Introduction

The complex organic substances like carbohydrates, proteins etc which combine in a specific manner to produce living systems and maintain it are called biomolecules. The branch of chemistry that deals with the study of chemical reactions that occur in living organisms is called biomolecules.

Carbohydrates

- They are polyhydroxy-aldehydes or ketones or substances which give these substances on hydrolysis and contain at least one chiral atom.
- They have general formula of $C_x(H_2O)$
- Rhamnose, deoxyribose, rhamnohexose do not obey this formula but are carbohydrates.

Types of carbohydrates

- Monosaccharide
- Oligosaccharide
- Polysaccharide

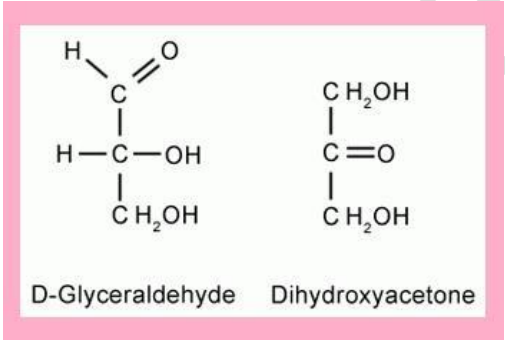
Monosaccharide

- These are simplest carbohydrate which can't be hydrolyzed further into smaller compounds.
- They are called as aldose or ketose depending upon whether they have aldehyde or ketone group.
- Depending upon the number of carbon atoms present they are called as triose, tetrose etc.
- All monosaccharide's are sweet smelling crystalline, water soluble and are also capable of diffusing through cell membranes.

For example: Glucose is aldohexose while fructose is a ketohexose. Both of them have 6 carbon atoms. The simplest monosaccharide is a triose (n=3).

Example: Glyceraldehyde and Dihydroxyacetone. They have one or more asymmetric carbon and are optically active.

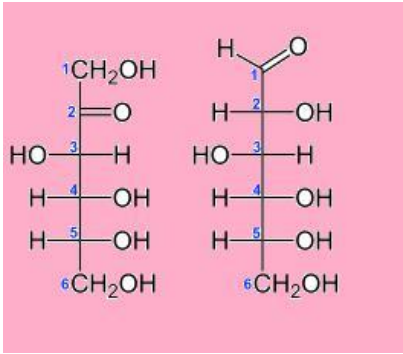
Their structures are:



Configuration

All naturally occurying monosaccharides belong to D—series that is OH group at their penultimate C-atom.

Open chain structures:



Glucose fructose

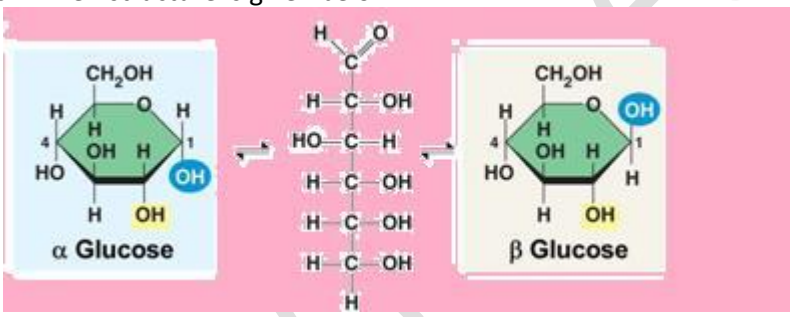
- D-glucose and D-mannose, differ only in configuration at C-2 and are known as epimers.
- Similarly D-glucose and D-galactose, differ in configuration around C-4 atom and are also known as epimers.
- Thus a pair of diastereomers, differing only in configuration around C-2 or any other chiral carbon except C-1 is called epimers.

Close chain structure

- All the pentose's and hexoses exist in cyclic hemiacetal structure.
- In free state, they have generally six membered cyclic structure known as pyranose form and in combined state, some of them have 5 membered cyclic structure called as furanose .

Due to cyclic hemiacetal or hemiketal structure all the pentoses and hexoses exist in two stereoisomeric forms

- Alpha form
- Beta form
- Both alpha and beta form are Anomers.
- Their structure is given below :



Oligosaccharides

These carbohydrates on hydrolysis give 2 to 9 molecules of monosaccharides.

They are further of few types:

- Disaccharides ($C_{12}H_{22}O_{11}$): On hydrolysis, they give 2 molecules of monosaccrides which are held together by Glycosidic linkage

Example: sucrose etc

- Trisaccharides ($C_{18}H_{32}O_{16}$): On hydrolysis, they form three molecules of monosaccharides.

Example: raffinose

- Tetra-saccharides: ($C_{24}H_{42}O_{21}$): Such as stachyose which gives four monosaccrides on hydrolysis.

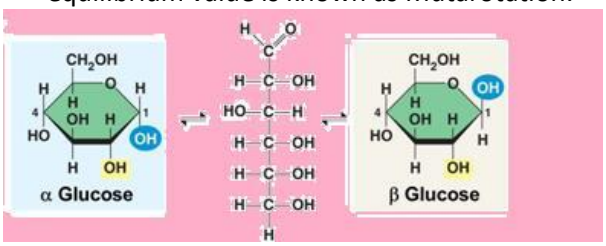
Polysaccharides

These are the carbohydrates which on hydrolysis, yield more than nine monosaccharides molecules.

Example: Starch etc

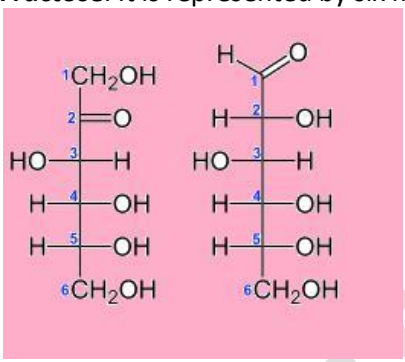
Mutarotation

- Glucose exist in two forms : i.e. alpha –D glucose with specific rotation of 112degree and beta D-glucose with specific rotation of +19 degree.
- However, when either of these two forms is dissolved in water and allowed to stand, it gets converted into same equilibrium mixture of both the alpha and beta forms with a small amount of open chain form having specific rotation of 52.7 degree.
- As a result of this, equilibrium the specific rotation of freshly prepared solution of alpha glucose decreases from +112 degree to 52.7 degree while that for beta glucose increases from +19 to 52.7 degrees.
- The phenomenon of change of change in specific rotation of optically active compounds with time to an equilibrium value is known as Mutarotation.



- The alpha D (+) glucose and beta (+) glucose, differ in configuration at C-1 carbon and the compounds differing in configuration at C-1 are called Anomers.

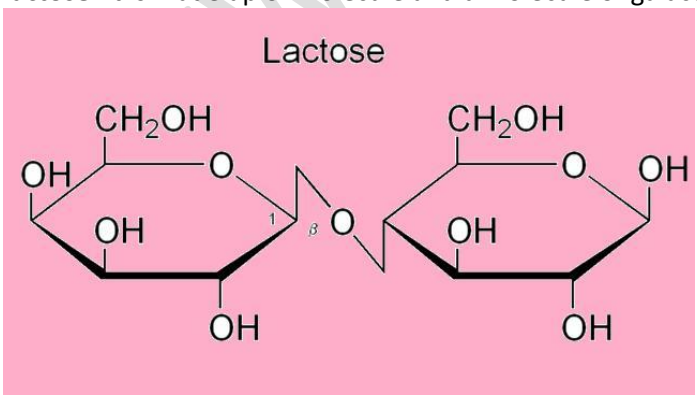
Fructose: It is represented by six membered ring as shown:



Beta –D+(fructose) **furanose structure**

Fructose is assigned furanose structure.

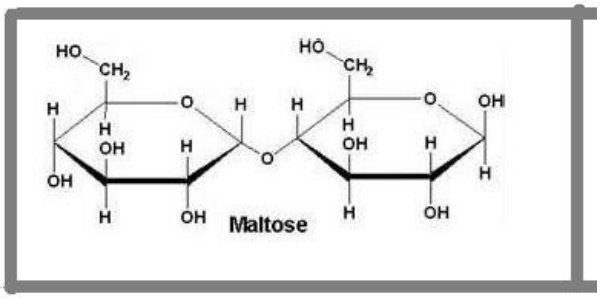
Lactose: It is made up of molecule and a molecule of galactose. The units are linked together.



Lactose

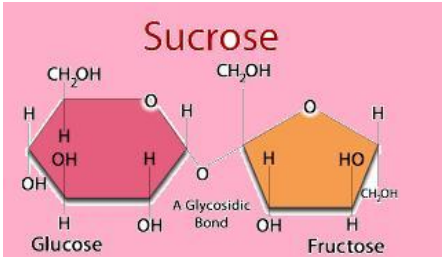
Maltose: It has the structure as shown below

- On treatment, with acid or with enzyme maltose gets hydrolysed to 2 molecules.
- That is alpha D-glucose.
- Since one of the glucose units exist in hemiacetal form it is a reducing sugar.



Sucrose: It has a structure shown below

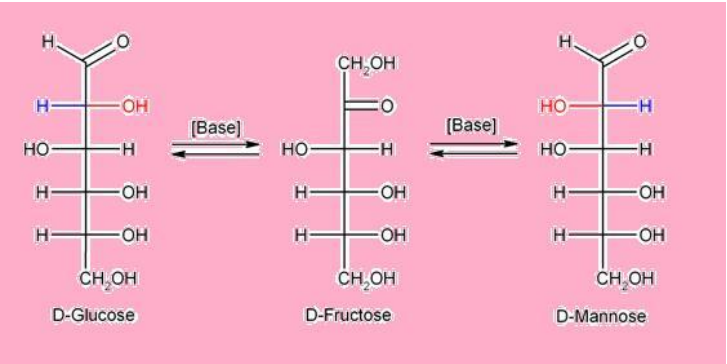
- On hydrolysis, with dilute mineral acid or enzyme invertase sucrose gives glucose and fructose in equal amounts.
- Sucrose and glucose are dextrorotatory while fructose is laevorotatory and has higher value of specific rotation.
- Thus the process is accompanied by inversion of optical activity. The mixture formed is invert sugar. That is sucrose àglucose + fructose



(water and invertase)

Sweetness of sugars

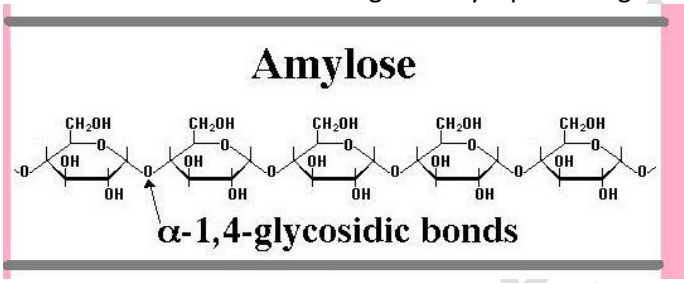
- All the monosaccharide and disaccharides are sweet in taste and hence also known as sugars.
- Sucrose is given sweetness value of 100. The sweetness of other sugars is compared with the value of sucrose.
- The sweetness of fructose -173, invert sugar 130, sucrose 100, glucose 74,glactose 32,maltose 32 and that of lactose is 16.
- All the monosaccharide and disaccharides are reducing agents due to hemiacetal and hemiketal forms which easily change in to aldehydic form in the alkaline medium.
- Although fructose doesn't contain any aldehydic group yet it gives Tollen's reagent test and Fehling's solution test because under the basic conditions of reagent the fructose gets converted into the mixture of glucose and mannose both of which contains aldehydic group.
- This is called Lobry De Bruyn Van Eikensten rearrangement.



- The alpha and beta glucose reacts with one molecule of ethanol to form the corresponding methyl glucosides.
- When glucose is treated with methanol in presence of HCl the hemiacetal form changes to acetal form.

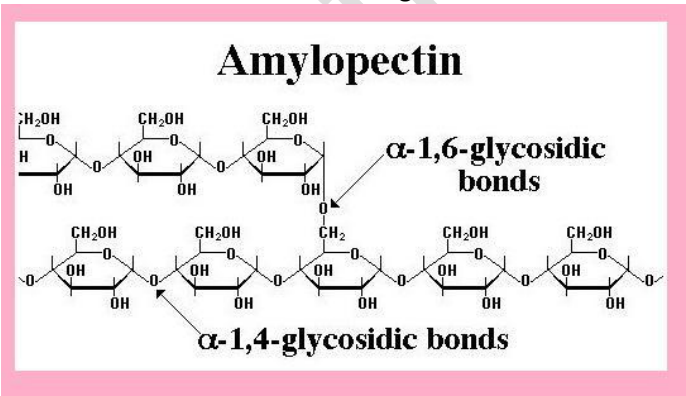
Starch: It serves as a storage polysaccharide in plants .It consist of two components of alpha glucose.

- **Amylase**
  - It is a linear polymer of glucose and is soluble in water.
  - Its percentage in starch is about 10-20 %.
  - These are linked together by alpha linkage involving C-1 of glucose unit to C-4 of the other.



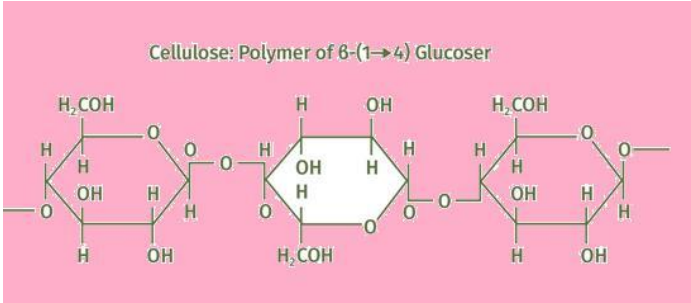
Amylopectin

- It is branched chain polymer of alpha glucose and is insoluble in water.
- There are about 1000 units of glucose.



(c) Cellulose

- It is found in all plants
  - It constitutes 50% of total organic matter in the living beings.
  - Cotton is pure cellulose.
  - Cellulose is linear polymer of beta D-glucose.
  - The chains are arranged to form bundles and linked together by hydrogen bonds between glucose molecules of adjacent organic solvents.
  - When it is treated with concentrated sulphuric acid in cold it slowly passes into solution.
  - This solution when diluted with water gives starch like substance amyloid which is known as parchment paper.
  - On boiling with water it is hydrolyzed into D-glucose.
  - Cellulose gives many useful products when treated with different chemicals like rayon, gum, cotton etc.
  - Cellulose is directly used in making cloth and paper.



Glycogen

- In glycogen there are about 25 glucose units. Its structure is similar to amylopectin and is a condensation polymer of alpha glucose.
- Glycogen in short term food storage in animals.

Tests for carbohydrates

- For this Molisch test is performed.
- In it Molisch reagent is used which is 10%alcoholic solution of alpha naphthol and it is added to aqueous solution of carbohydrate followed by concentrated sulphuric along the sides of tube.
- As a result a violet ring is formed at the junction of two layers.

Proteins

Introduction of proteins

- They are high weight polymers.
- They are polyamides that contain C, H, N, O and S.
- Proteins are derived from alpha amino carboxylic acid monomers.
- A simple protein may contain hundred even thousands of amino acid units.
- In living organisms twenty alpha amino acids occur which combine to form different protein molecules.

Amino acids

- A simple amino acid can be represented as R-CH$(NH)_2$COOH (carboxy group and amino group is present in it).

Alpha amino acids

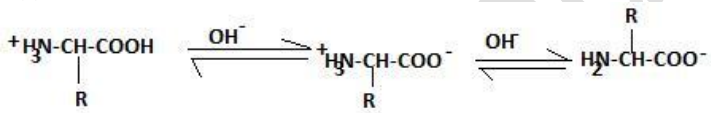
- The acid in which NH_2 group is present at carbon atom adjacent to the COOH group are called alpha amino acids.
- Alpha amino acids are the building blocks of proteins the alpha carbon of all amino acids is chiral, hence all amino acids exhibit stereoisomerism that is existence of D and L types of structures.
- All the naturally occurring amino acids, belong to L form category.
- In L amino acid NH_2 group lies left to the chiral carbon as shown :

  $H_2N\text{-}CH_2R$ (C0OH) L –amino acid
- Due to transfer of proton from carboxy to amino group, alpha amino acid exists as dipolar ion or called **as Zwitter ion.**

Zwitter ion

Isoelectric point

- Due to the zwitter ion structure, alpha amino acids are high meting crystalline solids and moderately soluble in water.
- In acidic medium caboxylate ion group act as a base and accepts a proton. Thus alpha amino acids exist as cations (I) under the influence of electric field.



(zwitter ion)

- In alkaline medium, NH_3^+groups act as an acid and thus loses a proton.
- Due to this, alpha amino acids exist as anions (III) and thus migrate towards the anode in the electric field.
- However, at some intermediate value of ph, the concentration of cationic form (I) and the anionic form (III) become equal.
- Hence, there is no migration in electric field. This pH is known as isoelectric point.

Types of amino acids

The amino acids are of two types:

- Essential
- Non essential

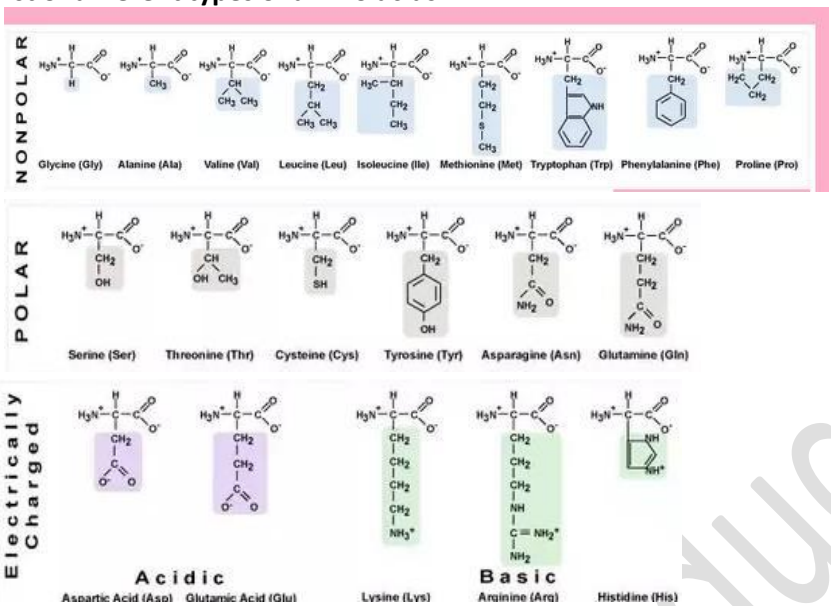
Essential amino acids

- The amino acids that can't be made in our body and must be supplied from outside.
- The lack of these amino acids in diet can cause lot of diseases like kwashiorkor (the disease in which water balance in body is disturbed).
- The essential amino acids are 10 in number out of all.

Non essential amino acids

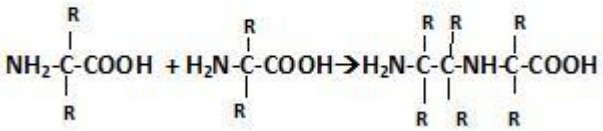
- They are those that can be synthesized in our body.
- Out of total 20 amino acids the 10 can be synthesized in the body.

List of different types of amino acids:



Polypeptide formation

- The interaction between amino group and carboxyl of amino group give compounds called peptides.
- The amide group –CONH in each such compound is called peptide linkage.
- Depending upon the number of amino acid, residues per molecule they are called as dipeptide, tripeptide etc.
- Peptides of molecular weight up to 10,000 are known as polypeptides and those with higher than 10,000 are called as proteins.
- Each polypeptide chain has a free amino group at one end and a free carboxyl group at other end.
- They are collectively called as end groups.
- The amino acid unit having $–NH_2$group is called **N-terminal end** and the amino acid unit having free –COOH group is called **C-terminal end.**



- In this NH-CH-CO is the repeating unit in polypeptide.

Structure of proteins

Proteins have three structures:

- Primary structure
- Secondary structure
- Tertiary structure

Primary structure: The sequence in which amino acids are arranged in protein is called primary structure. The sequence determines the function of a protein.

Secondary structure: The fixed configuration of polypeptide skeleton is known as secondary structure.

- There are two types of secondary structure :
- Alpha helix
- Beta pleated sheet

Alpha helix: If the size of group R is large, intermolecular hydrogen bonds are formed between CO of one amino acid residue and NH of the fourth amino acid residue in polypeptide chain which gives right handed alpha helix structure to the protein molecule.
Example: Alpha keratin in hair etc it is also elastic.

Beta pleated sheet: If the size of group R is small, intermolecular hydrogen bonds are formed between CO of one polypeptide chain with NH of the other chain. Thus the chains are bonded together forming a sheet which can slide over each other to form a three dimensional structure called beta pleated sheet.
Example: silk

Tertiary structure: It implies the three dimensional structure of proteins.
There are two types tertiary structure:

- Fibrous and globular.
- Proteins contain one or more polypeptide chains.
- A protein having one polypeptide chain is known as monomeric while that having more than one polypeptide chains is called oligomeric.
- The constituent peptide chains of an oligomeric protein are called protomers which are held together by weak forces.
- Native state: At normal pH and temperature each protein takes a shape which is energetically most stable.
- In amino acid the shape is specific and is known as native state.
- Globular proteins are tightly folded and give rise to spherical form.

Forces that stabilize protein structures

The forces that are present are as follows:

- Hydrogen bonding
- Anionic bonding
- Hydrophobic bonding
- Covalent bonding

Hydrogen bonding: These forces operate between a partially positive hydrogen and partially negative atom like O or N on the same or on another molecule.

Anionic bonding: A bonding between cation and anion of side chains resulting in side linkage.

Hydrophobic bonding: Some side chains in same amino acid are hydrophobic. In aqueous solutions proteins fold in such a way that these chains get clustered inside the folds .The polar side chains which are hydrophilic lie on the outside or surface of proteins.

Covalent bonding: The bond occurs between S atoms of two residues between two adjacent chains.

- Insulin which contains 51 amino acids is arranged in two polypeptide chains containing 21 and 30 amino acid residues connected by S-S cross links.

Denaturation of proteins

- The globular proteins, which are soluble in water on heating or on treatment of mineral acids or bases undergo coagulation or precipitation to give fibrous proteins which are insoluble in water.
- After coagulation, proteins lose their biological activity this is called denaturation.
- It can be reversible or irreversible.
- Coagulation of lactalbumin to form cheese and coagulation of albumins are examples of denaturation.

Classification of proteins

On the basis of composition, proteins are of following types :

- Simple proteins
- Conjugated proteins
- Derived proteins
- Fibrous proteins
- Globular proteins

Simple proteins: On hydrolysis they give only amino acids.
Example: Globulins and albumin

Conjugated proteins: They contain non protein group attached to the protein part. These non protein groups are called prosthetic groups.
Example: Nucleo-protein contains nucleic acid, phosphor-protein contains phosphoric acid contains phosphoric acid, glycol-proteins contains carbohydrates etc.

Derived proteins: These are the degradation products obtained by the hydrolysis of simple and conjugated proteins.
Example: Peptides, peptones etc

Fibrous proteins: They are long and thread like and tend to lie side by side to form fibers .In some cases, they are held together by hydrogen bonds at many points .these proteins serves as a chief structural material of animal tissues .

Globular proteins: The molecules of these proteins are folded into compact units and form spheroid shapes .Intermolecular forces are weak. These proteins are soluble in water or aqueous solution of acids, bases or salts .Globular proteins make up all enzymes, hormones ,fibrinogen etc.

Role of proteins

- They act as enzymes and transport agents.
- They are structural materials for nails, hair etc.
- Antibodies formed in body are globular proteins.
- They are metabolic regulators like insulin etc.

Hydrolysis of proteins

- Proteins are hydrolyses when boiled with acids or alkalis or when treated with enzymes .the hydrolysis takes place as:

Proteins àproteasesàpeptones àpolypeptides àsimple peptides àamino acids

- Every protein has an isoelectric point at which their ionization is minimum. Proteins have charged groups i.e. NH_3 and COO^- at the ends of peptide chain.
- They are amphoteric in nature.
- Protein accepts a proton in strong basic solution.
- The pH at which the protein molecule has no net charge is known as isoelectric point.

Enzymes

They are biological catalysts .Chemically all enzymes are globular proteins

Some important enzymes with their function:

1. **Lactase : convert lactose àglucose + glactose**
2. **Invertase : convert sucrose à glucose and fructose**
3. **Maltase : convert maltose à2glucose**
4. **Emulsion: convert cellulose àn glucose**
5. **Urease : convert urea àcarbon dioxide and water**
6. **And many more.**

Some industrial enzymes invertase and zymase are present in yeast .Enzyme diastase is used as converting starch to maltose , a sugar .the names of all enzymes end with the suffix “ase”.

Properties of enzymes

- Enzymes are required only in small amounts.
- They are highly specific.
- Enzymes are efficient catalyst: they speed up reaction.
- They work at optimum pH, at optimum temperature.
- Their mechanism is controlled by various mechanisms and stopped by various organic and inorganic compounds.
- The action of enzymes follows lock and key mechanism .however enzyme action is inhibited by certain organic molecules called inhibitors.

Vitamins

- They are the chemical substances which are needed in small amounts for the growth of human beings.
- They can’t be synthesized in our body therefore need to taken from outsource.
- Their deficiency can cause one or other type of disease.

The following vitamins with their function and deficiency disease are listed below:

Vitamin	Source	Function
A	Milk, butter, egg yolk, carrot, tomato, green vegetables	- night vision, - healthy skin
B	Yeast, eggs, liver	- Releases energy from carbohydrates - Healthy nervous system - Healthy skin - Formation of red blood cells
C	Fresh fruits and vegetables	- healing of wounds - resistance to disease
D	Butter, fish oils, eggs	- strong bones and teeth
E	Cereals, green vegetables	- May be needed for reproduction - Helps to fight against diseases
K	Milk, butter, egg yolk, carrot, tomato, green vegetables	- clotting of blood

The diseases caused by them with their symptoms:

Vitamin/ Mineral	Deficiency disease/disorder	Symptoms
Vitamin A	Loss of vision	Poor vision, loss of vision in darkness (night), sometimes complete loss of vision
Vitamin B1	Beriberi	Weak muscles and very little energy to work
Vitamin C	Scurvy	Bleeding gums, wounds take longer time to heal
Vitamin D	Rickets	Bones become soft and bent
Calcium	Bone and tooth decay	Weak bones, tooth decay
Iodine	Goiter	Glands in the neck appear swollen, mental disability in children
Iron	Anaemia	Weakness

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Nucleic acids

- Nucleic acids are the polymers in which nucleotides are monomers. These are biomolecules present in nuclei of all living cells in the form of nucleoproteins .They are also called as polynucleotides .

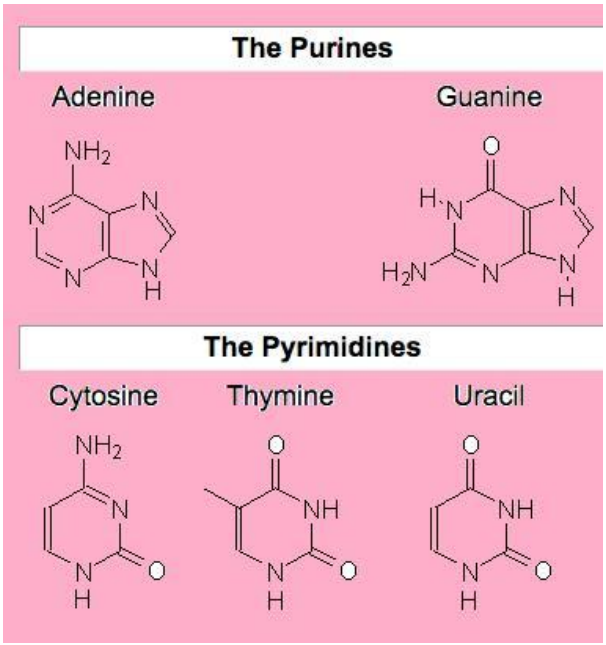
They help in the role of transmission of hereditary characters and synthesis of proteins.

Each nucleotide consists of 3 parts:

- A pentose sugar
- A nitrogenous base
- A phosphate group
- The nitrogenous base and a pentose sugar are called as nucleoside.

Nitrogenous bases are of two types: Purines and Pyrimidines

- Purines: adenine and guanine
- Pyrimidines: cytosine , thiamine and uracil



Please note that Purines and Pyrimidines are linked together by hydrogen bonds

- Adenine always bond with thiamine by double bond or vice versa.
- Cytosine always pairs with guanine by triple bond or vice versa.

Types of nucleic acids

- Deoxyribonucleic acid (DNA)
- Ribonucleic acid (RNA)

DNA

- It occurs in nucleus of cell. It has double stranded helical structure

DNA contains:

- Deoxyribose sugar
- Nitrogenous bases :
- Purines (adenine and guanine), Pyrimidines (thiamine and cytosine)
- A phosphate group
- It can undergo replication
- It helps in transfer of genetic information from parents to offspring

RNA

- It occurs in cytoplasm of cell

It consist of:

- Ribose sugar
- Nitrogenous base
- Purines: adenine and guanine
- Pyrimidines: cytosine and uracil
- A phosphate group

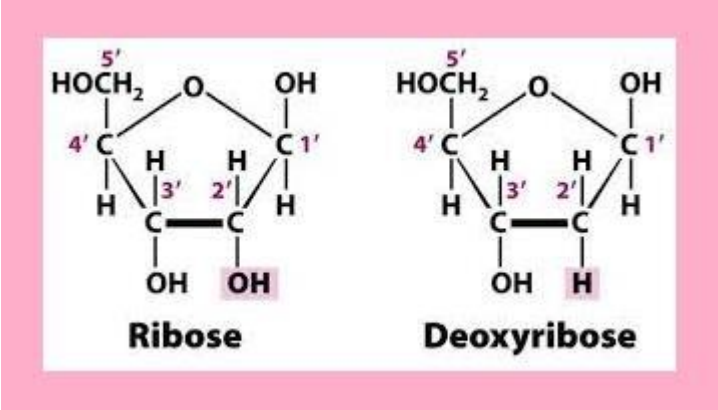
- It has a single strand helical structure
- It doesn't undergo replication
- It controls synthesis of proteins

The structure of deoxyribose and ribose sugar is given:

Structure of nucleic acids

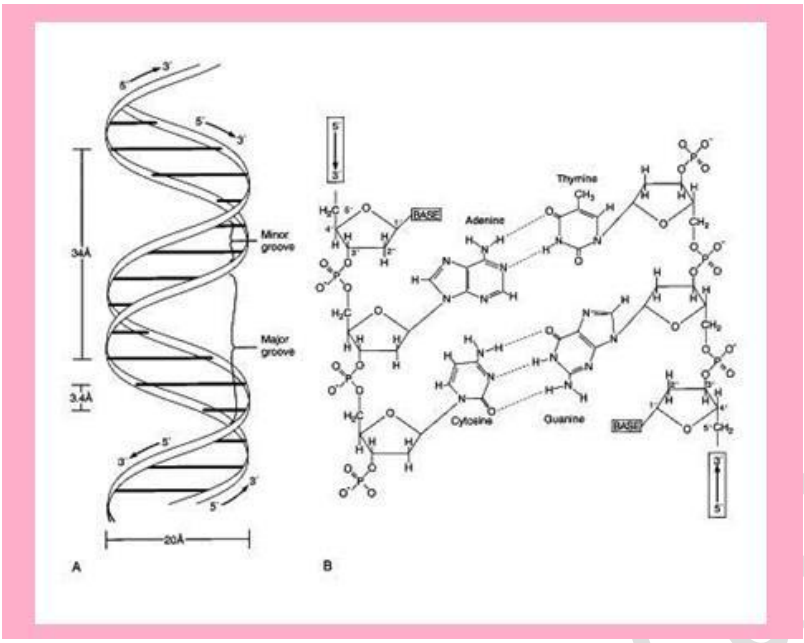
1. **Primary structure**

- The nucleic acids are formed by the condensation of thousands of molecules of nucleotides.
- On hydrolysis the nucleotides produces phosphoric acid and nucleoside .it means nucleosides on hydrolyses form Purine and Pyrimidines base and sugar moiety.
- A nucleic acid-- $^{NH}{}_3$ànucleotides –$^{aq\ NH3}$à nucleosides + phosphoric acid –$^{dilute\ HCL}$--àPurines + Pyrimidines + sugar.
- Nucleotides are building blocks of nucleic acids.
- These nucleotides are linked together with one another in a particular sequence, phosphate groups forming bridges between C-5 of the sugar residue of the one nucleoside and C-3 of the sugar residue of the other nucleoside.
- The manner in which the sugar, phosphate and bases are linked with one another in nucleic acids is known as primary structure of nucleic acids.



2. **Secondary structure:**

- Watson and Crick explained the double helix structure of DNA. The nucleotides in each strand are connected by phosphate ester bond and bases of one strand by hydrogen bonds.
- Adenine pairs with thiamine through two double hydrogen bonds whereas cytosine pairs with guanine by triple hydrogen bonds.
- The two strands of DNA are complementary to each other that is if one side there is Purine then on other side at same position Pyrimidine is present. For example if base sequence on strand is ACTCGCCA, then on the other strand the sequence will be complementary that is: TGAGCGGT
- **The primary and secondary structure is shown below:**



Watson and Crick model of DNA

Functions of nucleic acids

- **Replication**: The genetic information of cell is contained in the sequence of bases A, T, C and G in DNA molecule .In the division of cell, DNA molecules replicate and makes exact copies of themselves so that each daughter cell will have DNA identical to that of the parent cell.
- **Protein synthesis: The** specific information coded on DNA has to be translated and expressed in the form of synthesis of specific proteins which performs various functions in the cell. This synthesis is done in two steps:
- Transcription and translation.
- **Gene and genetic code**: Each segment of DNA molecule that codes for specific protein or a polypeptide is known as The relationship between nucleotides triplets and the amino acids are called the genetic code .This is gene and genetic code.
- **Mutation**: It is a chemical change in DNA molecule, which leads to the synthesis of proteins with a changed amino acid sequence.
    - These changes are caused by radiation, viruses or chemical agents.
    - The majority of changes in DNA are replicated by special enzymes in the cell, but if there is failure to repair by the enzymes then it can cause mutation.