CHAPTER NAME :
CARBOHYDRATES

CLASS: B.SC. II
SEM-II
SUB: ORGANIC CHEMISTRY

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CLASSIFICATION OF CARBOHYDRATES

Carbohydrates are mainly classified into four different groups:

- **Monosachharides**
- **Disaccharides**
- **Oligosaccharides**
- **Polysaccharides**

Carbohydrates – polyhydroxyaldehydes or polyhydroxy-ketones of formula $(CH_2O)_n$, or compounds that can be hydrolyzed to them. (aka sugars or saccharides)

Monosaccharides – carbohydrates that cannot be hydrolyzed to simpler carbohydrates; eg. Glucose or fructose.

Disaccharides – carbohydrates that can be hydrolyzed into two monosaccharide units; eg. Sucrose, which is hydrolyzed into glucose and fructose.

Oligosaccharides – carbohydrates that can be hydrolyzed into a few monosaccharide units.

Polysaccharides – carbohydrates that are are polymeric sugars; eg Starch or cellulose.

MONOSACCHARIDES

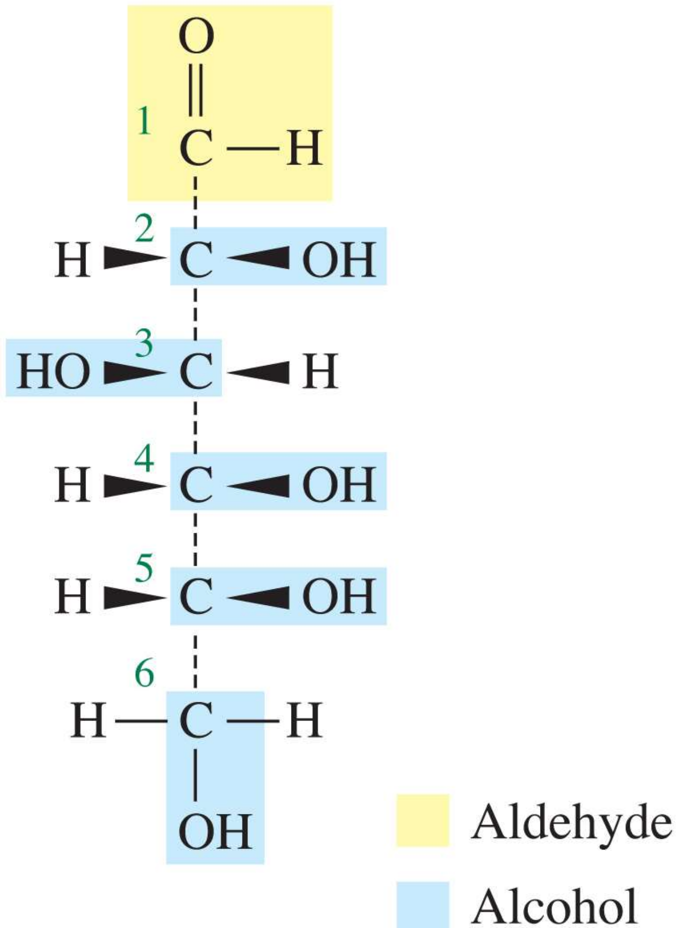
- Monosaccharides contain the elements carbon, hydrogen, and oxygen, and have the general formula $C_n(H_2O)_n$, where *n* is a whole number 3 or greater.
- Monosaccharides contain several functional groups. They contain the hydroxyl group represented as –OH. They also contain a ***carbonyl group***, which is an oxygen double bonded to a carbon atom. The carbonyl group may be an aldehyde or a ketone.

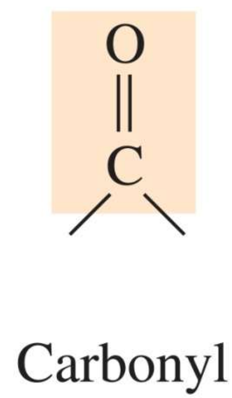
MONOSACCHARIDES ARE FURTHER CLASSIFIED ON THE BASIS OF:

- **Aldehyde or Ketone Group:**
  - Aldomonosaccharides (Aldoses).
  - Ketomonosaccharides (Ketoses).
- **Carbon Chain Length.**
  - Trioses.
  - Tetroses.
  - Pentoses.
  - Hexoses.
  - Heptoses.

MONOSACCHARIDES

The functional groups of glucose are shown in the figure below.





MONOSACCHARIDES

- Monosaccharides that contain an aldehyde group are referred to as an ***aldose***. Those that contain a ketone group are referred to as a ***ketose***.

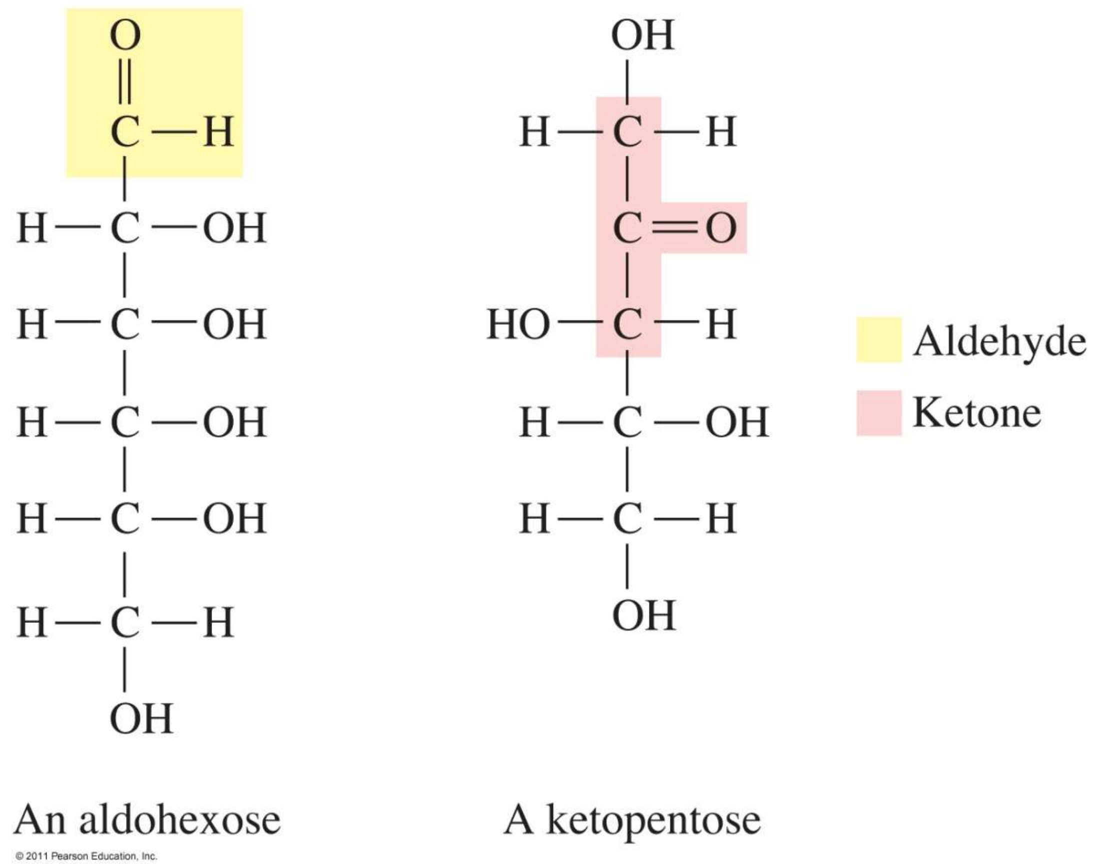
- Monosaccharides are classified according to the number of carbon atoms. Most common monosaccharides have three to six carbon atoms.
  - *Triose* contains three carbons.
  - *Tetrose* contains four carbons.
  - *Pentose* contains five carbons.
  - *Hexose* contains six carbons.

MONOSACCHARIDES

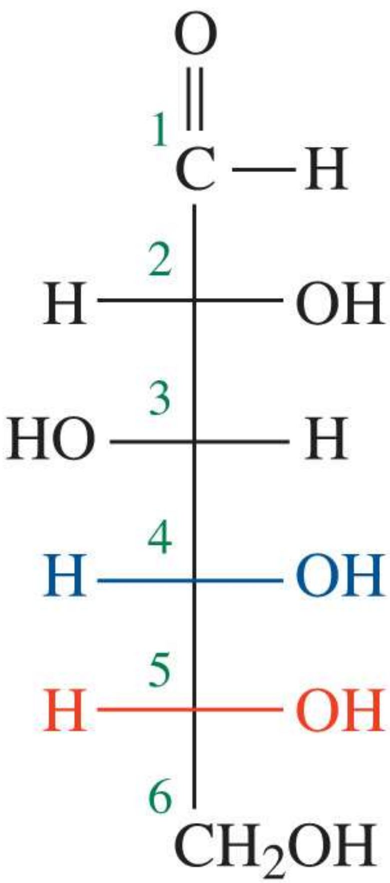
- Carbohydrates are further classified on whether they contain an aldehyde or ketone group.
- For example, glucose, the most abundant monosaccharide found is nature, contains six carbons and an aldehyde group. It is classified as an ***aldohexose***.
- Fructose, known as fruit sugar, contains six carbons and a ketone group. It is classified as a ***ketohexose***.

MONOSACCHARIDES

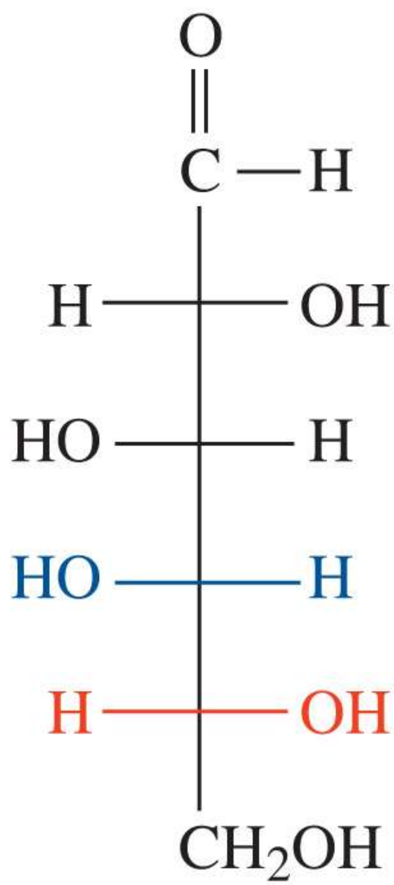
Aldohexose and ketopentose differ in the number of carbon atoms and in the type of carbonyl group they contain.



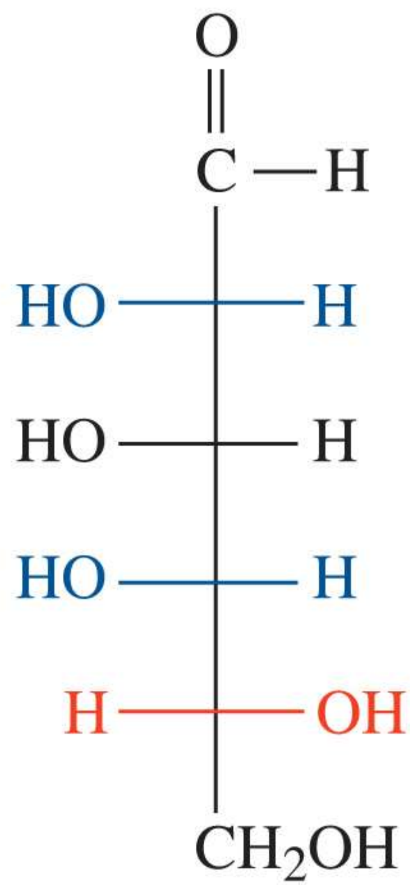
MONOSACCHARIDES



D-Glucose



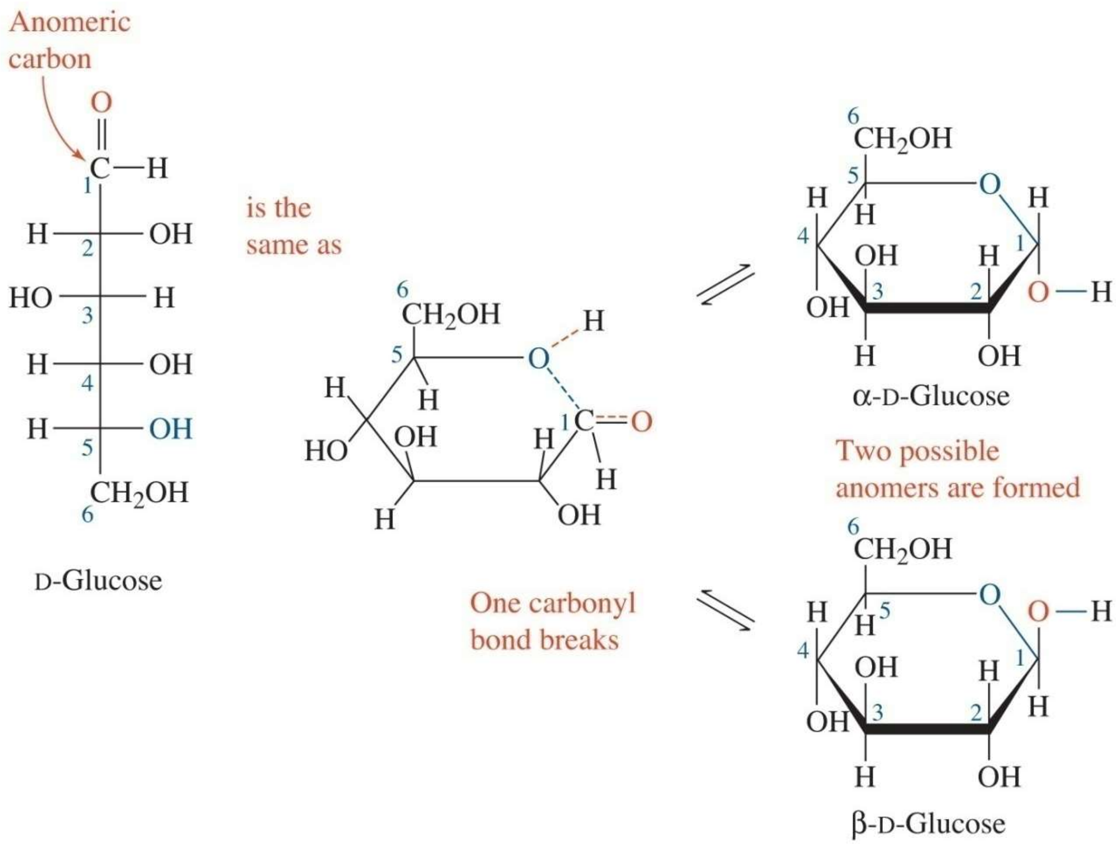
D-Galactose



D-Talose

RING FORMATION—THE MONOSACCHARIDE STRUCTURE

A hemiacetal can form within a monosaccharide since it contains both a carbonyl and several hydroxyl functional groups.



RING FORMATION—THE MONOSACCHARIDE STRUCTURE

- The carbonyl carbon that reacts to form the hemiacetal is referred to as the ***anomeric carbon***.

- Two ring arrangements can be produced. These are termed ***anomers***, and are referred to as the alpha (α) and beta (β) anomer.

- The position of the –OH group on the anomeric carbon relative to the position of the carbon outside the ring determines the type of anomer present.

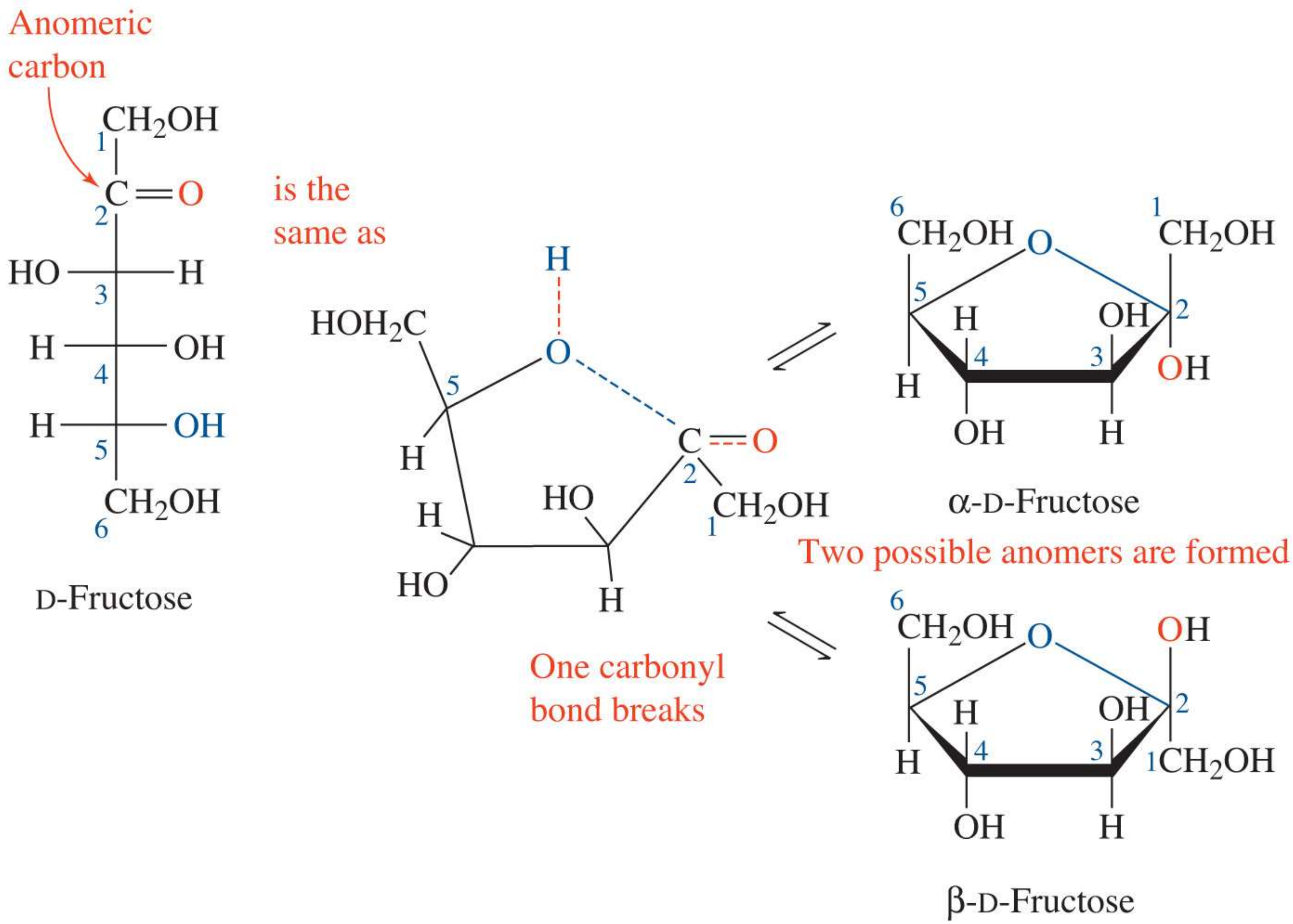
RING FORMATION—THE MONOSACCHARIDE STRUCTURE

- In the six-member ring (five carbons and an oxygen) form of D-isomers, called a ***pyranose***, carbon 6 is always drawn on the top side of the ring.
- In the α anomer, the –OH on the anomeric carbon is trans to the carbon outside the ring.
- In the ß anomer, the –OH on the anomeric carbon is cis to the carbon outside the ring.

RING FORMATION—THE MONOSACCHARIDE STRUCTURE

- D-Fructose contains both a ketone group and several hydroxyl groups.
- The ring structure of D-fructose contains four carbons and an oxygen to form a five-membered ring called a ***furanose***.
- In a furanose, carbons 1 and 6 remain outside the ring.

RING FORMATION—THE MONOSACCHARIDE STRUCTURE



RING FORMATION—THE MONOSACCHARIDE STRUCTURE

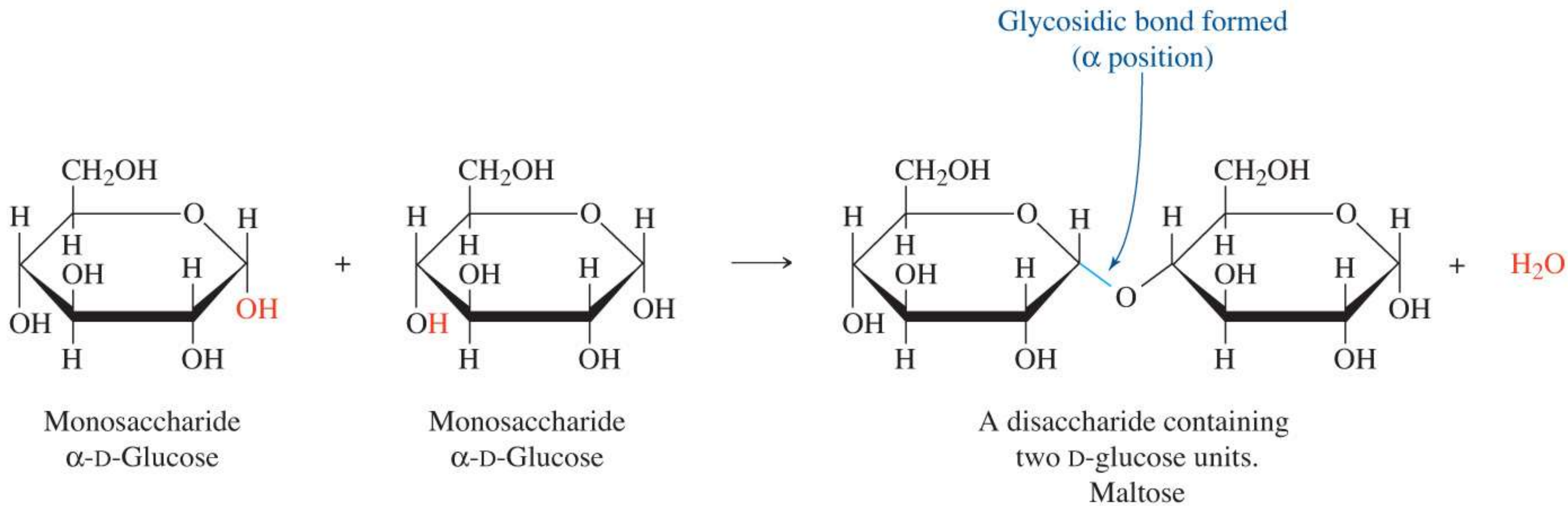
- In a five-membered and six-membered ring, the anomers are distinguished similarly.
- In the alpha anomer, the –OH on the anomeric carbon is trans to the carbon outside the ring.
- In the beta anomer, the –OH on the anomeric carbon is cis to the carbon outside the ring.

DISACCHARIDES

Condensation and Hydrolysis—Forming and Breaking Glycosidic Bonds

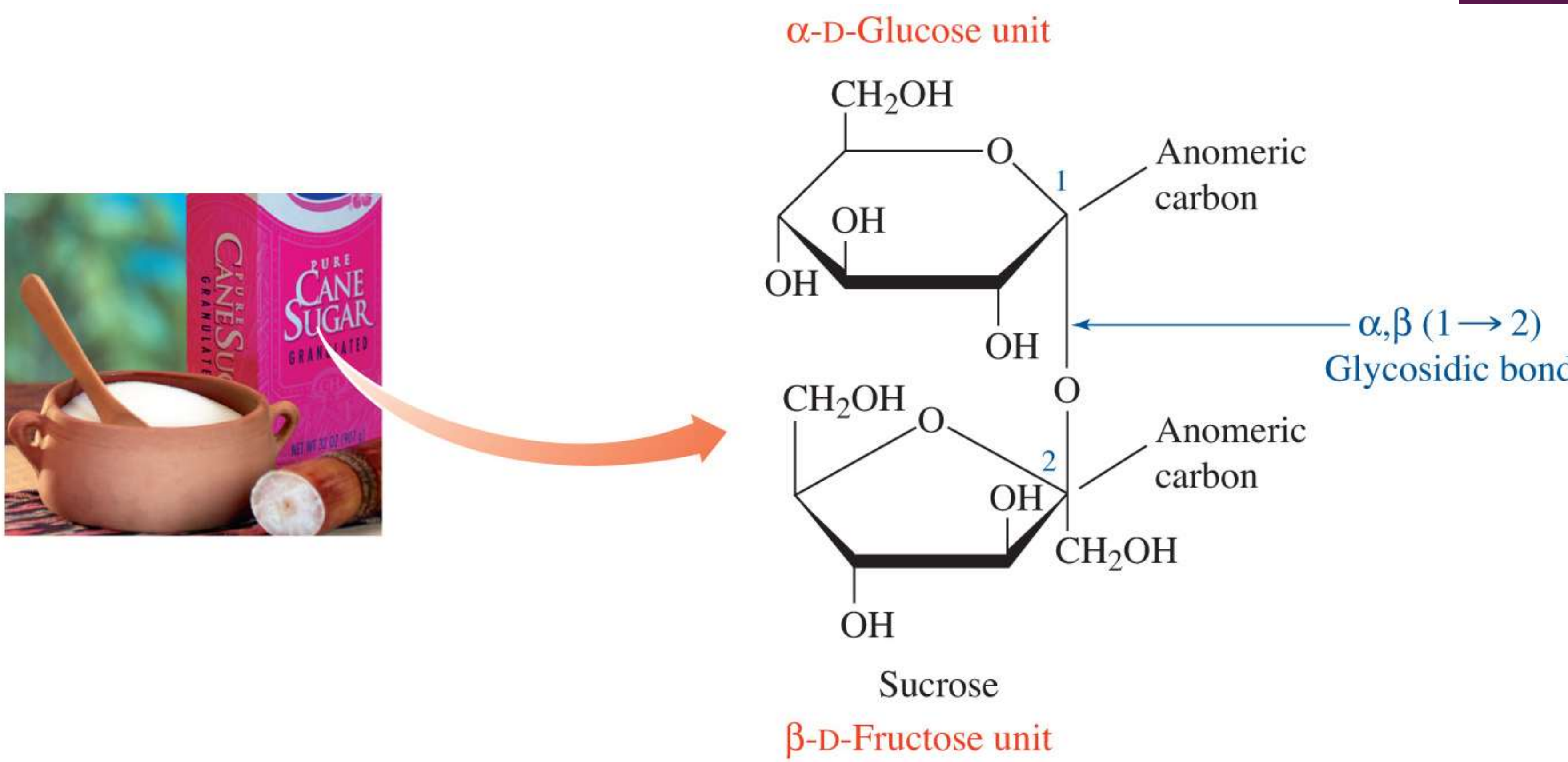
- The –OH group that is most reactive in a monosaccharide is the one on the anomeric carbon.
- When this hydroxyl group reacts with another hydroxyl group on another monosaccharide a ***glycosidic bond*** is formed.

DISACCHARIDES, CONTINUED



Formation of glycosides is an example of another type of organic reaction. During this reaction, a molecule of water is eliminated as two molecules join.

DISACCHARIDES



POLYSACCHARIDES

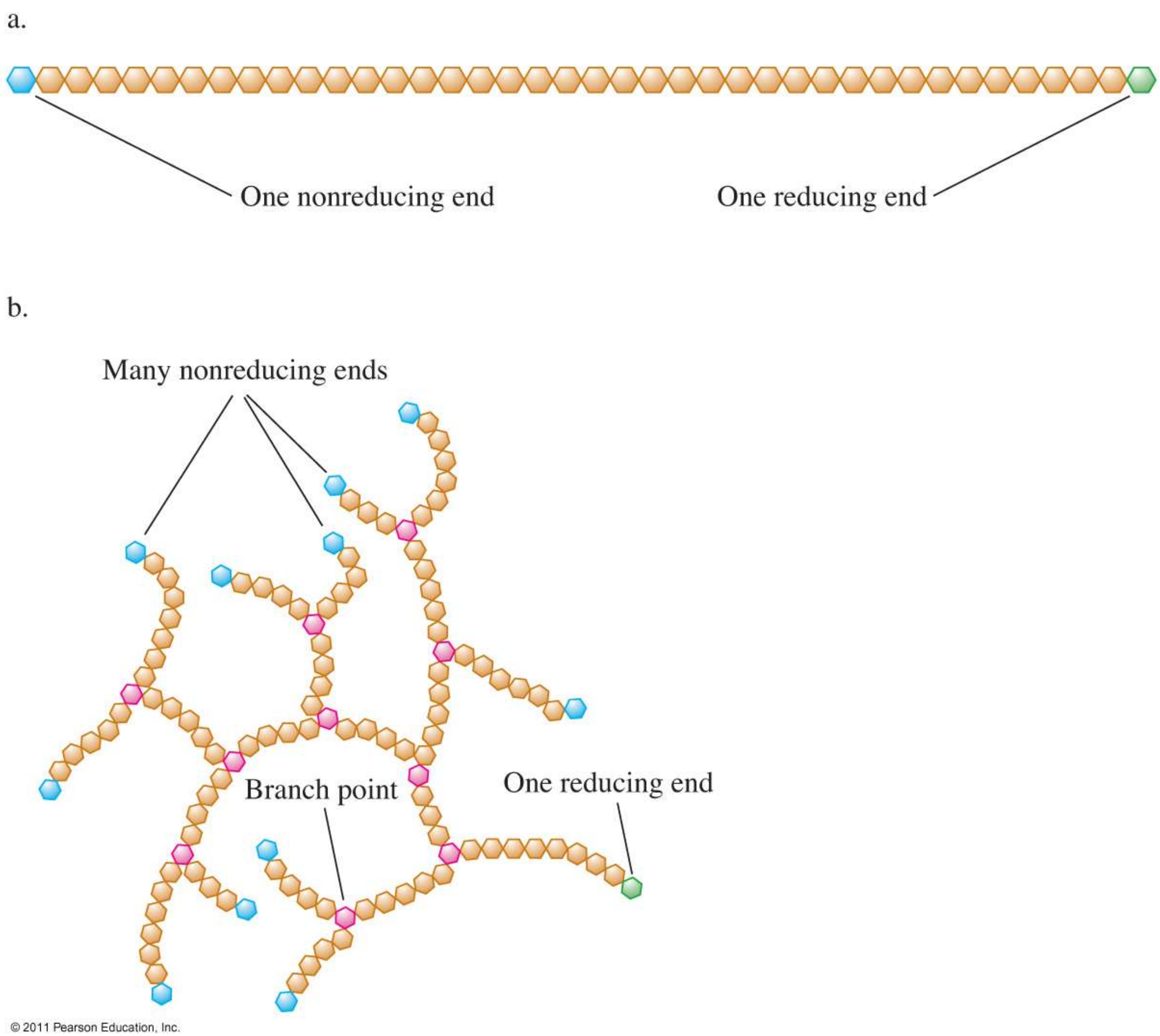
Polysaccharides

Polysaccharides are large molecules of monosaccharides that are connected to each other through their anomeric carbons. There are two types of polysaccharides:

1. ***Storage polysaccharides*** contain only 〈-glucose units. Three important ones are starch, glycogen, and amylopectin.

2. ***Structural polysaccharides*** contain only β-glucose units. Two important ones are cellulose and chitin. Chitin contains a modified β-glucose unit.

5.6 POLYSACCHARIDES, CONTINUED



Storage Polysaccharides

Amylose and amylopectin—starch

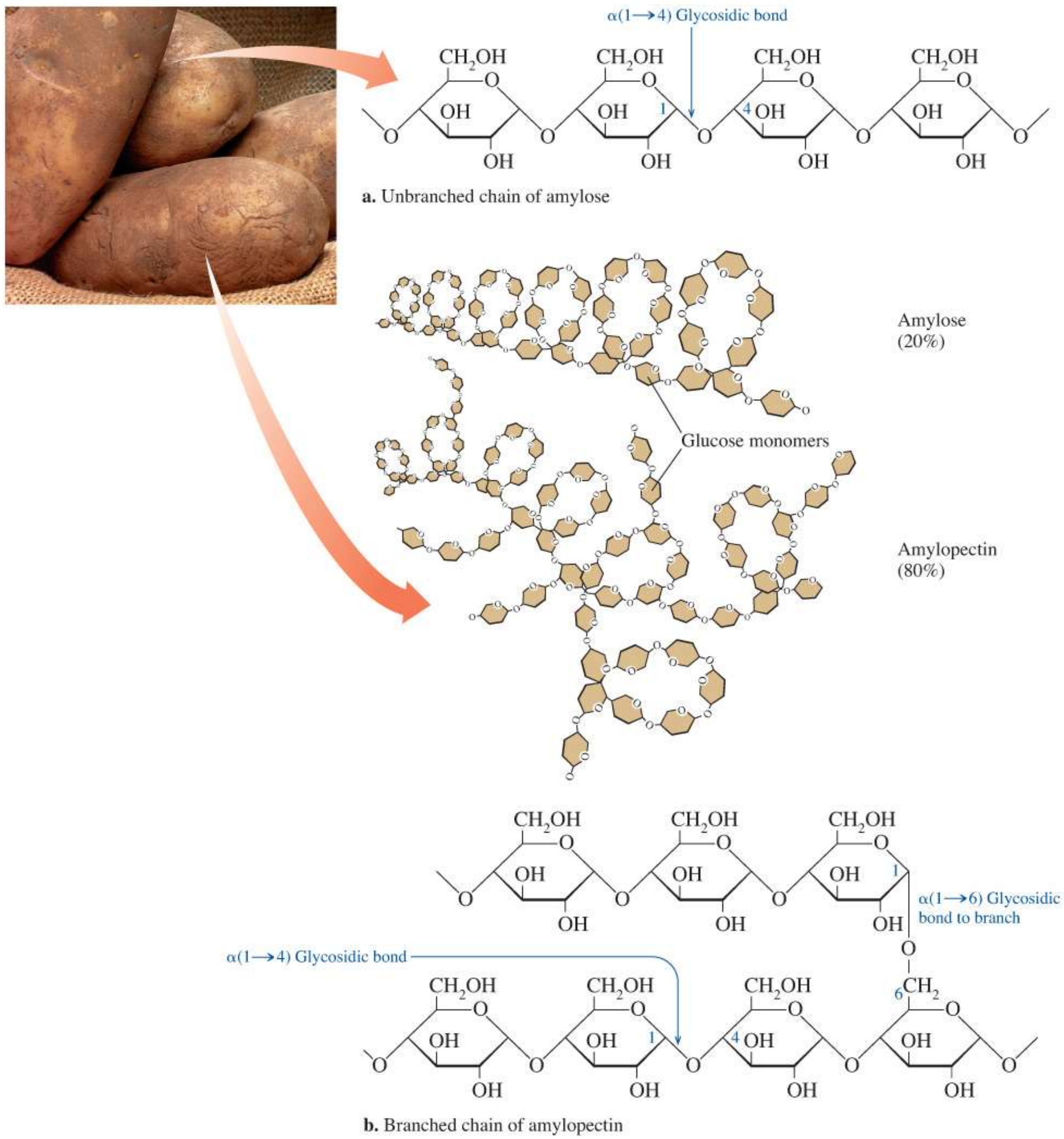
- ***Starch*** is a mixture of amylose and amylopectin and is found in plant foods.
- Amylose makes up 20% of plant starch and is made up of 250–4000 D-glucose units bonded α(1→4) in a continuous chain.
- Long chains of amylose tend to coil.
- Amylopectin makes up 80% of plant starch and is made up of D-glucose units connected by α(1→4) glycosidic bonds.

POLYSACCHARIDES

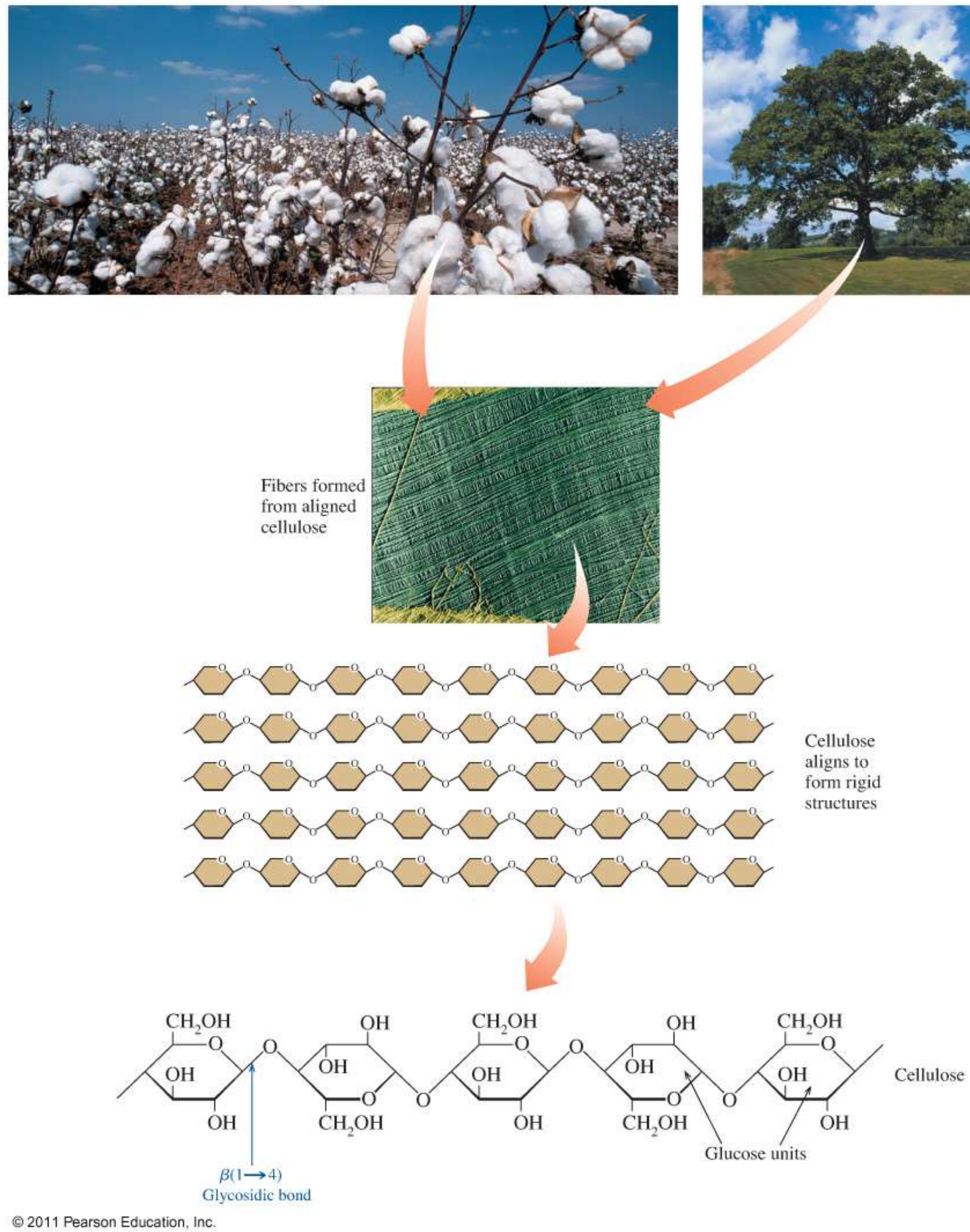
Amylose and amylopectin—starch

- About every 25 glucose units of amylopectin, a branch of glucose units are connected to the glucose by an α(1→6) glycosidic bond.
- During fruit ripening, starch undergoes hydrolysis of the α(1→4) bonds to produce glucose and maltose, which are sweet.
- When we consume starch, our digestive system breaks it down into glucose units for use by our bodies.

5.6 POLYSACCHARIDES, CONTINUED



5.6 POLYSACCHARIDES, CONTINUED

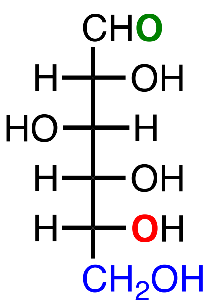


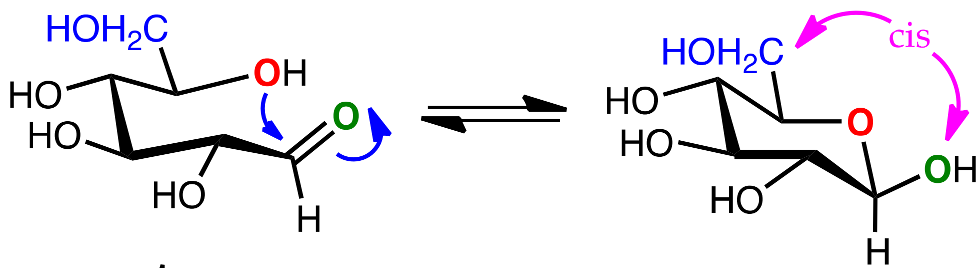
POLYSACCHARIDES

Cellulose

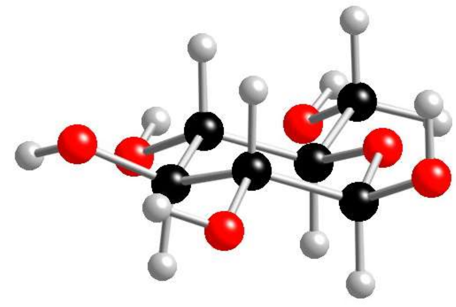
- Cellulose is an insoluble fiber in our diet because we lack the enzyme cellulase to hydrolyze the $\beta(1\rightarrow4)$ glycosidic bond.
- Whole grains are a good source of cellulose.
- Cellulose is important in our diet because it assists with digestive movement in the small and large intestine.
- Some animals and insects can digest cellulose because they contain bacteria that produce cellulase.

Mutarotation. The α- and β-anomers are in equilibrium, and interconvert through the open form. The pure anomers can be isolated by crystallization. When the pure anomers are dissolved in water they undergo mutarotation, the process by which they return to an equilibrium mixture of the anomer.

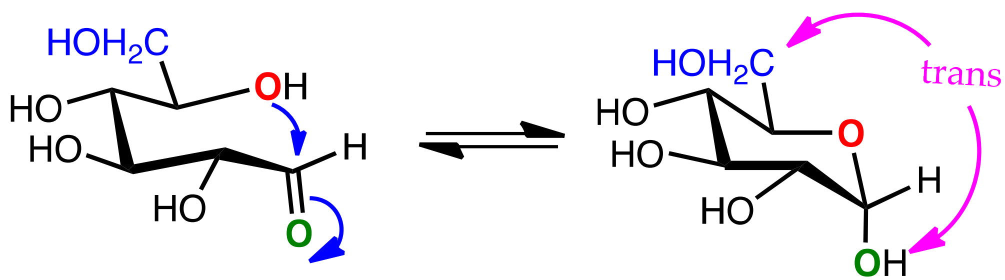




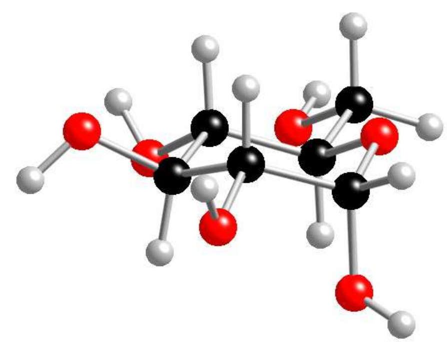
β-D-Glucopyranose (64%)
(β-anomer: C1-OH and CH_2OH are cis)



$[\alpha]_D$ +18.7°



α-D-Glucopyranose (36%)
(α-anomer: C1-OH and CH_2OH are trans)



$[\alpha]_D$ +112.2°

acid-catalyzed mechanism: p. 1037

CHAPTER SUMMARY

Ring Formation—The Truth about Monosaccharide Structure

- A hydroxyl group and the carbonyl group can react to enclose the hydroxyl's oxygen in a ring.
- Because the carbonyl group is planar, two possible ring arrangements about the anomeric carbon occur when the ring forms. These are termed the ***α*** and β ***anomers***.

CHAPTER SUMMARY

Disaccharides

- Condensation and hydrolysis are common reactions that occur in biomolecules.
- ***Condensation reactions*** produce a water molecule while bonding two molecules together.
- ***Hydrolysis reactions*** consume a molecule of water while a molecule is broken into two smaller molecules.

CHAPTER SUMMARY

Disaccharides

- Carbohydrates form glycosides when an anomeric carbon reacts with a hydroxyl group on a second molecule. The bond formed is called a ***glycosidic bond***.

- Glycosidic bonds are named by designating the anomer of the reacting monosaccharide and the carbons that are bonded, for example, $\alpha(1 \rightarrow 4)$.

CHAPTER SUMMARY

Polysaccharides

- A ***polysaccharide*** consists of many monosaccharide units bonded together through glycosidic bonds.
- Glucose is stored as glycogen in animals and starch in plants.
- Starch consists of ***amylose***, a linear chain of glucose, and ***amylopectin***, a branched chain of glucose.

