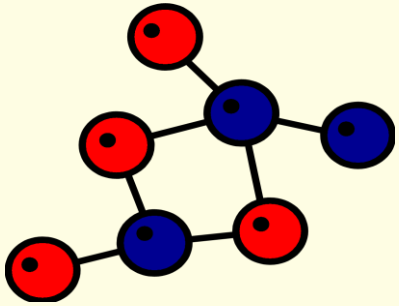
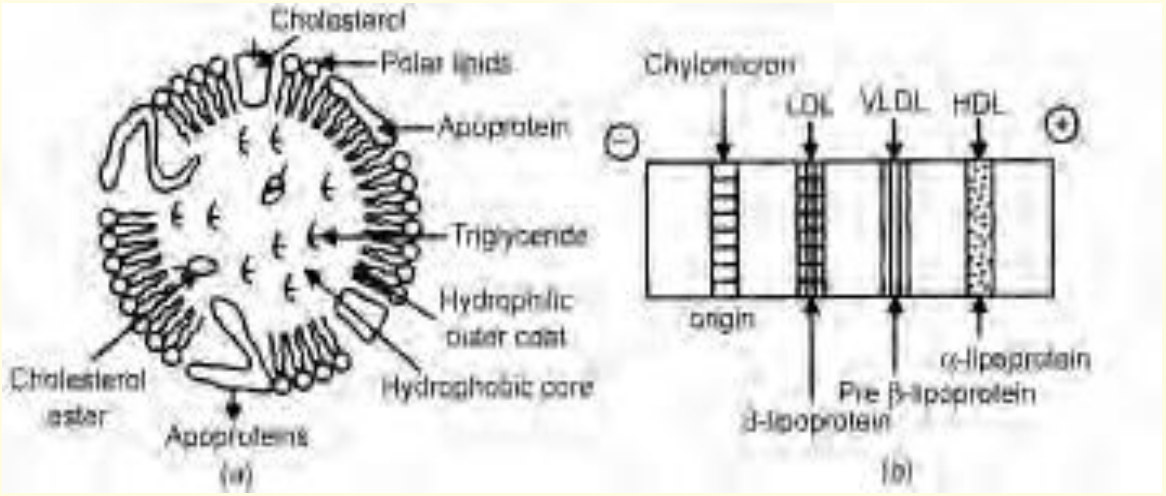


CARBOHYDRATES

L - 2

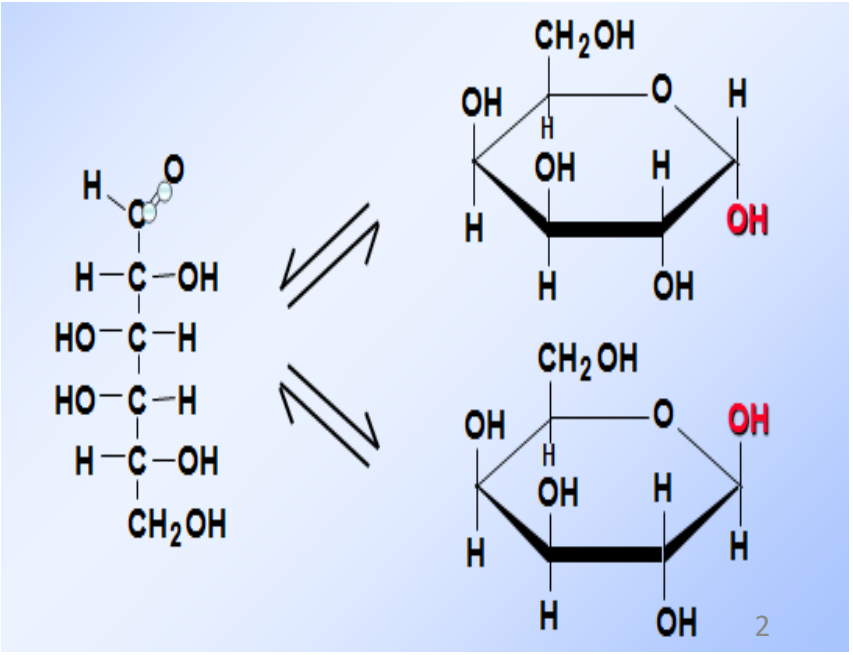


(*a*) Lipoprotein general structure
(*b*) Electrophoresis of lipoproteins

By Dr. Ibtisam. K

D-galactose

- Has a similar structure to glucose except for the –OH on Carbon 4.
- Cannot find in the free form in nature.
- Exist in the cellular membranes of the brain and nervous system.
- Combines with glucose in lactose (a disaccharide and a sugar in milk).



Structure of Disaccharide

Contain two molecules of same or different monosaccharide units.
A disaccharide is formed when a hydroxyl group on one monosaccharide reacts with the anomeric carbon of another monosaccharide to form a glycosidic bond.
Each disaccharide has a specific glycosidic linkage (depending on which hydroxyl reacts with which anomer)
The three most common disaccharides are maltose, lactose and sucrose
When hydrolyzed using acid or an enzyme, the following monosaccharide's are produced:

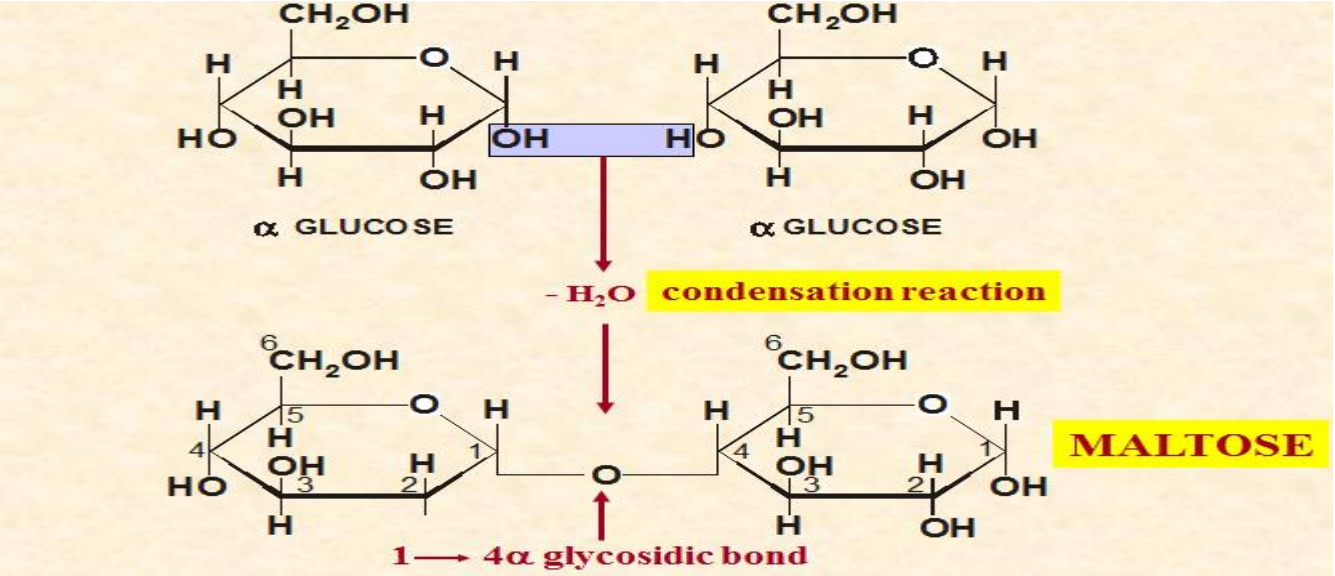
$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$

is cleaved to two monosaccharide's on hydrolysis these two monosaccharide's may be the same or different.

1 - Maltose [glucose + glucose]

It contains two glucose units. The anomeric carbon atom of first glucose and carbon atom 4 of the second glucose are involved in glycosidic linkage. The glycosidic linkage of maltose is symbolized as $\alpha\ (1 \rightarrow 4)$.

THE FORMATION OF MALTOSE



In this symbol, letter α-indicates the configuration of anomeric carbon atoms of both glucose units and numbers indicates carbon atoms involved in glycosidic linkage.

Systematic name for maltose is α-D glucopyranosyl-(1→4)-α-D glucopyranose.

Maltose is a reducing sugar because anomeric carbon of second glucose is free.

Source for maltose

Maltose is present in germinating cereals and in barley. Commercial malt sugar contains maltose. It may be formed during the hydrolysis of starch.

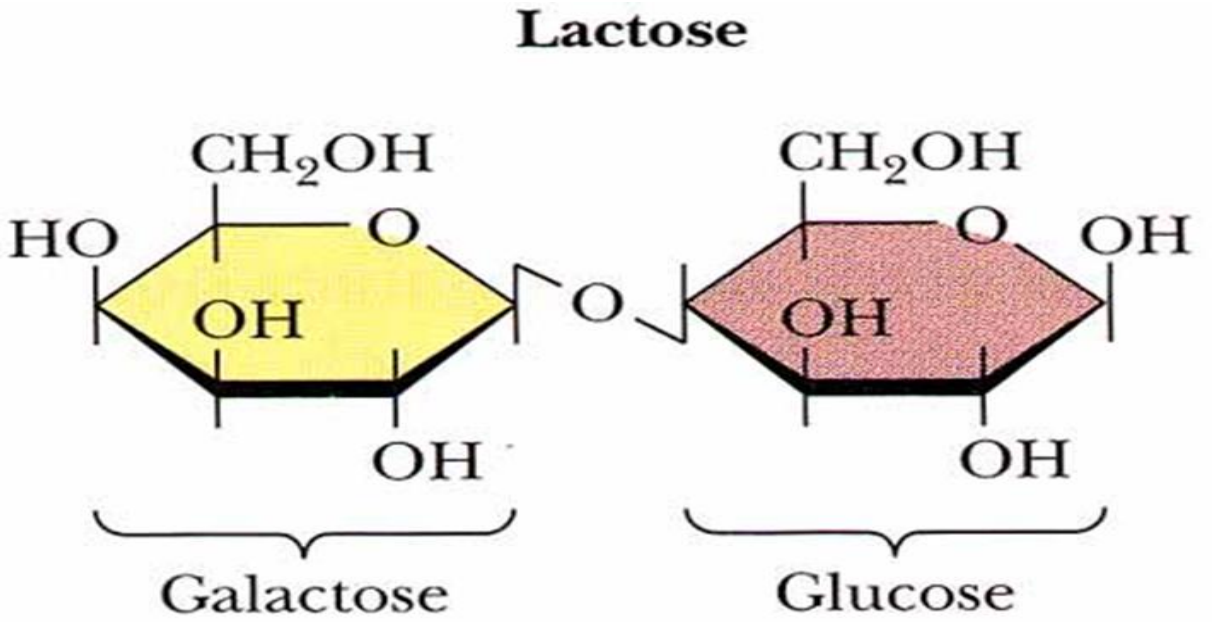
2- LACTOSE

Structure

It contains one glucose and one galactose. The anomeric carbon atom of galactose and carbon atom 4 of glucose are involved in glycosidic linkage. It is symbolized as β (1→4). The systematic name for lactose is β-D galactopyranosyl-(1→4)-β-D glucopyranose. Lactose is a reducing sugar because anomeric carbon of glucose is free.

Source for lactose

Lactose is synthesized in mammary gland and hence it occurs in milk.

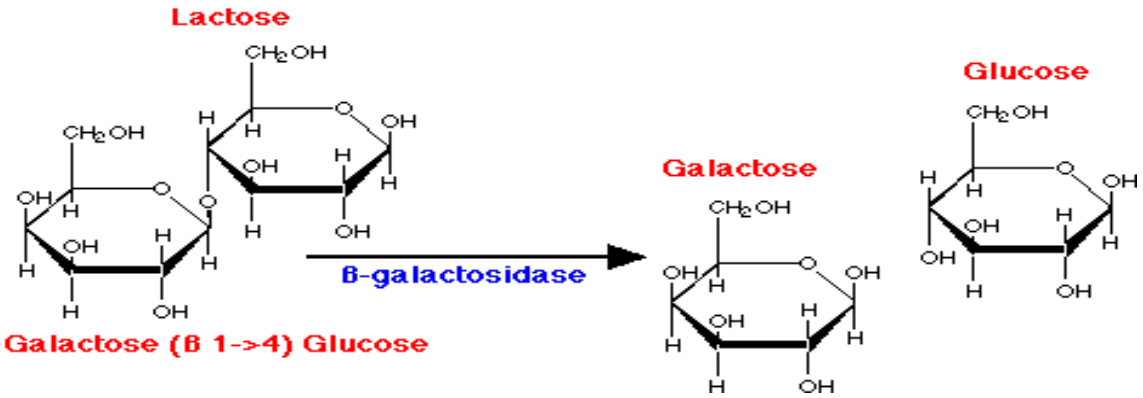


Digestion of lactose

The intestinal villi secrete an enzyme called lactase (β-D-galactosidase) to digest lactose, and produce glucose and galactose, which can be absorbed.

- More than half of the world's adults are lactose intolerance.
- Lactose intolerance is the inability to metabolize lactose, because the lactase is absent in the intestinal system or its availability is lowered.

- In the absence of lactase, lactose remains uncleaved and passes intact into the colon.
- The operons of enteric bacteria quickly switch over to lactose metabolism, and produces copious amounts of gas (a mixture of hydrogen, carbon dioxide, and methane).
- This, in turn, may cause a range of abdominal symptoms, including stomach cramps, bloating, and flatulence.
- Treatment for this disorder is simple to remove lactose from diet.

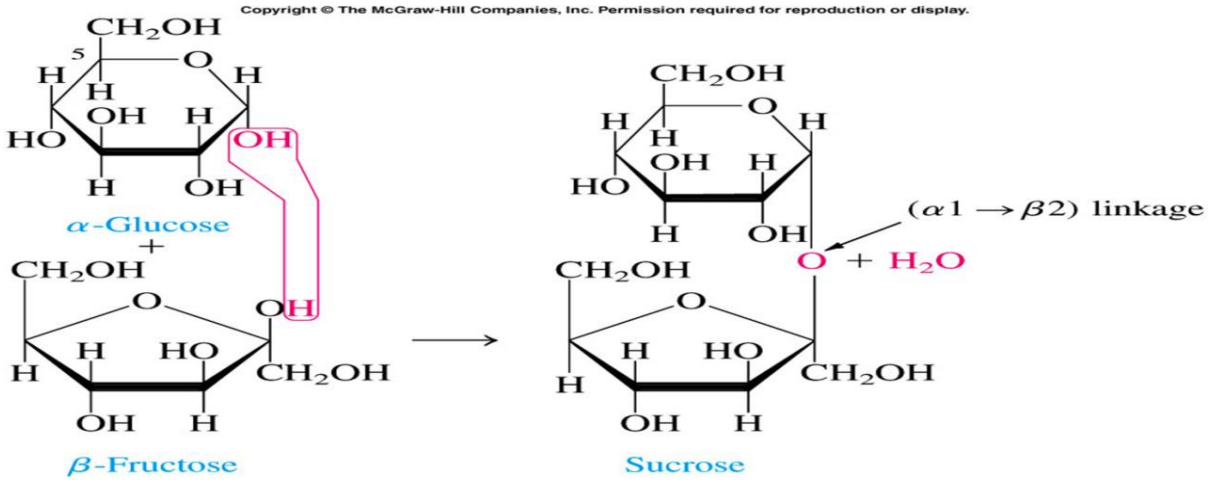


3- Sucrose

- Sucrose (table sugar) consists of one glucose molecule and one fructose molecule linked by an **α , β -1,2-glycosidic** bond.
- Sucrose is the most abundant disaccharide and is commercially produced from sugar cane and sugar beets.
- The full name of sucrose is α-D-glucopyranosyl-(1→2)-β-D-fructofuranose. Sucrose is a non reducing sugar because both the functional groups of glucose and fructose are involved in glycosidic linkage.

Source of sucrose

- **Ripe fruit juices like pineapple, sugar cane, juice and honey are rich sources for sucrose. It also occurs in juices of sugar beets, carrot roots and sorghum.**



Polysaccharide

They are polymers of monosaccharides. They contain more than ten monosaccharide units.
The monosaccharides are joined together by glycosidic linkage.

Classification of Polysaccharides

Polysaccharides are classified on the basis of the type of monosaccharide present. The two classes of polysaccharides are homo-polysaccharides and hetero-polysaccharides.

(a) **Homopolysaccharides.** They are entirely made up of one type of monosaccharides . On hydrolysis, they yield only one kind of monosaccharide.
(*b*) **Heteropolysaccharides.** They are made up of more than one type of monosaccharides. On hydrolysis they yield more than one type of monosaccharides.

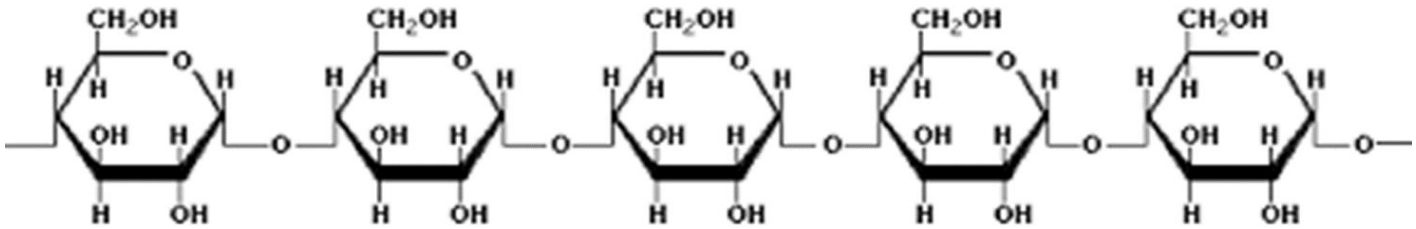
Homopolysaccharides

Important homopoly-saccharides are starch, glycogen, cellulose, dextran and dextran and inulin and chitin. All these contain glucose as repeating unit. Other name for homopolysaccharides are homoglycans.

Homopolysaccharide

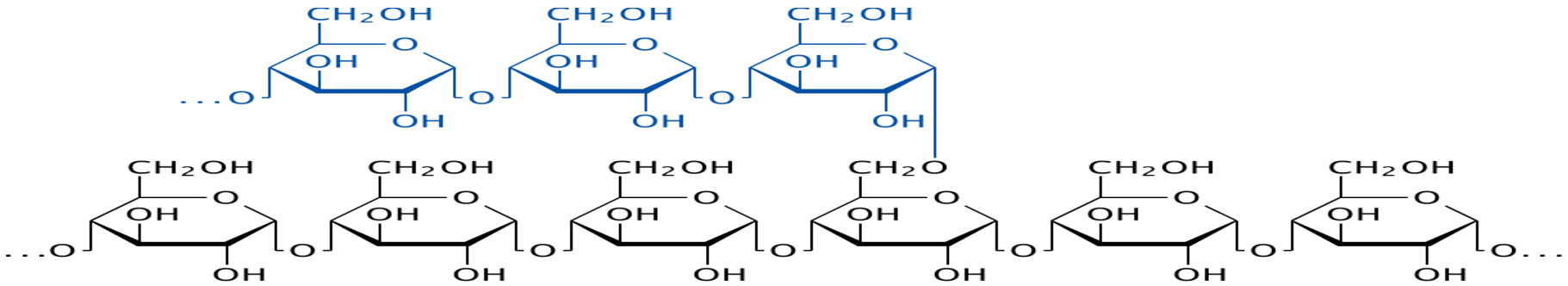
Starch

1. It consist of two parts. A minor amylose component and a major amylopectin component.
2. **Amylose** is a straight-chain polymer of glucose units. **α(1→4)** glycosidic linkage is present between glucose units.



3. In contrast **amylopectin** is a branched molecule. In the linear portion of amylopectin **α(1→4)** glycosidic linkage exist between glucose units whereas **α(1→6)** glycosidic linkage exist at branch points between glucose residues. The branching occurs in amylopectin for every 2-30 glucose units.

4. Amylose has helical coiled secondary structure and usually 6 glucose residue make one turn. Because of branching secondary structure of amylopectin is a random coil structure.



Amylopectin

Function

1. It is the major polysaccharide present in our food.

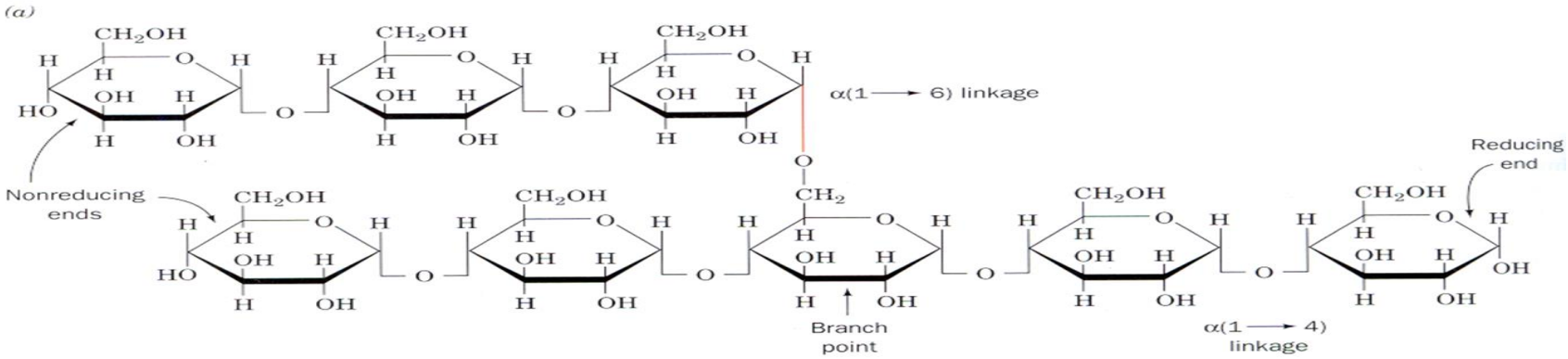
2. It is also called as storage polysaccharide because it serve as reserve food material in plants.

3. It is present in food grains, tubers and roots like rice, wheat, potato and vegetables.

Glycogen

1. The structure of glycogen is similar to that of amylopectin of starch. However, the number of branches in glycogen molecule is much more than amylopectin.
2. like amylopectin, g **α(1→4)** lycogen is a nonlinear polymer of D-glucose units joined by **α(1→4)** and **α (1→6)** glycoside bonds .
3. There is one branch point for 6-7 glucose residues.

The total amount of glycogen in the body of a well-nourished adult is about 350 g (about 3/4 of a pound) divided almost equally between liver and muscle.

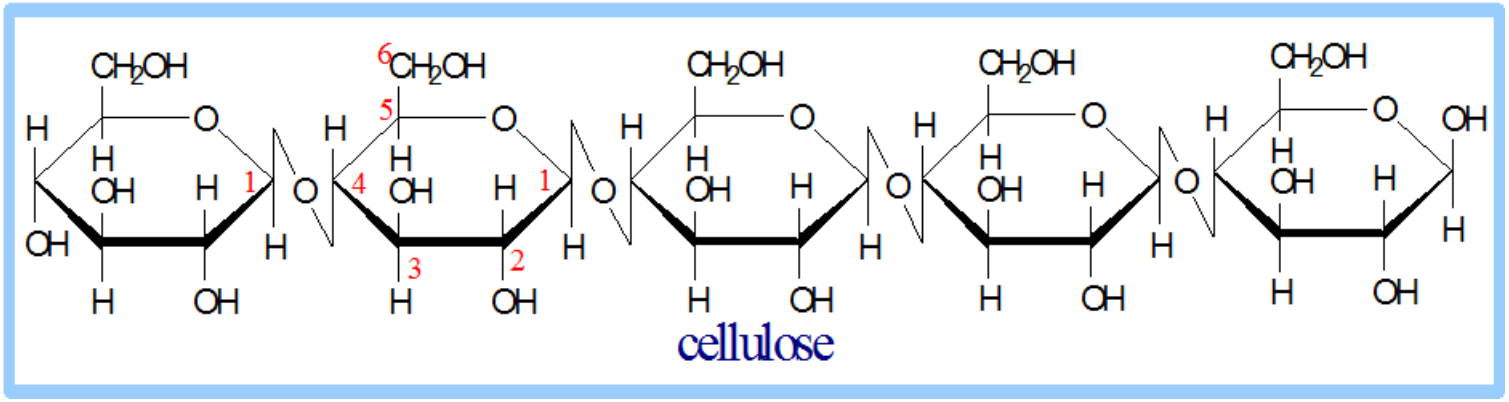


Function

1. It is the major storage polysaccharide (carbohydrate) in human body.
2. It is mainly present in liver and muscle.
3. It is also called as animal starch.

Cellulose

- Cellulose is a linear polymer of D-glucose units joined by β-1,4-glycoside bonds
  - It has an average molecular weight of 400,000 g/mol, corresponding to approximately 2800 D-glucose units per molecule cellulose chain is much stiffer than starch
  - Chains line up side by side into well-organized water-insoluble fibers in which the OH groups form numerous intermolecular hydrogen bonds
  - Arrangement of parallel chains in bundles gives cellulose fibers their high mechanical strength
  - Cellulose is insoluble in water
  - Digested by *Cellulase* enzyme in animals which is absent in human body .
  - Acts as dietary fiber and adds bulk to the food and helps in peristalsis .



B- Heteropolysaccharide

They are polymer of different monosaccharide units or their derivatives

They are also called as mucopolysaccharides and glycosaminoglycans. Mucopolysaccharides consist of repeating disaccharide units. The disaccharide consist of two types monosaccharides.

The mucopolysaccharides are component of connective tissue. Hence, they are often referred as structural polysaccharides. The mucopolysaccharides are also found in mucous secretions. The mucopolysaccharides combines with proteins like collagen and elastin and forms extracellular medium or ground substance of connective tissue. Mucopolysaccharides are also components of extracellular matrix of bone, cartilage and tendons. The complex of mucopolysaccharide and protein is called as proteoglycan. Mucopolysaccharides also function as lubricants and shock absorbers. Few important mucopolysaccharides or glycosaminoglycans (GAGs) are:

1- Hyaluronic Acid (HA)

The repeating disaccharide of hyaluronic acid consist of glucuronic acid and N acetylglucosamine.

————(β-Glucuronic acid————N-acetylglucosamine)n————

Hyaluronic acid

Functions

1. It is present in synovial fluid and function as lubricant.
2. It is also present in skin, loose connective tissue, umbilical cord and ovum.
3. It is present in vitreous body of eye.

Medical importance

1. As the age advances hyaluronic acid is replaced by-dermatan sulfate in synovial fluid. Dermatan sulfate is not a good lubricant, hence age related pains develop in old people.

2. In young people, vitreous is clear elastic gel in which hyaluronic acid is associated with collagen. As the age advances the elasticity of vitreous is reduced due to decreased association between collagen and hyaluronic acid. As a result, vision is affected in older people.

3. Hyaluronic acid of tumour cells has role in migration of these cells.

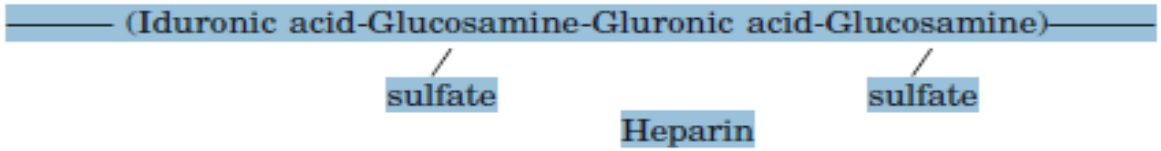
4 . Hyaluronic acid is involved in wound healing (repair). In the initial phase of wound healing (repair), hyaluronic acid concentration increases many fold at the wound site. It allows rapid migration of the cells to the site of connective tissue development.

5. Hyaluronic acid helps in scarless repair. If suitable levels of HA are maintained during would healing scar formation is reduced or even prevented.

6. HA content of skin decreases as age advances this is the reason for increased susceptibility of aged people for scar formation.
7. Pneumonia, meningitis and bacteremia causing pathogenic bacteria contains hyaluronte lyase. Hydrolysis of HA by this enzyme facilitates invasion of host by these bacteria.

2-Heparin

1. The repeating disaccharide unit of heparin consist of glucosamine and either iduronic acid or glucuronic acid.
2. Majority of uronic acids are iduronic acids. Further amino groups of glucosamine is sulfated.

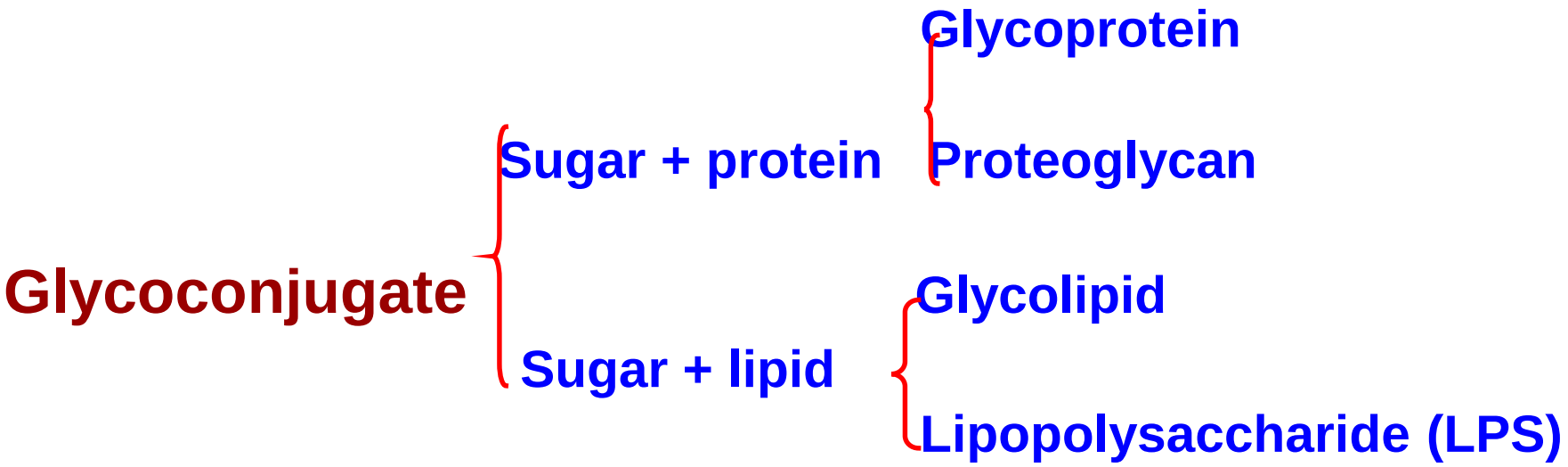


Functions

1. Heparin is a normal anti-coagulant present blood.
2. It is produced by mast cells present in the arteries, liver, lung and skin.
3. Unlike other glycosaminoglycans, heparin is an intracellular component.

Glycoconjugate (complex saccharide)

Glycoconjugates: carbohydrates covalently linked with other chemical species.

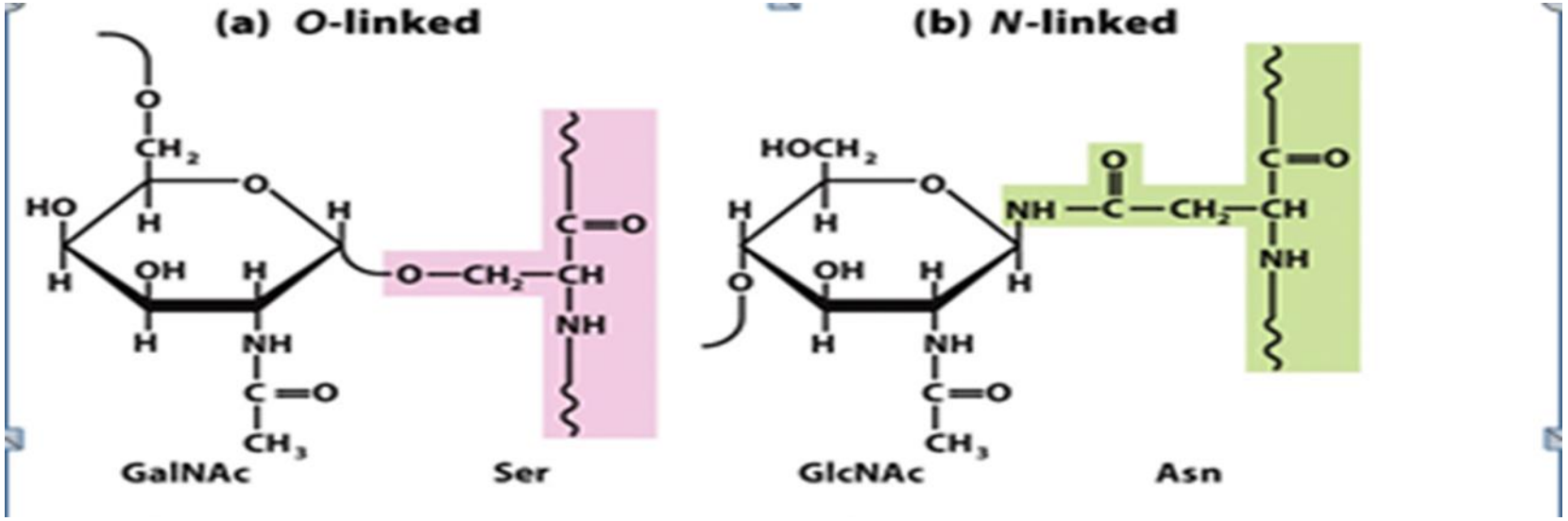


- **Glycoconjugates are very important compounds. They are involved in cell-cell interactions, including cell-cell recognition, and cell-matrix interactions.**

- **Proteoglycan – mostly carbohydrate, with a little protein**
- **Glycoprotein – mostly protein with a little carbohydrate**

Glycoproteins

- Glycoproteins: proteins that contain oligosaccharide chains (glycans) covalently attached to their polypeptide side-chains.
- O-Glycosidic and N-glycosidic linkages.
- They are found in mucous fluids, tissues, blood and in cell membrane. Further oligosaccharide is composed of fucose, N-acetyl glucosamine, galactose and glucose.
- The oligosaccharide chains have important functions like:



Functions of glycoproteins

1. Oligosaccharide present on the surface of erythrocytes are responsible for the classification of blood groups. They determine blood group and hence they are called as blood group substances.

2. Oligosaccharides determine the life span of proteins.
3. Cell-cell recognition depends on oligosaccharide chains of glycoproteins.
4. Glycoproteins of some invertebrates function as antifreezing agents.

Sialic Acids

1. Sialic acids are acyl derivatives of neuraminic acid.
2. Neuraminic acid is a 9 carbon sugar consisting of mannosamine and pyruvate. Usually amino group of mannosamine of neuraminic acid is acetylated. Hence, N-acetyl neuraminic acid (NANA) is an example for sialic acid.

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Functions

1. Oligosaccharides of some membrane glycoproteins contains a terminal sialic acid.
2. Sialic acid is an important constituent of glycolipids present in cell membrane
   and nervous tissue

Proteoglycan

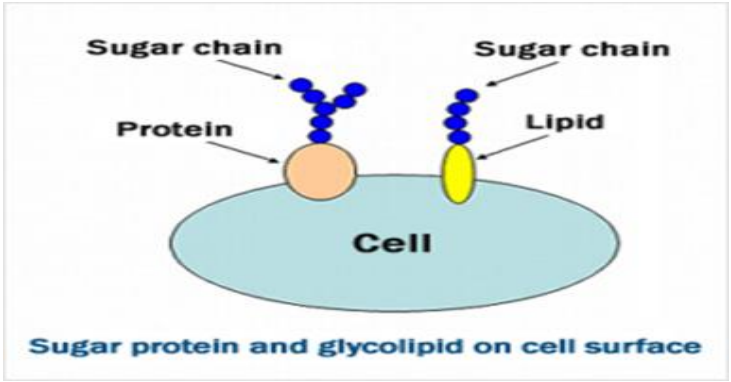
A special type of glycoprotein with sugar weighing about 95% .
On cell surface or Extracellular matrix
Essential components of tissue (particularly connective tissue).

Functions of proteoglycans:

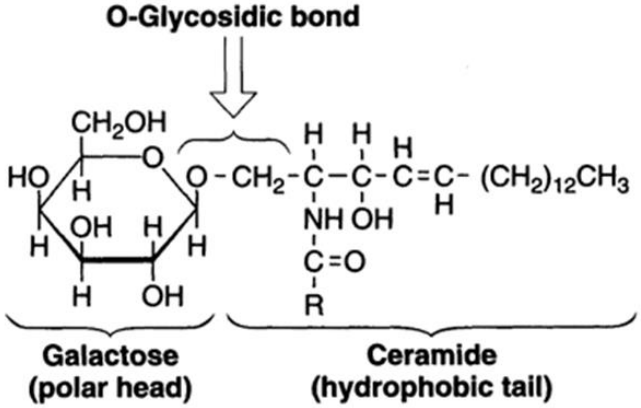
- Compressibility (lubricants, shock-absorbers)
- Adhesion
- Structure
- Anticoagulant (heparin)

Glycolipids

- Glycolipids are carbohydrate-attached lipids.
- Their role is to provide energy and also serve as markers for cellular recognition.
- Glycolipids have a carbohydrate bound to the alcohol of a lipid via a glycosidic link. Frequently a glucose or galactose is bound to the primary alcohol of a ceramide.
- These compounds are found in the cell membranes of nerve and brain cells.
- The carbohydrate component is linked by an O-glycosidic bond to ceramide



Sugar protein and glycolipid on cell surface



Galactocerebroside
(a glycosphingolipid)

Roles of glycolipids

- Glycolipids have important roles in cell interactions, growth, and development
- They are very antigenic (blood group antigens);
- Act as surface receptors for some toxins and viruses;
- And undergo major changes during cell transformation