Biomolecules

DISCLAIMER

Biomolecules

INTRODUCTION

- All the elements present in a sample of earth's crust are present in a sample of living tissue.
- Approximately 95% percent of the cellular material is composed of carbon, hydrogen and oxygen.

Element	% Weight	
	Earth's crust	Human body
Hydrogen (H)	0.14	0.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.5
Nitrogen (N)	very little	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	negligible
• Adapted from CNR Rao, Understanding Chemistry, Universities Press, Hyderabad.		

TABLE. A COMPARISON OF ELEMENTS PRESENT IN NON-LIVING AND LIVING MATTER*

- The other non-metal elements such as N, P, Cl, and S etc., and metals such as Ca, K, Na, Mg constitute less than 5% of total material in the cell. Copper, cobalt, zinc, manganese, molybdenum and chromium occur in traces.

Component	Formula
Sodium	Na^+
Potassium	K^+
Calcium	Ca^{++}
Magnesium	Mg^{++}
Water	H_2O
Compounds	NaCl, $CaCO_3$, PO_4^{3-} , SO_4^{2-}

TABLE. A LIST OF REPRESENTATIVE INORGANIC CONSTITUENTS OF LIVING TISSUES

- The biomacromolecules in the cellular pool possess low melting point, simple conformity and higher solubility.
- Biomacromolecules are large sized with high

Definition

Biomolecules: All the carbon compounds that we get from living tissues can be called 'biomolecules'.

Previous Year's Question

Concentration of minerals inside a cell in desending order is

(1) Ca – K – Na
(2) Na – K – Ca
(3) K – Ca – Na
(4) K – P – Ca.

Definition

Cellular pool: The sum total of different types of molecules present in a cell is termed as cellular pool. The cellular pool consists of water, salts, ions, organic compounds, and colloidal organic molecules. There are over 5000 chemicals in cellular pool.

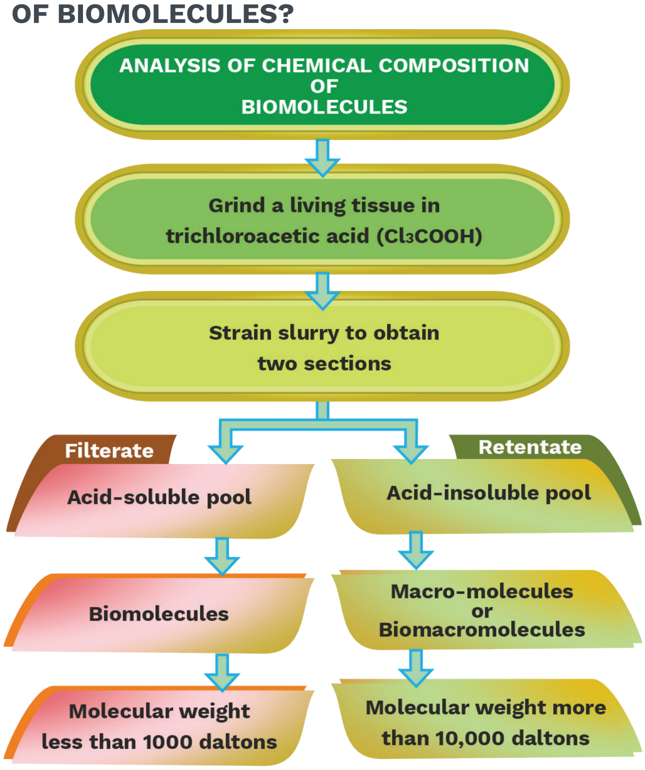
molecular weight and are formed by the condensation of **micromolecules** so are called **polymers**.

- Only three types of macromolecules, i.e., polysaccharides ,proteins, and nucleic acids are found in living systems.

Component	% of the total cellular mass
Water	70–90
Proteins	10–15
Carbohydrates	3
Lipids	2
Nucleic acids	5–7
Ions	1

TABLE. AVERAGE COMPOSITION OF CELLS

HOW TO ANALYSE THE CHEMICAL COMPOSITION OF BIOMOLECULES?



Previous Year's Question

The most abundant component of a cell is

(1) Water
(2) Lipid
(3) Protein
(4) Cellulose

Rack Your Brain

What are the two fractions into which the chemical compounds of a cell or living tissue can be divided?

Previous Year's Question

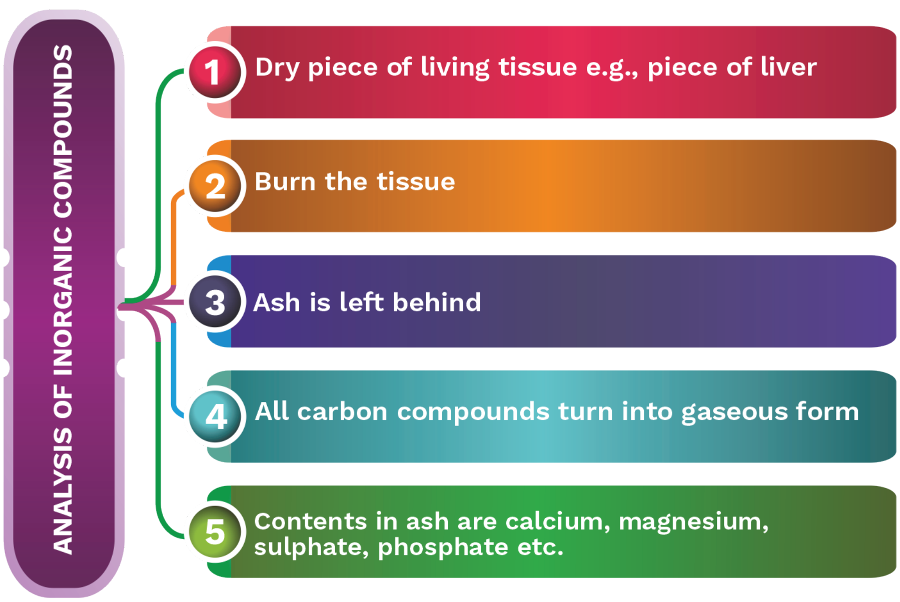
Maximum amount of iron occurs in

(1) Leucocytes
(2) Erythrocytes
(3) Bone cells
(4) Proteins

Note : Generally lipids do not polymerise to form macromolecules. Molecular weights of lipids do not exceed 800 daltons. But these are associated with cell membranes so get separated in the macromolecular friction. So these are present in the acid insoluble pool.

Note: The acid soluble pool represents roughly the cytoplasmic composition. The macromolecules from cytoplasm and organelles become the acid insoluble fraction. Together they represent the entire chemical composition of living tissues or organisms.

ANALYSIS OF INORGANIC COMPOUNDS



MICROMOLECULES (Biomolecules)

- Molecules of low molecular weight, found in the acid-soluble pool.
- These include -
  - sugars
  - amino acids
  - nucleotides
  - minerals
  - water

Definition

Micromolecules or biomolecules: Molecules which have molecular weight less than one thousand daltons and are found in the acid-soluble pool.

SIMPLE CARBOHYDRATES (SUGARS)

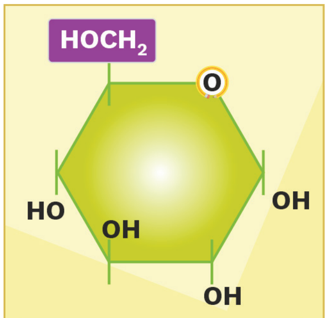
- Categories:
  - Monosaccharides
  - Oligosaccharides

Rack Your Brain

Name two acid-soluble inorganic substances in the ash of a plant.

Monosaccharides

- General formula is $C_nH_{2n}O_n$
- Carbohydrates consists of carbon, hydrogen and oxygen in the ratio of 1:2:1
- Monosaccharides are colourless, sweet tasting solids that show oxidation, esterification and fermentation. Due to asymmetric carbon, these exist in different isomeric forms. These can rotate polarized light hence are dextrorotatory and laevorotatory.
- These cannot be hydrolysed further into smaller carbohydrates.
- Types of small carbohydrates on the basis of carbon atoms are given in the table:

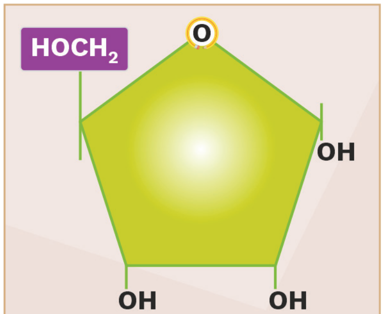


$C_6H_{12}O_6$ (Glucose)

S.no.	Sugar	Number of C-atoms	Example
1	Trioses	3 Carbon atoms	Glyceraldehyde
2	Tetroses	4 Carbon atoms	Erythrose
3	Pentoses	5 Carbon atoms	Ribose and deoxyribose
4	Hexoses	6 Carbon atoms	Glucose and fructose
5	Heptoses	7 Carbon atoms	Sedoheptulose

Common Sugar Found in Animals are Hexoses.

- **Glucose,** a common animal sugar is also called grape sugar or blood sugar or corn sugar and is dextrose.
- **Galactose** is one of the units of **lactose** (disaccharide).
- **Fructose** is fruit sugar and sweetest of all sugars. It is found in fruit, nectar and honey. It is a ketose sugar. Fructose units are found in **inulin** (polysaccharide) found in roots of Dahlia.
- **Pentose sugar** is found in nucleotides and nucleic acids.



$C_5H_{10}O_5$ (Ribose)

- The aldehyde or ketone group of a mono-saccharide reacts with the alcoholic group of other molecule of same type of sugar or with the molecule of other type of sugar resulting in the formation of glycosidic bond.
- Glycosidic bonds break on hydrolysis to give rise to its component sugars.

Oligosaccharides

- These carbohydrates are formed by condensation of 2-9 monosaccharide units.
- The smallest and most common oligosaccharides are disaccharides such as sucrose, maltose, lactose.
- **Sucrose**, the commercial sugar or cane sugar (made up of glucose and fructose) is obtained from sugarcane and sugar beet. It is a non-reducing sugar.

Glucose + Fructose $\longrightarrow$ Sucrose + Water

- **Maltose** is a reducing sugar and made up of two molecules of glucose.
- **Lactose** the milk sugar (made up of glucose and galactose) is a reducing sugar. It is not found in plants.

Gray Matter Alert!!!

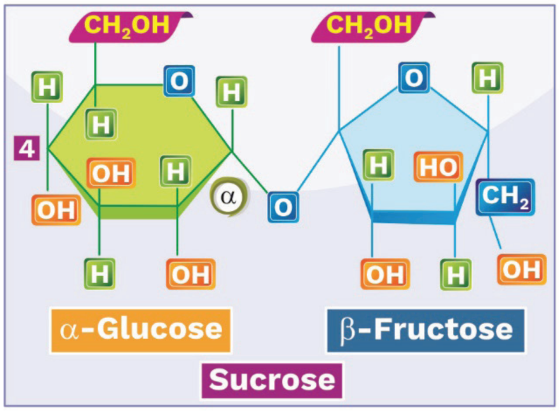
Glycosidic bond - A bond formed by the joining of aldehyde or ketone group of a monosaccharide to alcoholic group of another organic compound.

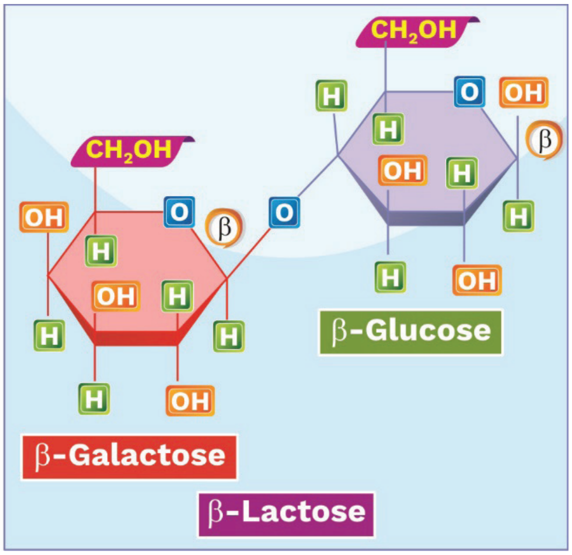
Gray Matter Alert!!!

Glycogen - α-glucose chains arranged in a highly branched form.

Gray Matter Alert!!!

Galactose is important constituent of glycolipids and glycoproteins.





- **Sweetening index of few carbohydrates**

Carbohydrate	Sweetening Index
Sucrose	100
Maltose	32
Lactose	16

Functions of Carbohydrates

- Glucose is the main respiratory substrate in all the living beings. It is the storage carbohydrate such as **starch** in plants and **glycogen** in animals.
- Glucose is the blood sugar of human beings.
- Monosaccharides make the structural components.
- Fructose is the common fruit sugar.
- Sucrose is the reserve food in sugarcane and sugar beet.
- ATP, DNA, RNA, NAD, NADP, FAD etc., are formed by interaction of many carbohydrates.
- Oligosaccharides take part in recognition, attachment and antigen specificity.

AMINO ACIDS

- They are micromolecules(organic compounds) made up of carbon, hydrogen, oxygen and nitrogen (sometimes sulphur also).
- Amino acids are organic compounds containing an amino group and an acidic group as substituents on the same carbon i.e., the central carbon atom also called chiral carbon.
- **Carboxylic group** (COOH) provides an acidic property whereas **amino group** (NH_2) gives it a basic reaction.
- They are substituted methane's. There are four substituent group occupying the four valency positions. These are hydrogen, carboxyl group, amino group and variable group designated as R group.
- Based on the nature of R group amino acids are of various types.

Gray Matter Alert!!!

Normal level of blood glucose is 80-120mg/100ml of blood. If it exceeds then the condition is called glucosuria.

Previous Year's Question

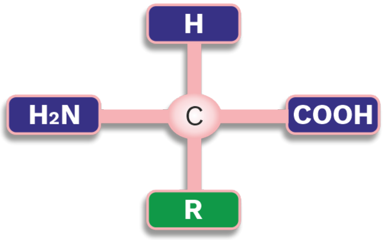
Glycogen is a polymer of
(1) galactose
(2) glucose
(3) fructose
(4) sucrose.

Definition

Essential amino acids: These cannot be synthesised in our body. Dietary proteins are the source of essential amino acids. The 9 essential amino acids are- histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

Gray Matter Alert!!!

Asymmetric carbon atom - A carbon atom which is covalently bonded to four different groups.

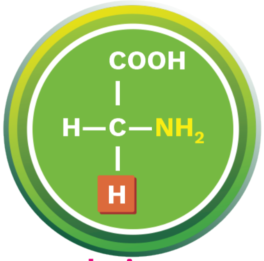


> **Definition**
>
> **Non-essential amino acids:** These are synthesised in our body.

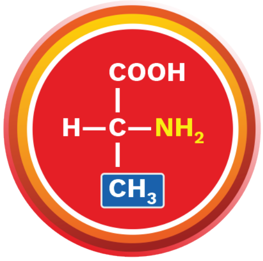
- The R group in the proteinaceous amino acids can be a hydrogen (the amino acids is called glycine), a methyl group (alanine), hydroxyl methyl (serine), etc.
- The chemical and physical properties of amino acids are essentially of the amino, carboxyl and the R functional groups.
- **Based on number of amino and carboxyl groups amino acids are of three types-**
  - Acidic amino acid
  - Basic amino acid
  - Neutral amino acid

> **Previous Year's Question**
>
> Amino acids are mostly synthesised from
> (1) mineral salts
> (2) fatty acids
> (3) volatile acids
> (4) α–ketoglutaric acid.

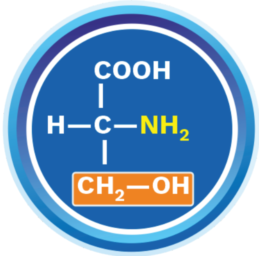
LIST OF PRINCIPAL AMINO ACIDS	
I. Neutral	Glycine (Gly), Alanine (ala), Valine (Val), Leucine (Leu)
II. Acidic	Isoleucine (Ile), Aspartic acid (Asp), Asparagine (amide, Asn), Glutamic acid (Glu), Glutamine (amide, Gln)
III. Basic	Arginine (Arg), Lysine (Lys)
IV. S-Containing	Cysteine (Cys), Methionine (Met)
V. Alcoholic	Serine (Ser), Thereonine (Thr)
VI. Aromatic	Phenylalanine (Phe), Tyrosine (Try), Tryptophan (Try), Proline (Pro)



Glycine

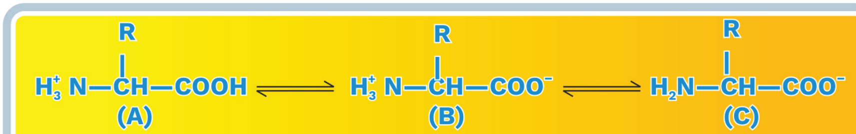


Alanine



Serine

- A particular property of amino acids is the ionizable nature of $-NH_2$ and $-COOH$ groups. Hence in solutions of different pH, the structure of amino acids changes.



B is called zwitterionic form.

Definition

Zwitterion: Molecule that contains an equal number of positively and negatively charged functional groups.

- There are only of **twenty one** types of amino acid in living organisms

Functions of Amino acids

- Building blocks of proteins and enzymes.
- Components of antibodies.
- IAA is a plant hormone synthesised by tryptophan.
- Tyrosine gives rise to hormones like thyroxin, adrenalin and melanin.

Previous Year's Question

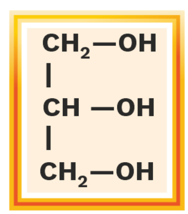
Lipids are insoluble in water because lipid molecules are
(1) hydrophilic
(2) hydrophobic
(3) neutral
(4) zwitter ions.

LIPIDS

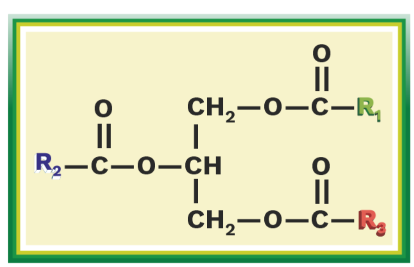
- Lipids are hydrocarbon containing molecules (fatty acids) and are water insoluble.
- A fatty acid has a **carboxyl group** attached to the R group.
- The R group can be a methyl ($-CH_3$), or ethyl ($-C_2H_5$) or higher number of $-CH_2$ groups (1 carbon to 19 carbons).
- Examples —
    - o **Palmitic acid has 16 carbons including carboxyl carbon.**
    - o **Arachidonic acid has 20 carbon atoms including the carboxyl carbon.**
- In lipids, fatty acids which are present are esterified with glycerol called glyceride.
- Glyceride can be monoglyceride, diglyceride and triglyceride (depending on the number of chains of fatty acids).
- Glycerol is a simple lipid which is trihydroxy propane.
- Many lipids have both glycerol and fatty acids.

$CH_3-(CH_2)_{14}-COOH$

Fatty acid
(Palmitic acid)



Glycerol



TRIGLYCERIDE
(R_1, R_2 AND R_3 ARE FATTY ACIDS)

Types of Fatty Acids

- **Saturated fatty acid -** No double bonds found(C-C).
- **Unsaturated fatty acid-** One or more double bonds are present(C=C).

Comparison Between Fats and Oils

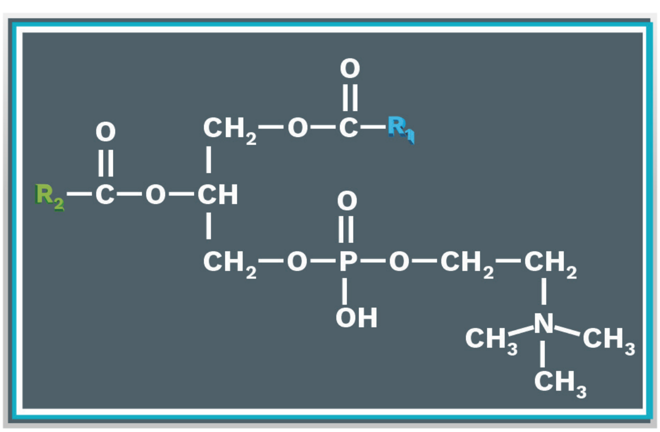
S.no.	Fats	Oils
1.	Solid at room temperature.	Liquid at room temperature.
2.	No double bonds present in their fatty acids.	One or more double bonds present in their fatty acids.
3.	High melting point.	Low melting point.
4.	Found in animals.	Found in plants.
5.	Examples are butter, ghee, etc.	Examples are mustard oil, gingely oil, etc.

Rack your Brain

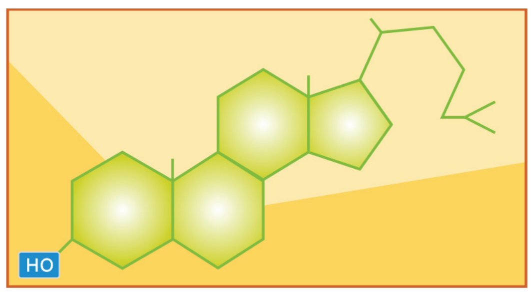
Chemically what is lecithin?

Phospholipids

- These have phosphorous and a phosphorylated organic compound in them.
- Essential constituent of cell membranes e.g., **lecithin**.
- The neural tissues have complex phospholipids.



Phospholipid (Lecithin)



Cholesterol

Carbon Compounds with Heterocyclic Rings

- **Nitrogen bases:** Adenine, guanine, cytosine, uracil, and thymine.

Previous Year's Question

A typical fat molecule is made up of-

(1) One glycerol and one fatty acid molecule
(2) Three glycerol and three fatty acid molecules
(3) Three glycerol molecules and one fatty acid molecule
(4) One glycerol molecule and three fatty acid molecules.

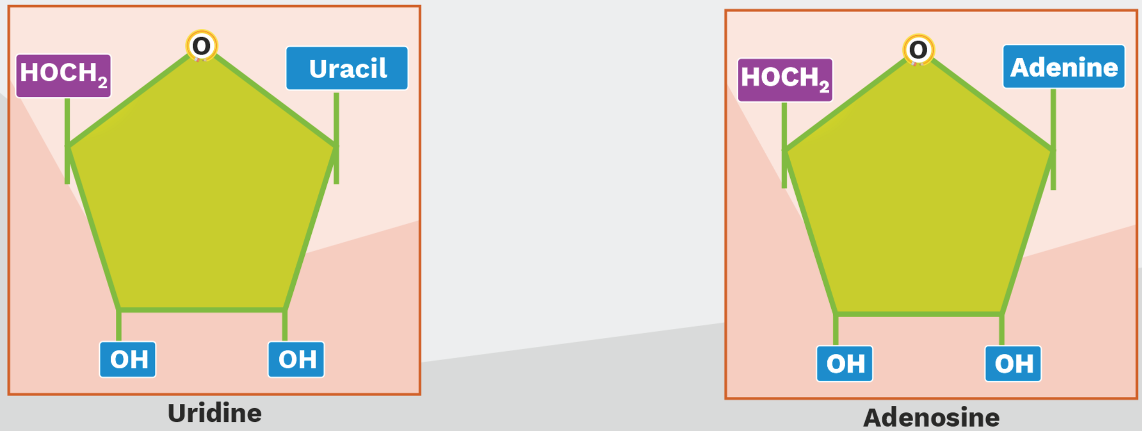


FIG. DIAGRAMMATIC REPRESENTATION OF NUCLEOSIDES

- **Nucleoside** is formed when ribose sugar is attached with nitrogen base (Glycosidic bond).
- Examples of nucleosides- Adenosine, guanosine, thymidine, uridine and cytidine

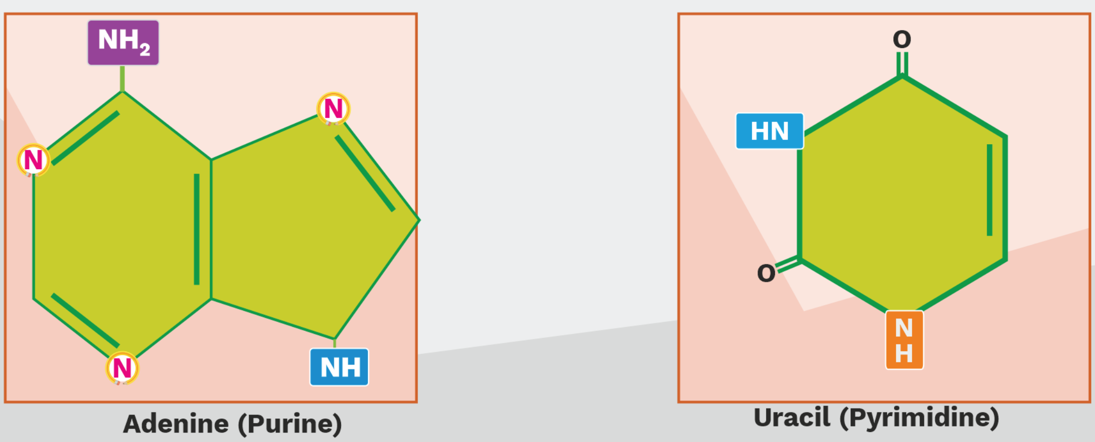


FIG. DIAGRAMMATIC REPRESENTATION OF NITROGEN BASES

PRIMARY METABOLITES PRIMARY AND SECONDARY METABOLITES

Primary Metabolites

- These are essential for the growth of the cell. They are produced continuously during the growth phase and are involved in primary metabolic processes such as respiration and photosynthesis.

Previous Year's Question

Which is distributed more widely in a cell?

(1) Lipids
(2) Inorganic compounds
(3) Carbohydrate
(4) Protein

- Primary metabolites include sugars, amino acids, tricarboxylic acids, the universal building blocks, and energy sources.
- Proteins, nucleic acids, and polysaccharides are also considered as primary metabolites

Secondary Metabolites

- These are called specilised metabolites like different organic compounds produced by bacteria, fungi or plants.
- These are not directly involved in physiological processes.
- Alkaloids, flavonoids, antibiotics, gums, essential oils, coloured pigments, etc.,

Previous Year's Question

An element not of much importance to plants is-
(1) Ca
(2) Zn
(3) Cu
(4) Na

Examples of Some Secondary Metabolites

Pigments	Carotenoids, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc.
Terpenoides	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastin, curcumin, etc.
Polymeric substances	Rubber, gums, cellulose

Previous Year's Question

The most diverse molecules in a cell are—
(1) Mineral salts
(2) Lipids
(3) Proteins
(4) Carbohydrates

Comparision Between Primary and Secondary Metabolites

Primary Metabolites	Secondary Metabolites
Formed during the growth phase.	Formed during the end or near the stationary phase of growth.
Directly involved in maintaining normal physiological processes.	No role known in growth, development, and reproduction.
Essential for proper growth.	Role in living organisms not discovered.
Examples are amino acids, ethanol, lactic acid, etc.	Examples are rubber, drugs, spices, scents, pigments, etc.

BIOMACROMOLECULES

Polysaccharides

- Polysaccharides are long chains of sugars (monosaccharides as building blocks).
- Depending on the composition polysaccharides are of two types:
  - Homopolysaccharides
  - Heteropolysaccharides

Homopolysaccharides

- A polymeric polysaccharide consisting of only one type of monosaccharide.
- Examples—
  - Cellulose and starch (in plants)
  - Glycogen in animals are polymers of glucose.
  - **Inulin** is a polymer of **fructose**.
- The right end of polysaccharide chain in these polymers is called the reducing end and the left end is called the non-reducing end.

Note : The reducing end of a polysaccharide chain has free anomeric carbon which is available to reduce other compounds. Hence, is called reducing end.

Starch (Amylum)

- Starch is a polysaccharide which has two components
  - Amylose
  - Amylopectin
- Starch forms helical secondary structures.
- Starch can hold iodine (I_2) molecules in the helical portions. Thus, gives blue-black colour with iodine.

Cellulose

- Cellulose does not contain complex helices and hence cannot hold I_2 molecules so, it does not react with iodine like starch.

Definition

Biomacromolecules: Those biomolecules which have molecular weight less than 1000 daltons are called biomicromolecules.

Gray Matter Alert!!!

Amylose - Polymer of α-glucose units arranged in a straight chain. The glucose units are joined by α, 1-4 glycosidic bonds.

Rack your Brain

Name the most abundant polysaccharide on earth.

Gray Matter Alert!!!

Amylopectin - Polymer of α-glucose units arranged in a branched chain. The glucose units of straight chain are joined by α, 1-4 glycosidic bonds while branches are joined by α, 1-6 glycosidic bonds.

- Paper (made from plant pulp) and cotton fibres are cellulosic.

Glycogen

- Main reserve food in animals, bacteria and fungi. It is also known as animal starch.
- Chemically, glycogen is similar to starch. Its molecule consists of a long much branched chain of about 30,000 glucose residues and a molecular weight of about 4.8 million.
- The successive glucose units are joined by α, 1-4 glycosidic bonds and branches are formed by α, 1-6 glycosidic bonds.

Previous Year's Question

Natural silk fibre is —
(1) Polyester
(2) Polyamide
(3) Lipid
(4) Polysaccharide

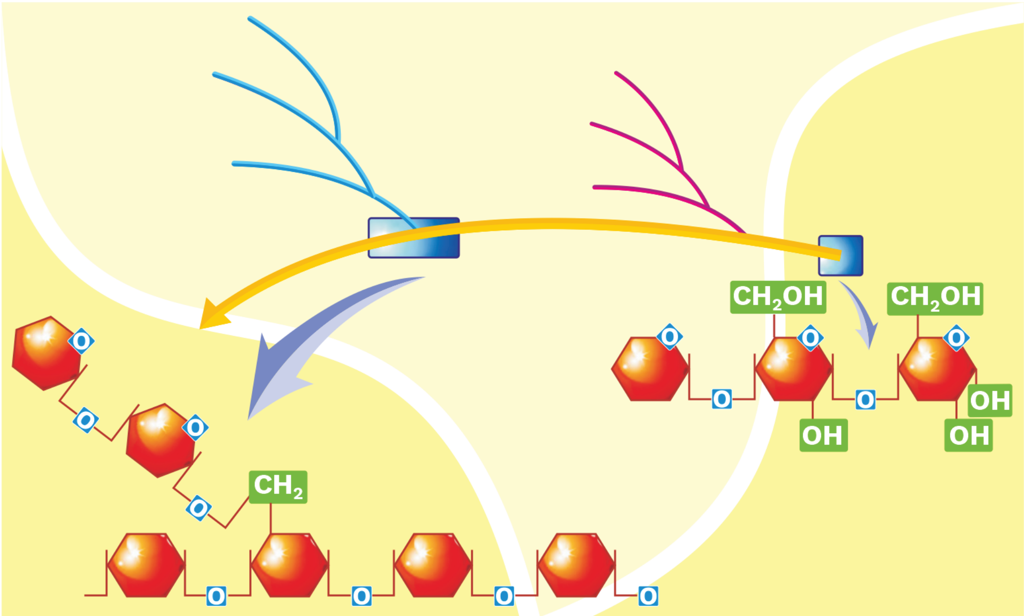


FIG. DIAGRAMMATIC REPRESENTATION OF A PORTION OF GLYCOGEN

- Glycogen is usually formed and stored in muscle cells and liver cells.
- Glycogen can also hold iodine molecules in the helical portion and gives red colour with iodine solution.

Chitin

- Long chain homopolymer of N-acetylglucosamine, an amide derivative of glucose.
- It forms exoskeleton of arthropods and fungal cell walls.

Gray Matter Alert!!!

Chitin - Polymer of N-acetyl glucosamine and the units are held by β-linkages.

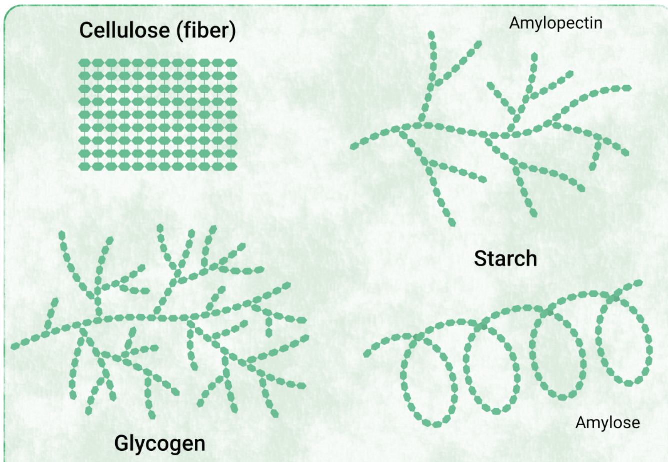


FIG. POLYSACCHARIDES

Heteropolysaccharides

- Formed by the condensation of either monosaccharide derivatives or more than one type of monosaccharide monomers.
- These have amino acids, sugar and chemically modified sugars (e.g., glucosamine, N-acetyl galactosamine, etc.).
- Examples —
  - Peptidoglycan found in bacterial cells.
  - Agarose an agal cell wall material.
  - Hyaluronan (a glycosaminoglycan) makes extra cellular matrix of skin in vertebrates.

BONDS BETWEEN MONOMERS OF POLYSACCHARIDE

Glycosidic Bond

- A **glycosidic bond** is a certain type of functional group that joins a **carbohydrate** (sugar) molecule to another group, which may or may not be another carbohydrate.
- Example: α, 1-4 linkage; α, 1-6 linkagel; β, 1-4 linkage, etc.
- In amylopectin the monomers are joined by α, 1-6 linkage as well as α, 1-4 linkage.
- In lactose β, 1-4 linkage joines the monomers.

Previous Year's Question

Glycogen is a polymer of
(1) Fructose
(2) Galactose
(3) Sucrose
(4) Glucose

Previous Year's Question

Chitin, that forms arthropod exoskeleton, is the second most abundant carbohydrate on earth. It is a —
(1) Storage polysaccharide
(2) Mucopolysaccharides
(3) Nitrogen containing structural heteropolysaccharide
(4) Structural oligosaccharide

Previous Year's Question

Starch is a polymer of a basic unit of
(1) Fructose
(2) Glucose
(3) Sucrose
(4) Maltose

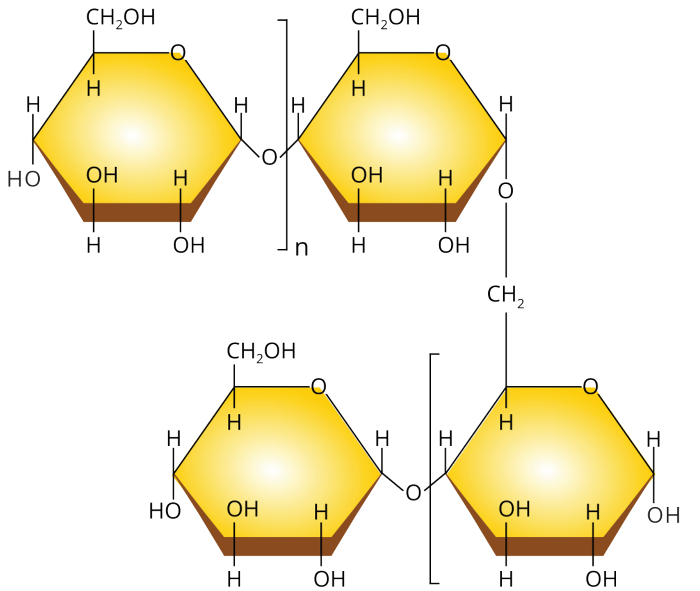


FIG. α 1-6 LINKAGE

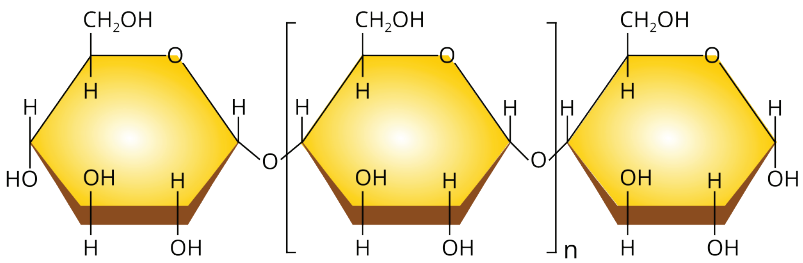


FIG. α 1-4 LINKAGE

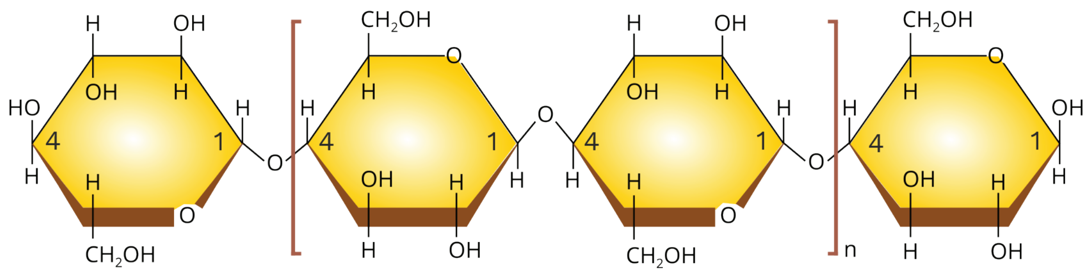
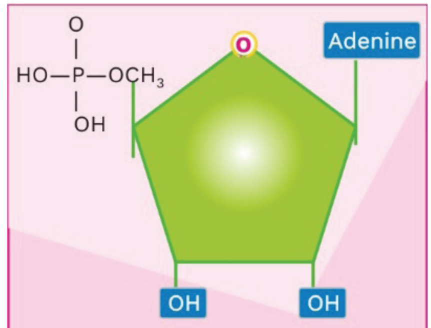


FIG. β 1-4 LINKAGE

NUCLEIC ACIDS

- Nucleotides are small complex compounds and the building blocks of nucleic acids i.e., RNA and DNA.

- A nucleotide has three chemically distinct components. One is a **heterocyclic compound**, the second is a **monosaccharide** and the third a **phosphoric acid** or phosphate.
- Examples of nucleotides- Adenylic acid, thymidylic acid, guanylic acid, uridylic acid and cytidylic acid
- Examples of nucleic acids are **deoxyribonucleic acid** (DNA) and **ribonucleic acid** (RNA)
- DNA is the genetic material of all organisms except few virus where RNA functions as genetic material.



Adenylic acid
Nucleotide

Components of Nucleic Acids			
Nucleic Acid	**Purines**	**Pyrimidine**	**Pentose Sugar**
DNA	Adenine and guanine	Thymine and cytosine	Deoxyribose
RNA	Adenine and guanine	Uracil and cytosine	Ribose

Purine

- It is a heterocyclic aromatic organic compound with a chemical formula of $C_5H_4N_4$. Its chemical structure is comprised of two carbon rings (a pyrimidine ring with an imidazole ring fused to it) and a total of four nitrogen atoms. Nitrogen atom are located at positions 1, 3, 7 and 9 of the two rings.

Rack Your Brain

Name the purines in RNA.

Pyrimidine

- It is a simple heterocyclic aromatic compound with a chemical formula $C_5H_4N_2$. It has one carbon ring or pyrimidine ring, composed of two nitrogen atoms that are located at positions 1 and 3 of the pyrimidine ring and four carbon atoms, with hydrogen atoms attached to each carbon. The carbon and nitrogen atoms are connected via alternating double and single bonds.

Note: Purines and pyrimidines both are water soluble.

Previous Year's Question

Which is not consistent with double helical structure of DNA?
(1) A = T, C = G
(2) Density of DNA decreases on heating.
(3) A + T/C + G is not constant.
(4) Both (a) and (b)

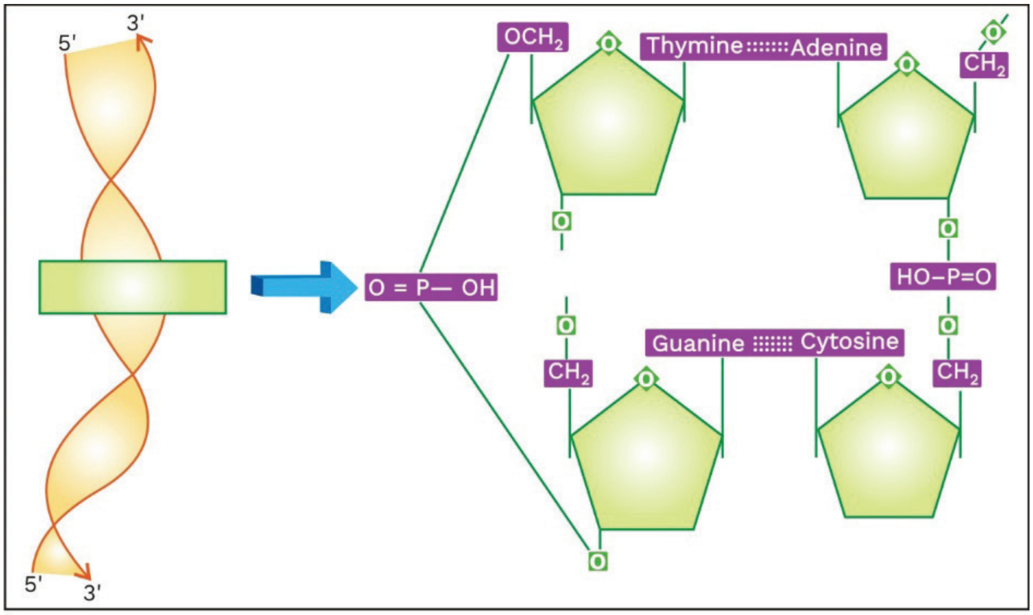


FIG. DIAGRAM INDICATING SECONDARY STRUCTURE OF DNA

Bonds in Nucleic Acids: Phosphodiester Bond

- A phosphodiester bond is a group of strong covalent bonds between a phosphate group and two other molecules over two ester bonds. Phosphodiester bonds make up the backbone of the strands of DNA.
- In DNA and RNA, the phosphodiester bond is the linkage between the 3 carbon atom of one sugar molecule and the 5 carbon of another, deoxyribose in DNA and ribose in RNA.

Previous Year's Question

Which of the following biomolecules do have a phosphodiester bond?
(1) Amino acids in a polypeptide
(2) Nucleic acids in a nucleotide
(3) Fatty acids in a diglyceride
(4) Monosaccharides in a polysaccharide

Gray Matter Alert!!!

Glycosidic bond joins pentose sugar to nitrogenous base in nucleosides or nucleotides.

Previous Year's Question

The difference between RNA and DNA is because of
(1) Sugar and base
(2) Sugar and phosphate
(3) Phosphate and base
(4) Sugar only

Gray Matter Alert!!!

Antiparallel - Two linear polymers that run parallel but in opposite direction.

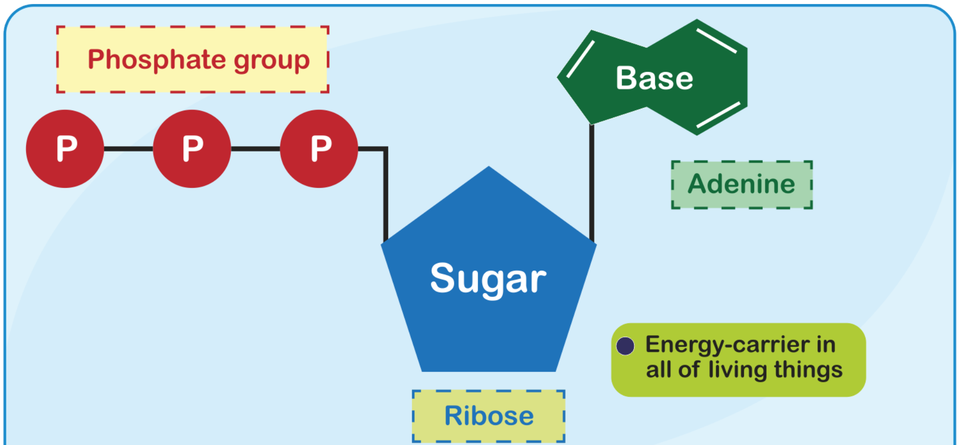


FIG. BASIC STRUCTURE OF ADENOSINE TRIPHOSPHATE (ATP)

PROTEINS (HETEROPOLYMER)

- Each protein is a polymer of amino acids. In an organism there are **21 types of amino acids** (e.g., alanine, cysteine, proline, tryptophan, lysine, etc.) which help in the formation of a protein. Hence, a protein is a heteropolymer.

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception (smell, taste, hormone, etc.)
GLUT-1	Enables glucose transport into cells

TABLE. SOME PROTEINS AND THEIR FUNCTIONS

STRUCTURE OF PROTEINS

Primary Structure

- Amino acids are linked in a single linear row which make the primary structure of a protein.
- The first amino acid (towards left) is also called as N-terminal amino acid. The last amino acid

Definition

Adenosine triphosphate: The most important form of energy currency in living systems is the bond energy in a chemical called adenosine triphosphate (ATP). It is a nucleotide with two additional phosphates.

Previous Year's Question

ATP is
(1) nucleotide
(2) nucleoside
(3) nucleic acid
(4) vitamin.

Definition

Heteropolymer: A polymer made up of different types of monomers.

(towards right) is called the C-terminal amino acid.

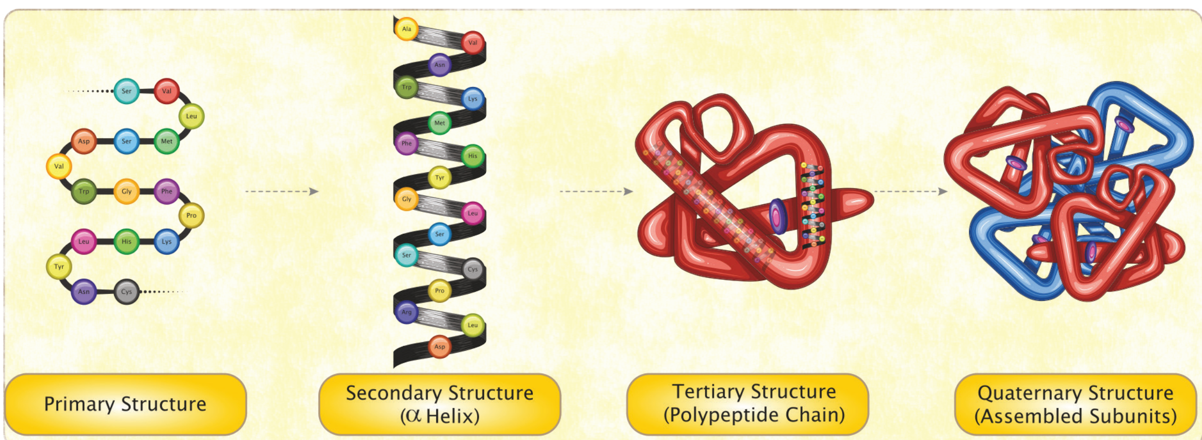
- Amino acids are linked by peptide bonds.

Secondary Structure

- Turning and twisting of primary structure takes place and the turns are stabilized by hydrogen bonds. This gives secondary structure to the protein.
- Example is the alpha helix and beta sheet

Tertiary Structure

- Folding and turning of secondary structures results in tertiary structure of a protein.
- Tertiary structure has a polypeptide chain as its backbone and to it are attached one or many secondary structures.
- Tertiary structure is stabilized by the formation of a hydrophobic core, salt bridges, hydrogen bonds, ionic bonds and disulfide bonds which help in maintaining the tertiary structure.



Quaternary Structure

- Assembly of more than one polypeptide or subunits gives quaternary structure to a protein. It is present in few proteins.
- Each subunit possess individual primary, secondary and tertiary structure.

Gray Matter Alert!!!

Most abundant proteins:
Ribulose bisphosphate Carboxylase-Oxygenase (RUBISCO)
(in the whole of the biosphere)
Collagen (in animal world).

Previous Year's Question

Which one is the most abundant protein in the animal world?
(1) Trypsin
(2) Haemoglobin
(3) Collagen
(4) Insulin

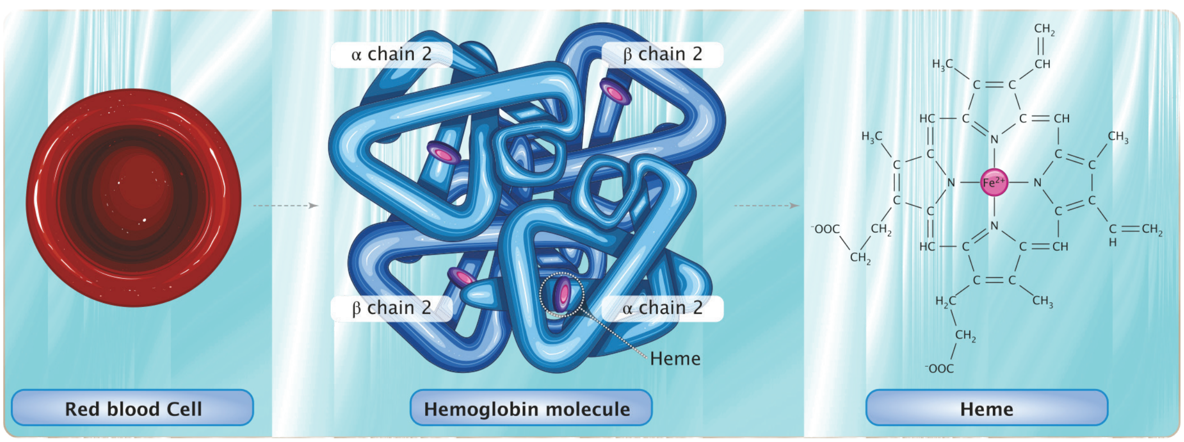
Rack Your Brain

Name the purines in DNA.

- The subunits are attached with each other by hydrogen bonds, ionic bonds, etc. (e.g., linear string or spheres, spheres arranged one upon each other in the form of a cube or plate, etc.).
- Example: **Hemoglobin**
  - Hemoglobin has a quaternary structure. It consists of two pairs of different proteins, the α and β chains.
  - There are 141 and 146 amino acids in the α and β chains of hemoglobin respectively.
  - Each subunit is linked covalently to a molecule of heme (iron component).
  - The two identical α chains and the two identical β chains are arranged tetrahedrally .
  - These units are held together by hydrophobic interactions, hydrogen bonding, and ion pairs (salt bridges) between oppositely charged amino acid side chains.

Previous Year's Question

Which of the following is a storage protein?
(1) Keratin
(2) Collagen
(3) Glutelin
(4) Haemoglobin



BOND LINKING BETWEEN MONOMERS IN A PRIMARY PROTEIN

Peptide Bond

- A peptide bond (amide bond) is a chemical bond formed between two molecules when the **carboxyl group** of one molecule reacts with the **amine group** of the other molecule, thereby **releasing a molecule of water** (H_2O).
- This is a dehydration synthesis reaction (also known as a condensation reaction), and usually occurs between amino acids. The resulting

Previous Year's Question

The primary structure of protein in due to
(1) Hydrogen
(2) Peptide bonds
(3) S-S linkage
(4) Ionic bonds

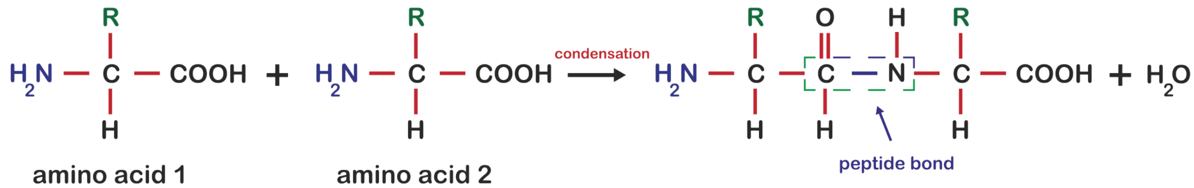
CO-NH bond is called a peptide bond, and the resulting molecule is an amide.

- The four-atom functional group -C(=O) NH- is called and amide group or (in the context of proteins) a peptide group. Polypeptides and proteins are chains or amino acids held together by peptide bonds, as is the backbone of Polyamides, such as nylons and aramids, are synthetic molecules (polymers) that possess peptide bonds.

Gray Matter Alert!!!

Conjugate protein - A protein having one or more non-protein prosthetic groups.

Condensation reaction of amino acids



Proteins are made up of amino acids joined together via peptide bonds

CONCEPT OF METABOLISM

- All the chemical reactions that occur in an organism are called metabolism. It is sum of all anabolic and catabolic processes.
- In metabolism either the compounds are made or broken down.
- A few examples for such metabolic transformations are-
  - Removal of CO_2 from amino acids making an amino acid into an amine.
  - Hydrolysis of a glycosidic bond in a disaccharide converting it into monosaccharides, etc.

Difference Between Anabolic and Catabolic Processes

S.No.	Anabolic Process	Catabolic Process
1	Conversion of simpler structure molecules to complex molecules.	Conversion of complex molecules into simple molecules.
2	Energy is consumed.	Energy is released and stored in the form of chemical bonds.

THE LIVING STATE

- living state is a non-equilibrium steady state to perform work. This is the reason for the living organisms to work continuously and prevent reaching the state of equilibrium.
- This is achieved by energy input. Metabolism provides a mechanism for the production of energy.
- Hence the living state and metabolism are synonymous.

ENZYMES

- Almost all enzymes are proteins.
- An enzyme, like a protein, has a primary structure, i.e., amino acid sequence of the protein.
- An enzyme also has the secondary and the tertiary structure.
- Enzymes catalysed reactions which are faster than uncatalysed reactions.
- For example enzyme **carbonic anhydrase** produces 600,000 molecules of carbonic acid per second. But in the absence of this enzyme only 200 molecules of carbonic anhydrase are formed in an hour.

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O} \xrightleftharpoons{\text{Carbonic anhydrase}} \underset{\text{carbonic acid}}{H_2CO_3}$$

FIG. REACTION OBSERVED HERE IS FASTER THAN THE UNCATALYSED REACTION

Theories for Binding of Enzymes

"Lock and Key" Model

- Enzymes are very specific, and it was suggested by Emil Fischer in 1894 that this was because both the enzyme and the substrate possess specific complementary geometric shapes that fit exactly into one another.

Definition

Living state. A non-equilibrium steady state to perform work continuously.

Previous Year's Question

Enzyme are polymers of

(1) Fatty acids
(2) Amino acids
(3) Nucleus and ribosomes
(4) Chromosomes

Definition

Enzymes: These are biocatalysts. They hasten certain biochemical reactions.

Previous Year's Question

Which of the following is the best evidence for the lock and key theory of enzyme action?

(1) All isolated enzyme have been identified as proteins
(2) Compound similar in structure to the substrate inhibit the reaction
(3) Enzymes are found in living organisms and speed up certain reactions
(4) Enzyme determine the direction of a reaction.

- This is often referred to as "the lock and key" model.
- This model explains enzyme specificity, it fails to explain the stabilization of the transition state that enzymes achieve.

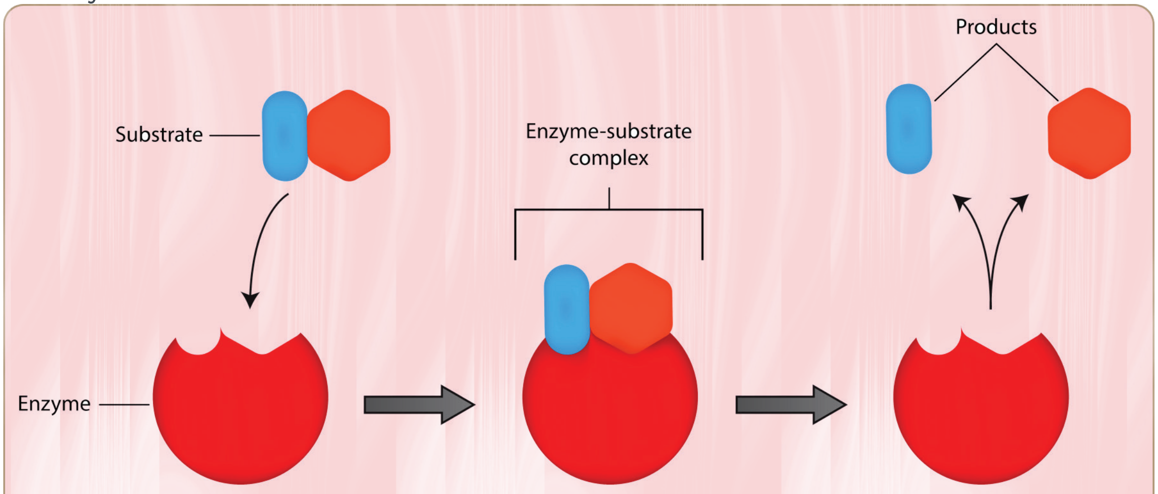


FIG. THE LOCK AND KEY MECHANISM

Induced Fit Model

- In 1958, Daniel Koshland suggested a modification to the lock and key model: since enzymes are rather flexible structures, the active site is continually reshaped by interactions with the substrate as the substrate interacts with the enzyme.
- Induced fit means a change in the conformation of an enzyme in response to substrate binding that renders the enzyme catalytically active.
- As a result, the substrate does not simply bind to a rigid active site; the amino acid side chains which make up the active site are molded into the precise positions that enable the enzyme to perform its catalytic function.
- In some cases, such as glycosidases, the substrate molecule also changes shape slightly as it enters the active site. The active site continues to change until the substrate is completely bound, at which point the final shape and charge is determined.

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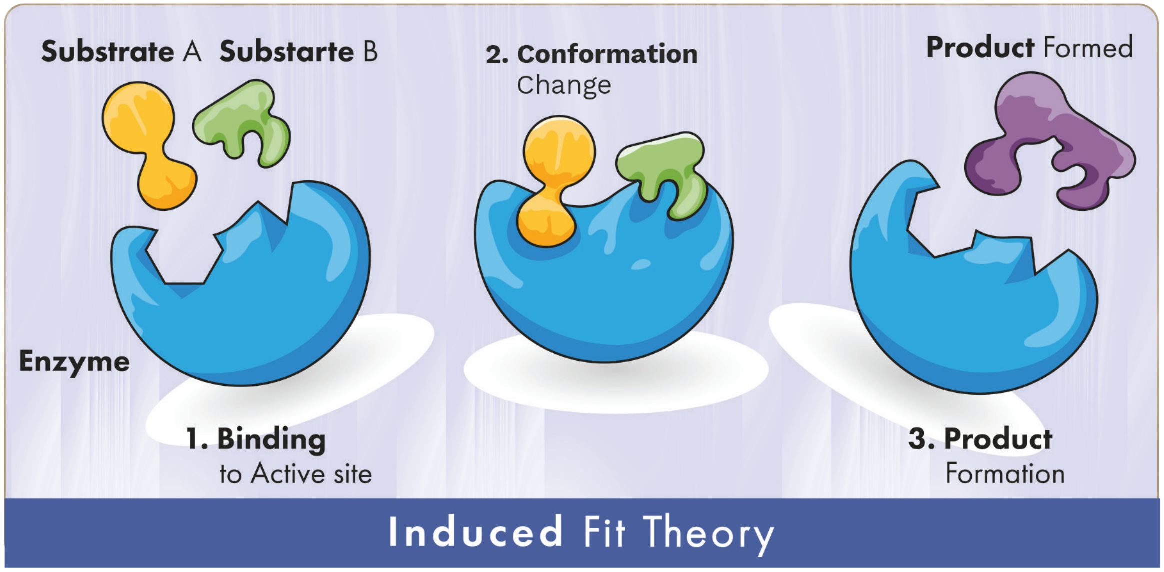
Active site-An area of the enzyme which attracts and holds particular substrate molecules and allow the chemical change.

Previous Year's Question

Enzymes are different from catalysts in

(1) Being proteinaceous
(2) Being used up in a reaction
(3) Fluctuating at a high temperature
(4) having a high rate of diffusion



Difference Between Inorganic Catalysts and Enzymes

Inorganic Catalysts	Enzymes
Efficiently work at high temperature and high pressure.	Get damaged at high temperature (above 40°C)and high pressure.
These are mineral ions or small molecules.	These are globular proteins.
These are not regulated by any other molecule.	These are regulated by specific molecules.
Less sensitive to pH.	More sensitive to pH.
Not synthesized by living cells.	Synthesized by living cells.

Note: Enzymes isolated from organisms who normally live under extremely high temperature (e.g., hot vents and sulphur springs), are stable and retain their catalytic power even at high temperatures (up to 80°C - 90°C).
Thermal stability is thus an important quality of such enzymes isolated from thermophilic organisms.

Mechanism of Enzymatic Action

- **Lowering the activation energy** by creating an environment in which the transition state is stabilized (e.g., straining the shape of a substrate by binding the **transition**

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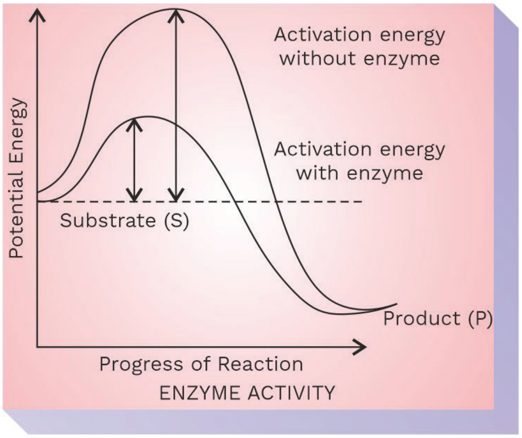
Activation Energy- Initial input of energy required to start a chemical reaction.

state, conformation of the substrate or product molecules, the enzyme distorts the bound substrate(s) into their transition state form, thereby reducing the amount of energy required to complete the transition).

- Lowering the energy of the transition state, but without distorting the substrate, by creating an environment with the opposite charge distribution to that of the transition state.
- **Providing an alternative pathway:** For example, temporarily reacting with the substrate to form an intermediate ES complex, which would be impossible in the absence of the enzyme.
- **Reducing the reaction entropy change** by bringing substrates together in the correct orientation to react.
- **Increase in temperatures** speed up reactions. If heated too much, the enzyme's shape deteriorates and only when the temperature comes back to normal does the enzyme regain its shape.
- Some enzymes like thermolabile enzymes work best at low temperatures.



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Isoenzymes - Multiple molecular forms of an enzyme occurring in the same organism and having a similar substrate activity.

Previous Year's Question

The enzymes having slightly different molecular structure but similar catalytic reaction are called
(1) Proenzyme
(2) Isoenzyme
(3) Coenzyme
(4) Holoenzyme

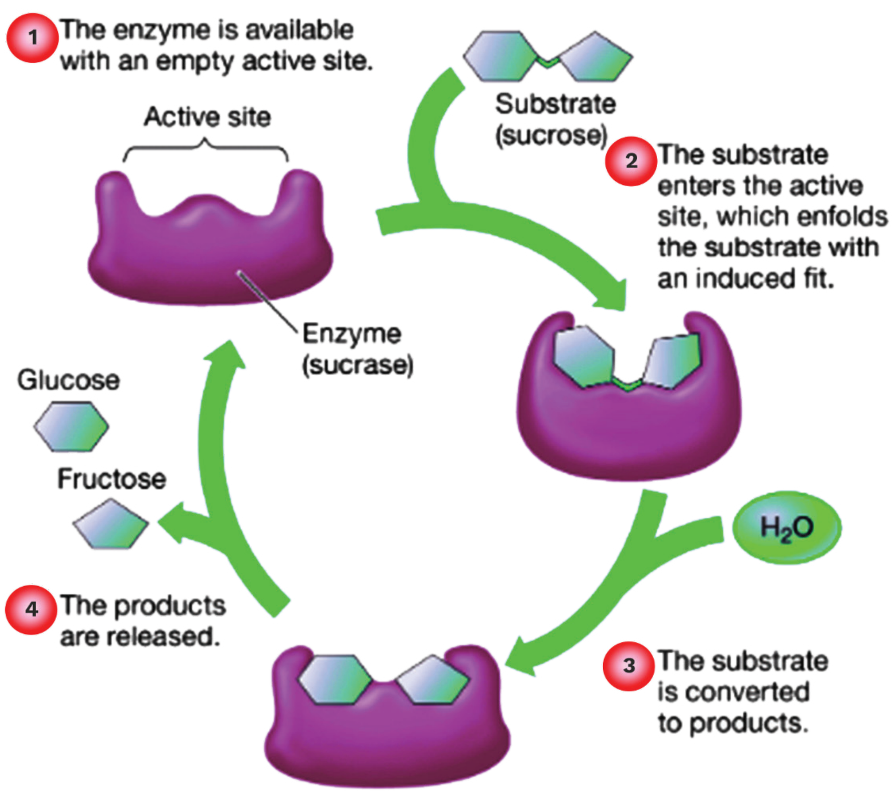
Previous Year's Question

Chemical reactions need energy for
(1) Entropy
(2) Oxidation
(3) Enthalpy (warm up)
(4) Activation

Note: Allosteric Enzyme - A regulatory enzyme whose catalytic activity is modulated by the binding of a specific metabolite at a site other than the active site.

The Catalytic Cycle of an Enzyme Action

Step I
Binding of substrate to the active site of the enzyme.
STEP II
Shape of the enzyme alters due to binding of the substrate to enzyme (enzyme-substrate complex is formed).
STEP III
Enzyme breaks the chemical bonds of the substrate and the new enzyme-product complex is formed.
STEP IV
Products are released from the enzyme and enzyme is free to enter new catalytic cycle.



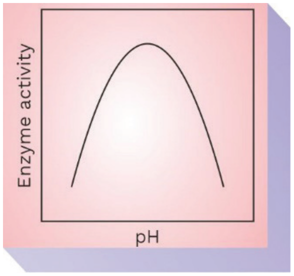
THE CATALYTIC CYCLE OF AN ENZYME

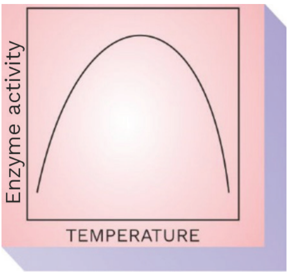
Note : The formation of the enzyme-substrate complex (ES) is essential for catalysis.

$$E + D \rightleftharpoons ES \longrightarrow EP \longrightarrow E + P$$

Factors Affecting Enzyme Activity

- **Temperature and pH**
  - Enzymes function in a narrow range of temperature and pH.
  - Highest activity is shown at a particular temperature and pH called the optimum temperature and optimum pH.
  - Activity declines both below and above the optimum value.
  - Low temperature renders the enzyme to inactive state.
  - High temperature denatures the enzyme.





- **Concentration of Substrate**
  - Initially increase in substrate concentration rises velocity of enzymatic reaction.
  - At maximum velocity (V_{max}) of the reaction there is no rise even if the concentration of the substrate is increased.
  - Reason is no free enzyme molecules to bind with the additional substrate molecules at V_{max} are left.
- **Effect of Inhibitor**
  - The inhibitor is a chemical which competes with the substrate to get attached to the enzyme.
  - Inhibitor is the chemical which shuts off enzymatic activity.

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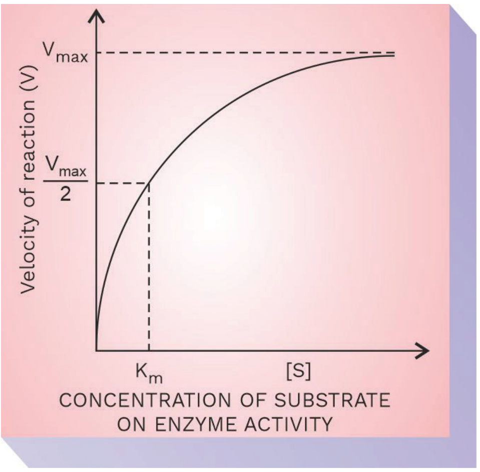
Free back inhibition (End product Inhibition) - Inhibition of an allosteric enzyme at the beginning of a metabolic sequences by the end product of the sequence.

Gray Matter Alert!!!

Competitive inhibition - Inhibition of enzyme activity by a substance having molecular structure similar to the substrate.



- This causes the enzyme inhibition and the chemical is called an inhibitor.
- **Competitive inhibitor:** The inhibitor closely resembles the substrate in its molecular structure. This similarity with the substrate, helps the inhibitor to compete with the substrate for the substrate binding site of the enzyme.
- Consequently, the substrate cannot bind and the enzyme action declines, e.g., **inhibition of succinic dehydrogenase by malonate** which closely resembles the substrate succinate in structure.
- Competitive inhibitors are often used in the control of bacterial pathogens.

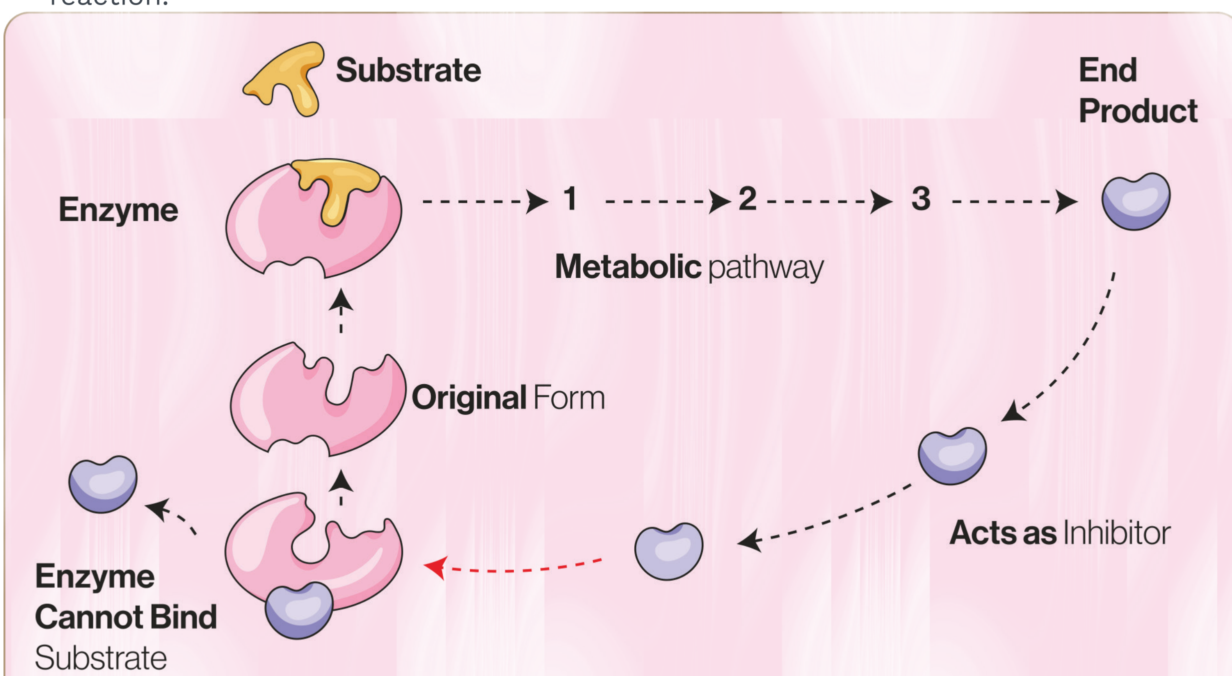
- **Feedback Inhibition**
  - Excess final product produced after catalysis binds with the enzyme away from the active side and changes the conformation of the binding site of the enzyme, thus stops the reaction.

Previous Year's Question

A coenzyme is
(1) Always a protein
(2) Often a vitamin
(3) A non-protein organic compound
(4) Often a metal

Previous Year's Question

A working combination of an apoenzyme and a coenzyme or cofactor is termed
(1) Prosthetic group
(2) Holoenzyme
(3) Enzyme-substrate complex
(4) Enzyme product complex



Feedback Inhibition

- **Denaturing of Enzymes**
  - Enzyme structures unfold (denature) when heated or exposed to chemical denaturants and this disruption to the structure typically causes a loss of activity.

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The term enzyme was coined by Wilhelm Kuhne.

Note: Denaturing is temporary and permanent. When the denaturing agent is removed the enzyme can regain its activity resuming its structure. Permanent denaturing cannot be reversed as broken bonds are not reformed.

CLASSIFICATION AND NOMENCLATURE OF ENZYMES

- Enzymes are divided into 6 classes each with 4-13 sub-classes and named accordingly by four digit number.

Rack Your Brain

Coenzymes FMN and FAD are derived from which vitamin?

Enzyme	Function(to catalyse)
Oxidoreductases or dehydrogenases	Oxidation-reduction between S and S′.
Transferases	Transfer of a group, G (other than hydrogen) between a pair of substrate S and S′.
Hydrolases	Hydrolysis of easter, either, peptide, glycosidic, C–C, C–halide or P–N bonds.
Lyases	Removal of groups from substrates by mechanisms other than hydrolysis leaving double bonds.
Isomerases	Inter-conversion of optical, geometric or positional isomers (all enzymes included).
Ligases	Linking together of 2 compounds, e.g., enzymes which catalyse joining of C–O, C–S, C–N, P–O etc. bonds.

Co-factors

- **Non-protein constituent** of an enzyme.
- Tight or transient association with the enzyme to make it catalytically active.
- Catalytic activity is lost when the co-factor is removed from the enzyme which testifies that they play a crucial role in the catalytic activity of the enzyme.

Rack Your Brain

The enzyme that joins a non-protein prosthetic group to form a fucntional enzyme is known as ––

- **Holoenzyme → Apoenzyme (protein portion) + Cofactor (non-protein portion)**
- Types of cofactors:
  - **Prosthetic groups**
  - **Co-enzymes**
  - **Metal ions.**

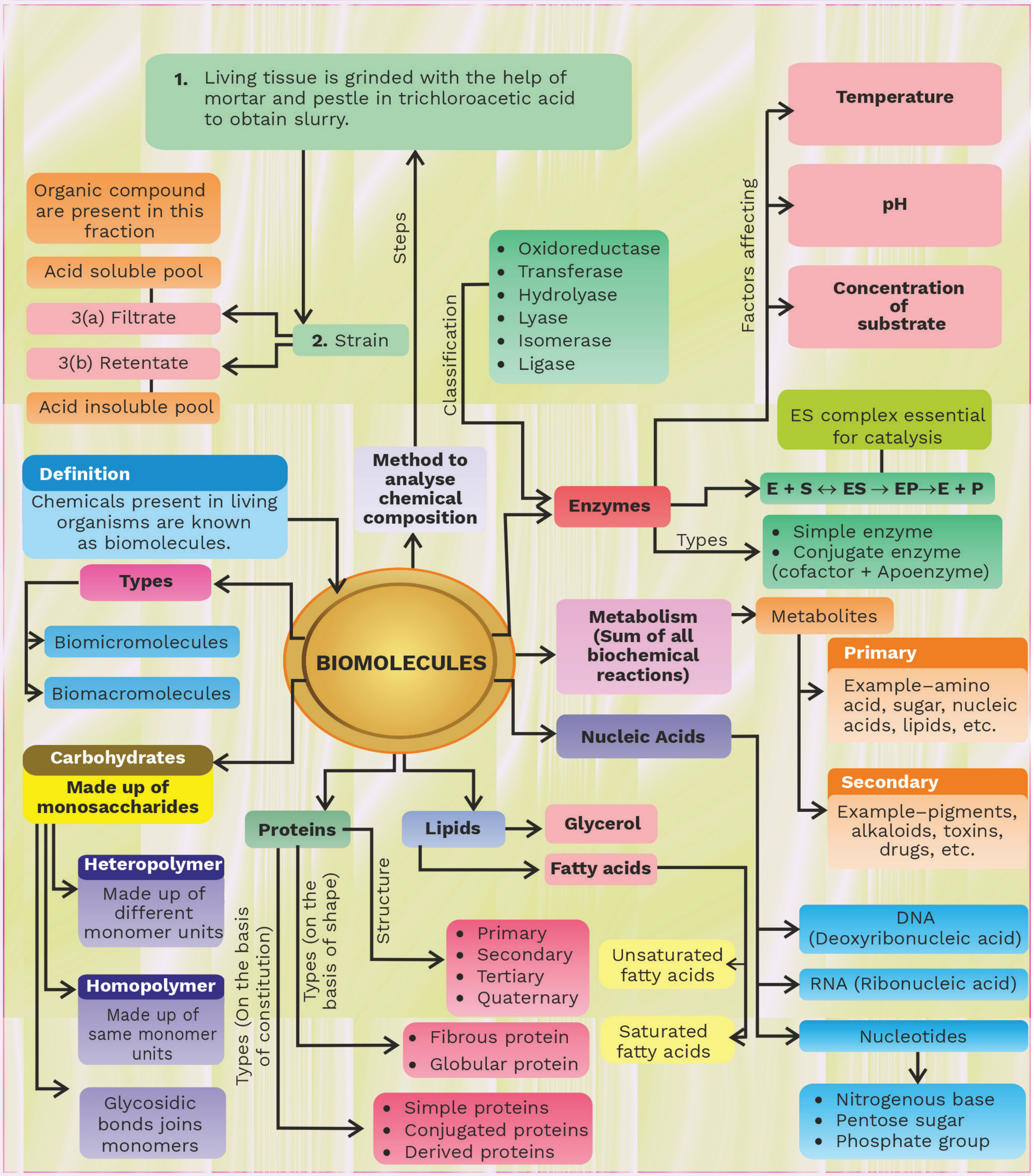
Cofactor	Chemical Nature	Type of Association with Apoenzyme	Example
Prosthetic Group	Organic	Tightly bound to the apoenzyme.	In peroxidase and catalase, haem is the prosthetic group and it is a part of the active site of the enzyme. These catalyze the breakdown of hydrogen peroxide to water and oxygen.
Co-enzyme	Organic	Association with the apoenzyme is only transient (binds during the course of catalytic reaction only).	Coenzyme nicotinamide adenine dinucleotide (NAD) and NADP contain the vitamin niacin.
Metal ion	Inorganic	Form coordination bonds with side chains at the active site and at the same time form one or more coordination bonds with the substrate.	Zinc is a cofactor for the proteolytic enzyme carboxypeptidase.

Previous Year's Question

Which one of the following biomolecules is correctly characterized?

(1) Lecithin a phosphorylated glyceride found in cell membrane.
(2) Palmitic acid an unsaturated fatty acid with 18 carbon atoms.
(3) Adenylic acid adenosine with a glucose phosphate molecule.
(4) Alanine amino acid contains an amino group and an acidic group anywhere in the molecule

Chapter Summary



SOLVED EXERCISE

Q1 **Carbohydrates are commonly found as starch in plant storage organs. Which of the following five properties of starch make it useful as a storage material?**

(A) Easily translocated
(B) Chemically non-reactive
(C) Easily digested by animals
(D) Osmotically inactive
(E) Synthesized during photosynthesis

The useful properties are

(1) (A), (C) and (E) **(2) (A) and (E)**
(3) (B) and (C) **(4) (B) and (D)**

A1 **(4)**

As starch is a polysaccharide, it is chemically non-reactive as compared to glucose which is a monosaccharide. It is osmotically inactive i.e., it doesn't interfere with the water potential of the cell sap. Thus, these two properties make starch useful as a storage material.

Q2 **Cellulose is the major component of cell walls of**

(1) Pseudomonas **(2) Saccharomyces**
(3) Pythium **(4) Xanthomonas**

A2 **(3)**

Pythium is a parasite fungus that belongs to class Oomycetes. its cell wall is made up of maximum cellulose and least chitin is present.

Q3 **A competitive inhibitor of succinic dehydrogenase is**

(1) α–ketoglutarate **(2) malate**
(3) malonate **(4) oxaloacetate**

A3 **(3)**

Malonate is an analog of succinate and it is a strong competitive inhibitor of enzyme succinic dehydrogenase.

Q4 **Chitin is a —**

(1) polymer

(2) homopolymer of glucose

(3) heteropolymer

(4) homopolymer of N-acetyl glucosamine

A4 **(4)**

Chitin is a homopolymer of N-acetyl glucosamine with β, 1-4 linkages. It is found in the exoskeletons of arthropods and in fungal cell walls.

Q5 **About 98 percent of the mass of every living organism is composed of just six elements including carbon, hydrogen, nitrogen, oxygen and**

(1) sulphur and magnesium

(2) magnesium and sodium

(3) calcium and phosphorus

(4) phosphorus and sulphur

A5 **(4)**

Mass of every living organism is composed of carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur.

Q6 **An organic substance bound to an enzyme and essential for its activity is called**

(1) isoenzyme

(2) coenzyme

(3) holoenzyme

(4) apoenzyme

A6 **(2)**

Coenzyme is an organic non-protein molecule that binds to an enzyme and catalyzes the reaction.

Q7 **The catalytic efficiency of two different enzymes can be compared by the**

(1) formation of the product **(2) pH of optimum value**

(3) K m value **(4) molecular size of the enzyme**

A7 **(3)**

The catalytic efficiency of two different enzymes can be compared by comparing their Michaelis Menten constant (Km value). Km value indicates the affinity of an enzyme for a substrate.

Q8 **Living cell contains 60 – 95% water. Water present in human body is**

(1) 60 – 65% **(2) 50 – 55%**

(3) 75 – 80% **(4) 65 – 70%**

A8 **(4)**

Water present in the human body is 65-70%.

Q9 **Adenine is**

(1) purine **(2) pyrimidine**

(3) nucleoside **(4) nucleotide**

A9 (1)

Adenine and guanine are purines.

Q10 **Three of the following statements about enzymes are correct and one is wrong. Which one is wrong?**

(1) Enzymes require optimum pH for maximal activity.

(2) Enzymes are denatured at high temperature but in certain exceptional organisms they are effective even at temperatures 80° 90°C.

(3) Enzymes are highly specific.

(4) Most enzymes are proteins but some are lipids.

A10 **(4)**

All enzymes are proteins except ribozymes (RNA molecule).