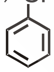
Chapter 16

Polymers, Biomolecules, Chemistry in Everyday Life

POLYMERS

SYNTHETIC POLYMERS AND THEIR APPLICATIONS

Addition Polymers

Polymer	Monomer	Application
Polyethylene	Ethene $\rightarrow$ $CH_2 = CH_2$	Packing material carry bags, insulation for electrical wires and cables... etc.
Polypropylene	Propene $\rightarrow CH_3 - CH = CH_2$	Packing of textiles and foods, linears for bags, heat shrinkage wraps, carpet fibres... etc.
Polystyrene or Styron	Styrene $\rightarrow C_6H_5 - CH = CH_2$	Plastic toys, house hold wares radio and television bodies
Neoprene	Chloroprene $CH_2 = \underset{\substack{\vert \\ Cl}}{C} - CH = CH_2$	shoe heels, stoppers, printing rollers
Buna-S	Styrene $\rightarrow$ $CH = CH_2$, Butadiene $\rightarrow$ $CH_2=CH-CH=CH_2$ 	Manufacture of tyres, rubber sole, water proof shoes
Polyacrylates	Methyl methacrylate $CH_2 = \overset{\substack{CH_3 \\ \vert}}{C} - COOCH_3$	Lenses, light covers, light shades, air craft windows... etc.
Polyethyl acrylate	$CH_2 = CH - COOC_2H_5$	Latex paints adhesives
Polyacrylonitrile (PAN)(orlon)	Acrylonitrile $\rightarrow$ $CH_2 = CH - CN$	For making clothes, carpets, blankets... etc.
Polyvinyl chloride (PVC)	Vinyl chloride $\rightarrow$ $CH_2 = CH - Cl$	Good electrical insulator, hose pipes, rain coats, hand bags... etc.
Polytetrafluoro ethylene (PTFE) (Teflon)	Tetrafluoro ethylene $\rightarrow$ $CF_2 = CF_2$	For nonstick utensils coating etc.

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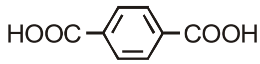
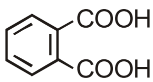
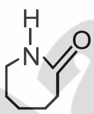
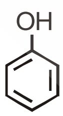
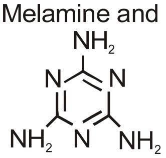
Condensation Polymers

Polymer	Monomer	Application
Terylene or dacron	(i) Ethylene glycol– $HO-CH_2-CH_2-OH$ (ii) Terephthalic acid – 	For wash and wear fabric tyre cords, seat belts and sails
Glyptal or Alkyd resin	(i) Ethylene glycol – $HO-CH_2-CH_2-OH$ (ii) Phthalic acid – 	Paints and Lacquers
Polymer	**Monomer**	**Application**
Nylon 6, 6	Adipic acid – $HOOC-(CH_2)_4-COOH$ Hexamethylenediamine – $H_2N-(CH_2)_6-NH_2$	Textile fabrics
Nylon 6, 10	$H_2N(CH_2)_6NH_2$ Hexamethylene diamine Sebacic acid – $HOOC-(CH_2)_8COOH$	Textile fabrics, carpets, bristles for brushes
Nylon 6	Caprolactam – 	Mountaineering ropes, tyre cords fabrics
Bakelite	Phenol  Formaldehyde, HCHO	As binding glue for wood varnishes, lacquers
Melamine Formaldehyde resin	Melamine and Formaldehyde  and HCHO	Non-breakable
Urea formaldehyde resin	(i) Urea $NH_2-\overset{\overset{O}{\|}}{C}-NH_2$ (ii) Formaldehyde HCHO	Buttons, bottle caps, surgical items

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Biodegradable Polymer

Name	Monomer	Uses
Poly-β-hydroxy butyrate-Co-β hydroxy valerate [PHBV].	(a) $CH_3-\overset{\overset{OH}{\vert}}{CH}-CH_2COOH$ 3- hydroxybutanoic acid (b) $CH_3-CH_2-\overset{\overset{OH}{\vert}}{CH}-CH_2COOH$ 3-hydroxypentanoic acid	As packaging orthopaedic devices and in controlled drug release.

BIOMOLECULES

Carbohydrates

1. Carbohydrates are mainly compounds of carbon, hydrogen and oxygen.
2. General molecular formula initially considered was $C_x(H_2O)_y$

   e.g., glucose – $C_6H_{12}O_6$, sucrose $C_{12}H_{22}O_{11}$ etc.

   But many of the compounds which behave as carbohydrates, do not follow the general molecular formula $C_x(H_2O)_y$ formula.
3. Thus carbohydrates are the class of compounds that include polyhydroxy aldehydes or polyhydroxy ketones.
4. Carbohydrates are also known as **saccharides**.

Classification

The carbohydrates are classified into three major classes

(i) Monosaccharides

(ii) Oligosaccharides

(iii) Polysaccharides

Monosaccharides

(i) Monosaccharides are simple sugars with single unit of polyhydroxy aldehyde or polyhydroxy ketones.

(ii) General molecular formula $C_nH_{2n}O_n$ (with some exceptions).

Oligosaccharides

(i) Oligosaccharides are made up of 2-9 units of monosaccharides or simple sugars.

(ii) Oligosaccharides with two, three and four monosaccharides respectively known as disaccharides, and trisaccharides and tetrasaccharides.

(iii) Sucrose is the example of this class.

$$\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}$$

Polysaccharides

(i) Polysaccharides are made up of 'n' number of monosaccharide units (above 10 carbon atoms).

(ii) Starch, cellulose and glycogen are the examples of this class.

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(iii) $\underset{\text{starch}}{(C_6H_{10}O_5)_n} \xrightarrow[H^+]{nH_2O} \underset{\text{glucose}}{nC_6H_{12}O_6}$

(iv) Homopolysaccharides are made up of single type of monosaccharides. Heteropolysaccharide is made up of two or more different types of monosaccharides.

> ***Note :*** *Monosaccharides and oligosaccharides are collectively known as **Sugars** as they are soluble in water and sweet in taste. Whereas polysaccharides on other hand are known as **Non-sugars**.*

Monosaccharide-Glucose

Glucose is known as **dextrose** and also known as grape sugar.

Preparation

Hydrolysis of cane sugar in presence of alcohol gives glucose (along with fructose)

$$\underset{\text{sugar}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

Glucose and Fructose have same molecular formula but different structural formula.

Chemical Properties

(i) **Reaction with PCl_5 :**

$$\begin{array}{c} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \\ \text{Glucose} \end{array} + 5PCl_5 \longrightarrow \begin{array}{c} CHO \\ | \\ (CHCl)_4 \\ | \\ CH_2Cl \\ \text{Penta-chloroglucose} \end{array} + 5POCl_3 + 5HCl$$

(ii) **Reaction with acetic anhydride :**

$$\begin{array}{c} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array} + (CH_3CO)_2O \longrightarrow \begin{array}{c} CHO \\ | \\ (CHOCOCH_3)_4 \\ | \\ CH_2OOCCH_3 \\ \text{Penta-acetate glucose} \end{array}$$

(iii) **Reduction :**

$$\begin{array}{c} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array} + 2H \xrightarrow[H_2O]{\text{Na-Hg}} \begin{array}{c} CH_2OH \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \\ \text{Sorbitol} \end{array}$$

(iv) **Reaction with Fehling's solution :**

$$\begin{array}{c} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array} + 2CuO \longrightarrow \begin{array}{c} COOH \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \\ \text{Gluconic acid} \end{array} + \underset{\text{red ppt.}}{Cu_2O}$$

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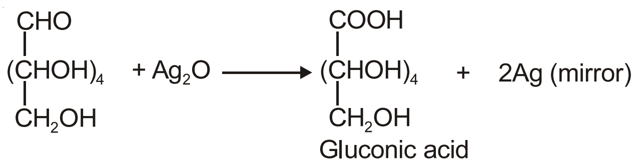
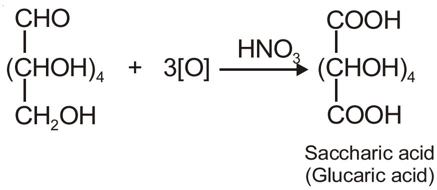
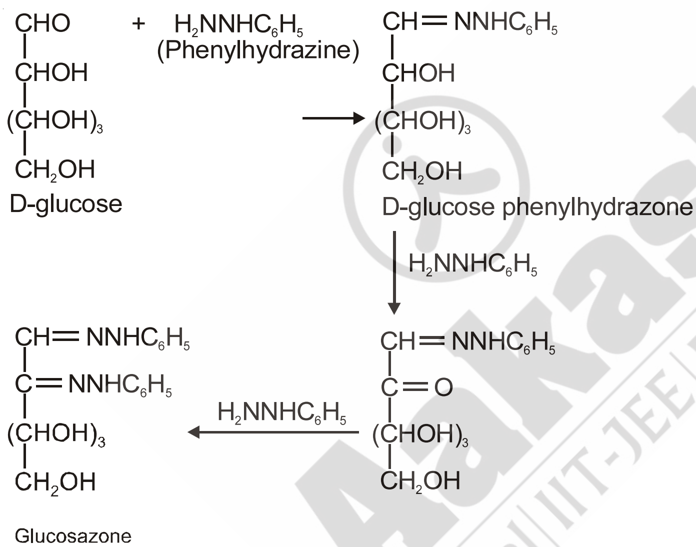
(v) **Reaction with Tollen's reagent :**



(vi) **Reaction with HNO_3 :**



(vii) **Reaction with phenylhydrazine :**



(viii) **Lobry de Bruyn-van Ekenstein rearrangement reaction :**

Glucose on reaction with dilute NaOH undergoes a reversible isomerisation and is converted into a mixture of D-Glucose, D-Mannose and D-Fructose.

D-Glucose $\rightleftharpoons$ D-Mannose $\rightleftharpoons$ D-Fructose.

Note : *Due to this isomerisation, fructose even it does not contain – CHO group reduces Fehling's solution and Tollen's reagent in alkaline medium.*

Structure of D-Glucose

(i) Open chain structure :

The reaction of glucose with

(a) HI to give hexane

(b) Hydroxylamine to form monoxime

(c) HCN to form cyanohydrin, gives the existence of the open chain structure of glucose

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(ii) Cyclic structure of glucose :

The open chain structure of glucose fails to explain

(a) Any reaction with $NaHSO_3$ and NH_3 , even though – CHO group is present.

(b) The reaction of glucose with Grignard reagent.

Disaccharides

(i) Disaccharides are composed of two molecules of monosaccharides linked by **glycosidic linkage**.

(ii) The disaccharides may be reducing or non reducing in nature depending upon linkage.

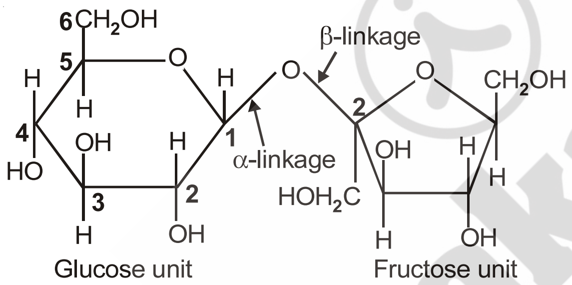
$$\text{Sucrose } (C_{12}H_{22}O_{11}) \xrightarrow{H_2O/H^+} \underset{(C_1)}{\alpha\text{-D Glucose}} + \underset{(C_2)}{\beta\text{-D Fructose}}$$

$$\text{Lactose } (C_{12}H_{22}O_{11}) \xrightarrow{H_2O/H^+} \underset{(C_4)}{\beta\text{-D Glucose}} + \underset{(C_1)}{\beta\text{-D Galactose}}$$

$$\text{Maltose } (C_{12}H_{22}O_{11}) \xrightarrow{H_2O/H^+} \underset{(C_1)}{\alpha\text{-D Glucose}} + \underset{(C_4)}{\alpha\text{-D Glucose}}$$

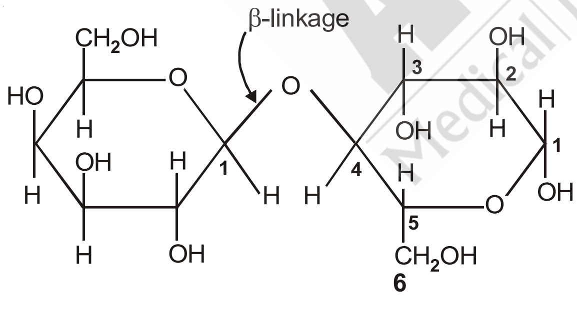
Structure of Sucrose, Lactose and Maltose

(i) Sucrose



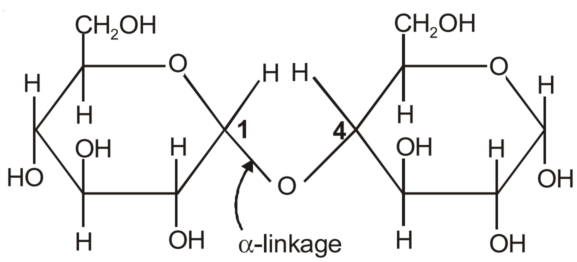
α,β-glycosidic linkage

(ii) Lactose



β-glycosidic linkage

(iii) Maltose



α-glycosidic linkage

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Polysaccharides :

In polysaccharides, thousands of monosaccharide units are joined together by glycosidic linkage.

Starch : $(C_6H_{10}O_5)_n$

$$\underset{\text{Starch}}{(C_6H_{10}O_5)_n} \xrightarrow{H^+/H_2O} \underset{\text{Maltose}}{C_{12}H_{22}O_{11}} \longrightarrow \underset{\text{D-glucose}}{C_6H_{12}O_6}$$

(i) Starch does not reduce Fehling's solution or Tollen's reagent.

(ii) Starch does not form an Osazone.

(iii) Starch is a mixture of two polysaccharides *i.e.*, amylose (15-20%) and amylopectin (80-85%). Amylose is water soluble and amylopectin is water insoluble component of starch.

Cellulose : $(C_6H_{10}O_5)_n$

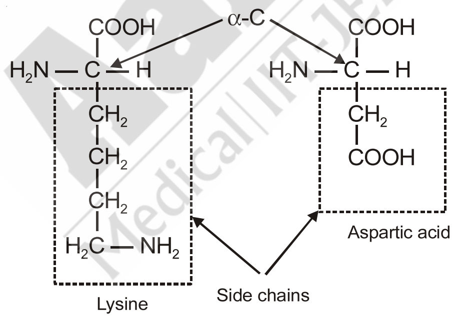
(i) Cellulose is a straight chain polysaccharide composed of only β D-glucose units with 1-4 β glucosidic linkage.

(ii) Cellulose does not reduce Tollen's reagent or Fehling's solution.

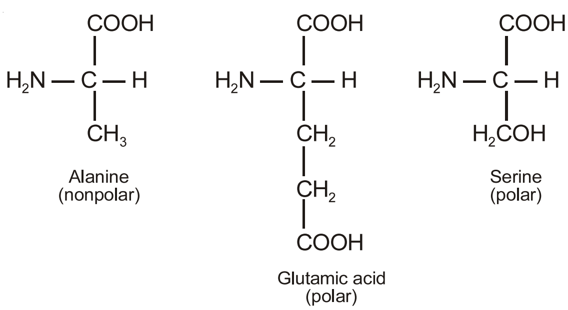
AMINO ACIDS

Proteins are made up of amino acids. All naturally occurring amino acids are α-amino acids, where amine group is connected with α-carbon of carboxylic acid. Amino acids have amphoteric character. A free amino group is basic, a free carboxyl group is acidic. **Lysine and Arginine** are **Basic Amino Acids** because they carry two amino groups and one carboxyl group is acidic. **Glutamic acid (glutamate) and Aspartic acid (aspartate)** contain one amino and two carboxyl groups each and are classified as **Acidic Amino Acids**. Alanine, glycine, valine and phenylalanine are **Neutral Amino Acids** as these contain one amino and one carboxyl group.

Amino acid (R = side chain)



Side chain of a basic and an acidic amino acids



Examples of polar and nonpolar amino acids

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Amino Acids which occur in Proteins: Glycine, alanine, serine, cysteine, aspartic acid, glutamic acid, asparagine, glutamine, methionine, threonine, valine, leucine, isoleucine, lysine, histidine, arginine, phenylalanine, tyrosine, tryptophan and proline.

PROTEINS

Proteins are polyamides formed from amino acids. The α-carbon atom of the amino acids is asymmetric and show optical isomerism (stereo). Proteins consist mainly of L isomers of amino acids. There are 20 commonly occurring amino acids in proteins. Amino acids form zwitter ion. Lack of essential amino acids in diet can cause diseases such as Kwashiorkor.

Peptide Bond and Structure of Proteins: Amino acids are joined together by an amide linkage called **peptide bond**.

Proteins are long polymers of amino acids linked by peptide bonds (polypeptides). The sequence in which the amino acids are arranged in a protein is called the primary structure.

The secondary structure arises due to the regular folding of the backbone of the polypeptide chain due to intramolecular hydrogen bonding in α-helix and intermolecular hydrogen bonding in β-plated sheet between the carboxyl and amino groups. Lead to the formation of α-helix and β-pleated sheet.

Tertiary Structure of Proteins: The tertiary structure of proteins represents overall folding of the polypeptide chain *i.e.,* fruther folding of the secondary structure. It gives rise to two major molecular shapes viz fibrous and globular. The main forces which stabilises the 2° and 3° structures of proteins are hydrogen bonds, disulphide linkages, van der Waals and electrostatic forces of attraction.

Quarternary structure of proteins : Some of the proteins are composed of two or more polypeptide chains referred to as sub-units. The spatial arrangement of these sub-units with respect to each other is known as quaternary structure.

ENZYMES

Enzymes are biological catalysts which increase the rate of biochemical reactions even under mild conditions of temperature and pH without taking part in reaction.

Properties of Enzymes :

(i) They speed up reactions up to ten million times compared to the uncatalyzed reactions.

(ii) They are very specific in their action on substrates and each enzyme catalyzes only specific type of reaction.

(iii) They are active at moderate temperature and pH.

(iv) The action of enzymes are inhibited by various organic and inorganic molecules.

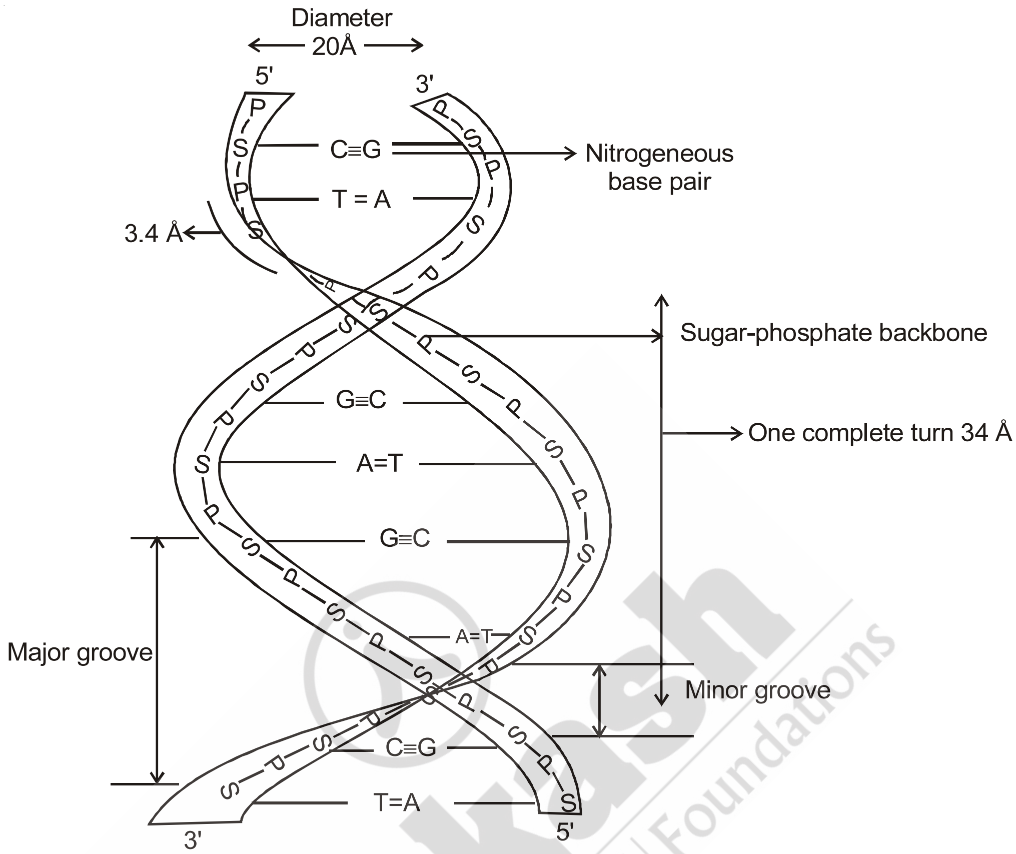
Enzymes and Diseases : Certain diseases are caused by enzyme deficiencies. The congenital disease phenylketonuria, is due to a deficiency of the enzyme phenylalanine hydroxylase. Albinism is another disease caused due to deficiency of an enzyme tyrosinase. Many heart attacks are caused by blood clot formation in a coronary artery. The enzyme streptokinase is used to dissolve the clot.

NUCLEIC ACIDS

1. Nucleic acids play an essential role in transmission of the hereditary characteristics and the biosynthesis of proteins.
2. There are two classes of nucleic acids : DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Nucleic acids are the long polymers in which the monomeric units are nucleotides. The structural units of nucleotides are made up of three essential components; a nitrogenous base, a pentose sugar (a 5-carbon sugar), and a phosphate group.
3. In nucleic acids, the individual nucleotides are linked through phosphate groups to give rise to long polynucleotide structures.

Structure of DNA

DNA consists of two strands of polynucleotides coiled around each other in the form of a double helix.



Functions of Nucleic Acids

Replication : The genetic information of the cell is contained in the sequence of the bases A, T, G and C in the DNA molecule.

The DNA sequence that codes for a specific protein or polypeptide is called a **Gene** and thus every protein in a cell has a corresponding gene. The relation between the nucleotide triplets and the amino acids is called the **GENETIC CODE**.

VITAMINS

Vitamins are organic compounds necessary for normal health but cannot be synthesised in human body. Deficiency of vitamins causes many disorders and diseases. Vitamins B and C are water soluble while vitamins A, D, K and E are fat soluble.

CHEMISTRY IN EVERYDAY LIFE

Chemicals in medicines

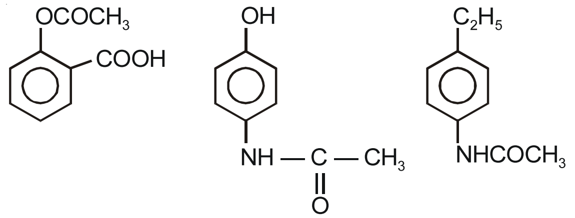
Chemical substances used for treatment of disease and for reducing the suffering from pain are called medicines or drugs. Chemotherapy is the science in which chemicals are used for the treatment of diseases.

Chemicals used in chemotherapy are frequently classified according to their action. Thus analgesics relieve pain, antipyretics reduce temperature, anti-inflammatories control inflammation and antibiotics kill bacteria and other micro-organisms.

Antipyretics

Antipyretics are substances used to bring down body temperature in high fever. e.g. Aspirin, Phenacetin and Paracetamol.

Aspirin is a common antipyretic. It should not be taken empty-stomach as it generates salicylic acid which may ulcerate stomach wall and can cause bleeding. Calcium and sodium salts of aspirin are more soluble and less harmful.



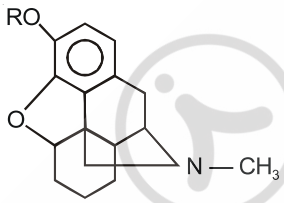
Aspirin

4–acetamidophenol (Paracetamol)

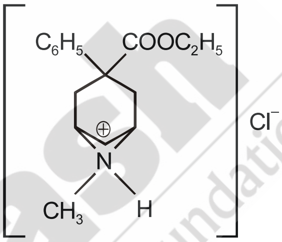
Phenacetin

Analgesics

These are drugs used for relieving pain. Aspirin and some other antipyretics act as analgesics also. Certain narcotics (which produce sleep and unconsciousness) are also used as analgesics. Examples of narcotics are morphine, marijuana, codeine, pethidine and heroin. They are known to be habit-forming.



R = H, Morphine
R = CH_3, Codeine



Pethidine hydrochloride

Antibiotics

Antibiotics are chemical substances produced by micro-organisms (bacteria, fungi and moulds) that can inhibit the growth or even destroy other micro-organisms. Penicillin is used against large number of infections caused by various bacteria. It is an effective drug for pneumonia, bronchitis, sore throat and abscesses. Other antibiotics like streptomycin and tetracycline are used against diseases caused by bacteria.

Some antibiotics are specific for certain diseases, for example, streptomycin for tuberculosis and chloramphenicol for typhoid.

Broad spectrum antibiotics are medicines effective against several different types of harmful micro-organisms, *e.g.,* tetracycline, chloramphenicol. Penicillin has a narrow spectrum. Ampicillin and amoxicillin are derivatives of penicillin.

Chloramphenicol is a broad spectrum antibiotic. It is rapidly absorbed from the gastro-intestinal tract and hence can be given orally in case of typhoid, dysentry, acute fever, certain form of urinary infections, meningitis and pneumonia.

Sulpha drugs like sulphanilamide, sulphadiazine and sulphaguanidine act against micro-organisms like antibiotics and have been used in place of them.

Tranquilizers

The chemical substances which act on the central nervous system and has a calming effect to reduce anxiety are specified as **tranquilizers**. They are used for the treatment of mental diseases they are also used for making sleeping pills. They are habit forming and should not be taken without proper prescription. They do not add any energy into the person but help to remove the emotional distress or depression and the person is able to work to his full capacity. The most commonly used tranquilizers are barbituric acid and its substituted derivatives such as luminal and seconal.

CHEMICAL IN FOOD

During processing of food, a number of chemicals are added to it to increase its life and also to make it more attractive. Some of these chemicals which are present in food are discussed below.

1. **Chemical preservatives :** Growth of micro organisms in a food material can be inhibited by adding certain chemical substances. Such chemical substances which are added to food materials to prevents their spoilage are known as chemical preservatives. The most commonly used preservatives includes table salt, sugar, vegetable oils and sodium benzoate. Sodium benzoate is used in limited quantity salts of sorbic acid and propanoic acid are also used as preservatives.

2. **Artificial sweetening agent :** Sugar is the natural sweeting agent. However, excess of sugar leads to many diseases such as obesity, diabetes. Many artificial sweetening agents have been isolated which are more sweeter than sugar. Ortho-sulphobenzimide also called saccharin is the first popular sweetening agent. Some other artificial sweetener are aspartame, sucralose, alitame etc.

CLEANSING AGENT

Two types of detergents are used as cleansing agent. These are soaps and synthesis detergents. These help in removal of fats which bind other materials to the fabric or skin.

These days detergents are much in vogue and get preference over soaps because they work even in hard water. Synthetic detergents are classified into three main categories namely anionic, cationic and non-ionic and each category has its specific use. Detergents with straight chain of hydrocarbons are preferred over branched chain as the latter are non-biodegradable and consequently cause environmental pollution.

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