Name of Unit	Biomolecules
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Class: B.Pharm. Semester	II
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Learning Outcome of Module 01

LO	Particular	Course Outcome Code
LO1	To learn about biomolecules and their classification.	BP203.1
LO2	To gain knowledge about the biological roles of carbohydrates, lipids, proteins and nucleic acids.	BP203.1
LO3	To Learn about synthesis of Proteins, Lipids, Nucleic Acids and carbohydrates.	BP203.1
LO4	To understand how biochemical changes relate to physiological alteration in the body.	BP203.1

Content Table

Topic
• Introduction and Classification of biomolecules • Chemical nature and Biological role of Carbohydrate, lipids, nucleic acids, amino acids and proteins • Concept of Free energy • Endergonic and Exergonic reaction • Relationship between free energy, enthalpy and entropy • Redox Potential • Energy rich compounds: classification, biological significances of ATP and cyclic AMP

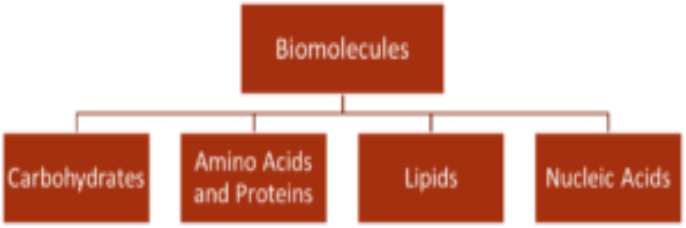
BIOMOLECULES

Biomolecules are molecules that occur naturally in living organisms. Biomolecules include macromolecules like proteins, carbohydrates, lipids, amino acids and nucleic acids.

It also includes small molecules like primary and secondary metabolites and natural products.

Biomolecules consist mainly of carbon and hydrogen with nitrogen, oxygen, sulphur and phosphorus. Biomolecules are very large molecules of many atoms which are covalently bound together.

Classification: A diverse range of bimolecular exists in biochemistry; the major class of biomolecules is carbohydrates, proteins, lipids, nucleic acids, amino acids, vitamins and hormones.



1. Carbohydrates

Carbohydrates are a good source of energy. Carbohydrates (polysaccharides) are long chains of sugars. Monosaccharides are simple sugars that are composed of 3-7 carbon atoms.

They have a free aldehyde or ketone group, which acts as reducing agents and are known as reducing sugars.

Disaccharides are made of two monosaccharides. The bonds shared between two monosaccharides are glycosidic bonds.

Monosaccharides and disaccharides are sweet, crystalline and water-soluble substances. Polysaccharides are polymers of monosaccharides. They are un-sweet and complex carbohydrates. They are insoluble in water and are not in crystalline form.

Example: glucose, fructose, sucrose, maltose, starch, cellulose etc.

2. Lipids

Lipids are composed of long hydrocarbon chains. Lipid molecules hold a large amount of energy and are energy storage molecules. Lipids are generally esters of fatty acids and are building blocks of biological membranes.

Most of the lipids have a polar head and non-polar tail. Fatty acids can be unsaturated and saturated fatty acids.

Lipids present in biological membranes are of three classes based on the type of hydrophilic head present:

- Glycolipids are lipids whose head contains oligosaccharides with 1-15 saccharide residues.
- Phospholipids contain a positively charged head which is linked to the negatively charged phosphate groups.
- Sterols, whose heads contain a steroid ring. Example steroid.

Example of lipids: oils, fats, phospholipids, glycolipids, etc.

3. Nucleic Acids

Nucleic acids are organic compounds with heterocyclic rings. Nucleic acids are made of a polymer of nucleotides. Nucleotides consist of a nitrogenous base, a pentose sugar and a phosphate group. A nucleoside is made of a nitrogenous base attached to a pentose sugar. The nitrogenous bases are adenine, guanine, thymine, cytosine and uracil. Polymerized nucleotides form DNA and RNA which are genetic materials.

4. Protein

Proteins are heteropolymers of stings of amino acids. Amino acids are joined together by the peptide bond which is formed between the carboxyl group and amino group of successive amino acids. Proteins are formed from 20 different amino acids, depending on the number of amino acids and the sequence of amino acids.

There are four levels of protein structure:

(i)**Primary structure of Protein -** Here protein exists as a long chain of amino acids arranged in a particular sequence. They are non-functional proteins.

(ii)**Secondary structure of protein -** The long chain of proteins is folded and arranged in a helix shape, where the amino acids interact by the formation of hydrogen bonds. This structure is called the pleated sheet. Example: silk fibers.

(iii)**Tertiary structure of protein -** Long polypeptide chains become more stabilized by folding and coiling, by the formation of ionic or hydrophobic bonds or disulfide bridges, these results in the tertiary structure of a protein.

(iv)**Quaternary structure of protein -** When a protein is an assembly of more than one polypeptide or subunits of its own, this is said to be the quaternary structure of protein. Example: Haemoglobin, insulin.

FUNCTIONS OF BIOMOLECULES

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

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

Lipids, the primary purpose of lipids in body are energy storage. Structural membranes are composed of lipids which form a barrier and controls flow of material in and out of the cell. Lipid hormones, like sterols, help in mediating communication between cells.

Nucleic Acids are the DNA and RNA; they carry genetic information in the cell. They also help in the synthesis of proteins, through the process of translation and transcription.

Carbohydrates

Carbohydrates are products of plants and are a part of an extremely large group of naturally occurring organic compounds. Canesugar, glucose, starch and so on are a few examples of carbohydrates.

- Carbohydrate is an organic compound, it comprises of only oxygen, carbon and hydrogen.
- The oxygen: hydrogen ratio is usually is 2:1.
- The empirical formula being $C_n(H_2O)_n$.
- Carbohydrates are hydrates of carbon; technically they are polyhydroxy aldehydes and ketones.
- Carbohydrates are also known as saccharides, the word saccharide comes from Greek word *sakkron* which means sugar.

CLASSIFICATION AND NOMENCLATURE OF CARBOHYDRATES

A) On the basis of Hydrolysis

1. **Monosaccharides:** The monosaccharides are polyhydroxy aldehydes or polyhydroxy ketones which cannot bedecomposed by hydrolysis to give simpler carbohydrates. e.g. Glucose, fructose, Galactose etc.

2. **Oligosaccharides:** The oligosaccharides (Oligo: few) are carbohydrates which yield a definite number (2-9) of monosaccharide molecules on hydrolysis.

a) **Disaccharides-** Which yield two monosaccharides molecules on hydrolysis. Which have molecular formula is $C_{12}H_{22}O_{11}$.e.g. Sucrose, maltose etc.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose Water Glucose Fructose

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2C_6H_{12}O_6$$

Maltose Water Glucose

b) **Trisaccharides -** Which yield three monosaccharides molecules on hydrolysis and have molecular formula is $C_{18}H_{32}O_{16}$.

$$C_{18}H_{32}O_{16} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6 + C_6H_{12}O_6$$

Raffinose Water Glucose Fructose Galactose

c) **Tetrasaccharides -** Which yield four monosaccharides molecules on hydrolysis and have molecular formula is $C_{22}H_{42}O_{21}$. eg: Stachyose

3. **Polysaccharides:** The carbohydrates which have higher molecular weight, yield many monosaccharide molecules on hydrolysis. E.g. Starch, glycogen, Dextrin, Cellulose etc.

$$(C_6H_{10}O_5)_n + H_2O \longrightarrow nC_6H_{12}O_6$$

Starch or Cellulose Water Glucose

In general monosaccharides and oligosaccharides are crystalline solids, soluble in water and sweet to taste, they are collectively known as sugars, the polysaccharides on the other hand are amorphous, insoluble in water and tasteless, they are called non-sugars.

A) On the basis of Physical Characteristics

Sugar: Characteristics of sugars are crystalline substances, taste sweet and readily water soluble. Because of their fixed molecular weight, sugars have sharp melting points. A few

examples of sugars are glucose, fructose, sucrose, lactose, etc.

Non-Sugars: Amorphous, Tasteless, water-insoluble substances with variable melting points e.g., Starch.

B) On basis of test with reagents (like Benedict's solution, Tollen's reagent and Fehling's solution):

Reducing Sugars: These have a free aldehyde (-CHO) or ketone group. These have the ability to reduce the cupric ions (Cu^{2+}; blue) in Fehling's or Benedict's Solution to cuprous ions (Cu^{+}; reddish) that separates out as cuprous oxide (Cu_2O) from the solution. Examples include maltose, lactose, gentiobiose, cellobiose, mannotriose.

Non-reducing Sugars: A free aldehyde or ketonic group is absent. No cuprous oxide (Cu_2O) producing chemical reaction takes place. Examples are sucrose, trehalose, raffinose.

Character	Monosaccharaides	Oligosaccharides	Polysaccharides
No. of sugar Molecules	1	2-9	More than 9
Glycoside bond	Absent	Present	Present
Molecular Weight	Low	Moderate	High
Taste	Sweet	Minimallysweet taste	Notaste
Solubility	Soluble	Soluble	Insoluble
Nature	Always reducing sugar	May or may not be	Always non reducing sugar
Example	Glucose, fructose, galactose	Sucrose, Maltose	Starch, Glycogen, Dextrin, Cellulose

Difference between monosaccharides, oligosaccharides & Polysaccharides

Properties of Carbohydrates

General properties of carbohydrates

- Carbohydrates act as energy reserves, also stores fuels, and metabolic intermediates.
- Ribose and deoxyribose sugars forms the structural frame of the genetic material, RNA and DNA.
- Polysaccharides like cellulose are the structural elements in the cell walls of bacteria and plants.
- Carbohydrates are linked to proteins and lipids that play important roles in cell interactions.
- Carbohydrates are organic compounds; they are aldehydes or ketones with many hydroxyl groups.

Physical Properties of Carbohydrates

Stereoisomerism- Compounds having same structural formula but they differ in spatial configuration. Example: Glucose has two isomers with respect to penultimate carbon atom. They are D-glucose and L-glucose.

Optical Activity- It is the rotation of plane polarized light forming (+) glucose and (-) glucose.

Diastereoisomers- It is the configurational changes with regard to C2, C3 or C4 in glucose. Example: Mannose, galactose.

Annomerism- It is the spatial configuration with respect to the first carbon atom in aldoses and second carbon atom in ketoses.

Chemical Properties of Carbohydrates

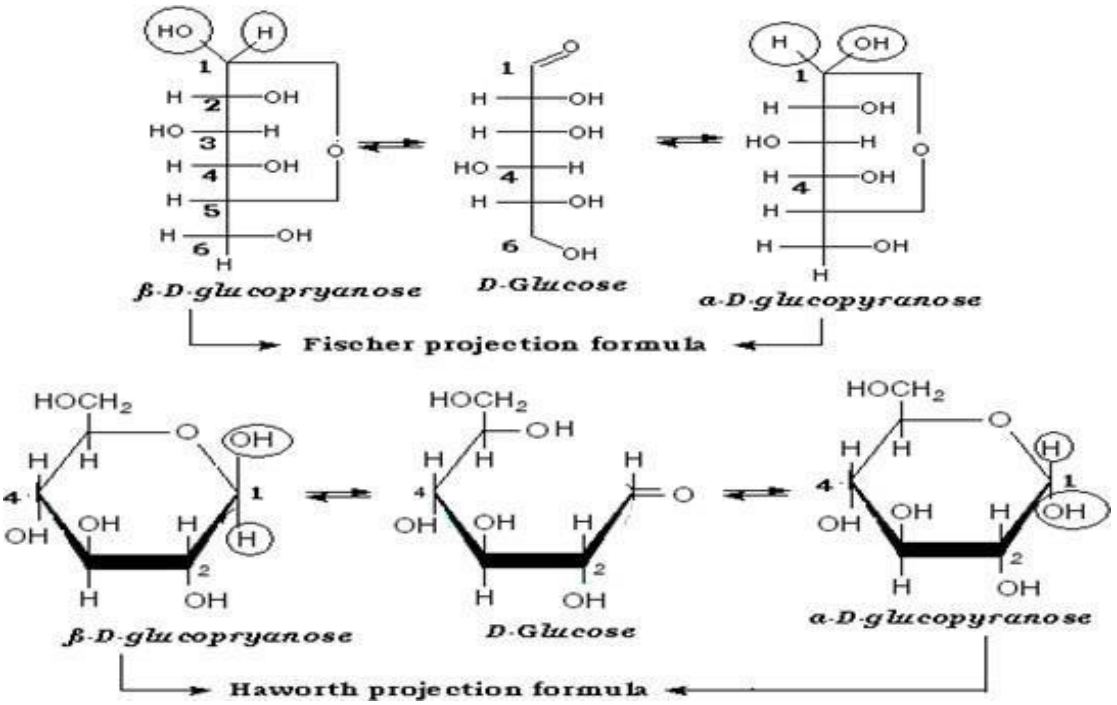
- Osazone formation with phenylhydrazine.
- Benedicts test
- Oxidation
- Reduction to alcohols

Structure of Carbohydrates

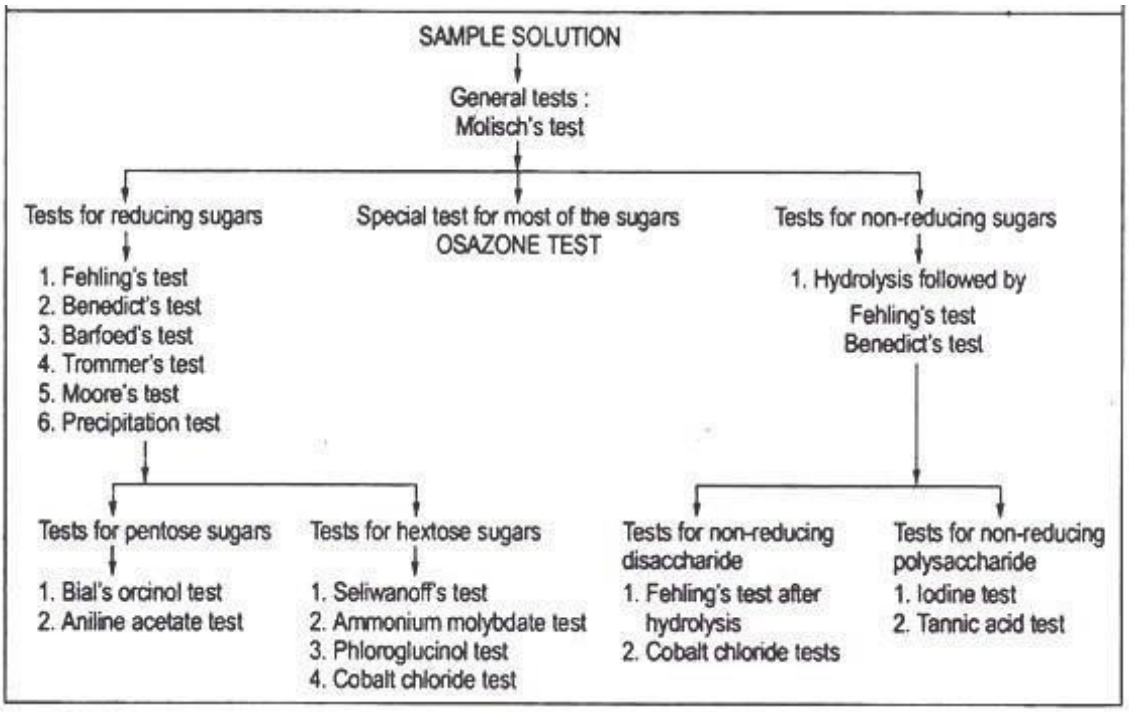
There are three types of structural representations of carbohydrates:

- Open Chain structure

- Hemi-acetal structure
- Haworth structure



Test for carbohydrate



Biological Role/Functions of Carbohydrates

- Carbohydrates are chief energy source, in many animals; they are instantsource of energy. Glucose is broken down by glycolysis/ kreb's cycle to yield ATP.
- Glucose is the source of storage of energy. It is stored as glycogen in animals and starch in plants.
- Stored carbohydrates act as energy source instead of proteins.
- Carbohydrates are intermediates in biosynthesis of fats and proteins.
- Carbohydrates aid in regulation of nerve tissue and are the energy source for brain.
- Carbohydrates get associated with lipids and proteins to form surface antigens, receptor molecules, vitamins and antibiotics.
- They form structural and protective components, like in cell wall of plants and microorganisms.
- In animals they are important constituent of connective tissues.
- They participate in biological transport, cell-cell communication and activation of growth factors.
- Carbohydrates those are rich in fiber content help to prevent constipation.
- Also they help in modulation of immune system.

Example of Carbohydrates

- **Monosaccharides-** Glucose, galactose, glycerose, erythrose, ribose, fructose.
- **Oligosaccharides-**Maltose, lactose, sucrose, raffinose, stachyose.
- **Polysaccharides-**Starch, glycogen, cellulose, pectin, inulin, hyaluonic acid.

Foods rich in carbohydrates are referred to as starchy foods. They are found in legumes, starchy vegetables, whole-grain breads and cereals. They also occur naturally with vitamins and minerals in foods like milk, fruits and milk products. They are also found in refined and processed products like candy, carbonated beverages and table sugar.

LIPIDS

Lipids are a heterogeneous group of water-insoluble (hydrophobic) organic molecules that can be extracted from tissues by non-polar solvents, because of their insolubility in aqueous solutions, body lipids are generally found compartmentalized, as in the case of membrane-associated lipids or droplets of triacylglycerol in adipocytes, or transported in plasma in association with protein, as in lipoprotein particles or on albumin.

Lipids are a major source of energy for the body, and they provide the hydrophobic barrier.

Lipids serve additional functions in the body, for example, some fat-soluble vitamin shave regulatory or coenzyme functions, and the prostaglandins and steroid hormones play major roles in the control of the body's homeostasis.

General characters of lipids

- Lipids are relatively insoluble in water.
- They are soluble in non-polar solvents, like ether, chloroform, and methanol.
- Lipids have high energy content and are metabolized to release calories.
- Lipids also act as electrical insulators, they insulate nerve axons.
- Fats contain saturated fatty acids; they are solid at room temperatures. Example- animal fats.
- Plant fats are unsaturated and are liquid at room temperatures.
- Pure fats are colorless; they have an extremely bland taste.
- The fats are sparingly soluble in water and hence are described are hydrophobic substances.
- They are freely soluble in organic solvents like ether, acetone and benzene.
- The melting point depends on the length of the chain of the constituent fatty acid and the degree of unsaturation.
- Geometric isomerism, the presence of a double bond in the unsaturated fatty acid of the lipid molecule produces geometric or cis-trans isomerism.
- Fats have an insulating capacity, they are bad conductors of heat.
- Emulsification is the process by which a lipid mass is converted to a number of small lipid droplets. The process of emulsification happens before the fats can be absorbed by the intestinal walls.

- The fats are hydrolyzed by the enzyme lipases to yield fatty acids and glycerol.
- The hydrolysis of fats by alkali is called saponification. This reaction results in the formation of glycerol and salts of fatty acids called soaps.
- Hydrolytic rancidity is caused by the growth of microorganisms which secrete enzymes like lipases. These split fats into glycerol and free fatty acids.

Classification of lipids

Simple lipids: Esters of fatty acids with various alcohols.

- ***Fats:*** Esters of fatty acids with glycerol. Oils are fats in a liquid state.
- ***Waxes:*** Esters of fatty acids with higher molecular weight monohydric alcohols.

Complex lipids: Esters of fatty acids containing groups in addition to an alcohol and a fatty acid.

- ***Phospholipids:*** Lipids containing, in addition to fatty acids and alcohol, a phosphoric acid residue. They frequently have nitrogen-containing bases and other substituents, e.g, in glycerophospholipids the alcohol is glycerol and in sphingophospholipids the alcohol is sphingosine.
- ***Glycolipids(glycosphingolipids):*** Lipids containing a fatty acid, sphingosine, and carbohydrate.
- ***Other complex lipids:*** Lipids such as sulfolipids and amino lipids. Lipoproteins may also be placed in this category.

Precursor and derived lipids: These include fatty acids, glycerol, steroids, other alcohols, fatty aldehydes, ketone bodies, hydrocarbons, lipid-soluble vitamins and hormones.

Essential fatty acids

Two fatty acids are dietary essentials in humans

- **Linoleic acid**, which is the precursor of arachidonic acid, the substrate for prostaglandin synthesis.

- **α-linolenic acid** is the precursor for growth and development.

Essential fatty acid deficiency can result in scaly dermatitis, as well as visual and neurologic abnormalities.

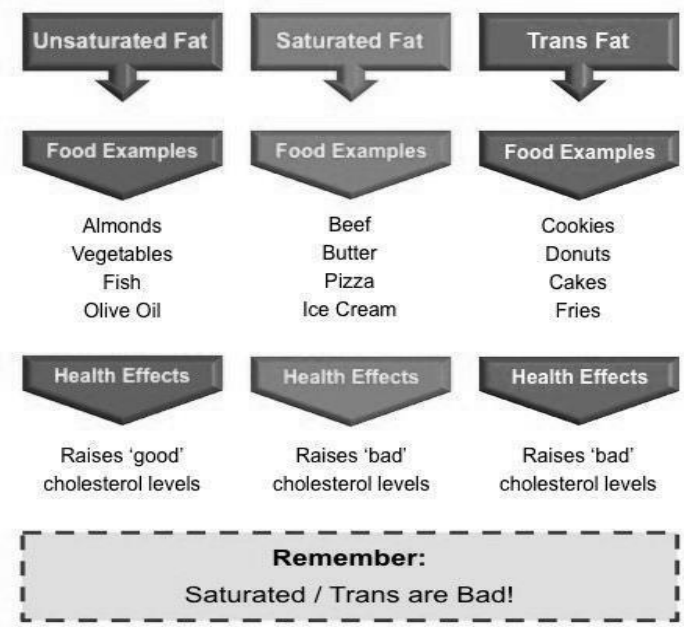
Regulating Blood Cholesterol Levels

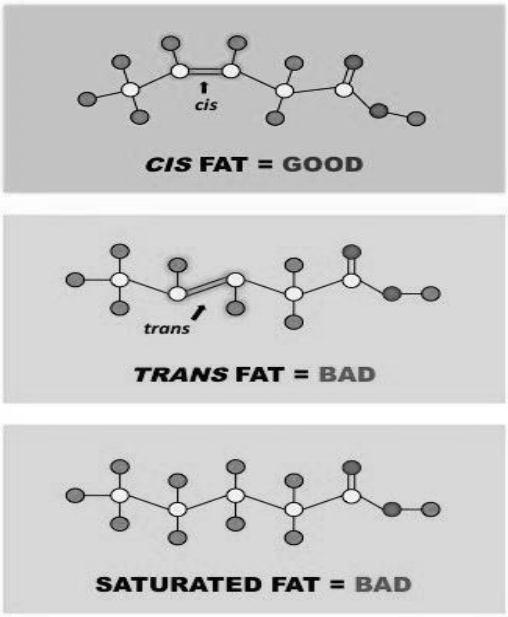
Fats and cholesterol cannot dissolve in blood and are consequently packaged with proteins (to form lipoproteins) for transport.

Low-density lipoproteins (LDL) carry cholesterol from the liver to the rest of the body.

High-density lipoproteins (HDL) scavenge excess cholesterol and carry it back to the liver for disposal.

Hence LDLs raise blood cholesterol levels (bad) while HDLs lower blood cholesterol levels (good).





High intakes of certain types of fats will differentially affect cholesterol levels in the blood.

Saturated fats increase LDL levels within the body, raising blood cholesterol levels.

Trans fats increase LDL levels and decrease HDL levels within the body, significantly raising blood cholesterol levels.

Unsaturated (cis) fats increase HDL levels within the body, lowering blood cholesterol levels.

Lipid Health Claims

There are two main health claims made about lipids in the diet:

Diets rich in saturated fats and trans fats increase the risk of CHD (Coronary Heart Disease).

Diets rich in monounsaturated and polyunsaturated (cis) fats decrease the risk of CHD.

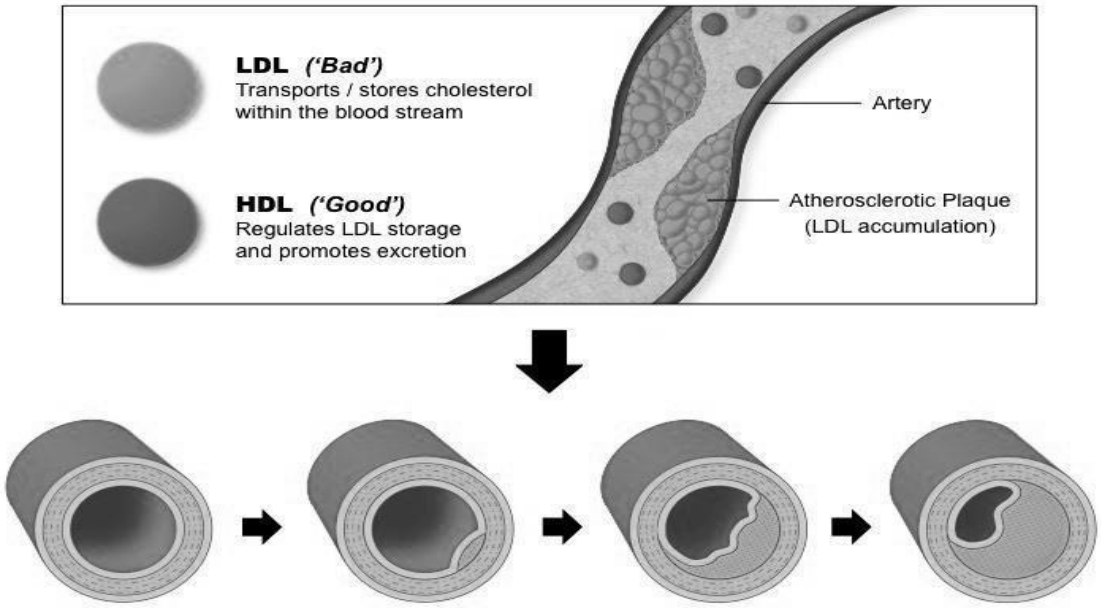
Health Risks of High Cholesterol

High cholesterol levels in the bloodstream lead to the hardening and narrowing of arteries (atherosclerosis).

When there are high levels of LDL in the bloodstream, the LDL particles will form deposits in the walls of the arteries.

The accumulation of fat within the arterial walls leads to the development of plaques that restrict blood flow.

If coronary arteries become blocked, Coronary Heart Disease (CHD) will result-this includes heart attacks and strokes.

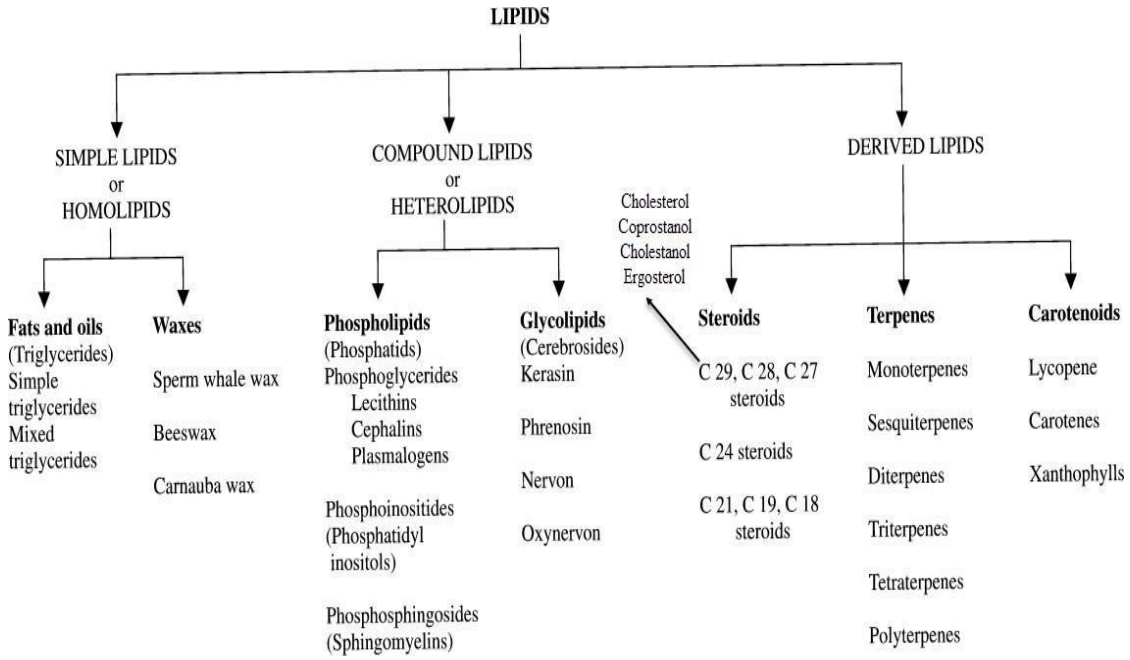


Examples of Lipids

- ***Fatty acids***- Oleic acid, Linoleic acid, Palmitoleic acid, Arachidonic acid.
- ***Fats and Oils*** –**Animal fats**-Butter, Lard, Human fat, Herring oil.

Plant oils-Coconut oil, Corn, Palm, Peanut, Sunflower oil.

- ***Waxes***-Spermacti, Beeswax, Carnauba wax.
- ***Phospholipids***- Lecithins, Cephalins, Plasmoalogens, Phosphatidyl inositols, Sphingomyelins.
- ***Glycolipids***- Kerasin, Phrenosin, Nervon, Oxynervon.
- ***Steroids***- Cholesterol.
- ***Terpenes***- Monoterpenes, Sesquiterpenes, Diterpenes, Triterpenes.
- ***Carotenoids***- Lycopene, Carotenes, Xanthophylls.



Biological Role of Lipids

1) **Food material:** Lipids provide food, highly rich in calorific value. One gram lipid produces 9.3 kilocalories of heat.
2) **Food reserve:** Lipids provide are insoluble in aqueous solutions and hence can be stored readily in the body as a food reserve.
3) **Structural component:** Lipids are an important constituent of the cell membrane.
4) **Heat insulation:** The fats are characterized for their high insulating capacity. Great quantities of fat are deposited in the subcutaneous layers in aquatic mammals such as whale

and in animals living in cold climates.

5) **Fatty acid absorption:** Phospholipids play an important role in the absorption and transportation of fatty acids.
6) **Hormone synthesis:** The sex hormones, adrenocorticoids, cholic acids and also vitamin D are all synthesized from cholesterol, a steroidal lipid.
7) **Vitamin carriers:** Lipids act as carriers of natural fat-soluble vitamins such as vitamin A, D and E.
8) **Blood cholesterol lowering:** Chocolates and beef, especially the latter one, were believed to cause many heart diseases as they are rich in saturated fatty acids, which boost cholesterol levels in blood and clog the arterial passage.
9) **Antibiotic agent:** *Squalamine*, a steroid from the blood of sharks, has been shown to be an antibiotic and antifungal agent of intense activity. This seems to explain why sharks rarely contract infections and almost never get cancer.

PROTEINS

Proteins are large biomolecules or macromolecules, consisting of one or more long chains of amino acid residues.

Proteins are known as building blocks of life.

Proteins are the most abundant intracellular macromolecules. They provide structure, protection to the body of multicellular organism in the form of skin, hair, callus, cartilage, ligaments, muscles, tendons. Proteins regulate and catalyze the body chemistry in the form of hormones, enzymes, immunoglobulin's etc.

General Characteristics of Proteins

- Proteins are organic substances; they are made up of nitrogen and also, oxygen, carbon and hydrogen.
- Proteins are the most important biomolecules; they are the fundamental constituent of the cytoplasm of the cell.
- Proteins are the structural elements of body tissues.
- Proteins are made up of amino acids.
- Proteins give heat and energy to the body and also aid in building and repair.

- Only small amounts of proteins are stored in the body as they can be used up quickly on demand.
- Proteins are considered as the bricks, they make up bones, muscles, hair and other parts of the body.
- Proteins like enzymes are functional elements that take part in metabolic reactions.
- Antibodies, blood haemoglobin are also made of proteins.
- Proteins have a molecular weight of 5 to 300 kilo-daltons.

Physical Properties of Proteins

- Proteins are colorless and tasteless.
- They are homogeneous and crystalline.
- Proteins vary in shape, they may be simple crystalloid structure to long fibrilar structures.
- Protein structures are of two distinct patterns-Globular proteins and fibrilar proteins.
- Globular proteins are spherical in shape and occur in plants. Fibrilar proteins are thread-like, they occur generally in animals.
- In general proteins have large molecular weights.
- Due to the huge size, proteins exhibit many colloidal properties.
- The diffusion rates of proteins are extremely slow.
- Proteins exhibit Tyndall effect.
- Proteins tend to change their properties like denaturation. Many a times the process of denaturation is followed by coagulation.
- Denaturation may be a result of either physical or chemical agents. The physical agents include shaking, freezing, heating etc. Chemical agents are like X-rays, radioactive and ultrasonic radiations.
- Proteins like the amino acids exhibit amphoteric property i.e., they can act as acids and alkalies.
- As the proteins are amphoteric in nature, they can form salts with both cations and anions based on the net charge.
- The solubility of proteins depends upon the pH. Lowest solubility is seen at isoelectric point, the solubility increases with increase in acidity or alkalinity.
- All the proteins show the plane of polarized light to the left, i.e., laevorotatory.

Chemical Properties of Proteins

- Proteins when hydrolyzed by acidic agents, like conc. HCl yield amino acids in the form of their hydrochlorides.
- Proteins when are hydrolyzed with alkaline agents leads to hydrolysis of certain amino acids like arginine, cysteine, serine etc., also the optical activity of the amino acids is lost.
- Proteins with reaction with alcohols give its corresponding esters. This process is known as esterification.
- Amino acid reacts with amines to form amides.
- When free amino acids or proteins are said to react with mineral acids like HCl, the acid salts are formed.
- When amino acid in alkaline medium reacts with many acid chlorides, acylation reaction takes place.
- **Xanthoproteic test-** On boiling proteins with conc. HNO_3, yellow color develops due to presence of benzene ring.
- **Folin's test-** This is a specific test for tyrosine amino acid, where blue colour develops with phosphomolybdotungstic acid in alkaline solution due to presence of phenol group.

Structure of Proteins

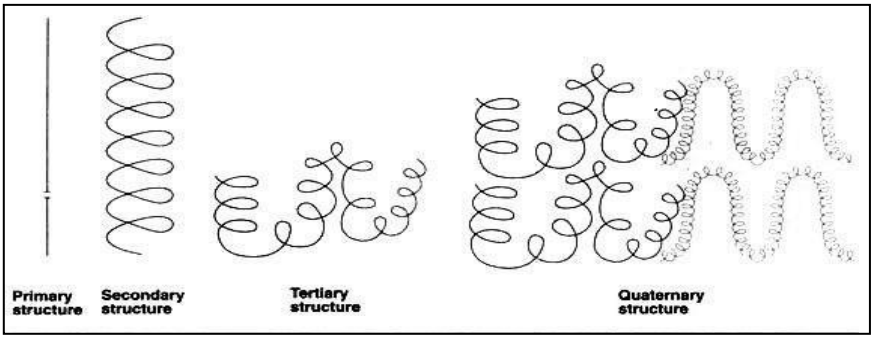
Proteins are constructed by polymerization of only 20 different amino acids into linear chains. Proteins are the polymers of L-α-amino acids. The structure of proteins is rather complex which can be divided into 4 levels of organization.

- **Primary structure:** The linear sequence of amino acids forming the backbone of proteins (polypeptides). Examples of protein with a primary structure are Hexosaminidase, Dystrophin.
- **Secondary structure:** The spacial arrangement of protein by twisting of the polypeptide chain. Example of protein with a secondary structure is Myoglobin.
- **Tertiary structure:** The three dimensional structure of a functional protein. Number of forces act to hold the polypeptide chain in this final configuration:
  - Polar/Nonpolar interactions
  - Hydrogen bonds

- Van der Waals Forces
- Ionic interactions
- Disulfide Bonds

Examples of protein with a tertiary structure are Globular Proteins (Enzymes) and Fibrous proteins.

- **Quaternary structure:** Some of the proteins are composed of two or more polypeptide chains referred to as subunits. The spacial arrangement of these subunits is known as quaternary structure. Examples of proteins with a quaternary structure are DNA polymerase and ion channels.



Secondary Structure of Proteins

Shape

Alpha Helix: Alpha Helix is a right-handed coiled rod-like structure.

Beta Pleated Sheet: Beta sheet is a sheet-like structure.

Formation

Alpha Helix: Hydrogen bonds form within the polypeptide chain in order to create a helical structure.

Beta Pleated Sheet: Beta sheets are formed by linking two or more beta strands by H bonds.

Bonds

Alpha Helix: Alpha helix has n+4 H-bonding scheme. i.e. Hydrogen bonds form between N-H group of one amino residue with C=O group of another amino acid, which is placed in 4 residues earlier.

Beta Pleated Sheet: Hydrogen bonds are formed in between the neighboring N-H and C=O groups of adjacent peptide chain.

R Group

Alpha Helix: -R groups of the amino acids are oriented outside of the helix.

Beta Pleated Sheet: -R groups are directed to both inside and outside of the sheet.

Number

Alpha Helix: This can be a single chain

Beta Pleated Sheet: This cannot exist as a single beta strand, there are must be two or more.

Type

Alpha Helix: This has only one type.

Beta Pleated Sheet: This can be parallel, anti-parallel and mixed.

Qualities

Alpha Helix: 100° rotation, 3.6 residues per turn and 1.5 Å rise from one alpha carbon to the second.

Beta Pleated Sheet: 3.5 Å rise between residues.

Amino Acid

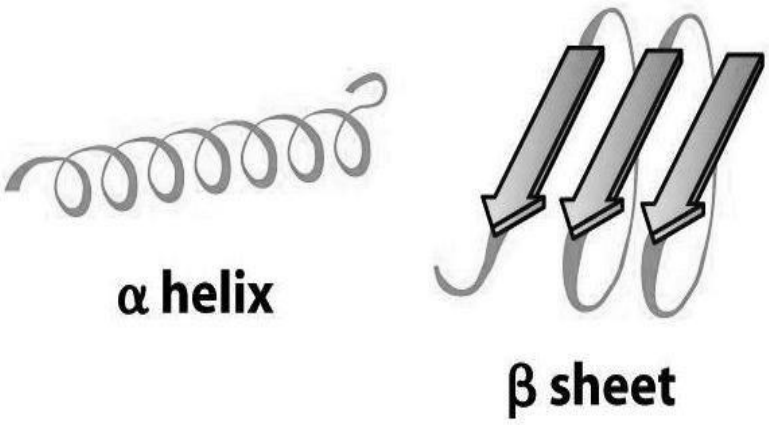
Alpha Helix: Alpha helix prefers the amino acid side chains, which can cover and protectthe backbone H-bondsin the core ofthe helix.

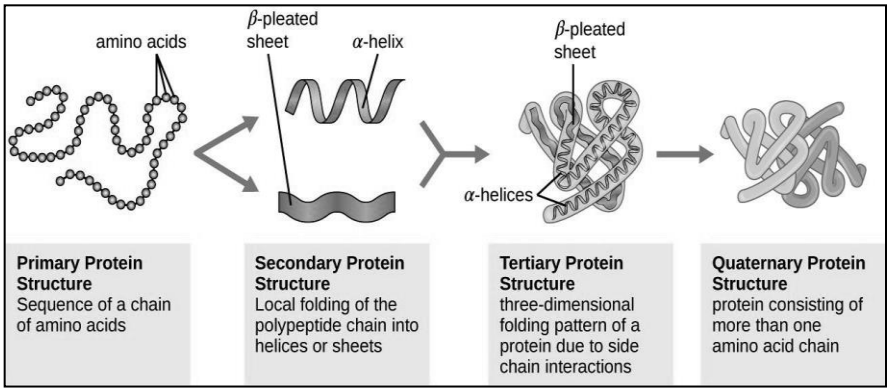
Beta Pleated Sheet: The extended structure leaves the maximum space free for the amino acid side chains. Therefore, amino acids with large bulky side chains prefer beta sheet structure.

Preference

Alpha Helix: Alpha helix prefers Ala, Leu, Met, Phe, Glu, Gln, His, Lys, Arg amino acids.

Beta Pleated Sheet: Beta sheet prefers Tyr, Trp, (Phe, Met), Ile, Val, Thr, Cys.





PROTEIN CLASSIFICATION

CLASSIFICATION OF PROTEINS BASED ON SHAPE

Globular or Corpuscular Proteins

- Globular Proteins have axial ratio less than 10 but not below 3 or 4.
- They are compactly folded and coiled and possess a relatively spherical or ovoid shape.
- They are usually soluble in water and in aqueous media.
- Example: Insulin, Plasma albumin, globulin enzymes.

Fibrous or Fibrillar Proteins

- These proteins have axial ratio more than 10, hence, they resemble long ribbons or fibres in shape.
- They are mostly found in animals and are not soluble in water or in solution of dilute acids.
- Fibrous proteins aid in protection and structural support.
- Example: Collagen, Keratin, Elastins, Fibroin

CLASSIFICATION OF PROTEINS BASED ON COMPOSITION AND SOLUBILITY

Simple Proteins or Holoproteins:

These proteins are made of only one type of amino acid, as structural component, on decomposition with acids, they liberate constituent amino acids. They are mostly globular type of proteins except for scleroproteins, which are fibrous in nature.

Simple proteins are further classified based on their solubility.

Protamines and histones

- These proteins occur only in animals and are basic proteins.
- They possess simple structure and low molecular, are water soluble and are not coagulated by heat.
- They are strongly basic in character due to the high content of lysine, arginine.
- Example: Protamines- salmine, clupine, cyprinine; Histones-nucleohistones, globin.

Albumins

- They are widely distributed in nature, mostly seen in seeds.
- They are soluble in water and dilute solutions of acids, bases and salts.
- Example: Leucosine, legumeline, serum albumin.

Globulins

- They are of two types, pseudoglobulins which are soluble in water.
- Other is euglobulins which are insoluble in water.
- They are coagulated by heat.
- Example: Pseudoglobulin, serum globulin, glycinine etc.

Scleroproteins or Albuminoids

- These occur mostly in animals and are commonly known as animal skeleton proteins.
- They are insoluble in water, and in dilute solution of acids, bases and salts.

CONJUGATED OR COMPLEX PROTEINS OR HETEROPROTEINS:

These are proteins that are made of amino acids and other organic compounds. The non-amino acid group is termed as prosthetic group.

Complex proteins are further classified based on the type of prosthetic group present.

Metalloproteins

These are proteins linked with various metals.

Example: casein, collagen, ceruloplasmin.

Chromoproteins

These are proteins that are coupled with a colored pigment.

Example: Myoglubin, Hemocyanin, cytochromes, flavoproteins.

Glycoproteins and Mucoproteins

These proteins contain carbohydrates as the prosthetic group.

Example: Glycoproteins- egg albumin, serum globulin, serum albumins; Mucoproteins- Ovomucoid, mucin.

Phosphoproteins

These proteins are linked with phosphoric acid.Example: casein.

Lipoproteins

Proteins forming complexes with lipids are lipoproteins.

Example: Lipovitellin, lipoproteins of blood.

Nucleoproteins

These are compounds containing nucleic acids and proteins.

Example: Nucleoproteins, nucleohistones, nuclein.

Derived Proteins

These are proteins that are derived from the action of heat, enzyme or chemical reagents.Derived proteins are of two types, primarily derived proteins and secondary derived proteins.

- **Primary derived proteins**

  Derivatives of proteins, in which the size of the protein molecule is not altered materially. Primary derived proteins are classified into three types- Proteans, Infra proteins and coagulated proteins. Example: edestan, coagulated egg-white.

- **Secondary derived proteins**

  While in secondary derived proteins, hydrolysis occurs, as a result the molecules are smaller than the original proteins.They are further classified into 3 types- Proteoses, Peptones and polypeptides

CLASSIFICATION OF PROTEINS ON BIOLOGICAL FUNCTION

Enzymic Proteins

They are the most varied and highly specialized proteins with catalytic activity. Enzymes catalyze a variety of reactions.

Example: Urease, catalase, cytochrome C.

Structural Proteins

These proteins aid in strengthening or protecting biological structures.

Example: Collagen, elastin, keratin

Transport or Carrier Proteins

These proteins help in transport of ions or molecules in the body.

Example: Myoglobin, hemoglobin

Nutrient and Storage Proteins

These proteins provide nutrition to growing embryos and store ions.

Contractile or Motile Proteins

These proteins function in the contractile system.

Example: Actin, myosin, tubulin.

Defense Proteins

These proteins defend against other organisms.

Example: Antibodies, Fibrinogen, thrombin.

Regulatory Proteins

They regulate cellular or metabolic activities.**Example:** Insulin, G proteins

Toxic Proteins

These proteins hydrolyze or degrade enzymes.**Example:** snake venom, ricin.

Milk Proteins

- Milk protein contains about 0.6-0.7% protein which is not precipitated on acidification to pH 4.7.
- This represents about 20% of the protein contained in skim milk. These whey proteins are separated into 2 fractions: lactalbumin and lactoglobulin.
- The name casein is assigned to the fraction precipitated by acidifying milk to a pH of 4.7. It is present in cow's milk (3-3.5%) and human milk (0.3-0.6%).
- Casein may be further purified by redissolving and precipitating again. It is of 3 types:

α, β and γ.

Function of Proteins

- Proteins are seen in muscles, hair, skin and other tissues; they constitute the bulk of body's non-skeletal structure. Example: The protein keratin is present in nails and hair.
- Some proteins are hormones and regulate many body functions. Example: Insulin hormone is a protein and it regulated the blood sugar level.
- Some proteins act enzymes, they catalyze or help in biochemical reactions. Example: Pepsin and Tripsin.
- Some proteins act as antibodies; they protect the body from the effect of invading species or substances.
- Proteins transport different substances in blood of different tissues. Example: Haemoglobin is an oxygen transport protein.
- Contractile proteins help in contraction of muscle and cells of our body. Example: Myosin is contractile protein.
- Fibrinogen a glycoprotein helps in healing of wounds. It prevents blood loss and inhibits passage of germs.

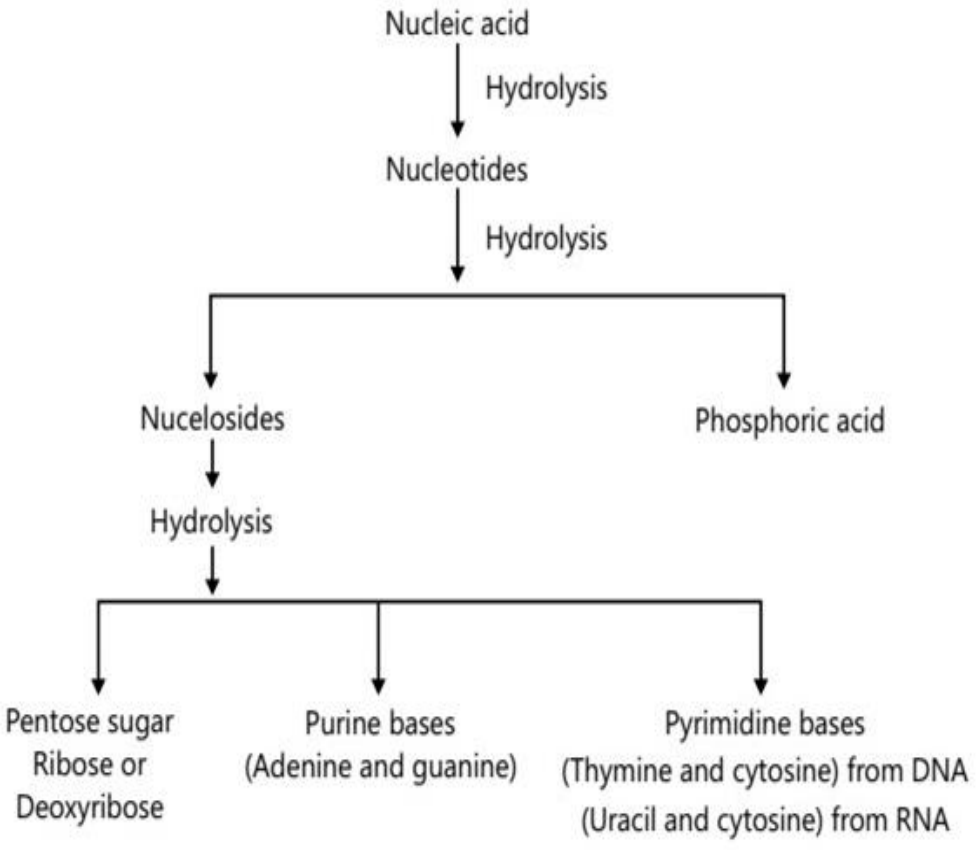
FUNCTION OF PROTEINS

Class of Protein	Function in the Body	Examples
Structural	Provide structural components	*Collagen* is in tendons and cartilage. *Keratin* is in hair, skin, wool, and nails.
Contractile	Movement of muscles	*Myosin* and *actin* contract muscle fibers.
Transport	Carry essential substances throughout the body	*Hemoglobin* transports oxygen. *Lipoproteins* transport lipids.
Storage	Store nutrients	*Casein* stores protein in milk. *Ferritin* stores iron in the spleen and liver.
Hormone	Regulate body metabolism and nervous system	*Insulin* regulates blood glucose level. *Growth hormone* regulates body growth.
Enzyme	Catalyze biochemical reactions in the cells	*Sucrase* catalyzes the hydrolysis of sucrose. *Trypsin* catalyzes the hydrolysis of proteins.
Protection	Recognize and destroy foreign substances	*Immunoglobulins* stimulate immune responses.

NUCLEIC ACIDS

Nucleic acids are vital biomolecules that present in the nuclei of all living cells as nucleoproteins. These are long chain polymers with a high molecular mass. Also called biopolymer, they have nucleotide as a repeating structural unit (monomer). These play an important role in the transmission of the heredity characteristics from one generation to the next and also in the biosynthesis of proteins. Therefore, the genetic information coded in nucleic acid governs the structure of protein during its biosynthesis and hence controls the metabolism in the living system.

Structure of Nucleic acids: The nucleic acid is the prosthetic component of nucleoproteins. Nucleic acid on stepwise hydrolysis gives the following products as shown in the chart.



Components of nucleic acid

Difference between DNA and RNA

The main points of difference between the two types of nucleic acids are given in the table.

	DNA	RNA
1	The pentose sugar present in it is 2- deoxy D(–) ribose.	It has D(–) ribose sugar.
2.	It contains cytosine and thymine as pyrimidine bases.	It contains cytosine and uracil as pyrimidine bases.
3.	DNA is double strand and pairing of bases is present throughout the molecule.	It is a single strand molecule looped back on itself. The pairing of bases in present only in helical part.
4.	It occurs in the molecules of the cell.	It mainly occurs in the cytoplasm of the cell.
5.	It is a very large molecule and the molecular weight varies from 6 million to 16 million amu.	It is a much smaller molecule and its molecular weight ranges from 20 thousand to 40 thousand amu.
6.	It has a characteristic property of replication.	It does not replicate.
7.	DNA controls the heredity character.	RNA only governs the biosynthesis of proteins.

- Adenine and guanine represent the purine bases of RNA; the pyrimidine bases are uracil and cytosine.
- The thymine in DNA is replaced by uracil in RNA.
- RNA is single-stranded, but double-stranded RNA is present in Reovirus and wound tumour virus.
- There are three major classes of RNA, each with specific functions in protein synthesis.

mRNA

- Messenger RNA is produced by DNA; the process is called transcription.
- Messenger RNA encodes the amino acid sequence of a protein in their nucleotide base sequence.
- A triplet of nitrogenous bases specifying an amino acid in mRNA is called a codon.

tRNA

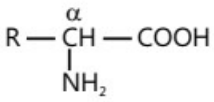
- tRNA is also known as soluble RNA (sRNA) as it is soluble in 1 molar solution of sodium chloride.
- Molecules of tRNA are single-stranded and relatively very small.
- tRNA identifies amino acids in the cytoplasm and transports them to the ribosome.
- Anticodon is a three base sequence in a tRNA molecule that forms complementary base pairs with a codon of mRNA.
- All transfer RNA possess the sequence CCA at their three ends; the amino acid is attached to the terminal as residue.

rRNA

- Ribosomal RNA is found in ribosomes of a cell and is also called insoluble RNA.
- The main function of rRNA is to provide a large surface for spreading of mRNA over ribosomes during the translocation process of protein synthesis.
- The relationship between the sequence of amino acids in a polypeptide with the base sequence of DNA or mRNA is genetic code.
- Genetic code determines the sequence of amino acids in a protein.
- A triplet would code for a given amino acid as long as three bases are present in a particular sequence.
- Later in a cell-free system. Marshall Nirenberg and Philip (1964) were able to show that GUU codes for the amino acid valine.
- The spellings of further codons were discovered by R. Holley, H. Khorana and M. Nirenberg.
- They have been awarded the Nobel Prize in 1968 for researches in the genetic code.

AMINO Acids

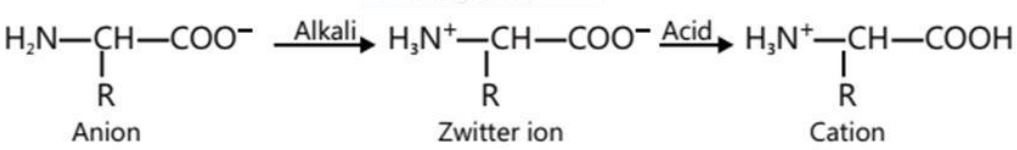
α-Amino acids: Carboxylic acids in which one α-hydrogen atom of an alkyl group is substituted by (-NH_2) group are called α-Amino acids. The general formula is:



Where R = H or alkyl group

Structure of α-Amino acids: The amino acids containing one carboxylic group and one amino group behave as a neutral molecule. This is because in aqueous solutions the acidic carboxylic group and basic amino group neutralize each other intramolecularly to produce an internal salt structure known as a zwitterions or dipolar ions.

However, the neutral zwitterion (dipolar ions) changes to the cation in an acidic solution and exist as an anion in an alkaline medium. Thus amino acids exhibit amphoteric character.



Therefore, amino acid exists as zwitter ion when the solution is neutral or pH 7. The pH at which the structure of an amino acid has no net charge is called its isoelectric point.

Classification of Amino Acids: Based on the relative number of –NH_2 and –COOH group, α-amino acids are classified in three main groups

a) **Neutral Amino acids:** Amino acids containing one –NH_2 group and one –COOH group. For example glycine, valine, alanine.

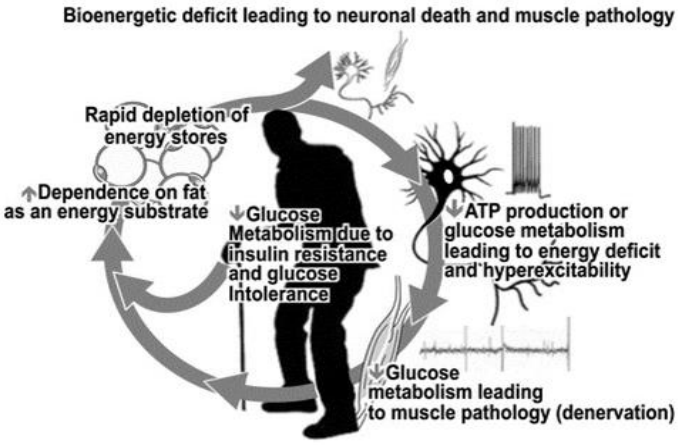
b) **Basic Amino acids:** These contain one -COOH group and two –NH_2 groups such as lysine and arginine.

c) **Acidic amino acids:** Amino acids containing two –COOH group and one –NH_2 group are called acidic amino acids, for example aspartic acid and glutamic acid.

BIOENERGETICS

Defination

- Bioenergetics means study of the transformation of energy in living organisms.
- The goal of bioenergetics is to describe how living organisms acquire and transform energy in order to perform biological work. The study of metabolic pathways is thus essential to bioenergetics.
- In a living organism, chemical bonds are broken and made as part of the exchange and transformation of energy. Energy is available for work (such as mechanical work) or for other processes (such as chemical synthesis and anabolic processes in growth), when weak bonds are broken and stronger bonds are made. The production of stronger bonds allows release of usable energy.
- Adenosine triphosphate (ATP) is the main "energy currency" for organisms; the goals of metabolic and catabolic processes are to synthesize ATP from available starting materials (from the environment) and to break down ATP (into adenosine diphosphate (ADP) and inorganic phosphate) by utilizing it in biological processes.
- In a cell, the ratio of ATP to ADP concentrations is known as the "energy charge" of the cell.
- A cell can use this energy charge to relay information about cellular needs; if there is more ATP than ADP available, the cell can use ATP to do work, but if there is more ADP than ATP available, the cell must synthesize ATP via oxidative phosphorylation.



- Living organisms produce ATP from energy sources via oxidative phosphorylation. The terminal phosphate bonds of ATP are relatively weak compared with the stronger bonds

formed when ATP is hydrolyzed (broken down by water) to adenosine diphosphate and inorganic phosphate. Here it is the thermodynamically favorable free energy of hydrolysis that results in energy release; the phosphoanhydride bond between the terminal phosphate group and the rest of the ATP molecule does not itself contain the energy.

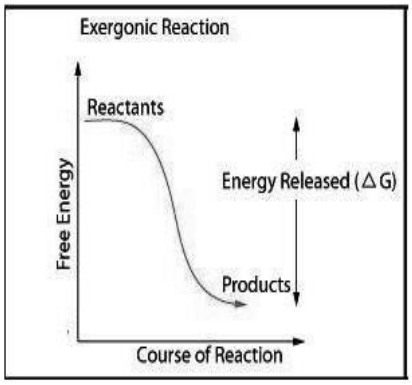
Types of Bioenergetics Reactions

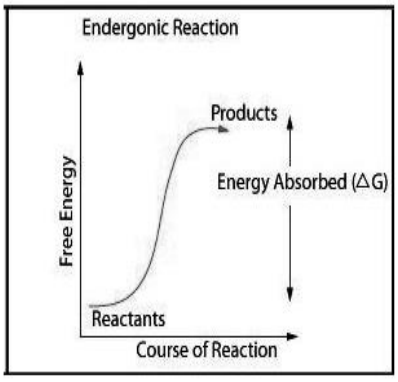
Exergonic Reaction: Exergonic implies the release of energy from a spontaneous chemical reaction without any concomitant utilization of energy. The reactions are significant in terms of biology as these reactions have an ability to perform work and include most of the catabolic reactions in cellular respiration. Most of these reactions involve the breaking of bonds during the formation of reaction intermediates as is evidently observed during respiratory pathways. The bonds that are created during the formation of metabolites are stronger than the cleaved bonds of the substrate. The release of free energy G, in an exergonic reaction (at constant pressure and temperature) is denoted as

$$\Delta G = G_{products} - G_{reactants} < 0$$

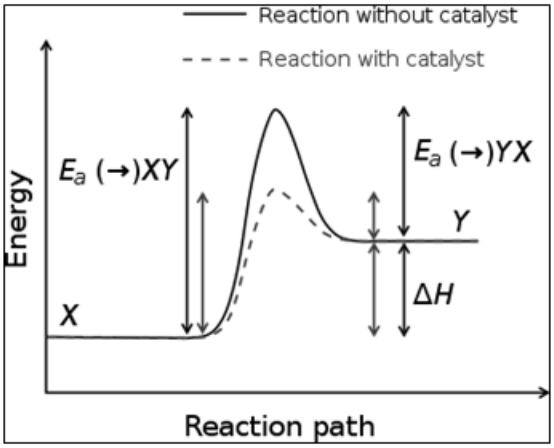
Endergonic Reactions: Endergonic in turn is the opposite of exergonic in being non-spontaneous and requires an input of free energy. Most of the anabolic reactions like photosynthesis and DNA and protein synthesis are endergonic in nature. The release of free energy, G, in an endergonic reaction (at constant pressure and temperature) is denoted as

$$\Delta G = G_{products} - G_{reactants} > 0$$





Activation Energy: Activation energy is the energy which must be available to a chemical system with potential reactants to result in a chemical reaction. Activation energy may also be defined as the minimum energy required starting a chemical reaction.



Examples of Major Bioenergetics Processes

Glycolysis is the process of breaking down glucose into pyruvate, producing net eight molecules of ATP in the process. Pyruvate is one product of glycolysis and can be shuttled into other metabolic pathways as needed by the cell. Additionally, glycolysis produces equivalents in the form of NADH (nicotinamide adenine dinucleotide) which will ultimately be used to donate electrons to the electron transport chain.

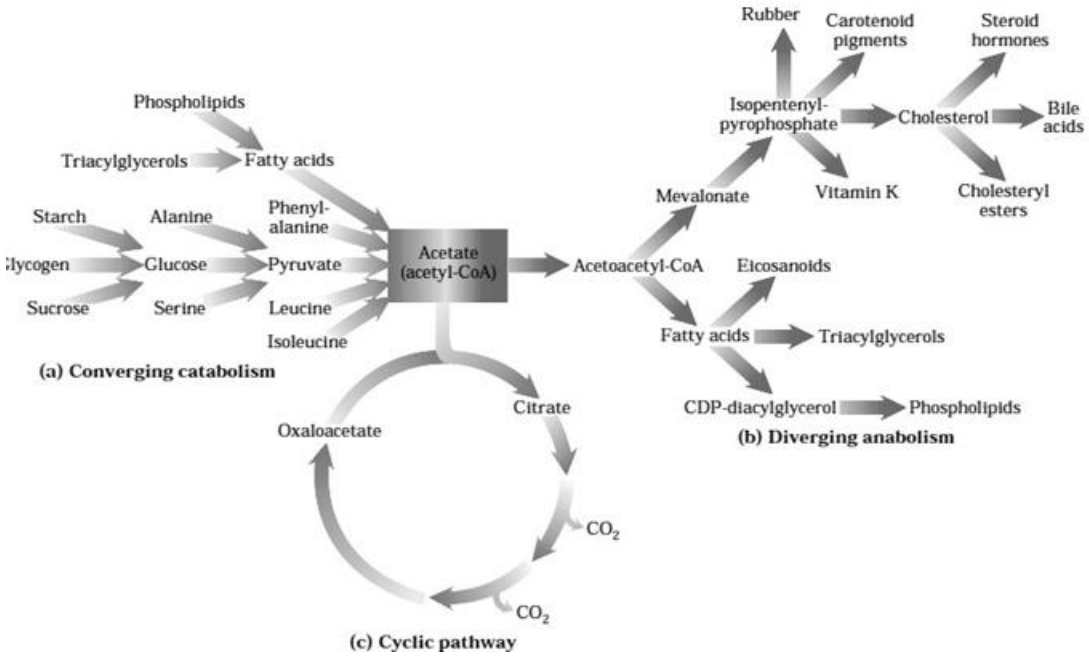
Gluconeogenesis is the opposite of glycolysis, when the cell's energy charge is low (the concentration of ADP is higher than that of ATP), the cell must synthesize glucose from carbon containing biomolecules such as proteins, amino acids, fats, pyruvate etc. For example, proteins can be broken down into amino acids and these simpler carbon skeletons are used to build/synthesize glucose.

The citric acid cycle is a process of cellular respiration in which acetyl coenzyme A, synthesized from pyruvate dehydrogenase, is first reacted with oxaloacetate to yield citrate. The remaining eight reactions produce other carbon-containing metabolites. These metabolites are successively oxidized, and the free energy of oxidation is conserved in the form of the reduced coenzymes $FADH_2$ and NADH. These reduced electron carriers can then be re-oxidized when they transfer electrons to the electron transport chain.

Ketosis is a metabolic process whereby ketone bodies are used by the cell for energy (instead of using glucose). Cells often turn to ketosis as a source of energy when glucose levels are low; e.g. during starvation.

Oxidative phosphorylation and the electron transport chain is the process where reducing equivalents such as NADPH, $FADH_2$ and NADH can be used to donate electrons to a series of redox reactions that take place in electron transport chain complexes. These redox reactions take place in enzyme complexes situated within the mitochondrial membrane. These redox reactions transfer electrons "down" the electron transport chain, which is coupled to the proton motive force. This difference in proton concentration between the mitochondrial matrix and inner membrane space is used to drive ATP synthesis via ATP synthase.

Photosynthesis, another major bioenergetic process, is the metabolic pathway used by plants in which solar energy is used to synthesize glucose from carbon dioxide and water. This reaction takes place in the chloroplast. After glucose is synthesized, the plant cell can undergo photophosphorylation to produce ATP.



Bioenergetics Relationship Between Free Energy, Enthalpy and Entropy

- Every living cell and organism must perform work to stay alive, to grow and to reproduce. The ability to harvest energy from nutrients or photons of light and to channel it into biological work is the miracle of life.

1st Law of Thermodynamics: The energy of the universe remains constant.

2nd Law of Thermodynamics: All spontaneous processes increase the entropy of the universe.

- The important state functions for the study of biological systems are:

The Gibbs free energy (G) which is equal to the total amount of energy capable of doing work during a process at constant temperature and pressure.

If ΔG is negative, then the process is spontaneous and termed exergonic.

If ΔG is positive, then the process is nonspontaneous and termed endergonic.

If Δ**G** is equal to zero, then the process has reached equilibrium.

The Enthalpy (H) which is the heat content of the system. Enthalpy is the amount of heat energy transferred (heat absorbed or emitted) in a chemical process under constant pressure.

When Δ**H** is negative the process produces heat and is termed exothermic.

When Δ**H** is positive the process absorbs heat and is termed endothermic.

The Entropy (S) is a quantitative expression of the degree of randomness or disorder of the system. Entropy measures the amount of heat dispersed or transferred during a chemical process.

When Δ**S** is positive then the disorder of the system has increased.

When Δ**S** is negative then the disorder of the system has decreased.

The conditions of biological systems are constant temperature and pressure. Under such conditions the relationships between the change in free energy, enthalpy and entropy can be described by the expression where T is the temperature of the system in Kelvin.

$$\Delta G = \Delta H - T\Delta S$$

[Δ**G**= *Gibbs Free Energy*; Δ**H**= *Change in Enthalpy*; **T** =*Temperature in* K; Δ**S** = *Change in Entropy*]

Three Thermodynamic Quantities

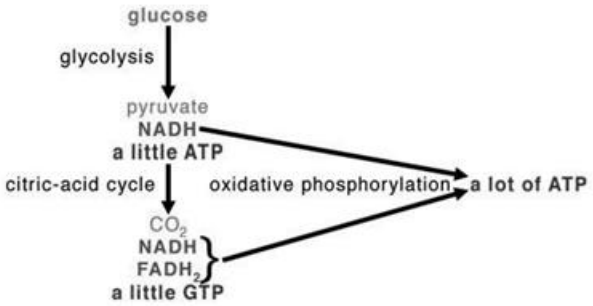
Quantity	Symbol	Measures	Units
Enthalpy	*H*	Heat	Energy
Entropy	*S*	Disorder	Energy/K
Free energy	*G*	Reactivity	Energy

Energy Rich Compounds

High energy phosphates act as energy currency of cell. Three major sources of high energy phosphates taking part in energy conservation or energy capture.

Oxidative phosphorylation (or OXPHO Sinshort)

- In metabolic pathway, cells use enzymes to oxidize nutrients, thereby releasing energy which is used to produce adenosine triphosphate (ATP). In most eukaryotes, this takes place inside mitochondria. Almost all aerobic organisms carry out oxidative phosphorylation. This pathway is probably so pervasive because it is a highly efficient way of releasing energy, compared to alternative fermentation processes such as anaerobic glycolysis.
- The process that accounts for the high ATP yield is known as **oxidative phosphorylation**.
- In glycolysis and the citric-acid cycle generate other products besides ATP and GTP, namely NADH and$FADH_2$. These products are molecules that are oxidized (i.e., give up electrons) spontaneously. The body uses these reducing agents (NADH and $FADH_2$) in an oxidation-reduction reaction.



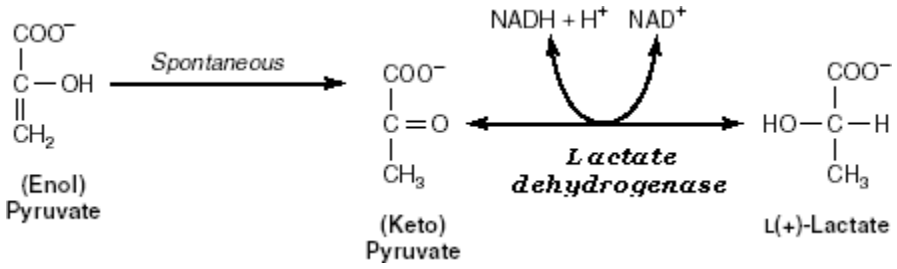
Glycolysis:

Cells use the glycolysis pathway to extract energy from sugars, mainly glucose, and store it in molecules of adenosine triphosphate (ATP) and nicotinamide adenine dinucleotide (NADH). The end product of glycolysis is pyruvate, which can be used in other metabolic pathways to yield additional energy.

During glycolysis ATP molecules are used and formed in the following reactions (aerobic phase).

Reactions Catalyzed	*ATP used*	*ATP formed*
a) Stage I: Glucokinase (for phosphorylation)	1	
Phosphofructokinase I (for phosphorylation)	1	
b) Stage II: Glyceraldehyde 3-phosphate dehydrogenase (oxidation of 2NADH in respiratory chain)		6
Phosphoglycerate kinase (substrate level phosphorylation)		2
c) Stage IV: Pyruvatekinase (substrate level phosphorylation)		2
Total	**2**	**10**
Net gain	**08**	

In the anaerobic phase oxidation of one glucose molecule produces 4-2= 2ATP.



TCA Cycle

- The citric acid cycle (CAC)–also known as the tricarboxylic acid (TCA) cycle or the Krebs cycle is a series of chemical reactions used by all aerobic organisms to release stored energy through the oxidation of acetyl-CoA derived from carbohydrates, fats, and proteins into carbon dioxide and chemical energy in the form of adenosine triphosphate (ATP).
- If one molecule of the substrate is oxidized through NADH in the electron transport chain three molecules of ATP will be formed and through $FADH_2$, two ATP molecules will be generated. As one molecule of glucose gives rise to two molecules of pyruvate by glycolysis, intermediates of citric acid cycle also result as two molecules.

Reactions	No.of ATP formed
1. 2 isocitrate → 2 α-ketoglutarate (2 NADH + 2H⁺) (2 × 3)	6
2. 2 α-ketoglutarate → 2 succinyl CoA (2 NADH + 2H⁺) (2 × 3)	6
3. 2 succinyl CoA → 2 succinate (2 GTP = 2ATP)	2
4. 2 succinate → 2 Fumarate ($2\ FADH_2$) (2 × 2)	4
5. 2 malate → 2 oxaloacetate (2 NADH + 2H⁺) (2 × 3)	6
Total No.of ATP formed	24

ENERGY SHUTTLES:

NADH: An energy shuttle which delivers high energy electrons to the electron transport chain where they will eventually power the production of 2 to 3 **ATP** molecules. When this electron shuttle is not carrying high energy electrons, meaning it has been oxidized (lost its electrons), it is left with a positive charge and is called NAD^+.

$FADH_2$: Another energy shuttle that carries high energy electrons to the electron transport chain, where they will ultimately drive production of 1 to 2 **ATP** molecules. The oxidized form of **$FADH_2$** is **FAD** and happens just like in **NADH**.

ATP: The basic energy currency of the cell. It's a form of energy that cells can use right away.

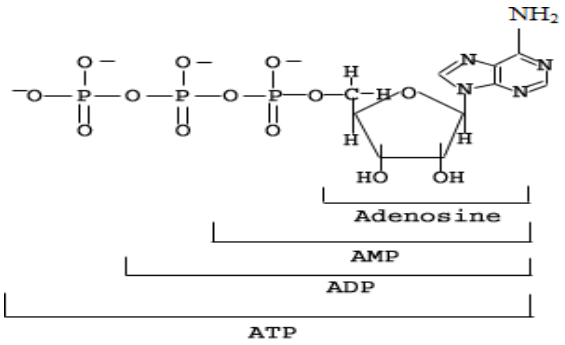
GTP: Similar to **ATP**, **GTP** can be easily converted to **ATP** in the cell.

ADENOSINE TRIPHOSPHATE (ATP)

- Adenosine-5'-triphosphate (ATP) is a multifunctional nucleotide used in cells as a coenzyme.
- It is often called the "molecular unit of currency" of intracellular energy transfer. ATP transports chemical energy within cells for metabolism.
- It is produced by photophosphorylation and cellular respiration and used by enzymes and structural proteins in many cellular processes, including biosynthetic reactions, motility, and cell division.
- One molecule of ATP contains three phosphate groups and it is produced by *ATP synthase*

from in organic phosphate and adenosine diphosphate (ADP) or adenosine monophosphate (AMP).

- The structure of this molecule consists of a purine base (adenine) attached to the 1' carbon atom of a pentose sugar (ribose). Three phosphate groups are attached at the 5' carbon atom of the pentose sugar. It is the addition and removal of these phosphate groups that inter-



convert ATP, ADP and AMP. When ATP is used in DNA synthesis, the ribose sugar is first converted to deoxyribose by *ribonucleotide reductase*.

- The three main functions of ATP in cellular function are:
  - Transporting organic substances—such as sodium, calcium, potassium—through the cell membrane.
  - Synthesizing chemical compounds, such as protein and cholesterol.
  - Supply in energy for mechanical work, such as muscle contraction.

- The standard amount of energy released from hydrolysis of ATP can be calculated from the changes in energy under non-natural (standard) conditions, then correcting to biological concentrations. The energy released by cleaving either a phosphate (P_i) or pyrophosphate (PP_i) unit from ATP at standard state of 1 Mare:

$$ATP + H_2O \rightarrow ADP + P_i \Delta G^\circ = -30.5 \text{ kJ/mol } (-7.3 \text{ kcal/mol})$$

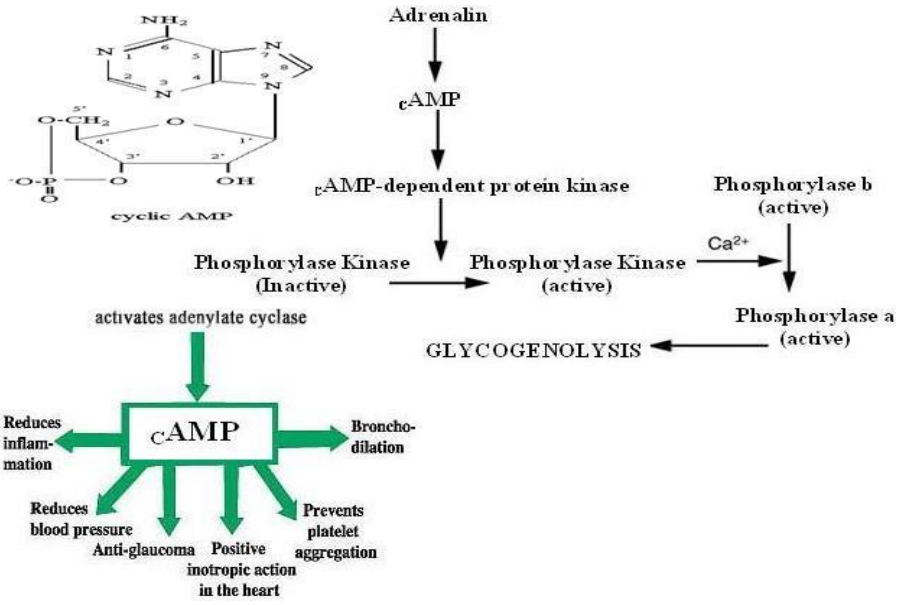
$$ATP + H_2O \rightarrow AMP + PP_i \Delta G^\circ = -45.6 \text{ kJ/mol } (-10.9 \text{ kcal/mol})$$

These values can be used to calculate the change in energy under physiological conditions and the cellular ATP/ADP ratio (also known as the Energy Charge). This reaction is dependent on a number of factors, including overall ionic strength and the presence of alkaline earth metal ions such as Mg^{2+} and Ca^{2+}. Under typical cellular conditions, ΔG is approximately −57kJ/mol (−14 kcal/mol).

CYCLIC ADENOSINE MONOPHOSPHATE

(cAMP, cyclic AMPor3'-5'-cyclicadenosinemonophosphate)

- It is a second messenger important in many biological processes. cAMP is derived from adenosine triphosphate (ATP) and used for intracellular signal transduction in many different organisms, conveying the cAMP-dependent pathway.
- cAMP is synthesised from ATP by adenylyl cyclase located on the inner side of the plasma membrane. *Adenylylcyclase* is activated by a range of signaling molecules through the activation of *adenylyl cyclase* stimulatory G(G_s)-protein-coupled receptors and inhibited by agonists of *adenylyl cyclase* inhibitory G (G_i)-protein-coupled receptors. Liver *adenylyl cyclase* responds more strongly to glucagon, and muscle adenylyl cyclase responds morestronglyto adrenaline.
- cAMP decomposition into AMP is catalyzed by the enzyme *phosphodiesterase*.



Function: cAMP is a second messenger, used for intracellular signal transduction, such as transferring the effects of hormones like glucagon and adrenaline, which cannot pass through the cell membrane. It is involved in the activation of *protein kinases* and regulates the effects of adrenaline and glucagon. It also regulates the passage ofCa^{2+}through ion channels. cAMP and its associated kinases function in several biochemical processes, including the regulation of glycogen, sugar, andlipid metabolism by activating protein kinase.

GUANOSINE TRIPHOSPHATE (GTP)

- Guanosine-5'-triphosphate (GTP) is a purine nucleoside triphosphate. It can act as a substrate for both the synthesis of RNA during the transcription process and of DNA during DNA replication.
- It also has the role of a source of energy or an activator of substrate in metabolic reactions, like that of ATP, but more specific. It is used as a source of energy for protein synthesis and gluconeogenesis.
- GTP is essential to signal transduction, in particular with G-proteins, in second-messenger mechanisms where it is converted to ***Guanosine diphosphate(GDP)*** through the action of GTPases.

USES:

Energy transfer GTP is involved in energy transfer within the cell. For instance, a GTP molecule is generated by one of the enzymes in the citric acid cycle. This is an amount to the generation of one molecule of ATP, since GTP is readily converted to ATP with nucleoside-diphosphatekinase (NDK).

Genetic translation During the elongation stage of translation, GTP is used as an energy source for the binding of a new amino-bound tRNA to the A site of the ribosome.

Mitochondrial function The translocation of proteins into the mitochondrial matrix involves the interactions of both GTP and ATP.

Very Short Answer Type Questions (2 marks)

1. What are monosaccharide's? Give few examples.
2. What is a disaccharide?
3. What are lipids or fats? State their characteristic.
4. What are phospholipids?
5. How glycoside bonds are formed?
6. What is meant by the tertiary structure of proteins?
7. Define Entropy and Enthalpy.
8. Name different types of RNA.
9. Explain the composition of triglycerides.
10. Define osazone formation.

Short Answer Type Questions (5 marks)

1. What is the difference between saturated and unsaturated fat?
2. Describe the structure of phospholipid.
3. Describe the structure and function of ATP.
4. How are amino acids bonded together? Describe how these bonds are formed?
5. Describe the primary structure of the protein.

Long Answer Type Questions (10 marks)

1. Enlist the functions of small carbohydrates?
2. Enumerate the functions of Lipids.
3. Enumerate the importance of Energy carriers.
4. Explain the functions of amino acids.