Biomolecules

Introduction: Biomolecules are the organic compound which form the basis of life i.e they build up the living system and responsible for their growth and maintence

The sequence that relates biomolecule to living organism is

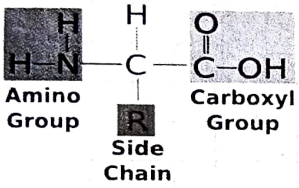
Biomolecules ⟶ Organelles → cells → Tissues → Organs → living organism

→ Living systems are made up of various complex biomolecules like carbohydrate, proteins, nucleic acids, lipids etc. Proteins and carbohydrates are essential constituents of our food.

→ In addition, some simple molecules like vitamins and mineral salts also play an important role in the function of organisms.

Amino Acids & Proteins

The compounds containing amino group (-NH_2) and carboxylic group (-COOH) are called amino acids.



where R= H, alkyl or aryl group.

→ except glycine ($H_2N-\underset{H}{\overset{H}{C}}-COOH$), others are optically active in nature.

* **Classification of amino acids** ⇒

⇒ α,β,γ - amino acids depending upon the position of $-NH_2$ with respect to -COOH group.

→ Neutral, having one $-NH_2$ and one -COOH group.

eg $NH_2-\underset{H}{\overset{H}{C}}-COOH$ (glycine)

→ Acidic, having one $-NH_2$ and two -COOH group

e.g $HOOC-CH_2-\underset{H}{\overset{NH_2}{C}}-COOH$ (Aspartic Acid)

→ Basic, having two or more $-NH_2$ and one -COOH group

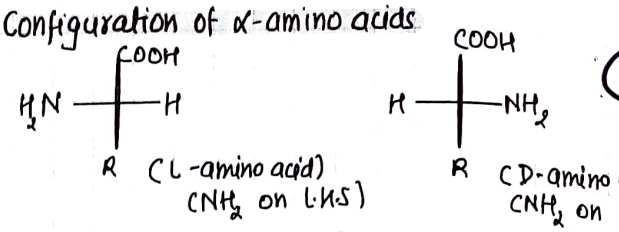
e.g $H_2N-(CH_2)_4-\underset{H}{\overset{NH_2}{C}}-COOH$ (Lysine)

* **Essential and Non-Essential Amino Acids:**

Those amino acids which can be synthesized by our body are known as non-essential amino acids while which can't be synthesized by our body so must be supplied through our diet are called essential amino acids.

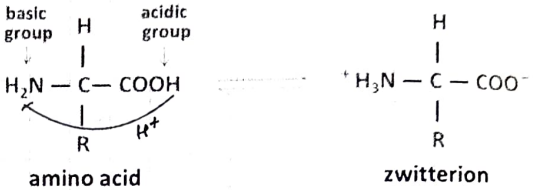
Essential	Conditionally Non-Essential	Non-Essential
Histidine	Arginine	Alanine
Isoleucine	Asparagine	Asparatate
Leucine	Glutamine	Cysteine
Methionine	Glycine	Glutamate

· Configuration of α-amino acids



→ Naturally occuring α-amino acids are L-amino acids D-amino acids occuer in some antibiotics and bacterial cell walls.

Zwitter ion: when a proton is migrated from carboxy group to amino group, a dual ion is formed and this dual ion is called zwitter ion

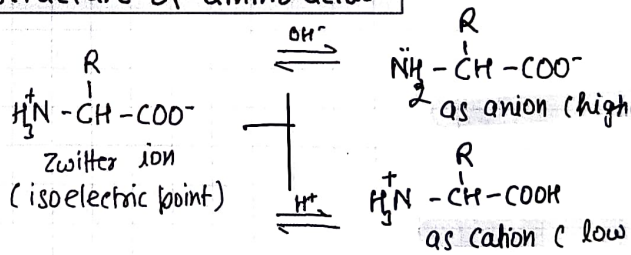


Isoelectric Point (P^I) Zwitter ion, which is electrically neutral can only exist at a speci pH, that pH is called isoelectric point which is different for all amino acids.

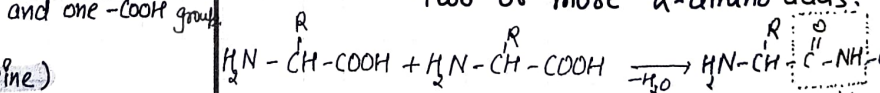
e.g P^I of Leucine pH = 6.0

P^I of Arginine pH = 10.8.

Structure of amino acids:



· **Peptide** ⇒ peptides are condensation products of two or more α-amino acids.



$-\overset{O}{\overset{\|}{C}}-NH-$ is known as peptide linkage or peptide bo

→ 2 molecules of α-amino acid form dipeptide.
3 molecules of α-amino acid form tripeptide.

→ Dipeptide has only one peptide bond.
Tripeptide has only two peptide bond.

Polypeptide: Condensation products of many amino (≃ 10000) is known as polypeptide and thos polypeptide which have molecular mass above than 10000 u are called proteins.

Proteins They are linear polymers of α-ami acid.

Str. of Proteins:

1.) **Primary Structure**: It simply reveals the sequence of amino acids.

2.) **Secondary Structure**: α-helix str. maintained by H-Bond or β-pleated sheet str. when R is small group.

3.) **Tertiary Structure**: The folding and superimposition of polypeptide chains forms a compact globular shape. termed as tertiary str.
It is stabilised by covalent, ionic, H-Bond and disulphide bonds.

4.) **Quaternary Structure**: The precise arrangement of constituents.

Classification on the Basis of Hydrolysis

Simple Protein: which give only α-amino acid upon hydrolysis e.g albumin

Conjugated Protein: These proteins give α-amino acid and non protein part, called prosthetic group

Protein	Prosthetic Group
Metalloproteins	Metal ions (Zn^{2+}, Fe^{2+}, Cu^{2+})
Haemoproteins	Haeme group
Glycoproteins	Carbohydrates
Lipoproteins	Lipid
Nucleoproteins	Nucleic acid (DNA, RNA)

Derived Proteins These are obtained by partial hydrolysis of simple or conjugated Proteins.

[Proteins → Proteoses → Pebtones → Polypeptides]

On the Basis of Molecular Shape

Fibrous Protein

Globular Protein

Do not have a tertiary structure.	Have tertiary structure. Quaternary may or may not be present
Long fibres or sheets in shape.	Spherical in shape
Insoluble in water	Dissolve in water to form colloidal solution
The length of polypeptide chain may vary in two samples of the same fibrous protein	The length of polypeptide chain is always identical in two samples of the same globular protein.
eg. Keratins, collagen, elastin and fibroin.	Egg albumin, serum globulin etc.

Primary str. of Proteins: Proteins may have one or more polypeptide chains
→ each polypeptide in a protein has amino acids linked with each other in a specific sequence and it is this sequence of amino acids that is said to be the 1° str. of that protein

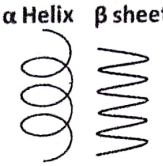
Any change in this 1° str. i.e the sequence of amino acid creats a different protein

Primary

Secondary Structure of Proteins:

The secondary str. of proteins refers to the shape in which a long polypeptide chain can exist.
They are found to exist in two different types of str.

α Helix β sheet



α-helix str. most common ways in which a polype-ptide chain form all possible H-Bond by twisting into a right handed screw (helix) with the -NH- group of each amino acid residue

β-pleated sheet str. In this str. all peptide chains are stretched out to nearly maximum extension and then laid side by side are held together by intermolecular H-Bond.

Tertiary str. of Proteins:

The tertiary str. of proteins represents overall folding of polypeptide chains i.e further folding of the secondary structure
It gives rise to 2 major molecular shapes i.e fibrous and Globular
The main forces which stabilize the 2° and 3° str. of proteins are H-Bonds, disulphide linkage, Van der waal and electrostatic forces of attraction.

TERTIARY STRUCTURE

Quaternary str. of Proteins

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

QUATERNARY STRUCTURE

Denaturation of Proteins

The process that changes the 3-D str. of native protein is called denaturation of proteins.
It can be caused by change in pH, change in temp. addition of electrolyte, addition of solvent like water, alcohol, acetone.

Nucleic Acids:

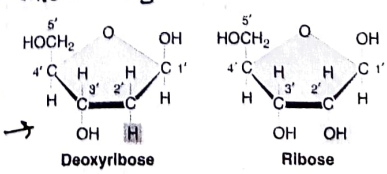
These are the polymers which are prepared by Nucleotide also known as polynucleotide

a nucleotide contain....

*) Pentose Sugar *) Nitrogenous Base *) Phosphate group.

Pentose Sugar: 5 carbon sugar either ribose or deoxy ribose

(not contain oxygen at 2nd position)



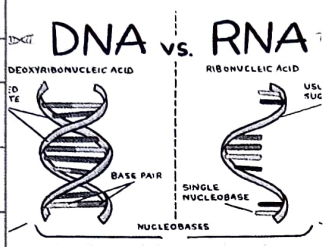
Nitrogeneous Base

Purine	Pyrimidine
→ Adenine	→ Thymine
→ Guanine	→ Uracil
	→ Cytosine

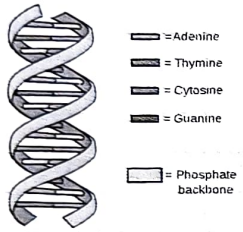
Bharat Sir

Two H-Bonds are present between A & T (A=T) while three hydrogen bonds are present between C & G (C≡G)

DNA	RNA
It is double stranded nucleic acid.	It is single stranded nucleic acid.
It contains deoxyribise sugar.	It contains ribose sugar.
It contains Thymine (T) as a nitrogenous base.	It contains Uracil (U) instead of Thymine.
It is the genetic and hereditary material of the cells.	It is involved in synthesis of proteins.
It is present in the nucleus of the cells.	It is present in both nucleus and cytoplasm.



Structure of D.N.A



DNA

It consist of two polynucleotide chains, each chain form a right handed helical spiral with ten based in one turn of the spiral

The two chains coil to double helix and run in opposite direction. These are held together by H-Bonding.

Types of RNA

1.) Messanger RNA (m-RNA) It is produced in the nucleus and carries information for the synthesis of protein.

2.) Transfer RNA It is found in cytoplasm. Its function is to collect amino acids from cytoplasm for protein synthesis.

3.) Ribosomal RNA (r-RNA) This provide site for protein synthesis

Functions of Nucleic Acid

- Direct the synthesis of protein
- Transfer the genetic informations.

→ **Replication** :- It is a process in which a molecule can duplicate.

→ **Template** It means pattern, in the process of replication of DNA, the parent strand serves as template.

Gene The portion of DNA carrying information about a specific protein is called gene.

Genetic Code: The relation between the amino acid and the the nucleotide triplet is called genetic code.

Codons The nucleotide bases in RNA function in group of three (triplet) in coding amino acid. These based triplets are called codons.

Bharat Panchal Sir

Bharat Panchal - Chemistry Guruji 2.0

Vitamins

The organic compounds other than carbohydrates proteins and fats which are required in the diet in small amount to perform specific biological functions, maintain normal health, growth and nutrition are called vitamins

Classification on the basis of Solubility 16

Fat Soluble Vitamins Vitamins A, D, E, K are soluble in fat and oils but insoluble in water. They are stored in liver and adipose (fat storing) tissues.

Water Soluble Vitamins - B group vitamins and C are soluble in water. water soluble vitamins must be supplied regularly in diet because they are readily excreted in urine and can not be stored in our body (except vitamin B12)

→ Vitamin K is responsible for coagulation of blood

Sl. No.	Name of Vitamins	Sources	Deficiency diseases
1.	Vitamin A	Fish liver oil, carrots, butter and milk	Xerophthalmia (hardening of cornea of eye) Night blindness
2.	Vitamin B_1 (Thiamine)	Yeast, milk, green vegetables and cereals	Beri beri (loss of appetite, retarded growth)
3.	Vitamin B_2 (Riboflavin)	Milk, eggwhite, liver, kidney	Cheilosis (fissuring at corners of mouth and lips), digestive disorders and burning sensation of the skin.
4.	Vitamin B_6 (Pyridoxine)	Yeast, milk, egg yolk, cereals and grams	Convulsions
5.	Vitamin B_{12}	Meat, fish, egg and curd	Pernicious anaemia (RBC deficient in haemoglobin)
6.	Vitamin C (Ascorbic acid)	Citrus fruits, amla and green leafy vegetables	Scurvy (bleeding gums)
7.	Vitamin D	Exposure to sunlight, fish and egg yolk	Rickets (bone deformities in children) and osteomalacia (soft bones and joint pain in adults)
8.	Vitamin E	Vegetable oils like wheat germ oil, sunflower oil, etc.	Increased fragility of RBCs and muscular weakness
9.	Vitamin K	Green leafy vegetables	Increased blood clotting time

ENZYMES

Enzymes are biocatalyst, almost all the enzymes are globular proteins. They are generally named after the compound or class of compound upon which they work

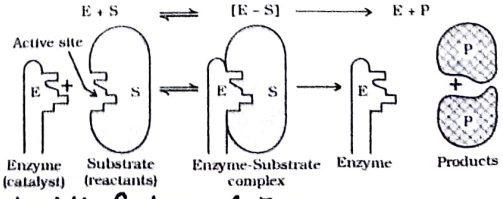
eg the enzyme that catalyse hydrolysis of maltose into glucose is named as maltase

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{Maltase}} \underset{\text{Glucose}}{2C_6H_{12}O_6}$$

Some Common Example

Substrate	Name	Product
Urea	Urease	$CO_2 + NH_3$
Maltose	Maltase	Glucose
Sucrose	Invertase	Glucose + Fructose
Starch	Amylase	Maltose
Proteins	Trypsin	Amino Acids

Mechanism Of Enzyme Action -



Characteristic feature of Enzyme:

- **Rate of Reaction** : They increase the rate of reaction upto 10^6 to 10^7 times.

- **Specific Nature** – Urease catalyse the hydrolysis of urea and not methyl urea, so these are specific in nature.
- **Optimum Temperature** – It is active at 20–30°C
- **pH of medium** – It is about 7, for pepsin 1.8–2.2, for trypsin 7.5–8.3
- **Concentration** – Dilute solutions are more effective
- **Amount of enzyme** – Very small amount can accelerate the reaction
- **Enzyme Inhibitors** – These compound inhibit the enzyme action, with the help of such compounds, the reaction can be controlled.

HARMONES

These are the chemical substance which are produced by endocrine (ductless) glands in the body. Harmones acts as chemical messenger.

Some examples of ductless (endocrine) glands are thyroid, pituitary, adrenal, pancreas, testes and ovaries.

Harmones are divided into three types:

(i) Steroids (ii) Proteins (iii) Amines

Name of endocrine gland	Hormones secreted
Testis	Testosterone
Ovary	Estrogen
Adrenal	Adrenaline
Thyroid glands	Thyroxin
Pituitary gland	FSH
Pancreas	Insulin

Carbohydrates

These are optically active poly hydroxy aldehydes / ketones or the substance which give these on hydrolysis are called carbohydrates.

General formula $C_x(H_2O)_y$

Classification on the basis of hydrolysis

- **Monosaccharides** – can not be hydrolysed further e.g glucose, fructose
- **Oligosaccharides** – give 2–10 molecules of monosaccharides e.g glucose, fructose
- **Polysaccharides** – give large no. of monosaccharides e.g starch, cellulose.

- Preparation of Glucose:

From Sucrose

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

From Starch

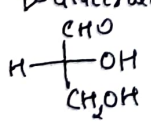
$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow{H^+} n\,C_6H_{12}O_6 \text{ glucose}$$

Structure

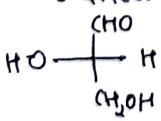
CHO ← one aldehyde group
(CHOH)$_4$ ← four 2° alcohol
CH$_2$OH ← one 1° alcohol

Str.

D-Gluceraldehyde



L-Gluceraldehyde



(D) means OH in R.H.S (L) means OH in L.H.S

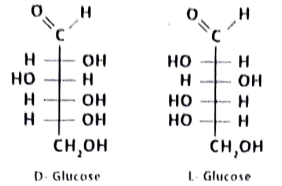
Bharat Panchal Sir

Bharat Panchal - Chemistry Guruji 2.0

Str. of Glucose

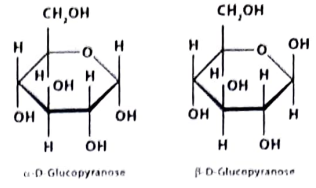
(17)

Fischer Projection



D- Glucose L- Glucose

Haworth Projection

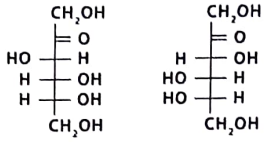


α-D-Glucopyranose β-D-Glucopyranose

Str. of fructose: {The C_1 is known as anomeric carbon and these compounds are called anomers}

Fischer Projection

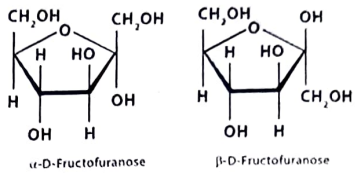
Fructose



D- Fructose L- Fructose

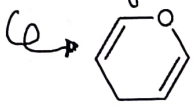
Haworth Projection

Fructose



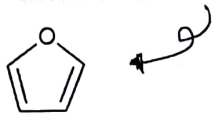
α-D-Fructofuranose β-D-Fructofuranose

Six membered cyclic ring



Pyran

Five membered Cyclic ring



Furan

Reducing Sugar

- Free Aldehydic or Ketonic group
- Reduce Fehling Soln or Tollen's Reagent
- e.g Maltose & Fructose

Non Reducing Sugar

- Do not have any free aldehydic or ketonic group.
- Do not reduce tollens Reagent and Fehling Soln
- e.g Sucrose

Chemical Properties of Glucose

•) (CHOH)$_4$(CHO)(CH$_2$OH) $\xrightarrow{\text{Acetic Anhydride}}$ (CH(O–C(=O)–CH$_3$))$_4$(CH$_2$–O–C(=O)–CH$_3$)

Glucose Penta acetate

•) (CHOH)$_4$(CHO)(CH$_2$OH) + [O] $\xrightarrow[H_2O]{Br_2}$ (CHOH)$_4$(COOH)(CH$_2$OH) Gluconic acid

•) (CHOH)$_4$(CHO)(CH$_2$OH) $\xrightarrow{HNO_3}$ (CHOH)$_4$(COOH)(CH$_2$OH) Saccharic acid

•) (CHOH)$_4$(CHO)(CH$_2$OH) $\xrightarrow[\Delta]{HI}$ (CH$_2$)$_4$(CH$_3$)(CH$_3$) n-Hexane

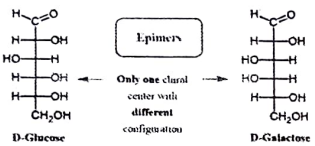
•) (CHOH)$_4$(CHO)(CH$_2$OH) $\xrightarrow{HN\text{-}OH}$ (CHOH)$_4$(CH$_2$O)(CH=N-OH) Glucoxine

•) (CHOH)$_4$(CHO)(CH$_2$OH) $\xrightarrow{HCN}$ (CHOH)$_4$(CH(OH)–CN)(CH$_2$OH) Glucose Cyano hydrin

Mutarotation – when either of the two forms of glucose is dissolved in water, there is a spontaneous change in specific rotation till the equilibrium value of +52.5°. This is known as mutarotation.

α-D(+) Glucose $\rightleftharpoons$ Equilibrium mixture $\rightleftharpoons$ β-D(+) Glucose
+111.5° +19.5°

- **Importance of Carbohydrate**
- Carbohydrates are essential for life in both plants and animals
- They are major portion of our food.
- Carbohydrates are used as storage molecule as starch in plants and glycogen in animals.
- Cell wall of bacteria and plants is made up of cellulose
- Honey has been used for a long time as an instant source of energy.
- Epimers Monosaccharides differing in configuration at a carbon other than anomeric carbon are called epimers e.g glucose and galactose differ in configuration at C4, hence called epimers.



Sugars and Non-Sugars

- monosaccharides and Oligosaccharides having sweet taste, soluble in water are known as **Sugars**
- Polysacchides which are insoluble in water and not sweet in taste are known as **non-sugars**

Bharat Panchal Sir

Bharat Panchal - Chemistry Guruji 2.0

DISACCHARIDES AND POLYSACCHARIDES-

CARBOHYDRATES	Hydrolysis Product	Linkage	Reducing Property
Sucrose (Disaccharide)	α-D Glucose & β-D Fructose	C-1(Glucose)& C-2 (fructose)	Non-Reducing
Maltose (Disaccharide)	α-D-Glucose	C-1 Glucose & C-4 Glucose	Reducing
Lactose (Disaccharide)	β-D-Galactose & β-D-Glucose	C-1 (Galactose) & C-4 (Glucose)	Reducing
Cellulose (Polysaccharide)	β-D-Glucose	C-1 (Glucose) & C-4 (Glucose)	Non-Reducing
Glycogen (Polysaccharide)	α-D-Glucose	C-1 (Glucose) & C-4 (Glucose)	Non-Reducing

MUTAROTATION When glucose is dissolved in water, then its specific rotation changes into an equilibrium value. This spontaneous change in specific rotation of an optically active substance to an equilibrium value is called mutarotation

The two anomers of glucose i.e α-D glucose & β-D Glucose in solution changes their specific rotation to an equilibrium value which is the rotation of a straight chain str.

α-D Glucose $\rightleftharpoons$ Open chain str. $\rightleftharpoons$ β-D-Glucose
(Sp. rotation = +110°) (Sp. rotation = +52.5°) (Specific rotation = +19.2°)

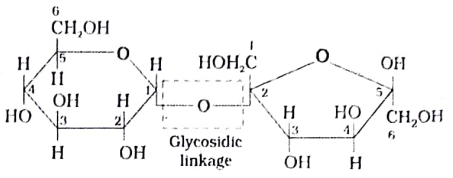
DISACCHARIDES Disaccharides are the carbohydrates which on hydrolysis with dilute acids or with enzyme give two molecules of either same or different monosaccharide

The two monosaccharides are joined together by an oxide linkage formed by loss of a water molecule This is actually an ether group and is called glycosidic linkage.

$$-\overset{|}{C}-OH + HO-\overset{|}{C}- \longrightarrow -\overset{|}{C}-O-\overset{|}{C}- + H_2O$$

SUCROSE

α-D-Glucose + β-D-Glucose

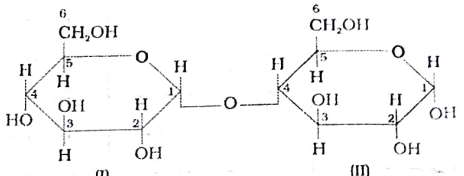


α-D-Glucose β-D-Fructose

Sucrose

MALTOSE

β-D-Galactose + β-D Glucose

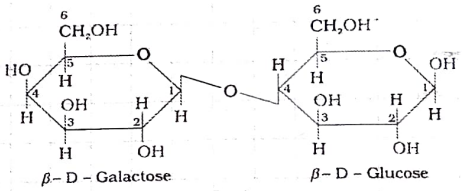


(I) α-D-Glucose (II) α-D-Glucose

Maltose

LACTOSE

β-D-Galactose + β-D-Glucose



β-D-Galactose β-D-Glucose

Lactose

INVERSION OF SUCROSE - Sucrose on dextro-rotatory but on hydrolysis either with dilute acid or with enzyme invertase, the solution is changed into laevo-rotatory solution.

As dextro rotatory sucrose is changed to laevo rotatory solution after hydrolysis. The sucrose is called "Invert sugar"

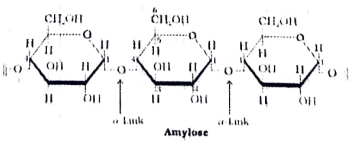
$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{dil. HCl}} C_6H_{12}O_6 + C_6H_{12}O_6$$
+66.5° D(+)-Glucose +52.5° D(-)-Fructose -92.4°

Since the laevo rotation of fructose (-92.4°) is more than dextro rotation of glucose (+52.5°), the mixture is laevo rotatory.

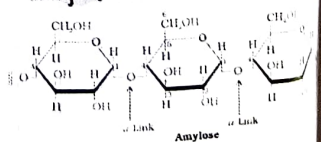
Polysaccharides

Starch it is a polymer of α-glucose units and it consists two components - Amylose and Amylopectin

Amylose



Amylopectin



It constitutes about 15-20% starch	It constitutes 80-85% starch
It is soluble in water soluble	It is water insoluble
These are long unbranched chain with C1-C4 glycosidic linkage of glucose	These are branched chain polymer of α-D-glucose units with C1-C4 glycosidic linkage and C1-C6 glycosidic linkage at branching.