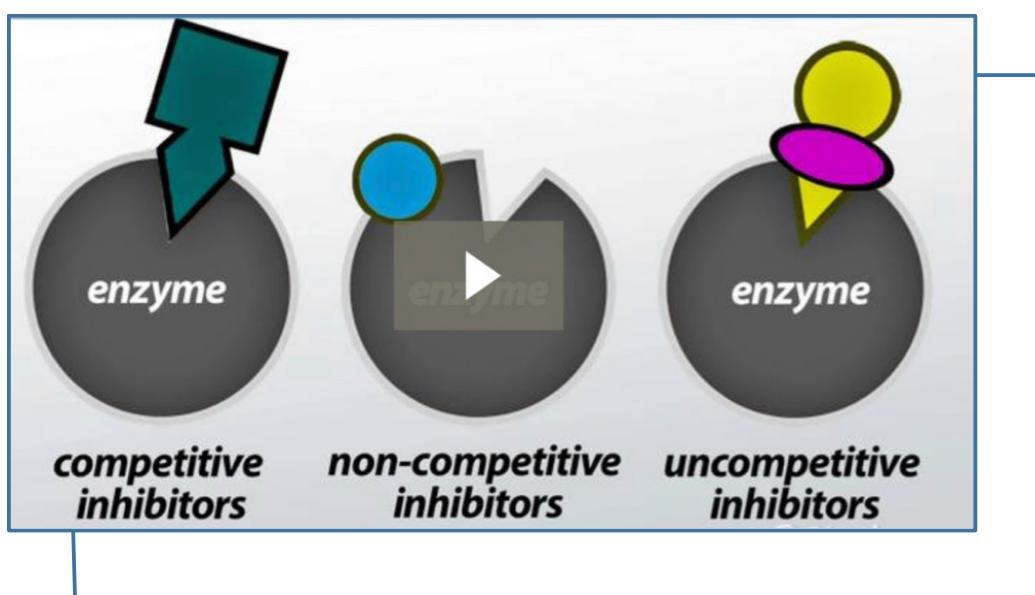
1. Cholesterol inhibits HMG CoA Reductase
2. Haem inhibits ALA Synthase [RLC] & stops haem Synthesis

- Feed back Inhibition is a natural phenomenon occurring in body.
- It is normally observed in regulation of enzymes and pathways.

SUICIDAL INHIBITION / MECHANISM BASED, INHIBITION

Example - Allopurinol Inhibits Xanthine oxidase by a proper mechanism

Suicidal Inhibition is unnaturally occurring phenomenon e.g Drugs



Describe suicide inhibition of enzymes.

Name one suitable example for suicidal inhibition of enzymes.

SUICIDE INHIBITION:

- Suicide inhibition, also called suicide inactivation or mechanism-based inhibition, is an irreversible type of enzyme inhibition.
- It occurs when an enzyme binds a substrate analog.
- During the normal catalysis reaction, this binding leads to the formation of an irreversible complex through a covalent bond.
- This complex renders the enzyme permanently inactive.

EXAMPLES:

- 5-fluorouracil acts as a suicide inhibitor of thymidylate synthase during thymine synthesis from uridine.
- This inhibition is crucial for halting the proliferation of rapidly dividing cells, including fast-growing cancer tumors.
- Cells die from a "thymineless death" because they lack thymine necessary for DNA synthesis.
- Often used in combination with methotrexate, a potent inhibitor of dihydrofolate reductase enzyme.
- Aspirin, which inhibits cyclooxygenase 1 and 2 enzymes.
- Nerve agents and pesticides like parathion irreversibly inhibit acetylcholinesterase .

TOPIC : ENZYMES REGULATION

Question. What are the Various ways of Enzyme Regulation ?

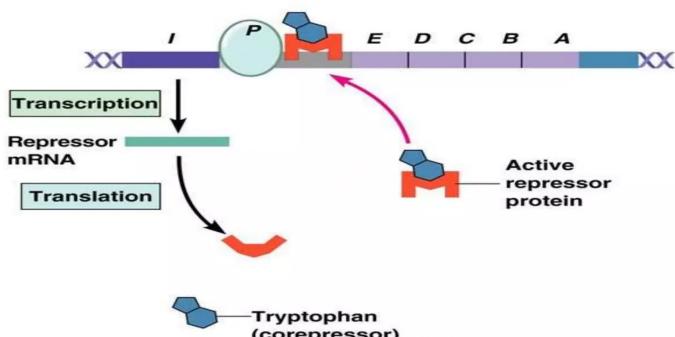
DEFINITION: process by which cells can turn on or turn off or modulate the activities which are the activities of various metabolic pathways by regulating the activity of enzyme.

Enzyme Regulation

I) Induction and Repression of Enzyme Synthesis:

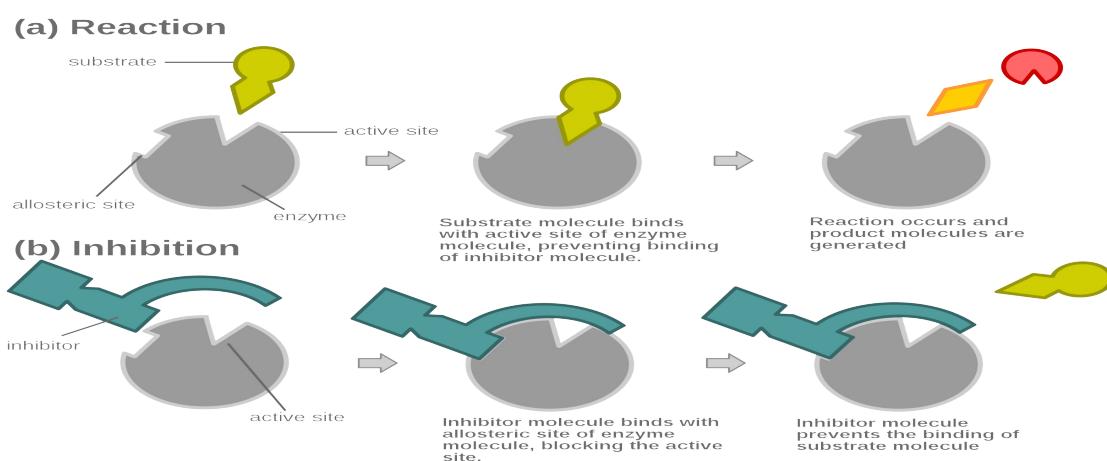
- Regulation of enzyme synthesis at the gene level.
- Induction increases enzyme synthesis, while repression decreases it.
- Examples:
 1. Insulin induces glycolytic enzymes and represses gluconeogenic enzymes.
 2. Glucagon induces pyruvate carboxylase and represses PFK.

Repression



II) Allosteric Regulation:

- Allosteric enzymes have allosteric sites different from the active site.
- Allosteric modifiers bind to these sites, either activating (allosteric activators) or inhibiting (allosteric inhibitors) enzyme activity.
- Classification based on effect on Km and Vmax:
 - a) K-Class allosteric enzymes: Change Km but not Vmax (substrate saturation kinetics like competitive inhibition).
 - b) V-Class allosteric enzymes: Change Vmax but not Km (substrate saturation kinetics like non-competitive inhibition).
- Allosteric enzymes show cooperativity, with positive and negative modifiers affecting active site activity.



III) Covalent Modification:

A) Irreversible Covalent Modification (Proenzymes or Zymogens):

- Some enzymes are synthesized as inactive proenzymes.
- Converted to active form by irreversible breakage of specific covalent peptide bonds.
- Example: Proteases in the GI tract (e.g., trypsinogen to trypsin).
- Significance: Protects tissue from auto-digestion and facilitates rapid activity.

B) Reversible Covalent Modification:

- Regulation by reversible phosphorylation and dephosphorylation.
- Phosphate groups control enzyme activity.
- Examples: Glycogen phosphorylase (phosphorylated form active, dephosphorylated form inactive) and glycogen synthase (phosphorylated form inactive, dephosphorylated form active).

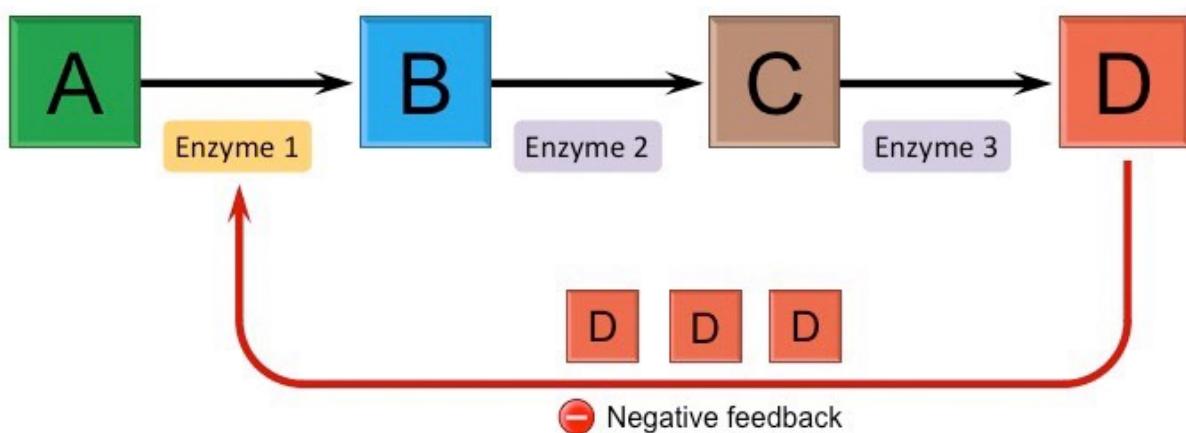
IV) Feedback Regulation:

1) Feedback Allosteric Inhibition:

- End product inhibits the key enzyme in a pathway.
- Regulation at the enzyme level.
- Example: ALA synthase in heme synthesis inhibited by excess heme.

2) Feedback Repression:

- End product represses the synthesis of the key enzyme at the gene level.
- Example: HMG CoA reductase in cholesterol synthesis repressed by excess cholesterol.
- Prevents excess synthesis of end products by regulating key enzymes in metabolic pathways.



Multienzyme Complexes:

- **Definition:** Multienzyme complexes refer to the localization of several enzymes catalyzing a sequence of consecutive reactions of a metabolic pathway into a macromolecular complex.

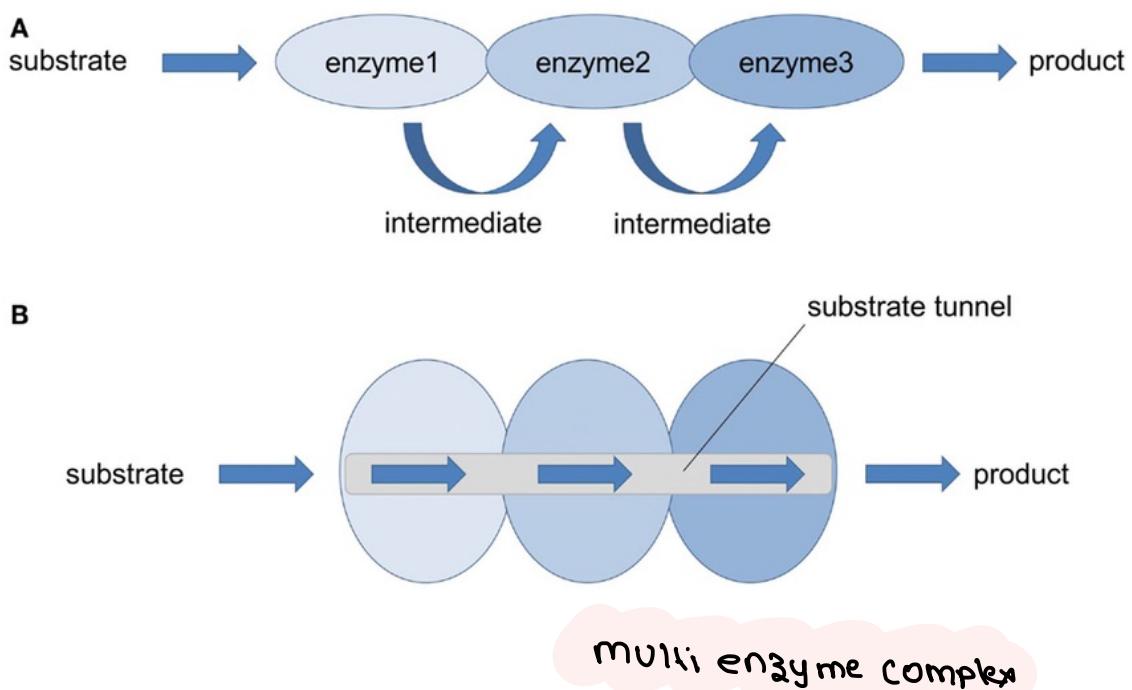
- **Examples:** Fatty acid synthase complex, alpha-ketoglutarate dehydrogenase complex, Pyruvate dehydrogenase complex, etc.

- **Complex Activity:** Multienzyme complexes are active only in their complex form. Individual enzyme activities within the complex cannot be separated through fractionation.

Significances of Multienzyme Complexes:

1. Efficiency: Multienzyme complexes increase the efficiency and speed of metabolic pathways by directly transferring intermediates from one enzyme to the next, preventing their dilution in the surrounding medium. This ensures an uninterrupted sequence of reactions until the pathway is completed.

2. Protection of Intermediates: Intermediates bound to multienzyme complexes are shielded from diversion into other metabolic pathways, thus enhancing the specificity of the pathway.



EXTRA EDGE

Enzyme Compartmentalization:

Definition: Enzyme compartmentalization refers to the organization of enzymes within distinct cellular locations, allowing for precise regulation of metabolic pathways.

Examples:

1. **Fatty Acid Metabolism:** Enzymes involved in fatty acid synthesis are primarily located in the cytosol, while those responsible for fatty acid degradation are found in mitochondria, ensuring these processes do not occur simultaneously.

2. **Heme Synthesis:** Heme, an important component for hemoglobin, is synthesized in one cellular compartment and then transported across membranes for further processing, preventing unwanted reactions.

Regulation: Enzyme compartmentalization enables the regulation of metabolic pathways by keeping specific enzymes in separate compartments, ensuring that each reaction occurs where and when needed, thus preventing unwanted or futile cycles.

Question: what are the DIAGNOSTIC and THERAPEUTICS USES of enzymes?

DIAGNOSTIC USES

1. SGOT, SGPT For Liver diseases

THERAPEUTICS USES

1. Lactase -> Lactose Intolerance
 2. Lactamase -> Penicillin Allergy
 3. Urokinase / Streptokinase - Converts Plasminogen - Plasmin
-> Used for lysis of Intravascular clots.
 4. Trypsin / chymotrypsin used for pain + inflammation in chronic back pain and sprain.
 5. Collagenase
-> Skin ulcers (reduces the format of scar tissue)
 6. Pepsin - Pancreatic insufficiency & chronic indigestion
 7. Asparaginase/ Glutaminase -> ALL (Acute Lymphoblastic Leukemia)
 8. Uricase -> Gout
 9. Alpha - 1 - Anti trypsin -> Emphysema
- IN ALL (Acute Lymphoblastic Leukemia), the cancer cell has high demand for Asparagine & Glutamine
- These enzymes break down these AA & ALL cell will die

COENZYMES AND COFACTORS

- Coenzymes provide additional chemically reactive functional groups besides those present in the amino acids of the apoenzymes
 - Are either small organic molecules or inorganic ions
- Metal ions often act as additional cofactors (Zn^{2+} , Mg^{2+} , Mn^{2+} & Fe^{2+})
 - A metal ion cofactor can be bound directly to the enzyme or to a coenzyme
- COENZYME
 - A small organic molecule, acting as a cofactor in a conjugated enzyme
- Coenzymes are derived from vitamins or vitamin derivatives
 - Many vitamins act as coenzymes, esp. B-vitamins.

Enzyme definitions

Term	Definition
Enzyme (simple)	Protein only enzyme that facilitates a chemical reaction
Coenzyme	Compound derived from a vitamin (e.g. NAD^+) that assists an enzyme in facilitating a chemical reaction
Cofactor	Metal ion (e.g. Mg^{2+}) that assists an enzyme in facilitating a chemical reaction
Apoenzyme	Protein only part of an enzyme (e.g. isocitrate dehydrogenase) that requires an additional coenzyme to facilitate a chemical reaction (not functional alone)
Holoenzyme	Combination of the apoenzyme and coenzyme which together facilitate a chemical reaction (functional)

Define the active site of enzymes.

ENZYME ACTIVE SITE

- The specific portion of an enzyme (location) where the substrate binds while it undergoes a chemical reaction
- The active site is a 3-D ‘crevice-like’ cavity formed by secondary & tertiary structures of the protein part of the enzyme
- Crevice formed from the folding of the protein Also called as binding cleft
- An enzyme can have more than only one active site
- The amino acids R-groups (side chain) in the active site are important for determining the specificity of the substrate

Question: What is Enzyme Specificity? Explain the concept of absolutely specific enzymes.

ABSOLUTE SPECIFICITY:

- An enzyme will catalyze a particular reaction for only one substrate
- Most restrictive of all specificities
- Not common
- Catalase has absolute specificity for hydrogen peroxide (H_2O_2)
- Urease catalyzes only the hydrolysis of urea

GROUP SPECIFICITY:

- The enzyme will act only on similar substrates that have a specific functional group
- Carboxypeptidase cleaves amino acids one at a time from the carboxyl end of the peptide chain
- Hexokinase adds a phosphate group to hexoses

LINKAGE SPECIFICITY:

- The enzyme will act on a particular type of chemical bond, irrespective of the rest of the molecular structure
- The most general of the enzyme specificities
- Phosphatases hydrolyze phosphate–ester bonds in all types of phosphate esters
- Chymotrypsin catalyzes the hydrolysis of peptide bonds

STEREOCHEMICAL SPECIFICITY:

- The enzyme can distinguish between stereoisomers
- Chirality is inherent in an active site (as amino acids are chiral compounds)
- L-Amino-acid oxidase catalyzes reactions of L-amino acids but not of D-amino acids

Explain the influence of various factors on enzyme activity. Explain the effect of temperature on enzyme activity.

Define metalloenzymes and provide two examples.

Factors affecting enzymatic activity – enzyme concentration, pH, temperature and substrate concentration.

Effect of pH and temperature on enzyme activity.

ENZYME ACTIVITY:

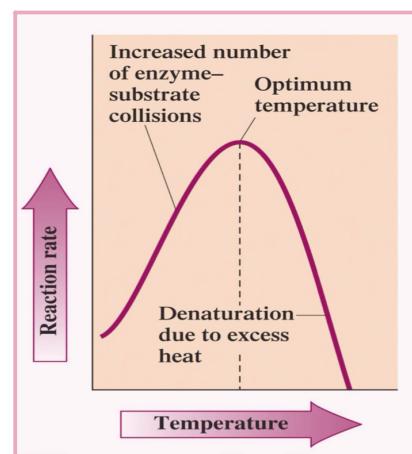
- Measure of the rate at which an enzyme converts substrate to products in a biochemical reaction.

4 Factors affect enzyme activity:

- Temperature
- pH
- Substrate concentration: [substrate]
- Enzyme concentration: [enzyme]

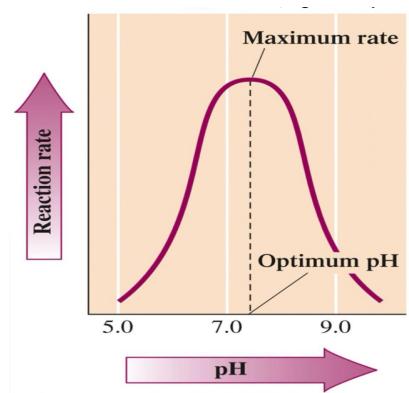
TEMPERATURE (t):

- With increased t the E_{KIN} increases More collisions Increased reaction rate
- Optimum temperature (t_{OPT}) is the temperature at which the enzyme exhibits maximum activity
 - The t_{OPT} for human enzymes = 37 degree Celsius
- When the t increases beyond t_{OPT} Changes in the enzyme's tertiary structure occur, inactivating & denaturing it (e.g. Fever)
- Little activity is observed at low t



pH:

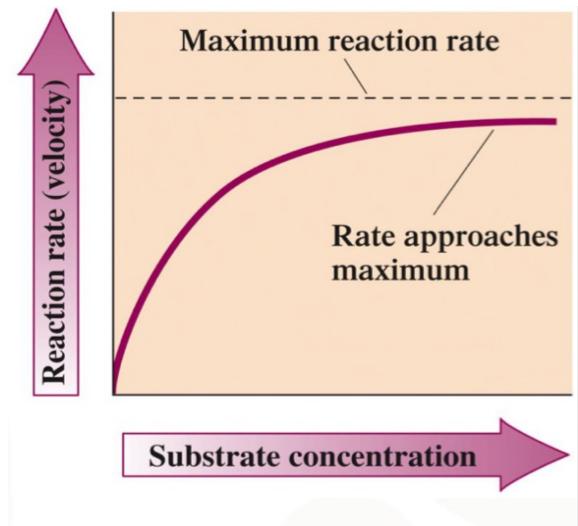
- Optimum pH ($pHOPT$) is the pH, at which the enzyme exhibits maximum activity
- Most enzymes are active over a very narrow pH range
 - Protein & amino acids are properly maintained
 - Small changes in pH (low or high) can result in enzyme denaturation & loss of function
- Each enzyme has its characteristic $pHOPT$, which usually falls within physiological pH range 7.0 - 7.5



- Digestive enzymes are exceptions:
 - Pepsin (in stomach) – $pHOPT = 2.0$
 - Trypsin (in SI) – $pHOPT = 8.0$

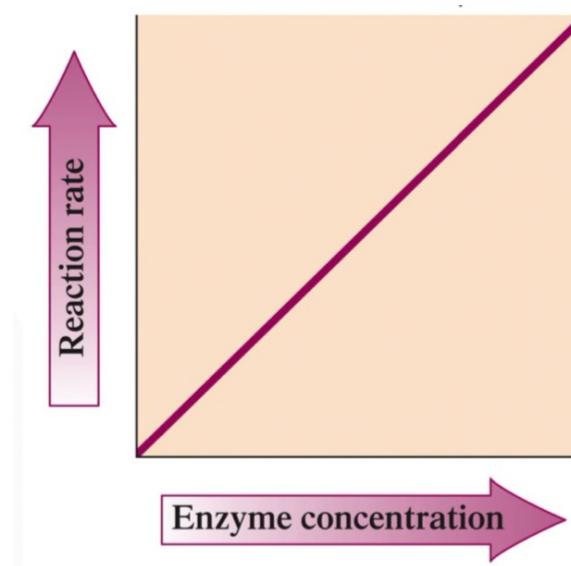
SUBSTRATE CONCENTRATION:

- If [enzyme] is kept constant & the [substrate] is increased.
 - The reaction rate increases until a saturation point is met
- At saturation the reaction rate stays the same even if the [substrate] is increased
 - At saturation point substrate molecules are bound to all available active sites of the enzyme molecules
- Reaction takes place at the active site
 - If they are all active sites are occupied the reaction is going at its maximum rate
- Each enzyme molecule is working at its maximum capacity
 - The incoming substrate molecules must “wait their turn”



ENZYME CONCENTRATION:

- If the [substrate] is kept constant & the [enzyme] is increased
 - The reaction rate increases
 - The greater the [enzyme], the greater the reaction rate
- RULE:
 - The rate of an enzyme-catalyzed reaction is always directly proportional to the amount of the enzyme present
- In a living cell:
 - The substrate is much higher than the enzyme
 - Enzymes are not consumed in the reaction
 - Enzymes can be reused many times



Effect of product concentration

The accumulation of reaction products generally decreases the enzyme velocity.

Enzyme Activation by Metals:

- Some enzymes require specific metallic cations (Mg^{2+} , Mn^{2+} , Zn^{2+} , etc.) or anions (Cl^-) for optimal activity.
- Metals act as activators by interacting with substrates, forming complexes, participating in reactions, or inducing enzyme conformational changes.

- Two categories:

- **Metal-activated enzymes** (e.g., ATPase with Mg^{2+} and Ca^{2+} , Enolase with Mg^{2+}): Metals can be easily exchanged with other ions.

Metalloenzymes : These enzymes hold the metals rather tightly which are not readily exchanged. e.g. alcohol dehydro- genase, carbonic anhydrase, alkaline phos- phatase, carboxypeptidase and aldolase contain zinc.

Phenol oxidase (copper);

Pyruvate oxidase (manganese); Xanthine oxidase (molybdenum); Cytochrome oxidase (iron and copper).

Km (Michaelis -Menton constant) with significance.

Definition:

Km is defined as the substrate concentration at half maximum velocity ($1/2 V_{max}$). Km is expressed in moles/ L.

Significance of Km:

1) Km is the characteristic feature of an enzyme for its substrate: It is a constant for an enzyme for its substrate. Km is termed as the signature of the enzymes.

2) Km is the measure of affinity of enzyme for its substrate:

Lower the Km value higher will be the substrate affinity of enzymes and vice versa. E.g.: Glucose is phosphorylated by glucokinase (liver enzyme) & hexokinase (present in all tissues). Both have different Km value for glucose.

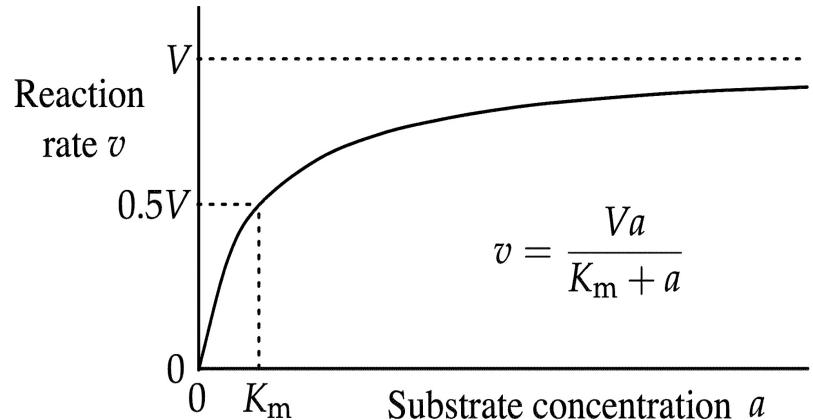
Km of glucokinase is 10 mmol/L & Km of hexokinase is 0.05 mmol/L.

This indicates hexokinase has more affinity than glucokinase for glucose.

3) Enzymes have 50 % efficiency at Km: At Km, enzymes have half the maximum velocity i.e. only 50% of enzymes are active (other 50% are free).

**Michaelis - Menten
equation**

$$V_0 = \frac{V_{max} [S]}{K_m + [S]}$$



4) Km value is helpful in understanding the natural substrate of enzymes that act on more than one substrates. For instance, hexokinase can phosphorylate glucose, fructose, galactose, mannose etc. But this enzyme has the lowest Km (maximum affinity) for glucose than other substrates. So, it can be concluded that the glucose is the natural substrate of hexokinase enzyme.

5) pH, temperature and inhibitors affect Km values.

6) Isoenzymes have different Km values for the same substrates.

Isoenzymes

Isoenzymes – definition, characteristics and clinical significance.

- **Definition:** Isoenzymes are distinct molecular forms of an enzyme that catalyze the same reactions within a single species.
- **Characteristics:**
 - 1) Isoenzymes possess different structures and physical/chemical properties.
 - 2) Despite these differences, all isoenzyme forms of an enzyme perform the same reaction, acting on the same substrate to produce identical products.
 - 3) Isoenzymes exhibit variations in amino acid compositions, electrophoretic mobility, and immunological properties. They can be separated via electrophoresis.
 - 4) Isoenzymes may have distinct K_m values (and V_{max}) for the same substrates.
 - 5) Isoenzymes frequently consist of multiple polypeptide chains, forming oligomeric units. For example, LDH has 4 polypeptide chains, and CK has 2 polypeptide chains.

Clinical Significance of Isoenzymes:

- Isoenzymes are valuable diagnostic markers for various diseases, as their tissue-specific distribution and regulation make them indicative of tissue damage or dysfunction.
- Measuring the levels of specific isoenzymes in the blood can aid in the diagnosis and monitoring of diseases.
- Examples of clinical significance include:
 - **LDH isoenzymes:** Elevated LDH1 levels in the blood can be indicative of myocardial infarctions, while increased LDH5 levels may suggest muscle dystrophies.
 - **CK isoenzymes:** Elevated CK-MM levels are associated with skeletal muscle disorders, like muscle dystrophies. Elevated CK-MB levels can indicate myocardial infarctions.

Extra edge

- Regulatory Role of Isoenzymes:

- Isoenzymes are typically found in different tissues and are regulated by distinct inducers, repressors, and allosteric modifiers based on the specific needs of those tissues. This tissue-specific regulation provides a point for the fine-tuning of enzyme activity in various parts of the body.

Describe the clinical significance of following enzymes: LDH, alkaline phosphatase, creatinine kinase, amylase, alanine transaminase.

LDH

Isoenzyme name	Composition	Electrophoretic migration	Present in	Elevated in
LDH 1 Heat resistant	(H ₄)	Fastest moving	Myocardium, RBC,kidney	myocardial infarction
LDH2 Heat resistant	(H ₃ M ₁)		Myocardium, RBC,kidney	Kidney disease,megalo blastic anemia
LDH3	(H ₂ M ₂)		brain	Leukemia,malignancy
LDH4 Heat labile	(H ₁ M ₃)		Lung,spleen	Pulmonary infarction
LDH5 Heat labile Inhibited by urea	(M ₄)	Slowest moving	Skeletal muscle, Liver	Skeletal muscle and liver diseases

6

Creatine kinase

Isoenzyme name	Composition	Present in	Elevated in
CK-1 Fast moving	BB	Brain,prostate,GL tract,lung,bladder,uterus,placenta	CNS diseases
CK-2 2% of total	MB	Myocardium/ Heart	Acute myocardial infarction
CK-3 Slow moving	MM	Skeletal muscle, Myocardium	

ALP

Orthophosphoric monoester phosphohydrolase

- produced In mucosa of small intestine, proximal convoluted tubule, bone, liver, placenta
- Catalyses alkaline hydrolysis of naturally occurring and synthetic substrates

Alpha 1 ALP-epithelial cells of biliary canaliculi

- Alpha 2 heat labile ALP- hepatic cells
- Alpha 2 heat stable ALP-not destroyed at 65°C inhibited by phenylalanine placental

Pre beta ALP - bone,heat labile

- Gamma ALP - intestinal cells inhibited by phenylalanine
- Leukocyte alkaline phosphatase -decreased in CML increase in lymphoma

Clinical significance

Hepatobiliary disease

- Hepatic carcinoma
- Hepatic metastases
- Pagets disease (10 - 25 times)
- Bone cancer
- Healing of bone fracture
- Osteomalacia and rickets
- Hyperparathyroidism
- Ca of ovary,uterus-regan isoenzyme
- Metastatic Ca of pleural surfaces -Nagao isoenzyme

ALT (Alanine transaminase) is rich in liver.

Normal serum level is 3 - 35 IU/L.

During liver diseases,

ALT is released into the blood and their level increases in the blood, which reflects a possible liver damage

AMYLASE

Amylase is produced in the salivary glands and pancreas. Elevated levels of amylase can be observed in the following conditions:

1. **Acute Pancreatitis:** This is a major cause of increased amylase levels. Inflammation of the pancreas leads to the release of amylase into the bloodstream.
2. **Mumps (Acute Parotitis):** Mumps is a viral infection that primarily affects the salivary glands, particularly the parotid glands. Inflammation of these glands can result in elevated amylase levels.
3. **Obstruction in Pancreatic Duct:** Any obstruction or blockage in the pancreatic duct can lead to increased amylase levels because the enzyme cannot flow into the intestines as it normally would.
4. **Severe Diabetic Ketoacidosis:** In rare cases, severe diabetic ketoacidosis, a complication of uncontrolled diabetes, can lead to increased amylase levels.

Diagnostic enzymes – examples and clinical significance.

- Diagnostic enzymes, also known as clinical enzymes, are intracellular enzymes.
- They lack a specific role in the bloodstream and are primarily located in specific tissues.
- When these corresponding tissues undergo normal wear and tear or are damaged, these enzymes are released into the bloodstream.
- In healthy individuals, the concentration of diagnostic enzymes in the blood is typically low and within normal levels.
- Elevated levels of diagnostic enzymes in the blood reflect possible damage to the specific tissue where these enzymes are abundant.
- Measurement of increased blood enzyme levels is essential for diagnosing diseases and conditions related to the affected tissues.
- The degree of enzyme elevation often correlates with the extent of tissue damage.
- Diagnostic enzymes also play a role in prognosis by helping assess disease severity and progression.

**** examples and clinical significance you can write from the prior answer ****

Cardiac markers for myocardial infarction.

.

1. Creatine Phosphokinase (CPK):

- CPK is the first enzyme to be released into circulation, appearing within 6-18 hours after an MI.
- It reaches its peak value within 24-30 hours and returns to normal levels by the 2nd or 3rd day.

2. Aspartate Transaminase (AST or SGOT):

- AST rises after CPK and reaches its peak within 48 hours of the MI.
- It takes 4-5 days to return to normal levels.

3. Lactate Dehydrogenase (LDH1):

- LDH1 typically rises from the second day after infarction.
- It reaches its peak by the 3rd or 4th day and takes about 10-15 days to return to normal levels.
- LDH is the last enzyme to rise and the last to return to normal levels in MI.

4. Cardiac Troponins (CT):

- Cardiac troponins, although not enzymes, are highly useful for early MI diagnosis.
- Troponin I and Troponin T are significant markers.
- Cardiac Troponin I (CTI) is released into circulation within four hours after the onset of MI, peaks within 12-24 hours, and remains elevated for about a week.

5. Myoglobin:

- Myoglobin is an early marker for MI diagnosis.
- However, it is not specific to cardiac diseases.

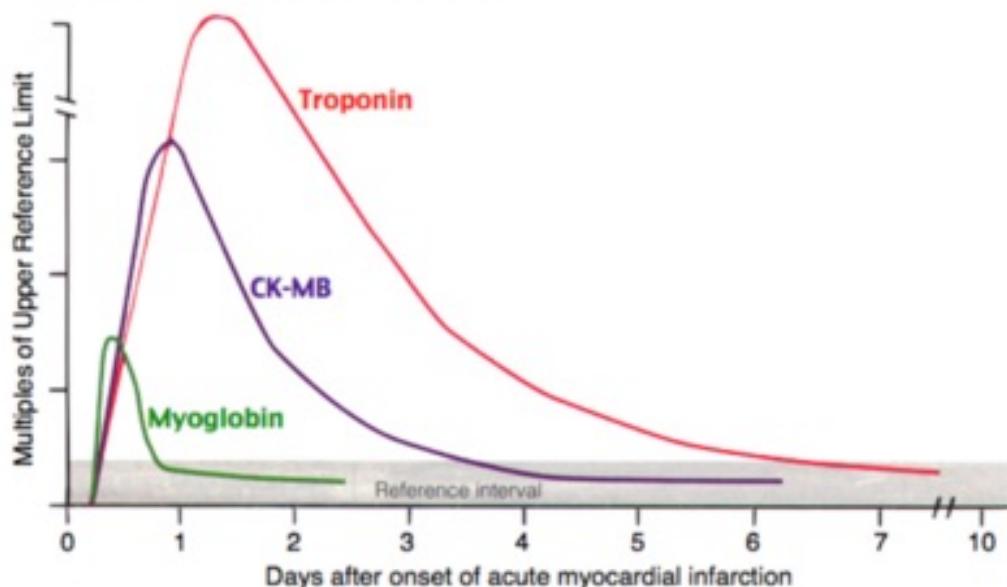
6. Brain Natriuretic Peptide (BNP):

- High serum concentrations of BNP are a marker for congestive cardiac failure.

TABLE 6.12 Summary of diagnostic markers used for the evaluation of acute myocardial infarction

Diagnostic marker	Time of peak elevation	Time of return to normal level	Diagnostic importance
Myoglobin	4-6 hrs	20-25 hrs	Earliest marker, however not cardiac specific.
Cardiac troponin I	12-24 hrs	5-9 days	Early marker and cardiac specific.
Cardiac troponin T	18-36 hrs	5-14 days	Relatively early marker and cardiac specific. However, elevated in other degenerative diseases.
Creatine phosphokinase (MB)	20-30 hrs	24-48 hrs	Cardiac specific and early marker.
Lactate dehydrogenase (LDH I)	48-72 hrs	10-15 days	Relatively late marker and cardiac specific.
Aspartate transaminase	30-48 hrs	4-6 days	Not cardiac specific.

Cardiac Biomarkers



- **Hepato-biliary markers.**

Enzymes Indicating Liver Damage (Hepatic Jaundice):

- ALT (SGPT): Normal level is 3 - 35 U/liter of serum.
- AST (SCOT): Normal level is 4 - 40 U/liter of serum.
- LDH (Particularly LDH isoenzyme 4): Normal level is 60 - 200 U/L.
 - These enzyme levels increase in cases of liver damage, such as hepatic jaundice.

Enzymes Indicating Biliary Diseases (Obstructive Jaundice):

- Alkaline Phosphatase (ALP): Normal serum level is 3 - 13 KA units/dL.
- GGT (γ -glutamyl transferase): Normal serum level is 7 - 50 U/L.
- 5'-Nucleotidase: Normal serum level is 2 - 17 U/L.
 - These enzyme levels increase during posthepatich jaundice or obstructive jaundice.
 - 5'-Nucleotidase is a better indicator of biliary diseases, as it is biliary-specific, while ALP may also increase in bone diseases and GGT may increase in alcoholic liver diseases.

Name two enzymes of pancreatic injury.

SERUM LIPASE

SERUM AMYLASE

Therapeutic enzymes:

Enzymes that are used in the treatment of certain diseases are called therapeutic enzymes

- **Streptokinase** obtained from streptococcus and urokinase obtained from urine of human beings are used in the lysis of the intravascular clots as they convert plasminogen to plasmin which lyses the clot.
- **Asparaginase** is used in the treatment of leukemia. Tumour cells have a high requirement for asparagine. Administration of intravenous asparaginase enzyme decreases the plasma level of asparagine and availability of asparagine to the tumor cells is decreased. This depresses the feasibility of tumor cells.
- **Papain** is used in the treatment of inflammation.
- **Antitrypsin** is used in the treatment of emphysema.
- **Collagenase** is used in the treatment of burns and ulcers.

Therapeutic uses of Enzymes

	Enzyme	Therapeutic use
1	Asparaginase	Acute Lymphatic Leukemia (cells need Asparagine for its growth)
2	Streptokinase	LYSE INTRACELLULAR CLOT
3	Uro kinase	Lyse Intracellular Clot
4	Plasminogen	PLASMIN /CLOT LYSIS
5	Streptokinase	DNA ase applied locally
6	Hyaluronidase	Enhance local anesthesia
7	Pancreatic (Lipase & Trypsin)	Pancreatic insufficiency – oral administration
8.	Papain	Anti-inflammatory
9.	Alpha Anti Trypsin	Emphysema

Multiple choice questions

Which of the following is a Lyase?

- A) Aldolase B
- B) Acetyl-CoA Carboxylase
- C) Fatty Acyl-CoA Dehydrogenase
- D) Acetyl-CoA Synthetase

Which of the following enzyme is not involved in oxidation-reduction reactions?

- A) Dehydrogenase
- B) Hydrolase
- C) Peroxidase
- D) Oxygenase

Which of the following is not a coenzyme?

- A) Lipoic acid
- B) ATP
- C) Vitamin K
- D) S-adenosyl methionine

Which of the following is not a copper-containing enzyme?

- A) Mitochondrial superoxide dismutase
- B) Cytosolic superoxide dismutase
- C) Tyrosinase
- D) Lysyl oxidase

Which of the following is the coenzyme group present in the enzyme xanthine oxidases ?

- A) Molybdenum
- B) Zine
- C) Manganese
- D) Copper

Answer

- 1.a
- 2.b
- 3.d
- 4.a
- 5.a

Essay Questions :

1. Define enzymes. Describe the classification and mechanism of action of enzymes.
2. Classify enzymes with examples. Enumerate the factors affecting the rate of enzymatic actions. Competitive inhibition of enzymes.

Short Questions

1. What are the Types of enzymes inhibition.
2. Distinguish between competitive and non-competitive inhibition of enzyme action with example.
3. What is a co-enzyme? How is it different from activator.
4. Creatine phosphor kinase
5. What is non competitive inhibition