Biochemistry

Carbohydrates

Lecture 4

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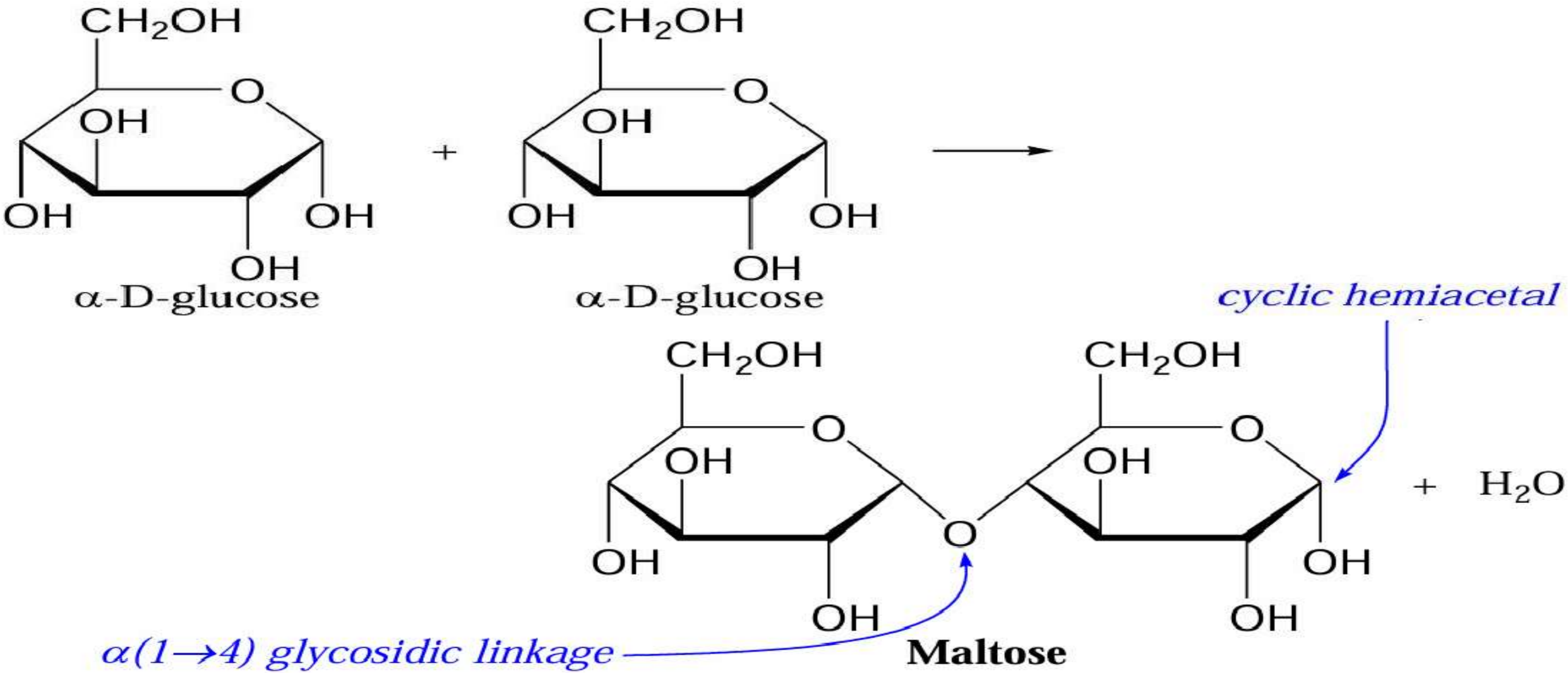
Disaccharides and Oligosaccharides

Disaccharides

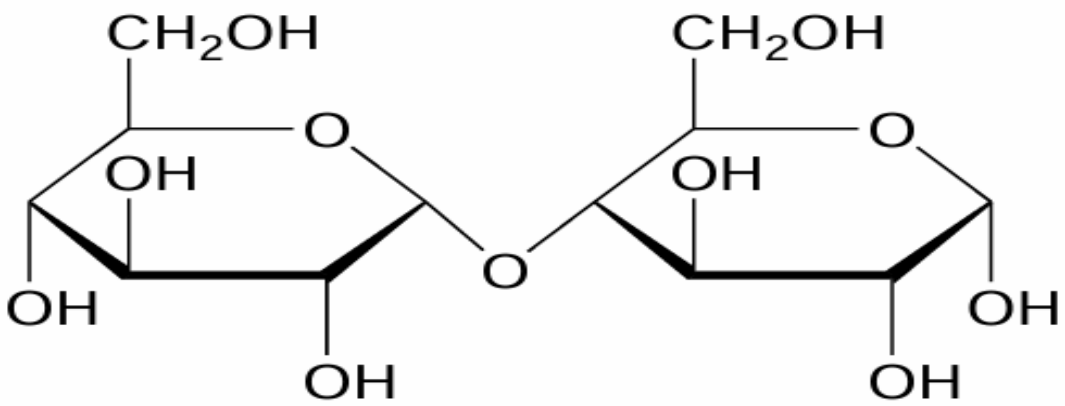
- Two monosaccharides can be linked together through a glycosidic linkage to form a **disaccharide**.



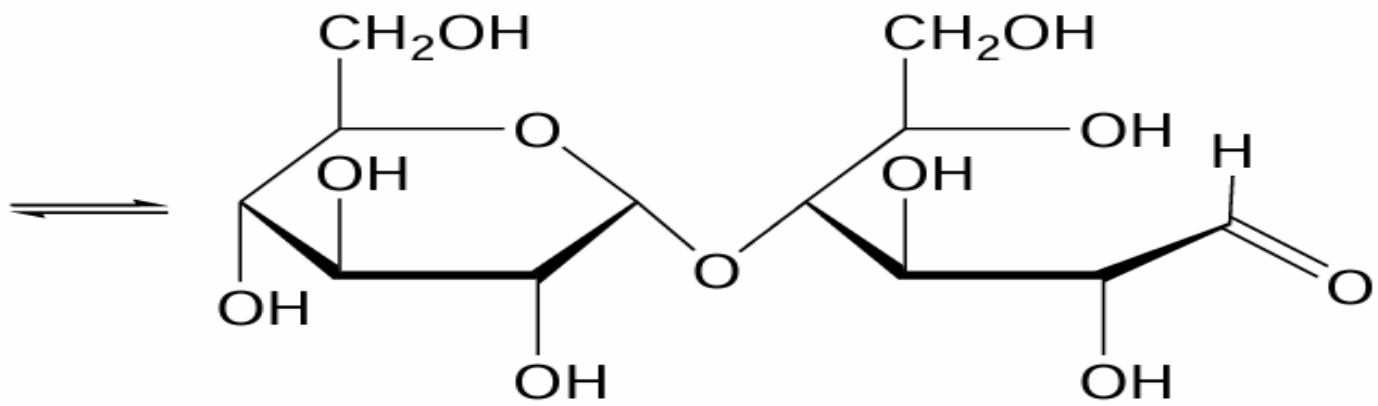
Disaccharides

- Disaccharides can be hydrolyzed into their mono-saccharide building blocks by boiling them with dilute acids or reacting them with the appropriate enzymes.
- Disaccharides that contain hemiacetal groups are reducing sugars.

$$\text{maltose} + H_2O \xrightarrow{H^+} \text{D-glucose} + \text{D-glucose}$$

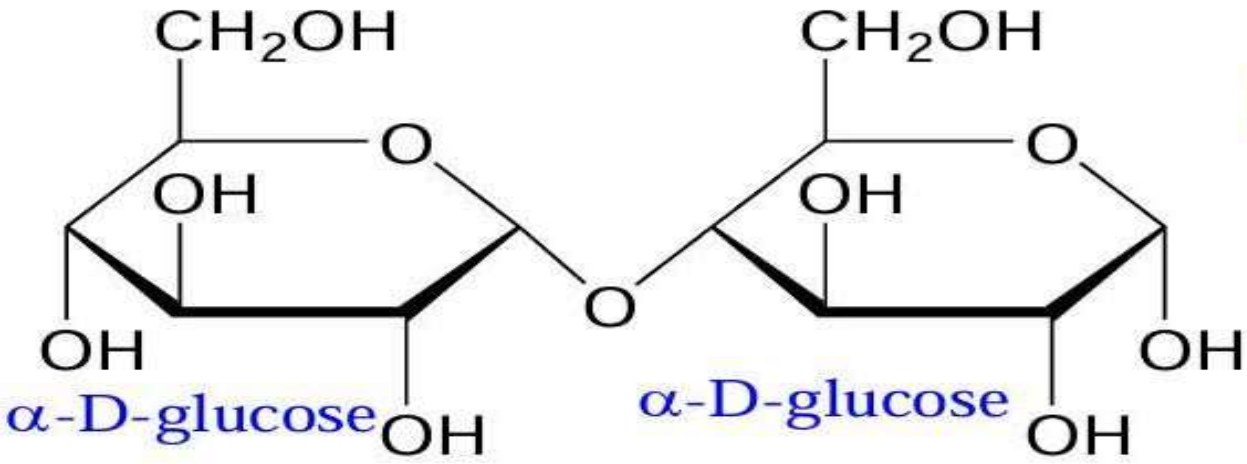


Maltose



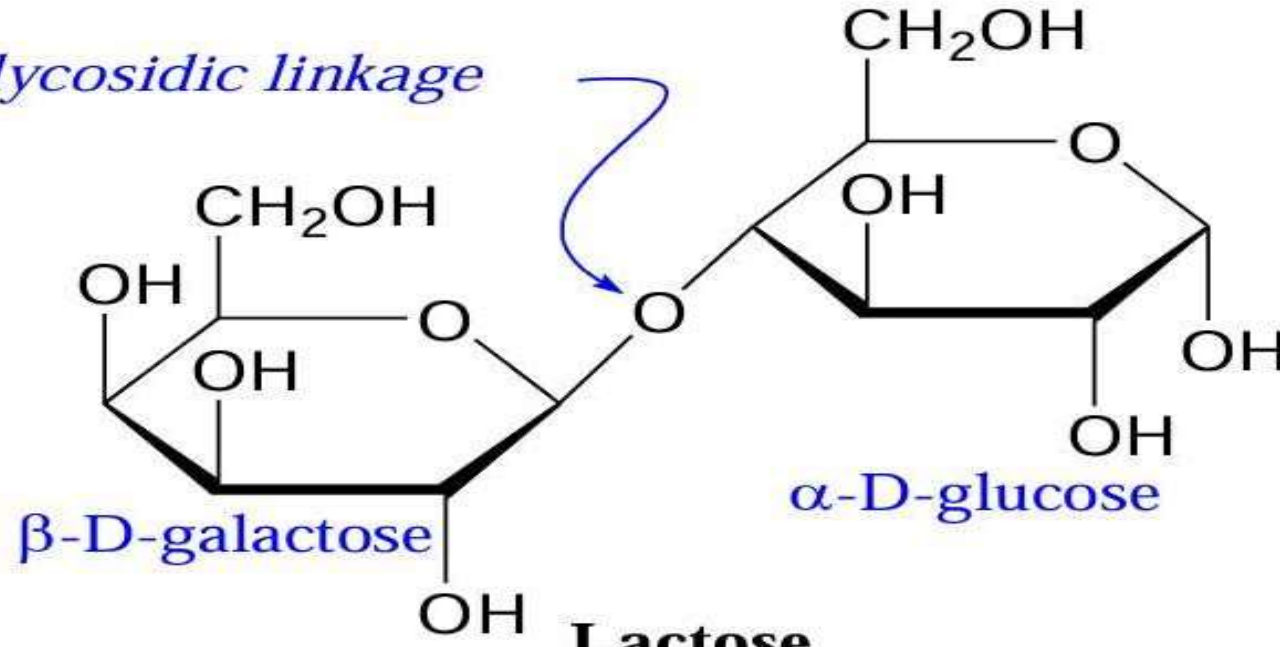
reacts with Benedict's reagent

Important Disaccharides



Maltose

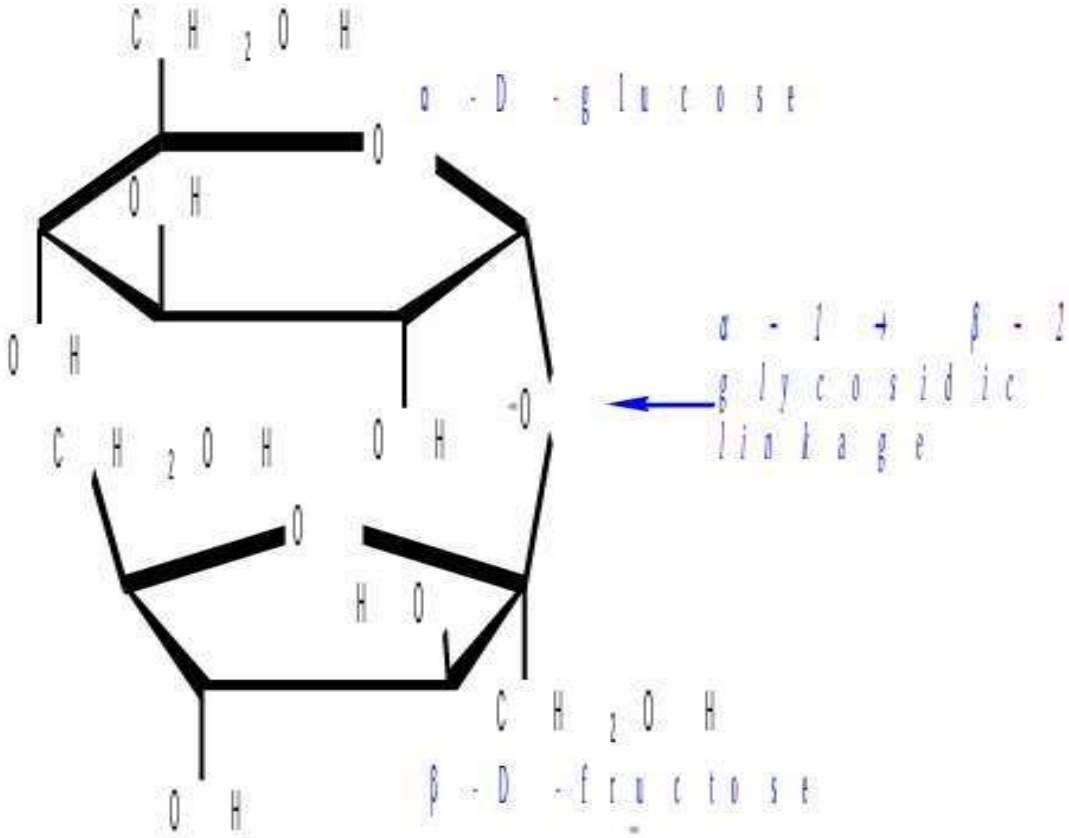
Also known as *malt sugar*. It is produced in germinating grain (such as barley) as starch is broken down during malting, and is formed during the hydrolysis of starch to glucose during digestion.

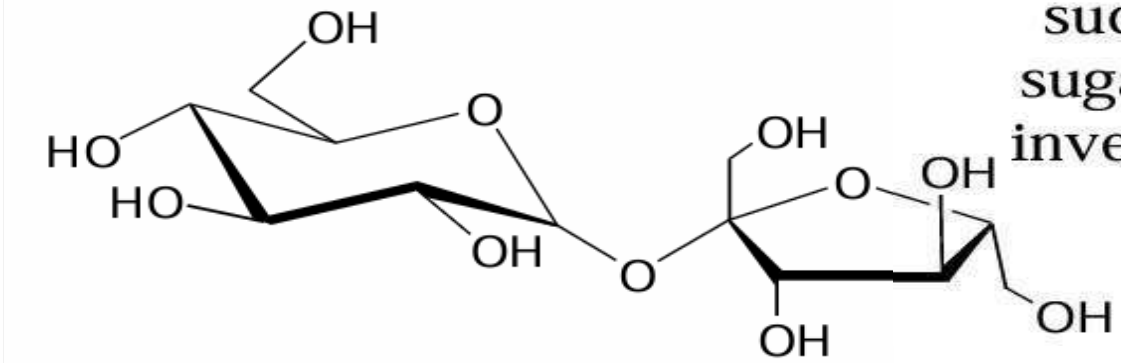


Lactose

Also known as *milk sugar*. Lactose constitutes 5% of cow's milk and 7% of human milk. It is digested by the enzyme *lactase*. Pure lactose is found in whey, the watery byproduct of cheese production.

Important Disaccharides





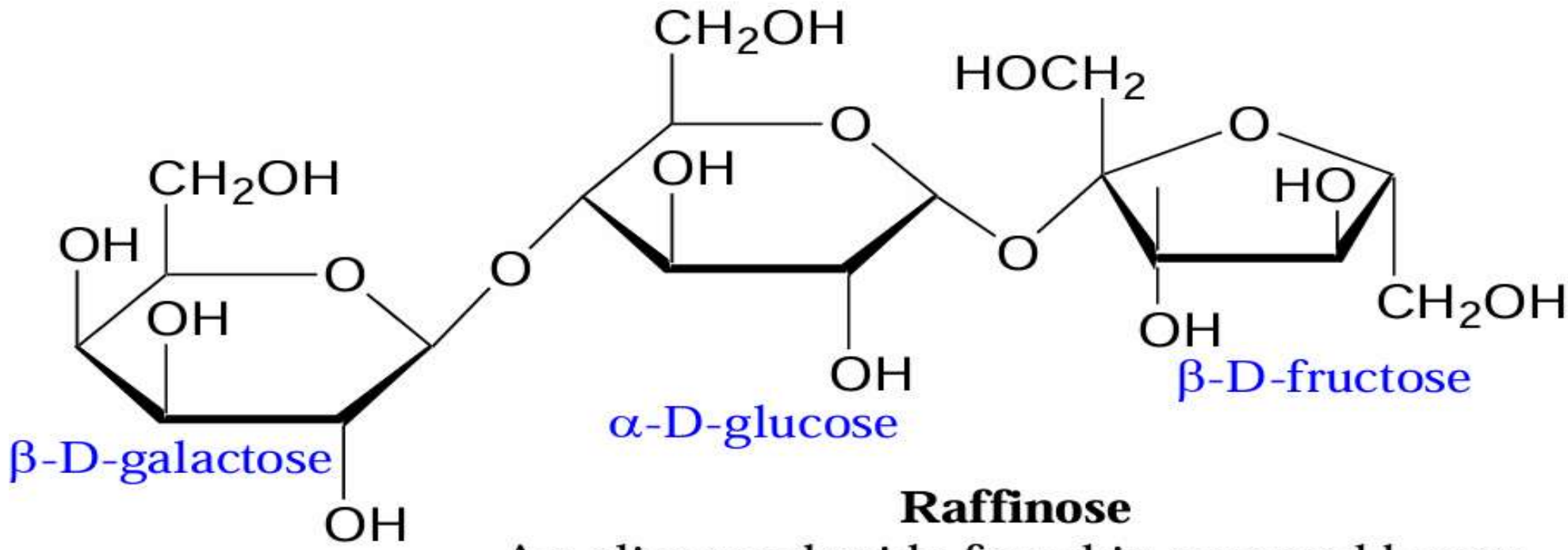
Sucrose

Also known as *table sugar*. Both anomeric carbons of glucose and fructose are tied together in the glycosidic linkage; thus neither ring can open, and sucrose is *not* a reducing sugar.

Sucrose is found in fruits, nectar, sugar cane, and sugar beets; maple syrup contains about 65% sucrose, with glucose and fructose present as well. *Caramel* is the solid residue formed from heating sucrose. A flavoring agent called *invert sugar* is produced by the hydrolysis of sucrose under acidic conditions, which breaks it apart into glucose and fructose; invert sugar is sweeter than sucrose because of the fructose. Some of the sugar found in honey is formed in this fashion; invert sugar is also produced in jams and jellies prepared from acid-containing fruits.

Oligosaccharides

- Oligosaccharides contain from 3 to 10 monosaccharide units.



Raffinose

An oligosaccharide found in peas and beans; largely undigested until reaching the intestinal flora in the large intestine, releasing hydrogen, carbon dioxide, and methane)

Polysaccharides

Polysaccharides

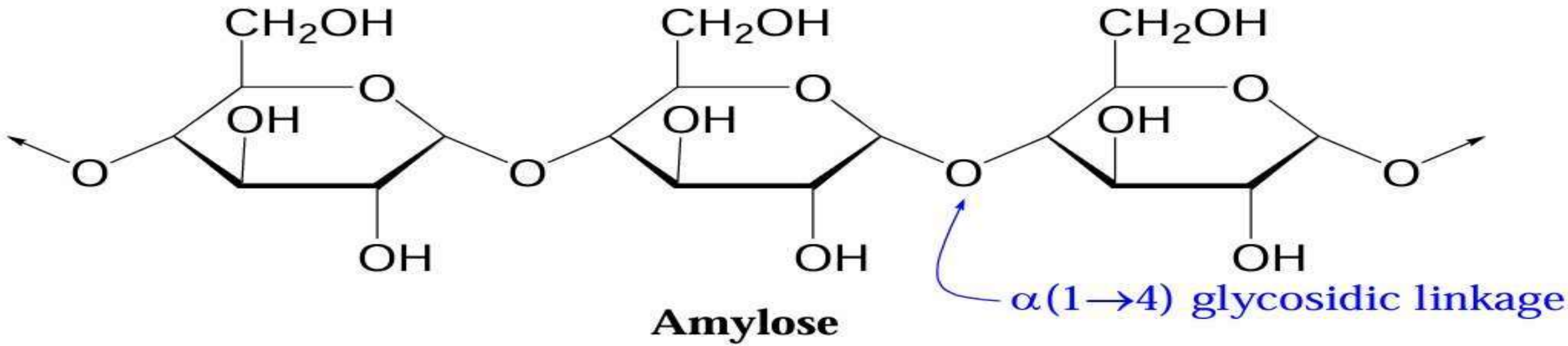
- **Polysaccharides** contain hundreds or thousands of carbohydrate units.
- Polysaccharides are *not* reducing sugars, since the anomeric carbons are connected through glycosidic linkages.
- We will consider three kinds of polysaccharides, all of which are polymers of glucose: *starch*, *glycogen*, and *cellulose*.

Starch

- **Starch** is a polymer consisting of D-glucose units.
- Starches (and other glucose polymers) are usually insoluble in water because of the high molecular weight.
  - Because they contain large numbers of OH groups, some starches can form thick colloidal dispersions when heated in water (e.g., flour or starch used as a thickening agent in gravies or sauces).
- There are two forms of starch: **amylose** and **amylopectin**.

Starch — Amylose

- **Amylose** consists of long, *unbranched* chains of glucose (from 1000 to 2000 molecules) connected by $\alpha(1\rightarrow4)$ glycosidic linkages.

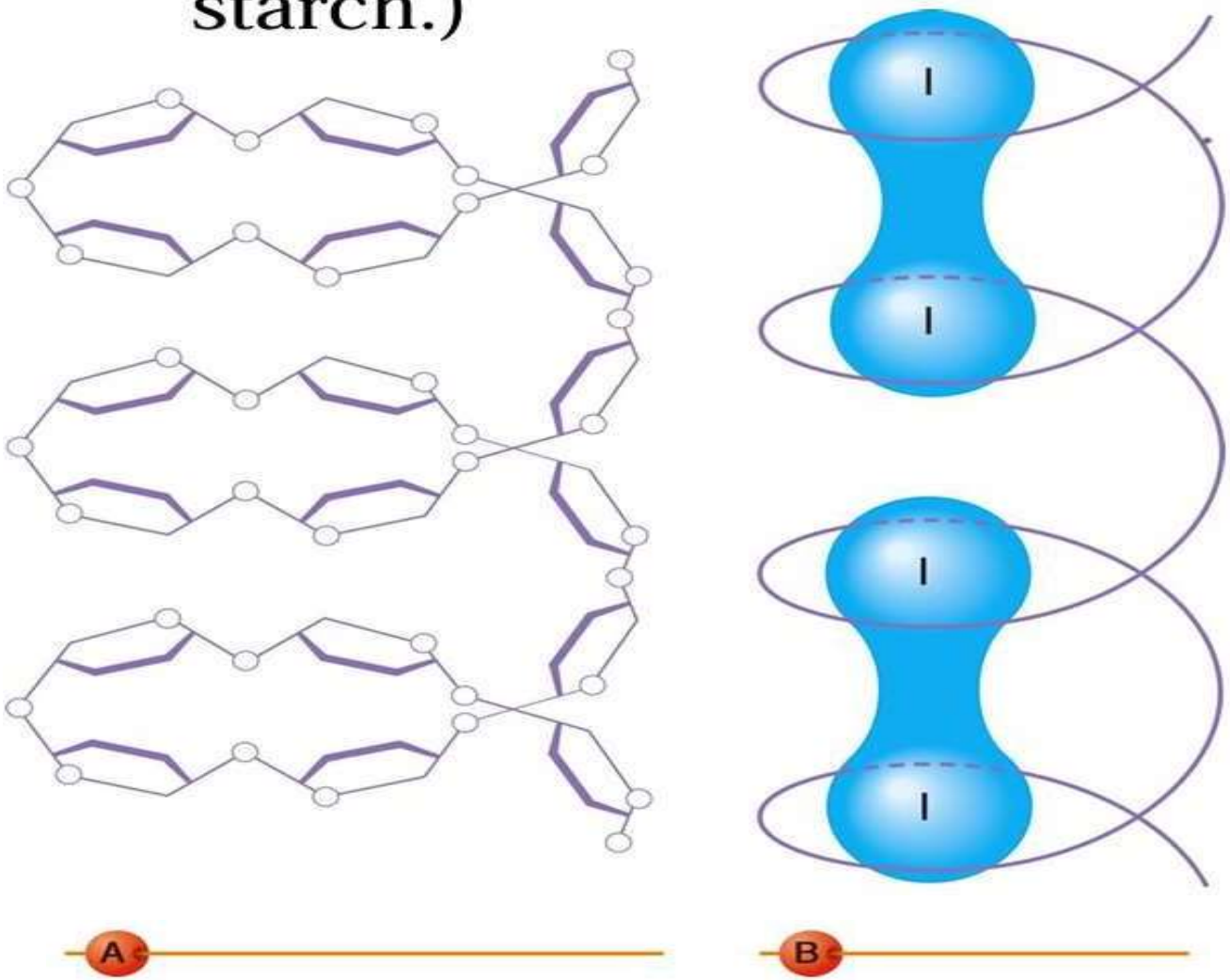


Amylose

- 10%-20% of the starch in plants is in this form.
- The amylose chain is flexible enough to allow the molecules to twist into the shape of a helix. Because it packs more tightly, it is slower to digest than other starches.

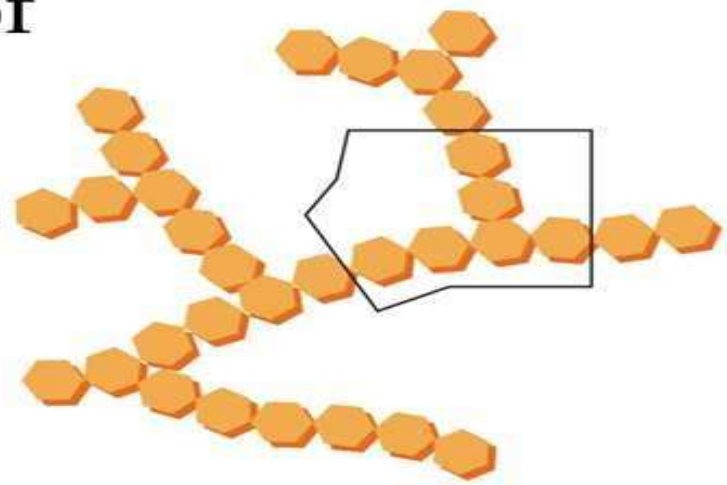
Starch — Amylose

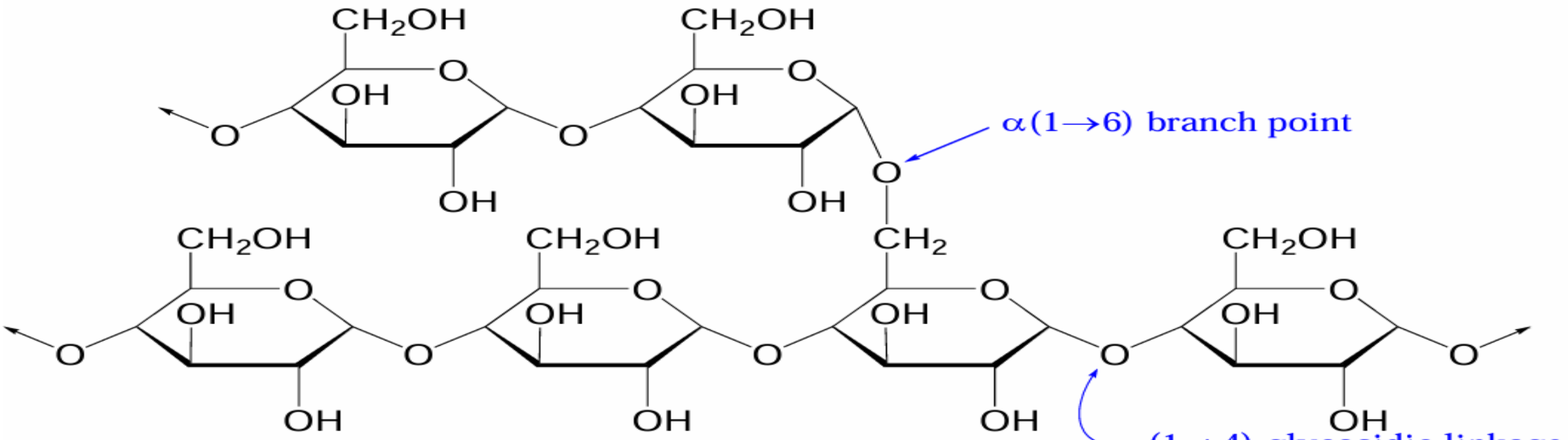
- Amylose helices can trap molecules of iodine, forming a characteristic deep blue-purple color. (Iodine is often used as a test for the presence of starch.)



Starch — Amylopectin

- **Amylopectin** consists of long chains of glucose (up to 10^5 molecules) connected by $\alpha(1\rightarrow4)$ glycosidic linkages, with $\alpha(1\rightarrow6)$ branches every 24 to 30 glucose units along the chain.
- 80%-90% of the starch in plants is in this form.

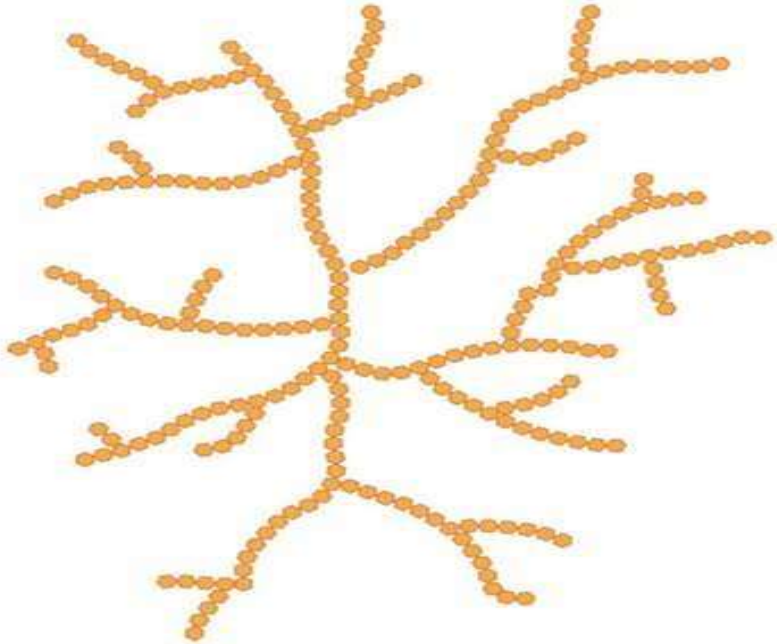




Amylopectin

Glycogen

- **Glycogen**, also known as *animal starch*, is structurally similar to amylopectin, containing both $\alpha(1\rightarrow4)$ glycosidic linkages and $\alpha(1\rightarrow6)$ branch points. Glycogen is even more highly branched, with branches occurring every 8 to 12 glucose units.
- Glycogen is abundant in the liver and muscles; on hydrolysis it forms D-glucose, which maintains normal blood sugar level and provides energy.



Starches (plants)

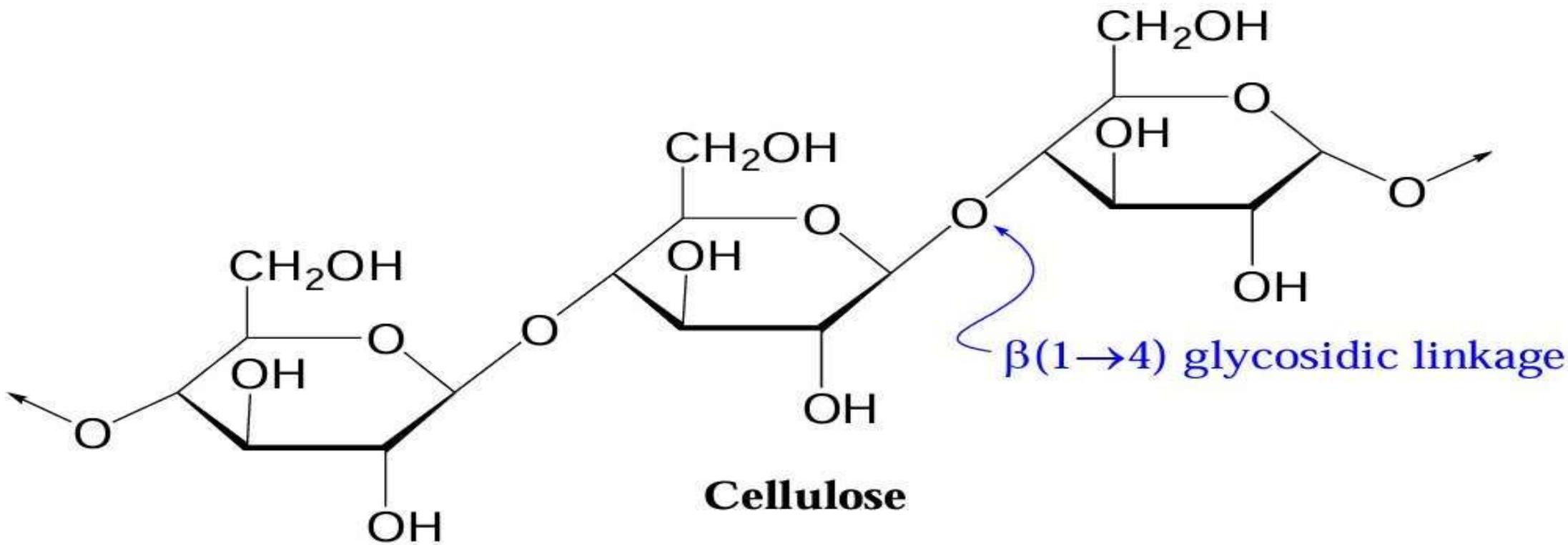
Amylose – unbranched

Amylopectin – branched

Glycogen (animals) – highly branched

Cellulose

- **Cellulose** is a polymer consisting of long, *unbranched* chains of D-glucose connected by β(1→4) glycosidic linkages; it may contain from 300 to 3000 glucose units in one molecule.



Cellulose

Cellulose

- Because of the β-linkages, cellulose has a different overall shape from amylose, forming extended straight chains which hydrogen bond to each other, resulting in a very rigid structure.
- Cellulose is the most important structural polysaccharide, and is the single most abundant organic compound on earth. It is the material in plant cell walls that provides strength and rigidity; wood is 50% cellulose.

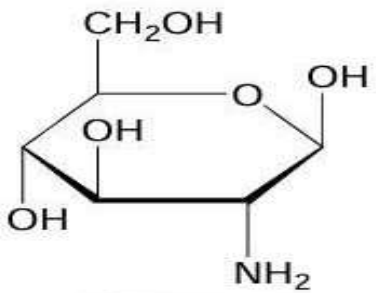
Plant cell wall

Cellulose

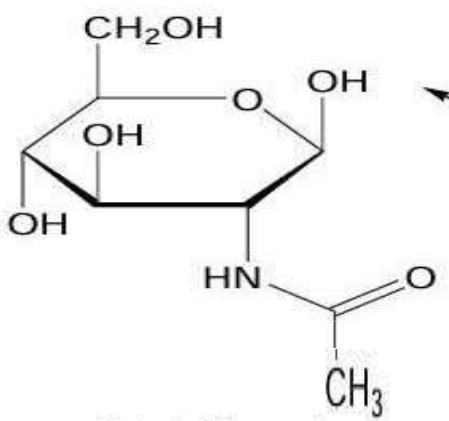
- Most animals lack the enzymes needed to digest cellulose, but it does provide roughage (dietary fiber) to stimulate contraction of the intestines and help pass food through the digestive system.
  - Some animals, such as cows, sheep, and goats (ruminants), process cellulose using colonies of bacteria in the digestive system which are capable of breaking down cellulose, and a series of stomachs to give cellulose a longer time to digest.
  - Some other animals have a longer intestinal tract (e.g., horses), and others reprocess digested food (e.g., rabbits) to allow more time for the breakdown of cellulose to occur.
- Cellulose is important industrially, from its presence in wood, paper, cotton, cellophane, rayon, linen, nitrocellulose (guncotton), photographic films (cellulose acetate), etc.

Chitin

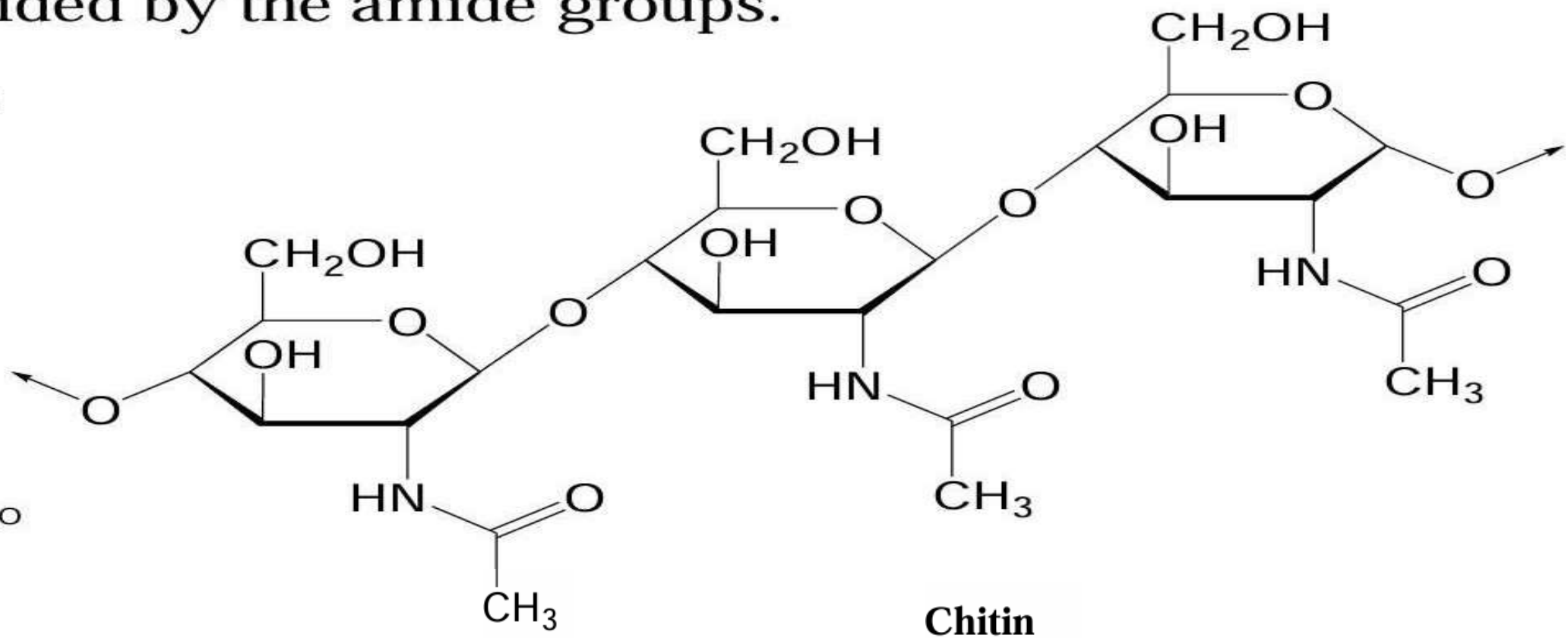
- **Chitin** is a polymer of N-acetylglucosamine, an amide derivative of the *amino sugar* glucosamine, in which one of the OH groups is converted to an amine (NH_2) group. The polymer is extremely strong because of the increased hydrogen bonding provided by the amide groups.



Glucosamine



N-Acetylglucosamine



Chitin

Chitin

- Chitin is the main component of the cell walls of fungi, the exoskeletons of arthropods such as crustaceans and insects, and the beaks of cephalopods. The chitin is often embedded in either a protein matrix, or in calcium carbonate crystals. Since this matrix cannot expand easily, it must be shed by molting as the animal grows.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