Carbohydrates

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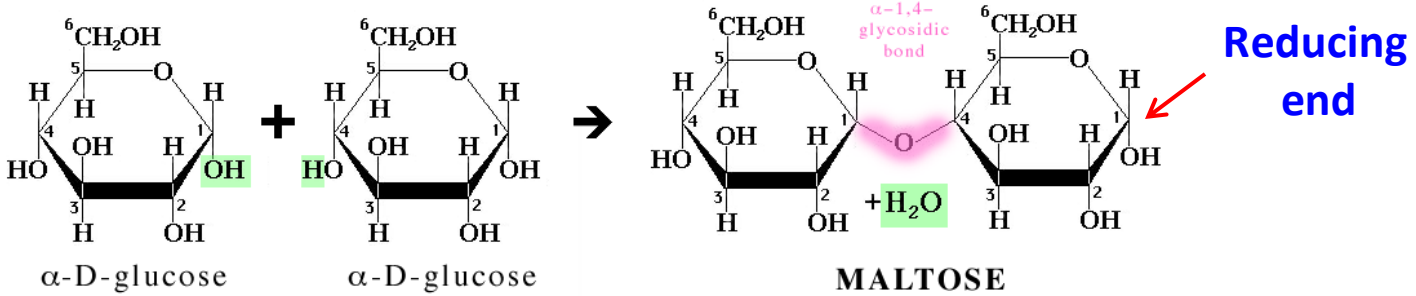
Disaccharides

- These are two monosaccharides linked together via the glycosidic bond. Three common disaccharides:
  - Maltose "malt sugar" consists of two α-glucose units, is a disaccharide released during the hydrolysis of the starch



α-D-glucopyranosyl-(1⟶4)-α-D-glucopyranose

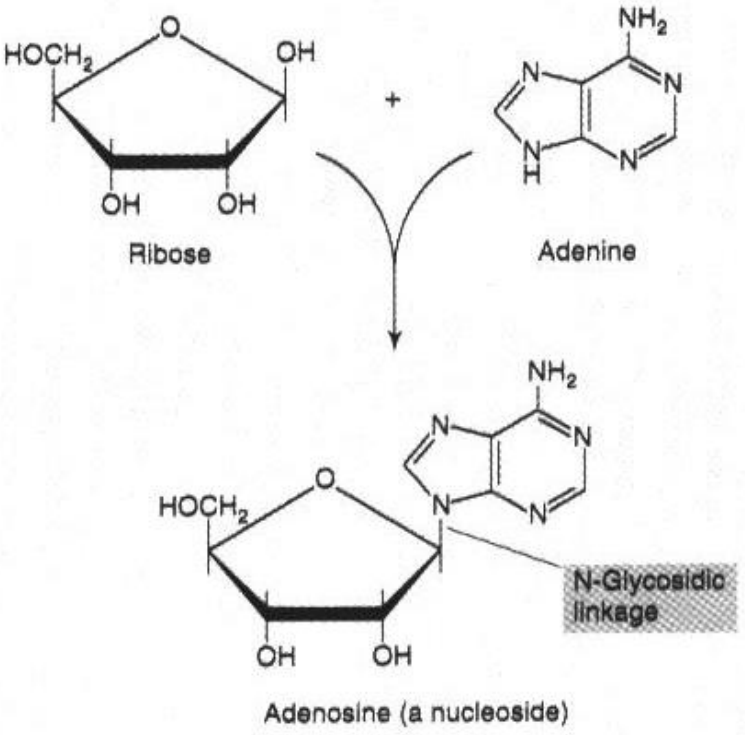
- Barely grains is used for preparation of malt beverage. During the degradation of starch, maltose sugar is produced.

Glycosidic bond

- Glycosidic bond is a type of covalent bond where the anomeric group of a sugar can condense with an alcohol. This type of bond is called O-glycosidic bond.

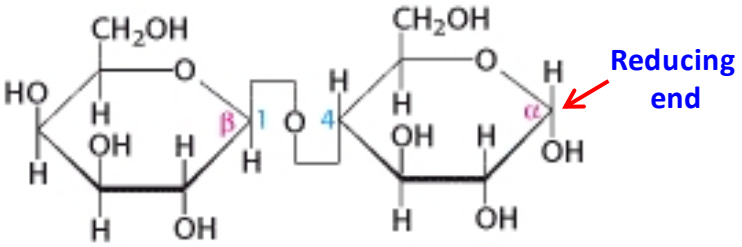
- N-glycosidic bond is another type of glycosidic bond which forms between the anomeric carbon of sugar and an amine.

e.g. the bonds that link D-ribose and D-deoxyribose to purines and pyrimidines in the nucleic acids: RNA & DNA, respectively.

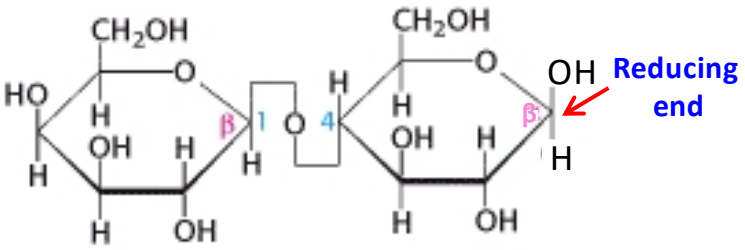


Disaccharides

- Lactose "milk sugar" consists of glucose & galactose, is a disaccharide occurs naturally in the milk **(dairy products)**



α-Lactose
β-D-Galactopyranosyl-(1→4)-α-D-glucopyranose



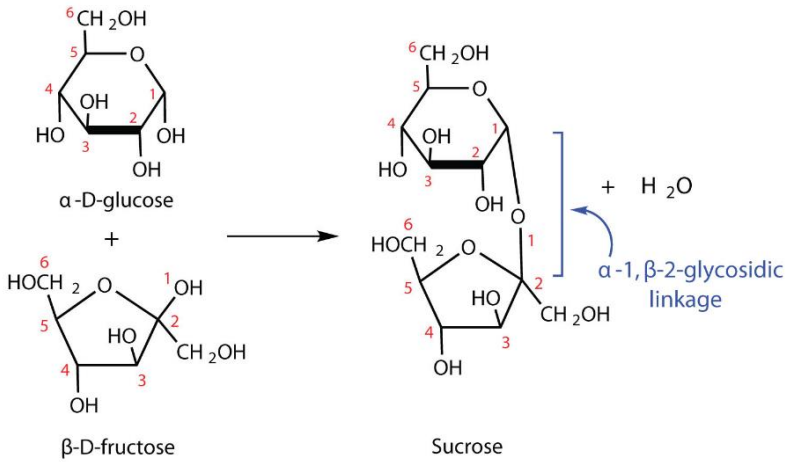
β-Lactose
β-D-Galactopyranosyl-(1→4)-β-D-glucopyranose

Disaccharides

- Lactose Intolerance: deficiency of lactase enzyme leading to **Gastrointestinal tract (GIT) disturbances such as:** nausea, bloating, abdominal cramps and diarrhea due to digestion of lactose **(intact)** by bacteria found in colon

Disaccharides

- Sucrose "table sugar" consists of glucose & fructose, is a disaccharide obtained commercially from cane or beet.

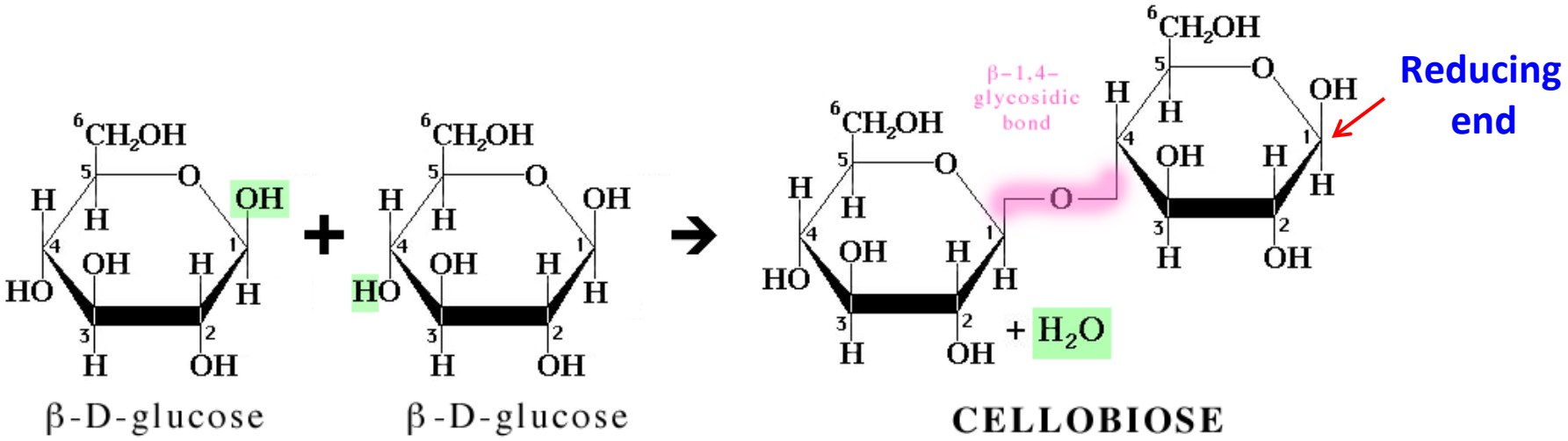


Sucrose
α-D-Glucopyranosyl-(1 → 2)-β-D-fructofuranose

- Sucrose is not a reducing sugar because the anomeric carbon of the second residue (the reducing end) is not free but involved in the glycosidic bond formation.

Disaccharides

- Cellobiose consists of two D-glucose residues linked by the β-glycosidic bond (C1 of one residue is joined to the oxygen atom attached at C4 of the second residue). It is released during cellulose degradation



- Cellobiose is an isomer of maltose (stereochemistry of the glycosidic bond which is **β** in cellobiose and **α** in maltose)

Polysaccharides

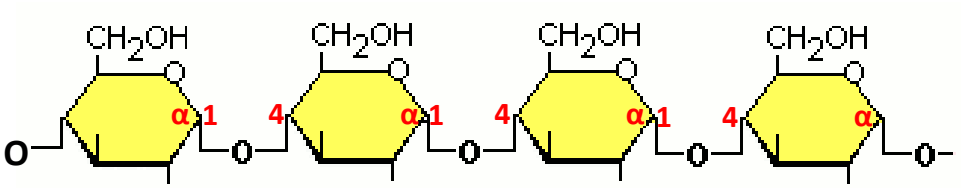
- Polysaccharides "glycans" are polymeric molecules consist of long chains of monosaccharide units bound together via the glycosidic linkages.
- Polysaccharides composed of same type of monosaccharides are called **homopolysaccharides** "homoglycans" and those consisting of more than one type are called **heteropolysaccharides** "heteroglycans" .
- They form branched as well as linear polymers.
- They are classified into:
  1. Storage polysaccharides like starch and glycogen
  2. Structural polysaccharides like cellulose and chitin

Storage Polysaccharides

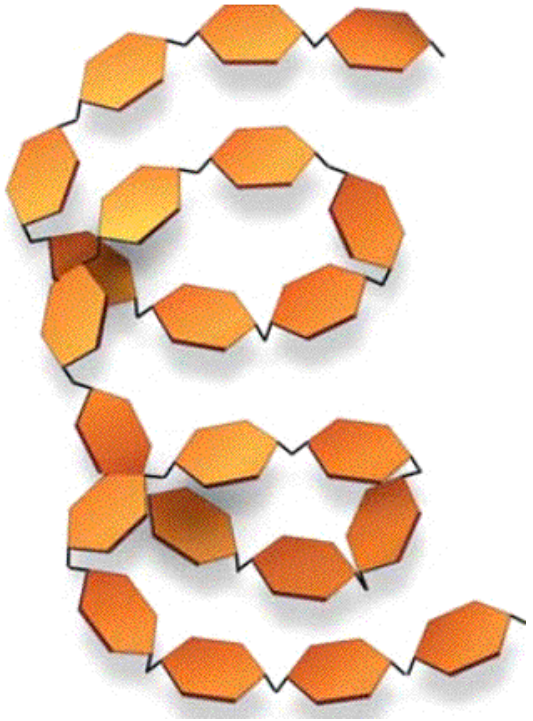
Starch: is the storage polysaccharides in plants.

- Polymer composed of glucose monomers
- a mixture of **amylose** (20%, water soluble) and **amylopectin** (80%, water insoluble) stored in plant cells as insoluble granules.

unbranched starch(linear)

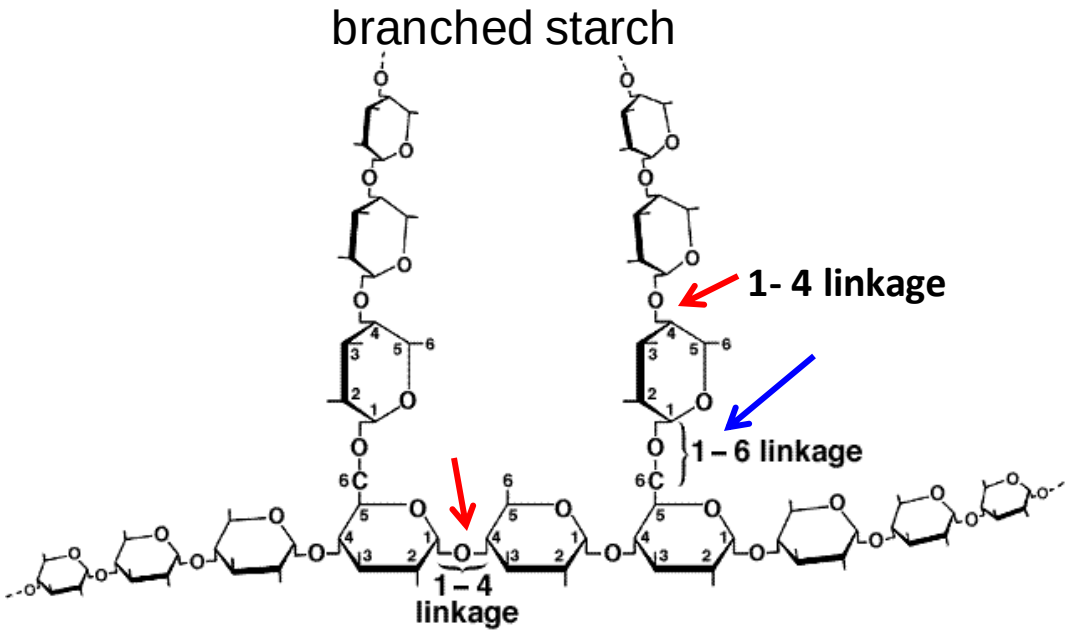


Amylose : α (1 ⟶4) glycosidic bonds

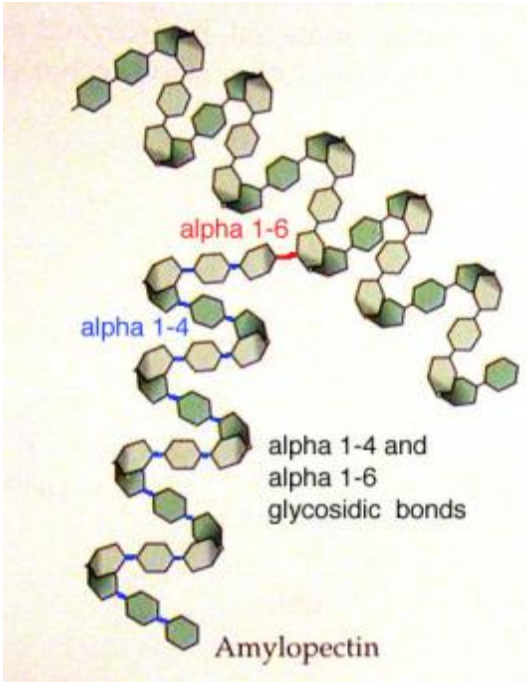


The helical structure of amylose

Storage Polysaccharides



Amylopectin: α (1 ⟶ 4) glycosidic bonds
with α (1 ⟶ 6) branch points (every 24-30 units)



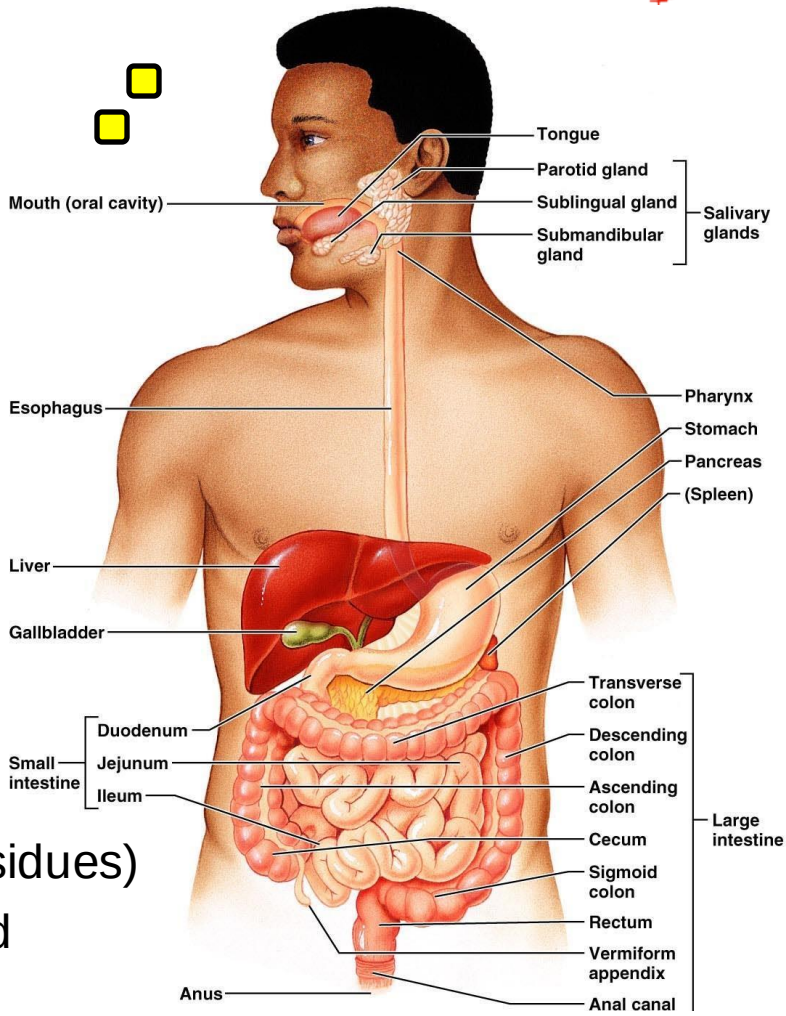
Digestion of starch

1. The salivary amylase enzyme randomly hydrolyses the α-(1⟶ 4) bonds

2. Starch digestion to small oligosaccharides continues in the small intestine by pancreatic amylase

3. Further hydrolysis by α-glucosidase (which remove one glucose residue at time) and by a debranching enzyme (which hydrolyzes specifically α-[1⟶ 6] bond

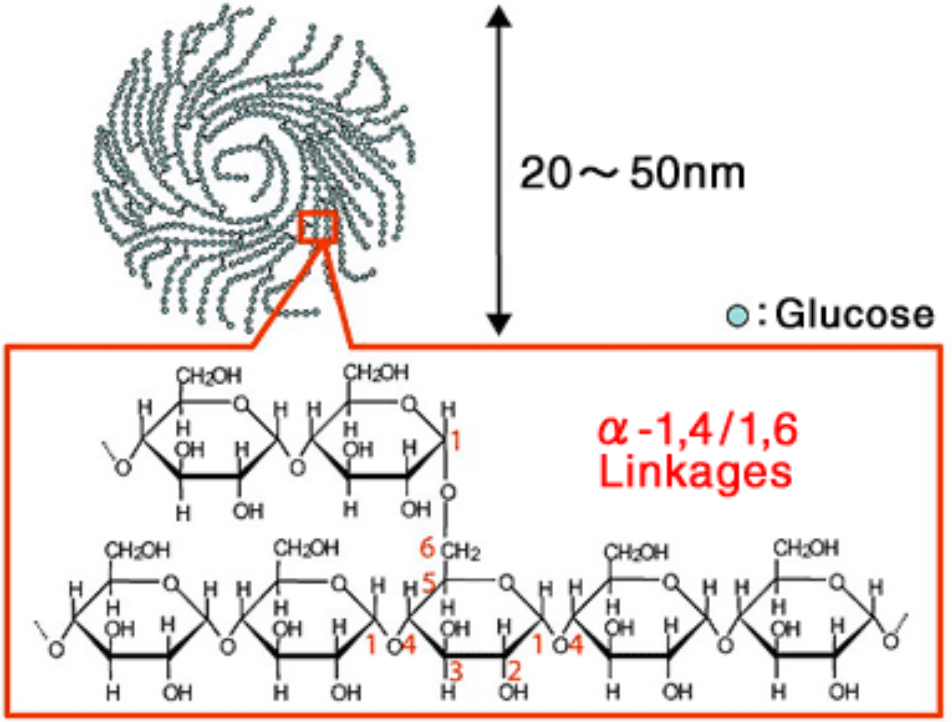
4. The produced monosaccharides (glucose residues) are absorbed by the intestine and transported to the bloodstream



Storage Polysaccharides

Glycogen: is the storage polysaccharide in animal & human

- Polymer composed of glucose units like amylopectin but glycogen is more highly branched with branch points occurring every 8-14 residues
- Mainly found in skeletal muscle (up to 1-2% of muscle mass) and liver cells (up to 10% of liver mass)

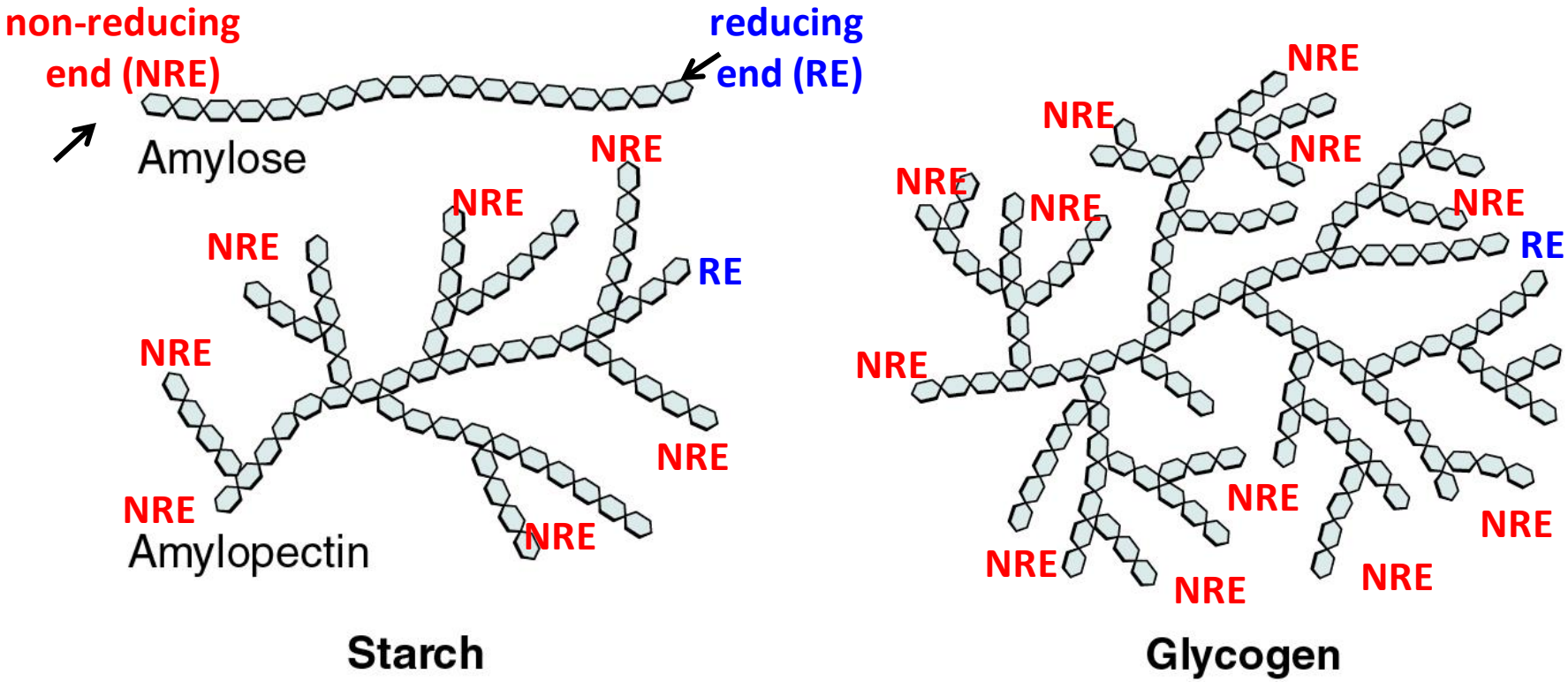


Synthesis & Breakdown of Glycogen

- Some tissues particularly the brain cells require a constant supply of blood glucose for survival
- Some tissues particularly liver and skeletal muscles store glucose in a form that can be rapidly mobilized (i.e. glycogen)
- Glycogen in synthesized (glycogenesis) when blood glucose is high and glycogen is degraded (glycogenolysis) releasing glucose into the blood stream when blood glucose is low (normal blood glucose level is 80-100 mg/dl)
- This balance between the need and availability is called metabolic homeostasis

Storage Polysaccharides

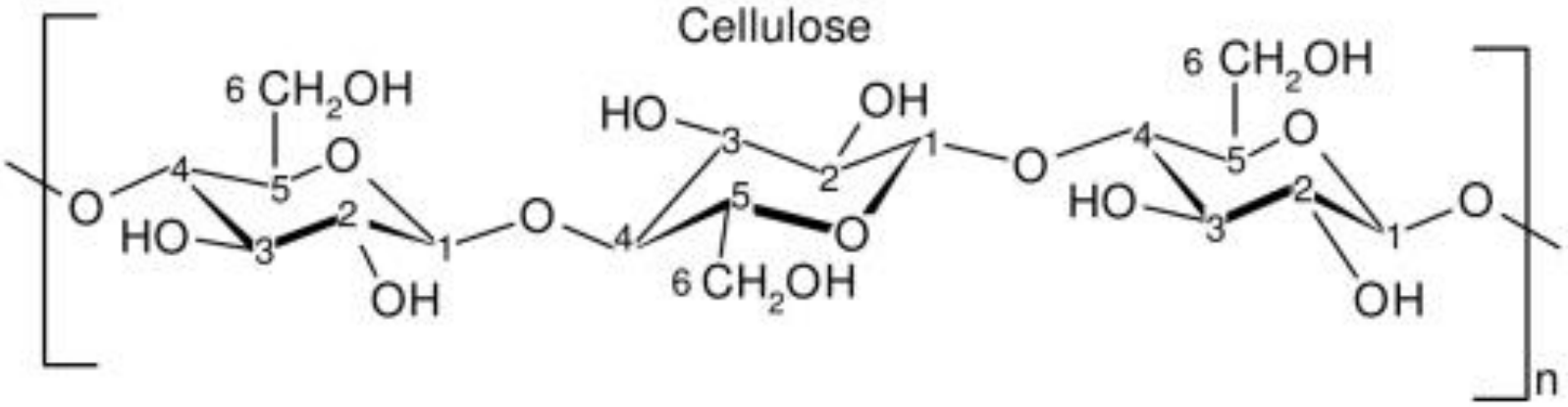
- Starch and glycogen have one reducing end (the molecule end containing a free anomeric carbon C1). On the other hand, the branches ends are all called non-reducing ends and being sites where enzymatic lengthening and degradation occur.



Structural Polysaccharides

Cellulose: the primary structural component of plant cell walls.

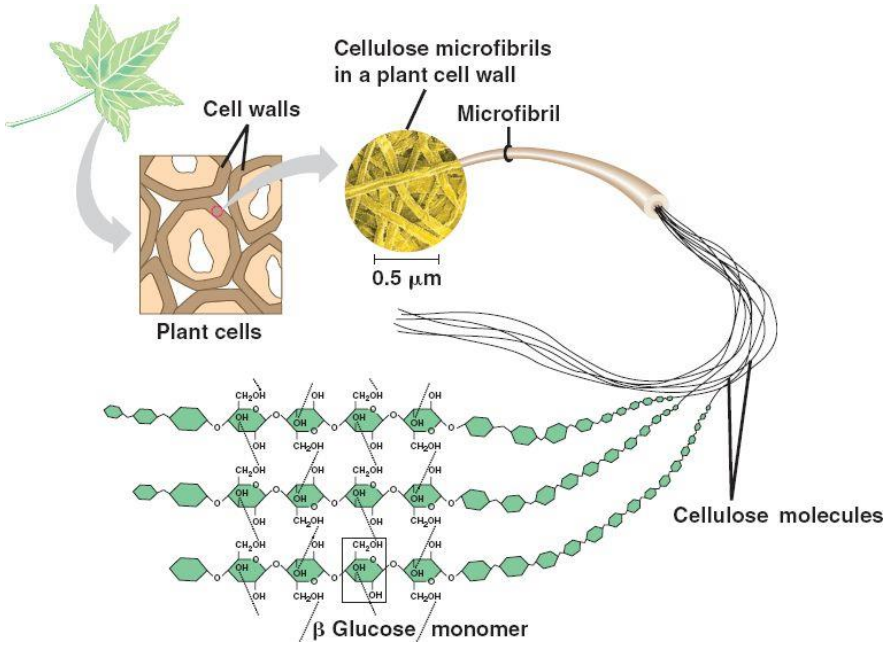
- A linear polymer of D-glucose residues linked via β-(1-4) glycosidic bonds.

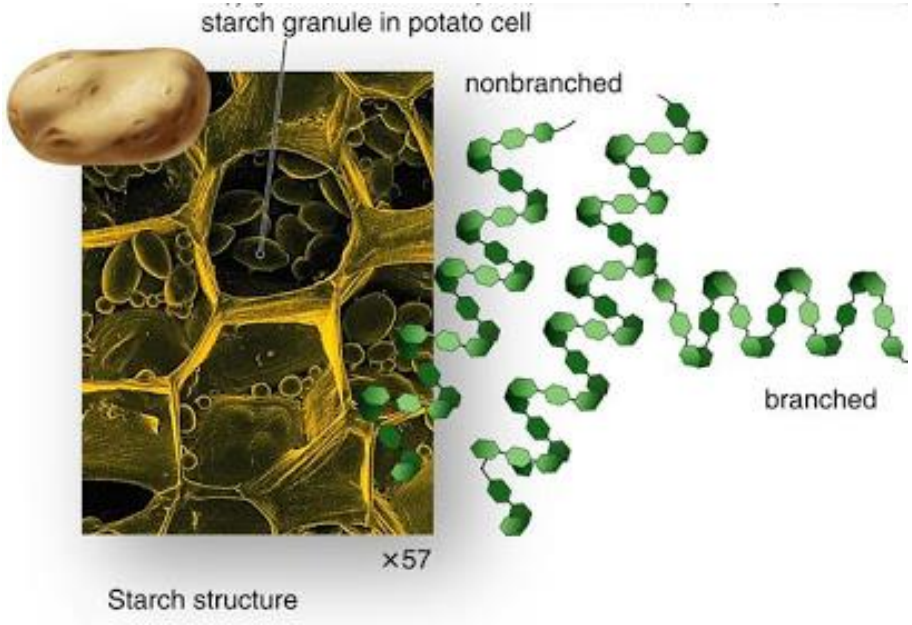


- It is the most abundant organic molecule on the earth. cellulose accounts for over half of the carbon in the biosphere.
- It adopts a very different molecular architecture from that of starch (hollow helix) due to its β-linkages.

Structural Polysaccharides

- Cellulose forms very long straight chains. The parallel chains interact with one another through H-bonds





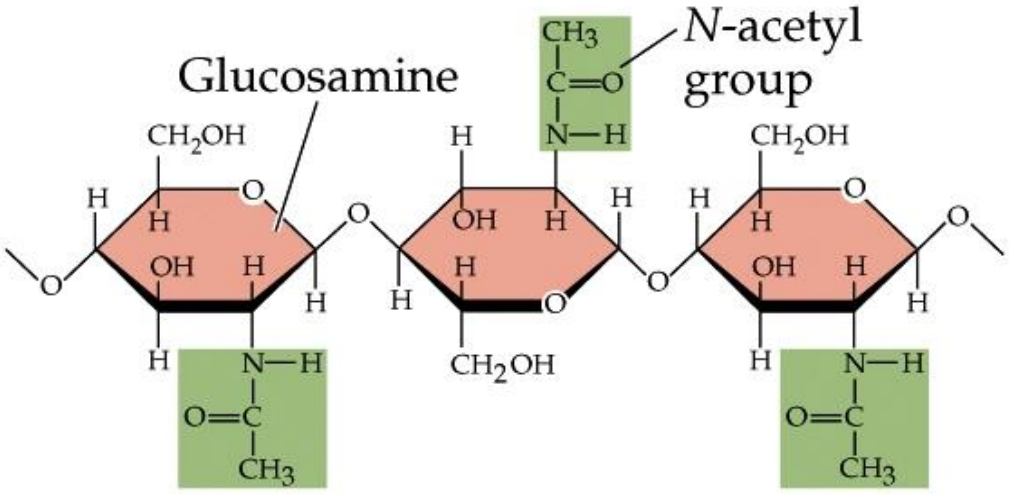
- Compared to humans, herbivores and termites can digest cellulose because they have cellulases enzymes “enzymes capable of hydrolyzing the β-(1-4) bonds of cellulose ”.

Structural Polysaccharides

- Cellulose rich food (like vegetables) is used in patients who have constipation

Chitin:

- It is the structural component of the exoskeletons of the invertebrates like insects and spiders. Also, it is the main component of the cell walls of fungi.
- A long chain polymer of N-acetyl-D-glucosamine residues joined by β-(1-4) bonds.



Structural Polysaccharides

- It has similar structure to cellulose with the only difference is the replacement of OH at C2 of each monomer with acetyl amine group

Chitosan: is a linear polysaccharide composed of randomly distributed β-(1-4)-linked D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit). It is produced **commercially** by deacetylation of chitin (e.g. by treating shrimp shells with the alkali sodium hydroxide).

Medical uses: it is useful in weight loss and obesity treatment plans because it can reduce fat absorption

Heteropolysaccharides

- Consist of two or more different monosaccharide units and are closely associated with lipid (glycolipids) or protein (glycoproteins)
- The naturally occurring heteroglycans are mostly found in the connective tissues (such as cartilage, tendon, blood vessel walls,…..etc)

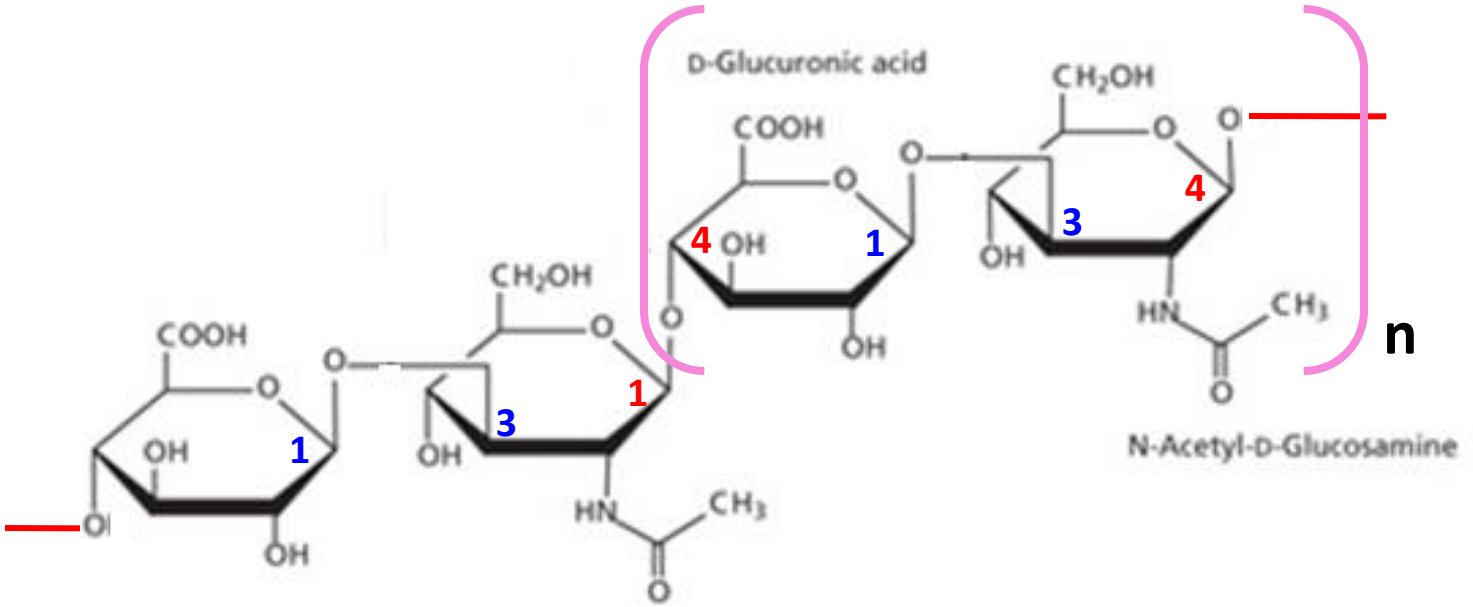
1. **Hyaluronic acid** (Hyaluronate)

- It is the major component of joint fluid (synovial fluid). It acts as a lubricating agent and shock absorber.

- It is also a major component of skin, where it is involved in tissue repair. Dry and scaly skin such as that caused by eczema may be treated with a prescription skin lotion containing sodium hyaluronate as its active ingredient.

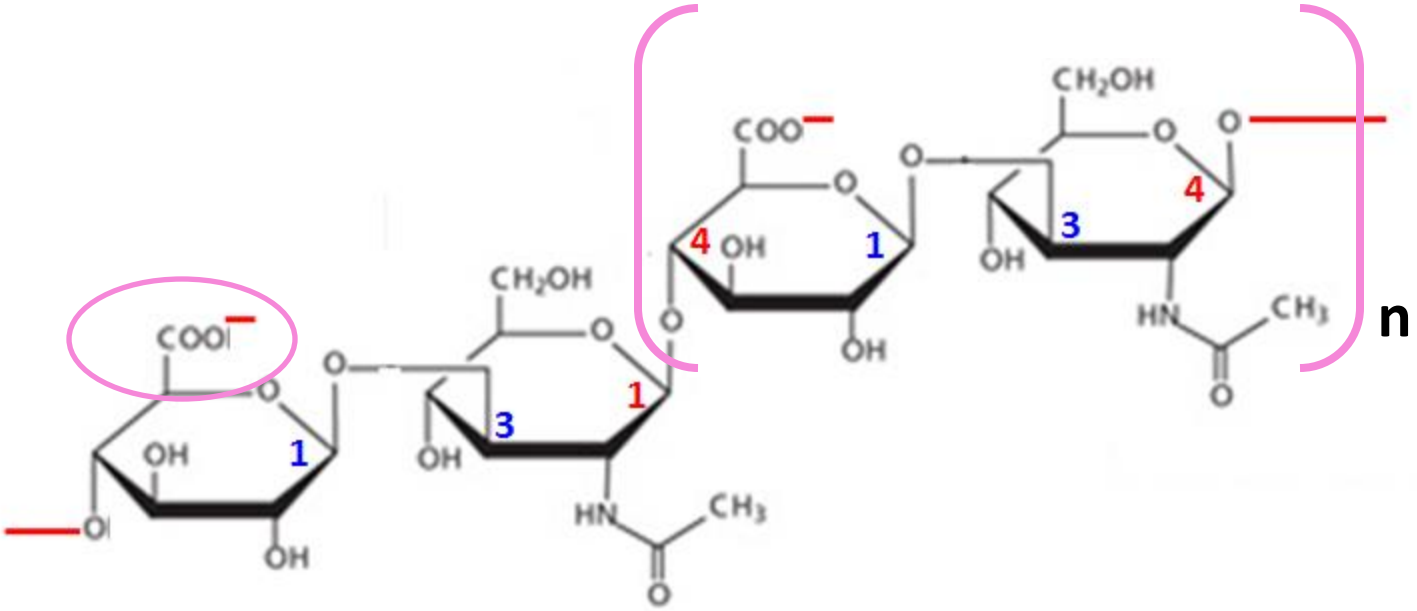
Heteropolysaccharides

- Hyaluronic acid is a **linear** polymer of the disaccharides " D-glucuronic acid and N-acetyl-D-glucosamine " linked via alternating **β-1,4** and **β-1,3** glycosidic bonds.



Hyaluronic Acid

Heteropolysaccharides



D-Glucuronate
(**anion**)

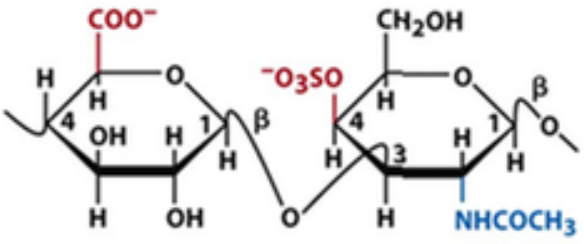
N-Acetyl-D-Glucosamine

Hyaluronate (anionic polymer)

Heteropolysaccharides

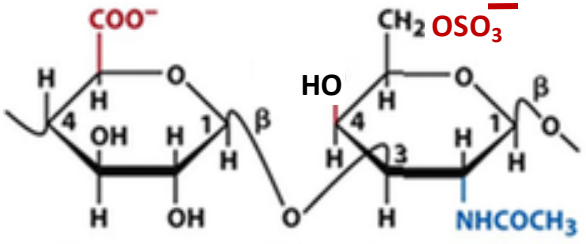
2. **Sulfated heteroglycans** these consist of sulfated disaccharide units such as: chondroitin sulfate, dermatan sulfate, keratan sulfate and heparin

   - **Chondroitin-4-sulfate & Chondroitin-6-sulfate** are unbranched polymers containing the disaccharide " D-glucuronic acid and N-acetyl-D-galactosamine " with the N-acetyl-D-galactosamine OH groups at position 4 and 6 being sulfated, respectively.



D-Glucuronate N-acetyl-D-galactosamine-4-sulfate

Chondroitin-4-sulfate



D-Glucuronate N-acetyl-D-galactosamine-6-sulfate

Chondroitin-6-sulfate

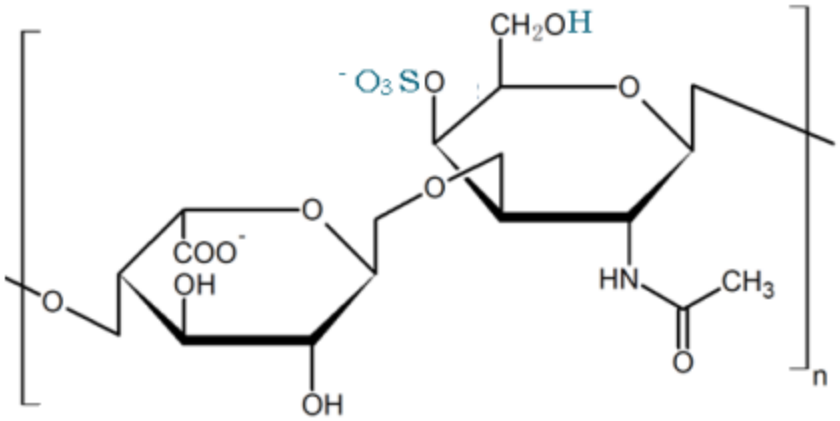
Heteropolysaccharides

- Chondroitin sulfate is a major component of cartilages. They provide them with resistance to compression. Loss of chondroitin sulfate from the cartilage is a major cause of osteoarthritis.

- Chondroitin is used as dietary supplement to treat osteoarthritis. It is commonly sold together with glucosamine

Heteropolysaccharides

- Dermatan sulfate: is a natural polysaccharide found mostly in the skin. It is a linear polymer of a disaccharide containing L-Iduronic acid (modified L-Idose sugar) and N-acetyl-D-galactosamine-4-sulfate

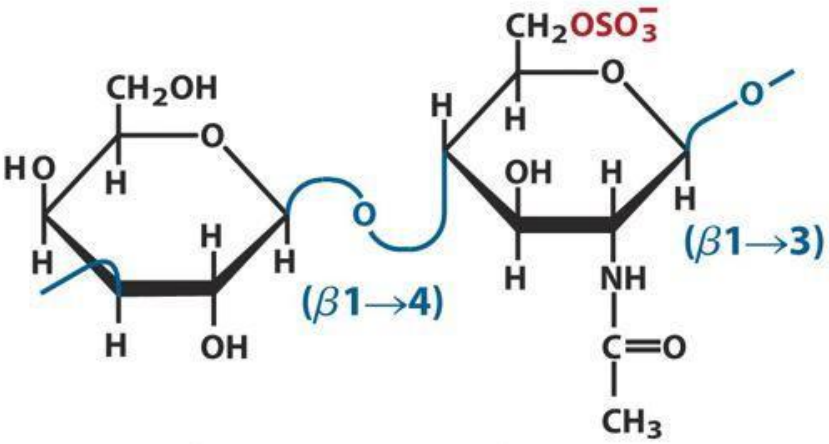


L-Iduronate N-acetyl-D-galactosamine-4-sulfate

Dermatan sulfate

Heteropolysaccharides

- Keratan sulfate: is a natural polysaccharide mainly found in the cartilage and bone. It is highly hydrated molecules which in joints can act as a cushion to absorb mechanical shock. This linear polymer is consisting of repeating disaccharide unit containing D-galactose and N-acetyl-D-glucosamine-6-sulfate

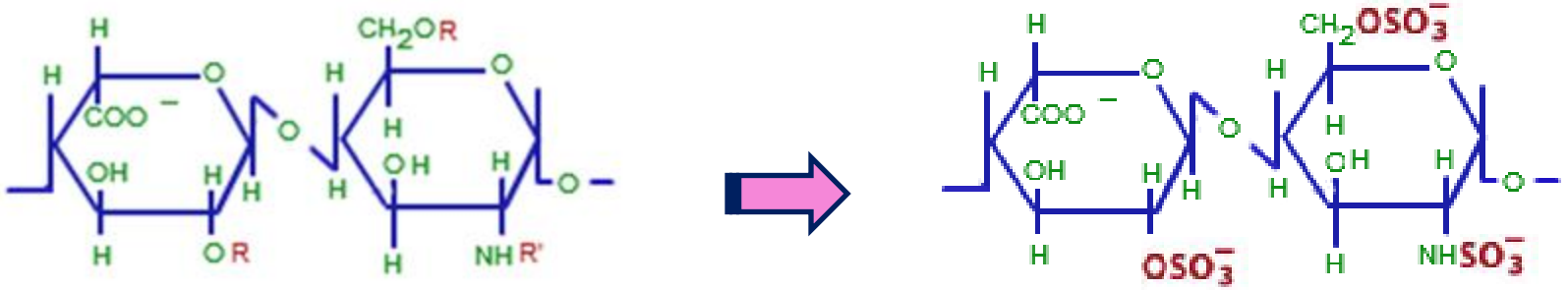


D-galactose N-acetyl-D-glucosamine-6-sulfate

Keratan sulfate

Heteropolysaccharides

- Heparin: is the most highly charged polymer of any known biological molecule. Heparin is a complex mixture of linear polysaccharide and it varies in the degree of sulphation of its sugar units. One example is the sulfated disaccharide unit containing L-Iduronate-2-sulfate and N-sulfo-D-glucosamine-6-sulfate



L-Iduronic acid D-glucosamine L-Iduronate-2-sulfate N-sulfo-D-glucosamine-6-sulfate

Heparin

Heteropolysaccharides

- Heparin is stored almost exclusively within the secretory granules of mast cells and it inhibits blood clotting. So, heparin is widely used as an injectable anticoagulant (e.g. postsurgical patients)