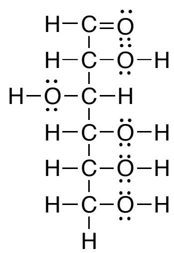
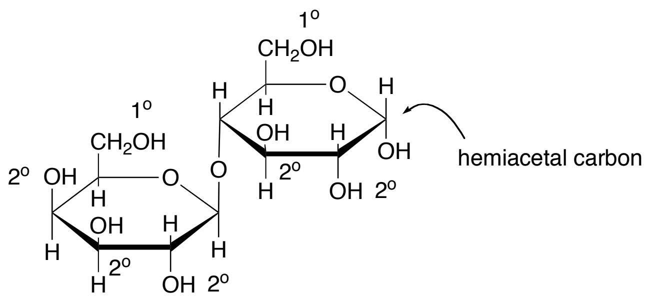
Chapter 20 Carbohydrates

Solutions to In-Chapter Problems

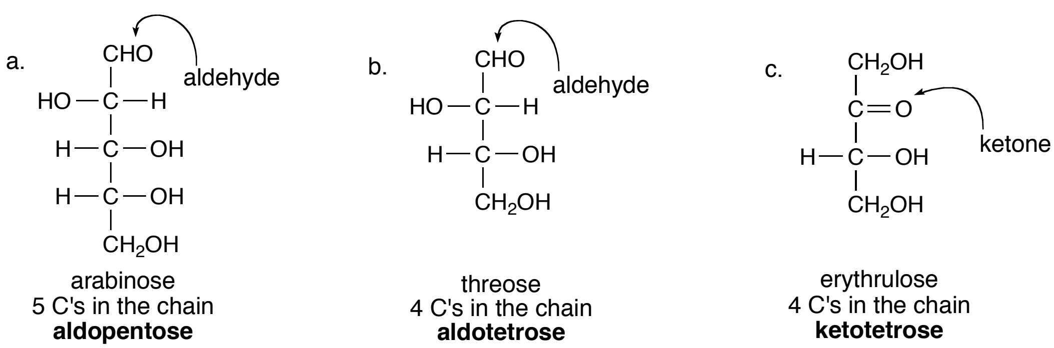
20.1 Draw the Lewis structure for glucose with all bonds and lone pairs drawn in.



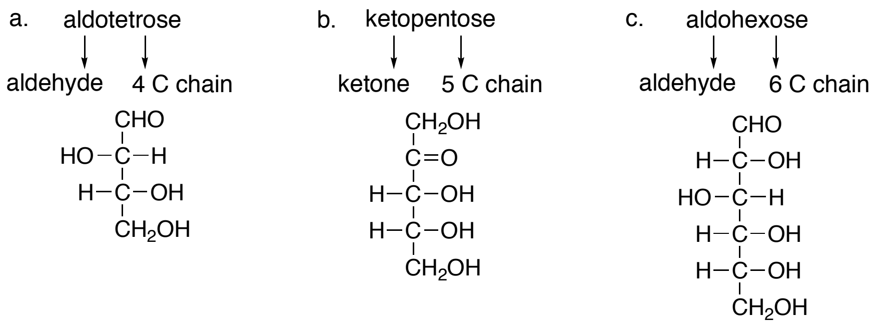
20.2 Label the hemiacetal carbon and the hydroxyl groups in lactose. Recall that a 1° hydroxyl group is bonded to a carbon bonded to one other carbon. A 2° hydroxyl group is bonded to a carbon bonded to two other carbons.



20.3 Classify each monosaccharide by the type of carbonyl group and the number of carbons in the chain as in Example 20.1.



20.4 Draw the structure of each monosaccharide.



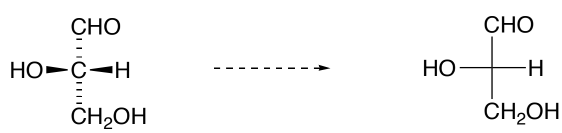
20.5 Water solubility increases with an increased number of polar groups. Hexane is a nonpolar hydrocarbon, insoluble in water. 1-Decanol is a long-chain alcohol and is slightly soluble in water due to the polar OH group. Glucose, with multiple hydroxyl groups, is water soluble.

hexane < 1-decanol < glucose

→ Increasing water solubility

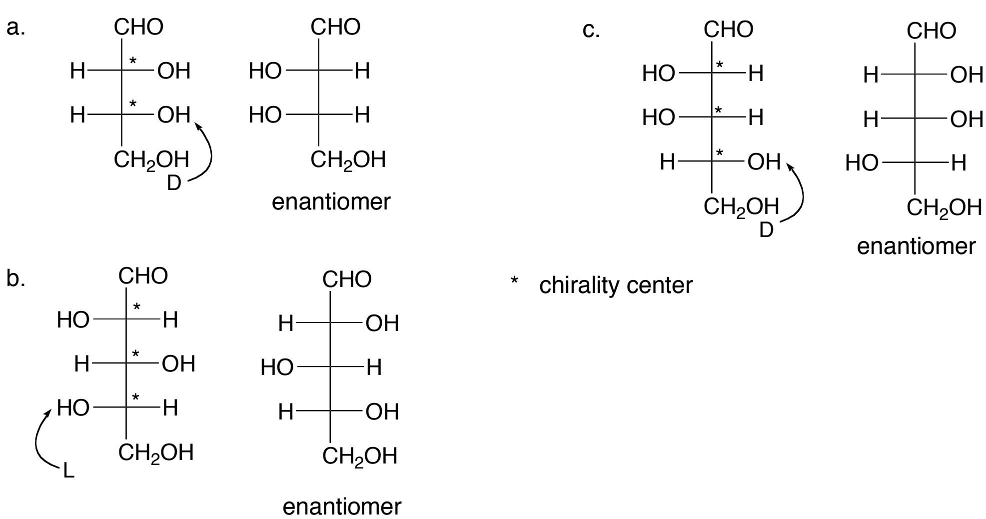
20.6 Recall that in a Fischer projection:

- A carbon atom is located at the intersection of the two lines of the cross.
- The horizontal bonds come forward, on wedges.
- The vertical bonds go back, on dashed lines.

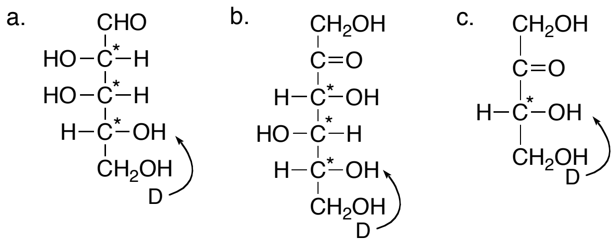


L-glyceraldehyde — Fischer projection formula

20.7 Use the definitions in Example 20.2 to [1] label all chirality centers; [2] classify the monosaccharide as D or L; [3] draw the enantiomer.



20.8 Answer each question about the monosaccharide.

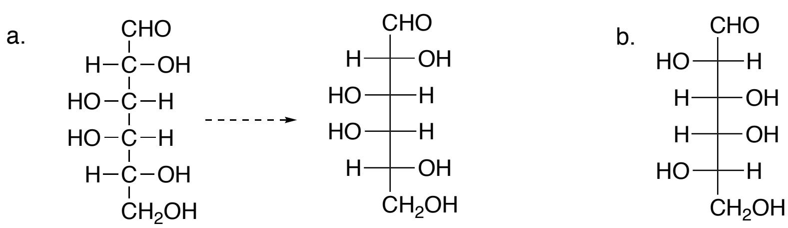


* chirality center

5 C's aldehyde aldopentose | 6 C's ketone ketohexose | 4 C's ketone ketotetrose

20.9 D-Glucose and D-fructose are constitutional isomers (same molecular formula, different connectivity) because glucose has an aldehyde group and fructose has a ketone group. D-Galactose and D-fructose are also constitutional isomers because galactose has an aldehyde group and fructose has a ketone group.

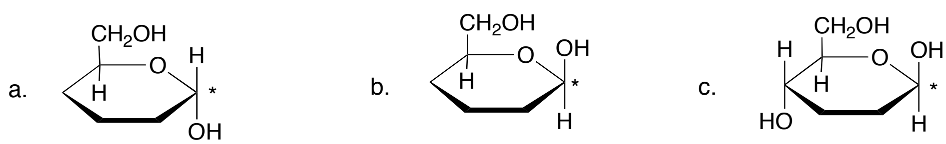
20.10 Draw the Fischer projection for D-galactose and its enantiomer.



D-galactose | Fischer projection | enantiomer All of the H and OH groups are on the opposite side.

20.11 The hemiacetal carbon is the carbon bonded to an OH and an OR group.

- The α anomer has the OH group drawn down, below the ring.
- The β anomer has the OH group drawn up, above the ring.

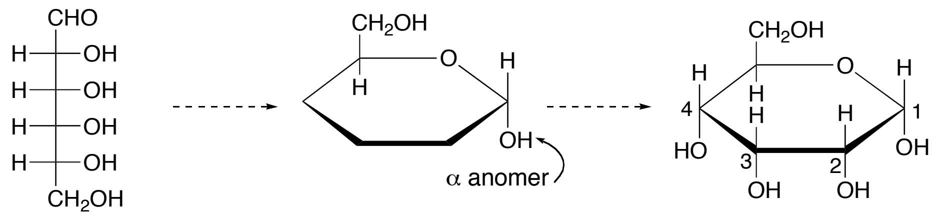


α anomer | β anomer | β anomer

* hemiacetal C

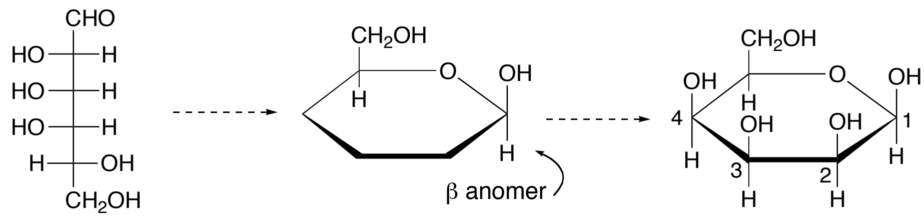
20.12 Convert each monosaccharide to the indicated anomer as in Example 20.3.

a.



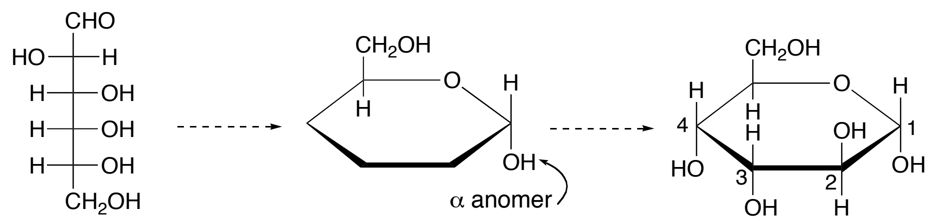
α anomer

b.



β anomer

c.

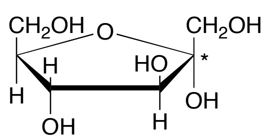


α anomer

20.13 The anomeric carbon is the carbon bonded to an OH and an OR group.

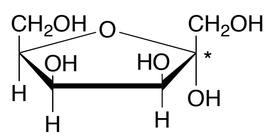
- The α anomer has the OH group drawn down, below the ring.
- The β anomer has the OH group drawn up, above the ring.

a.



α anomer

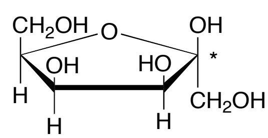
b.



α anomer

* anomeric C

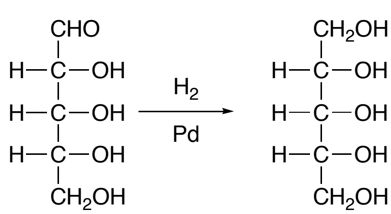
c.



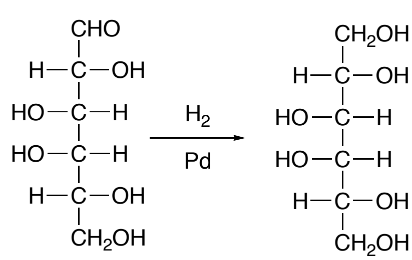
β anomer

20.14 Draw the products of each reduction reaction as in Example 20.4.

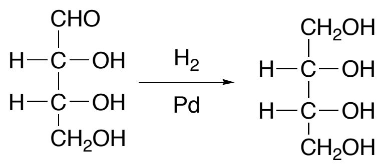
a.



b.

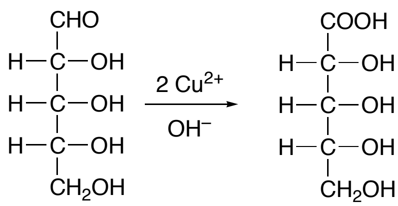


c.

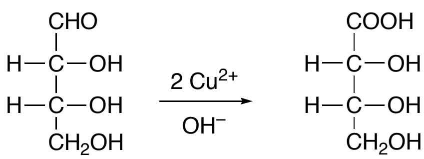


20.15 Draw the products of the oxidation of each monosaccharide as in Example 20.5.

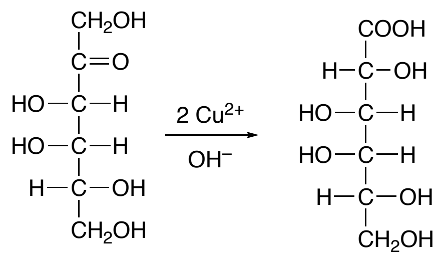
a.



b.

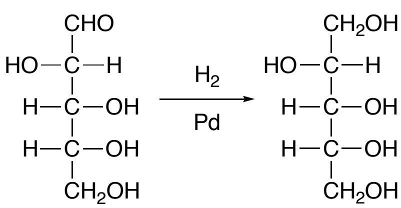


c.

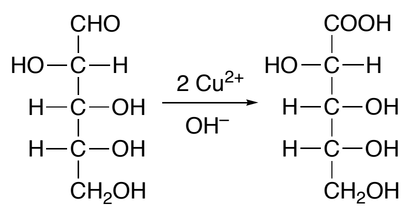


20.16 Draw the products of each reaction.

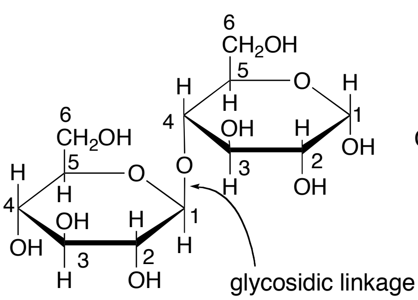
a.



b.

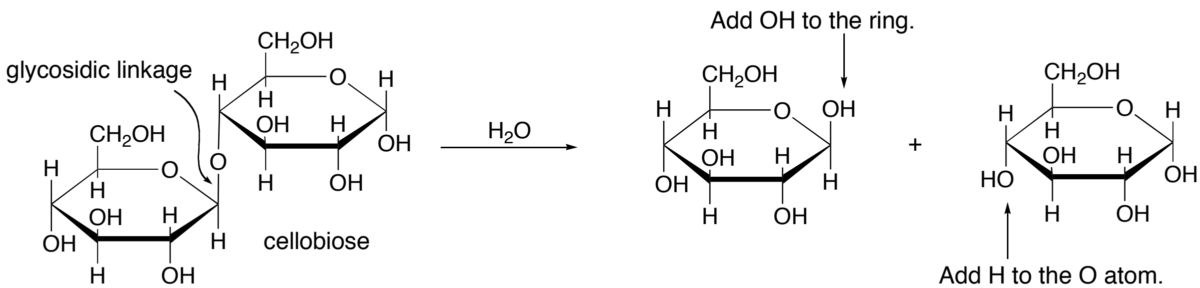


20.17 Answer each question about the disaccharide as in Example 20.6.

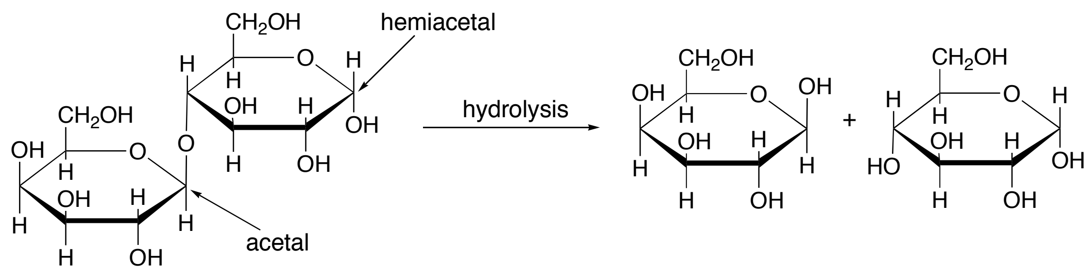


glycosidic linkage between C1 and C4
C–O bond of the glycosidic linkage drawn up = β
1→ 4-β-disaccharide

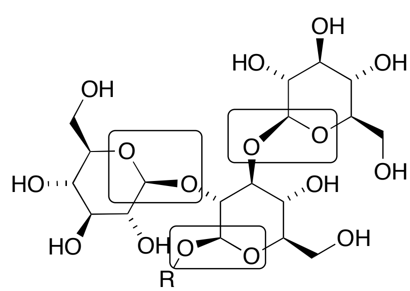
20.18 Draw the products of the hydrolysis of cellobiose as in Example 20.7.



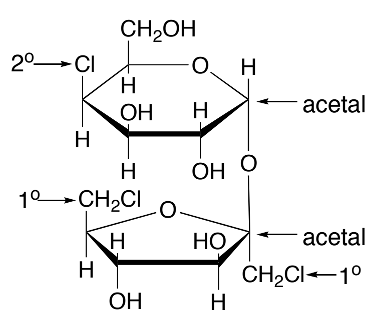
20.19 Label the acetal (C bonded to two OR groups) and hemiacetal (C bonded to an OH and an OR) groups in lactose.



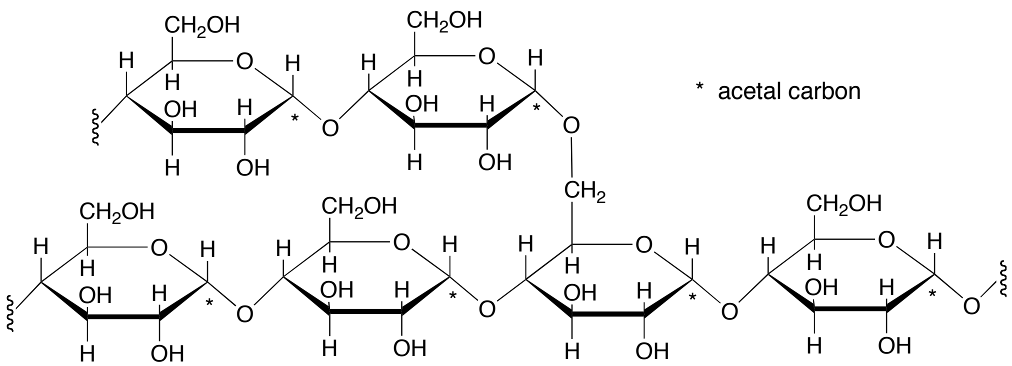
20.20 Locate the three acetals in rebaudioside A.



20.21 Label all the acetal carbons in sucralose, and classify the alkyl halides as 1°, 2°, or 3°.

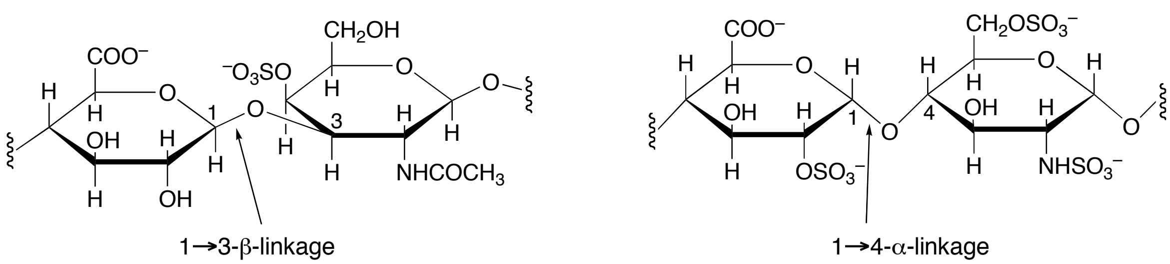


20.22 Label all the acetal carbons in amylopectin.



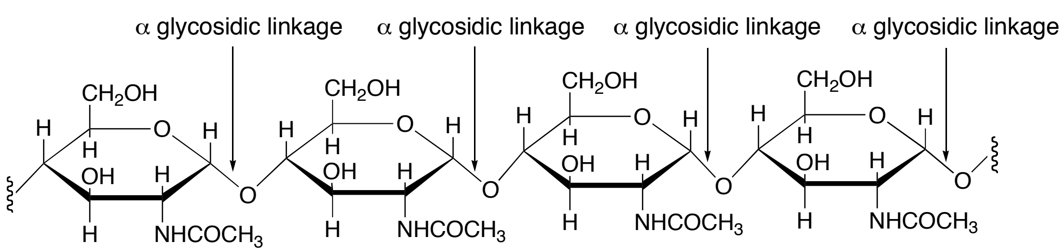
20.23 Cellulose is water insoluble because the many OH groups are already hydrogen bonded to other OH groups in the interior of the three-dimensional structure. The OH groups are therefore less available for hydrogen bonding to water.

20.24 Classify the glycosidic linkages in chondroitin and heparin as α or β. Recall that β glycosidic linkages have a C–O bond above the plane of the six-membered ring, and α glycosidic linkages have a C–O bond below the plane of the six-membered ring.

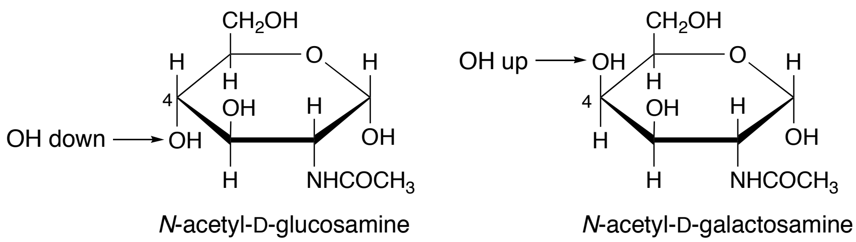


chondroitin heparin

20.25 Change the β glycosidic linkages to α glycosidic linkages in chitin.

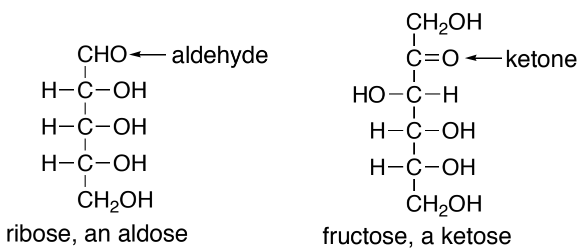


20.26 *N*-Acetyl-D-glucosamine and *N*-acetyl-D-galactosamine are stereoisomers because they differ only in the configuration at C4.

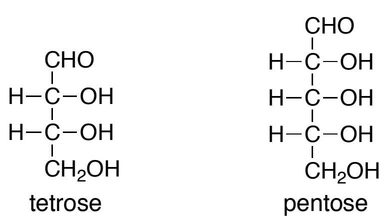


Solutions to End-of-Chapter Problems

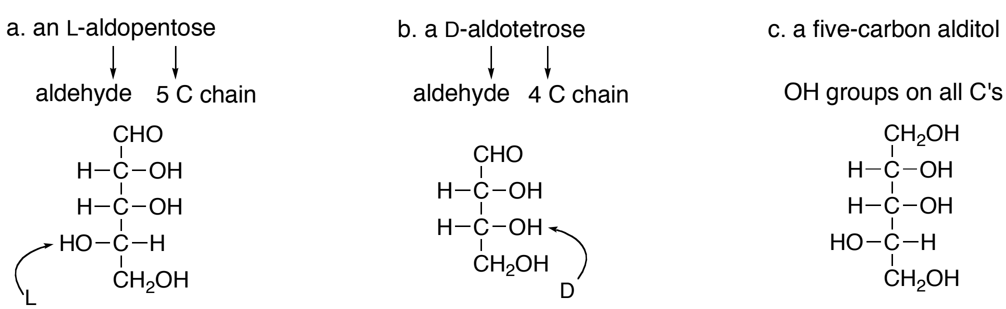
20.27 Aldoses are monosaccharides with a carbonyl group at C1, forming an aldehyde, and ketoses are monosaccharides with a carbonyl group at C2, forming a ketone.



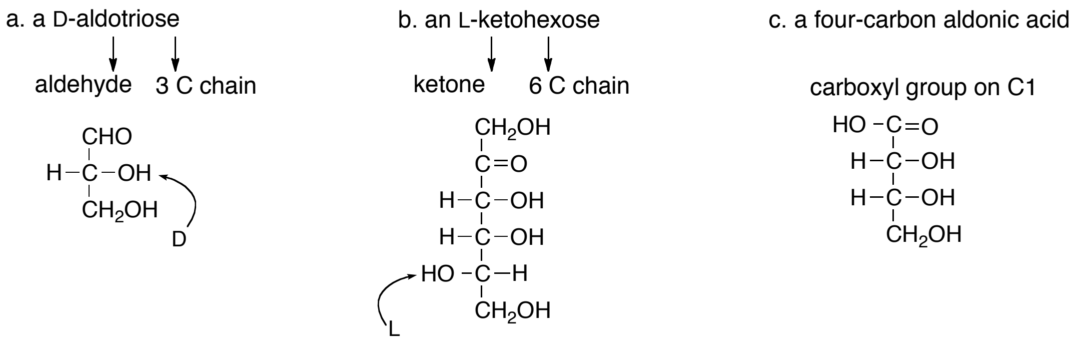
2.28 A tetrose is a monosaccharide that contains four carbons and a pentose is a monosaccharide that contains five carbons.



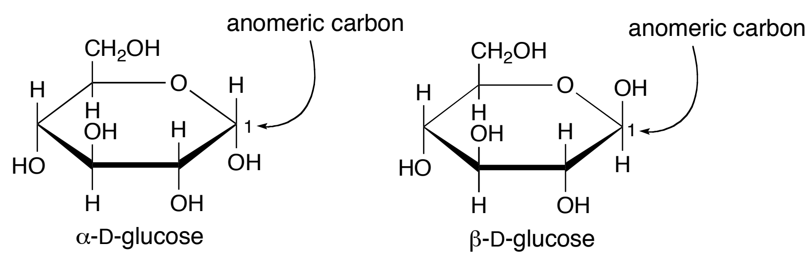
20.29 Draw the structure of each monosaccharide.



20.30 Draw the structure of each monosaccharide.

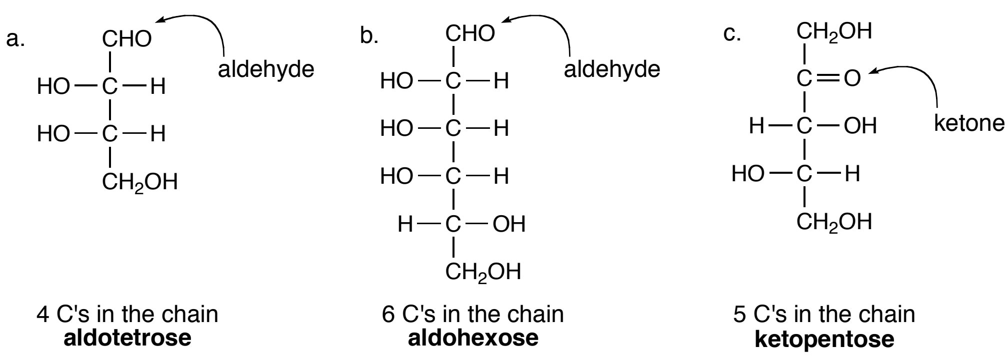


20.31 α-D-Glucose and β-D-glucose are not enantiomers because they differ in the orientation of only one OH at C1. Enantiomers are mirror images of each other, and therefore differ at all chirality centers.

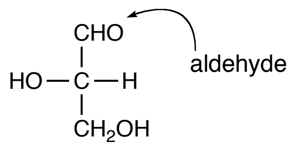


20.32 D-Fructose and L-fructose are enantiomers because they have the opposite configuration at every chirality center.

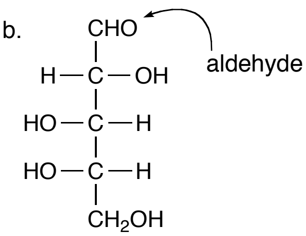
20.33 Classify each monosaccharide by the type of carbonyl group and the number of carbons in the chain as in Example 20.1.



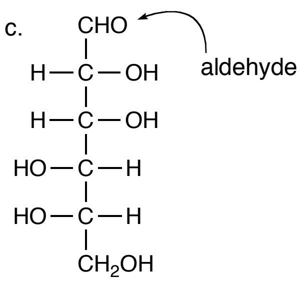
20.34 Classify each monosaccharide by the type of carbonyl group and the number of carbons in the chain as in Example 20.1.

a.


3 C's in the chain
aldotriose

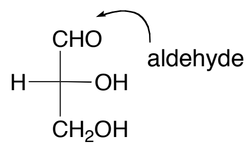
b.


5 C's in the chain
aldopentose

c.


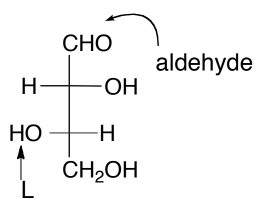
6 C's in the chain
aldohexose

20.35 Draw the Fischer projection and then classify the monosaccharide as in Example 20.1.

a.


b. 3 C's in the chain = aldotriose

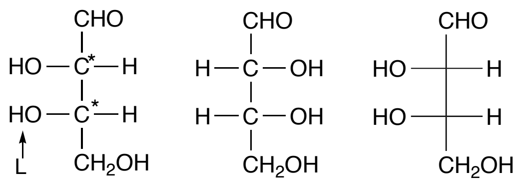
20.36 Draw the Fischer projection and then classify the monosaccharide as in Example 20.1.

a.


b. 4 C's in the chain = aldotetrose

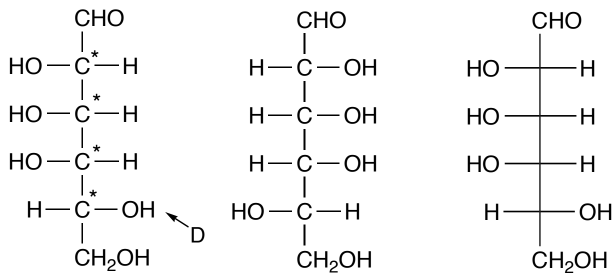
20.37 Answer each question about the monosaccharides.

a.



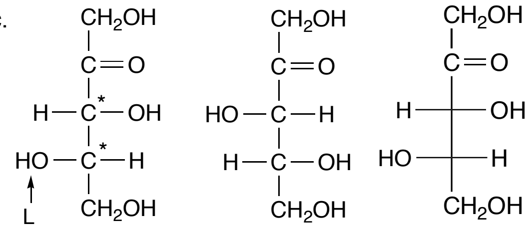
L-tetrose | enantiomer | Fischer projection

b.



D-hexose | enantiomer | Fischer projection

c.

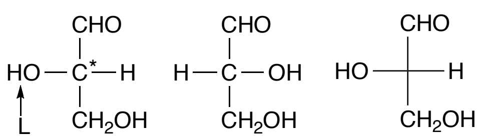


L-pentose | enantiomer | Fischer projection

* chirality center

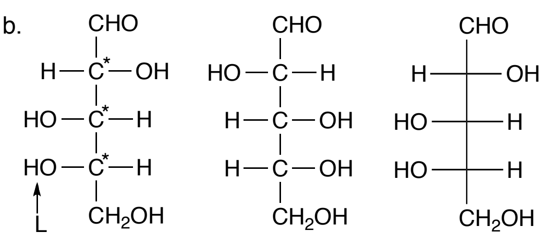
20.38 Answer each question about the monosaccharides in Problem 20.34.

a.



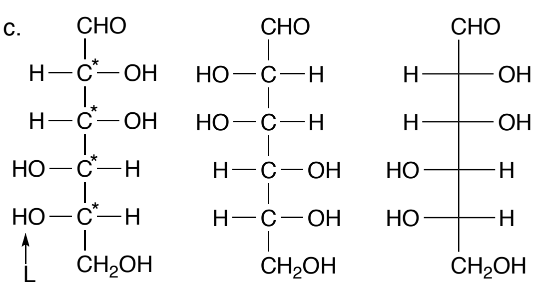
L-triose | enantiomer | Fischer projection

b.



L-pentose | enantiomer | Fischer projection

c.

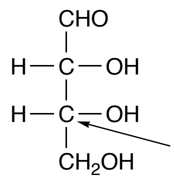


L-hexose | enantiomer | Fischer projection

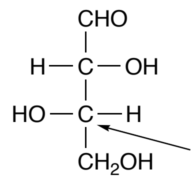
*chirality center

20.39 Answer each question about monosaccharides **A, B,** and **C.**

a. **A** and **B** are stereoisomers with a different three-dimensional arrangement at the indicated chirality centers.

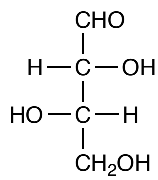


A

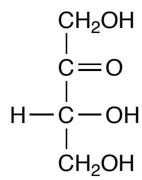


B

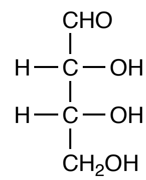
b. **B** and **C** (or **A** and **C**) are constitutional isomers.



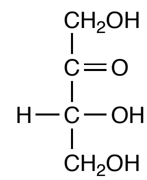
B
aldehyde



C
ketone

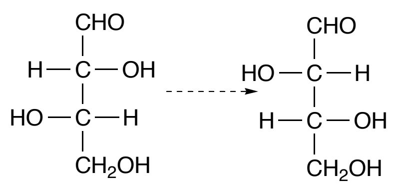


A
aldehyde



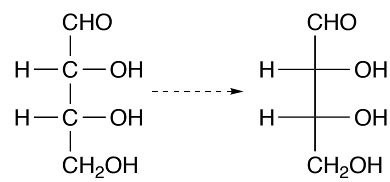
C
ketone

c. Enantiomer of **B:**



B

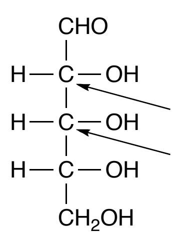
d. Fischer projection of **A:**



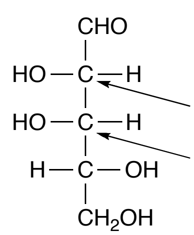
A

20.40 Answer each question about monosaccharides **D, E,** and **F.**

a. **D** and **F** are stereoisomers with a different three-dimensional arrangement at the indicated chirality centers.

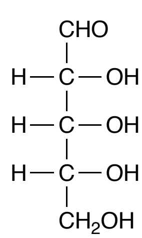


D

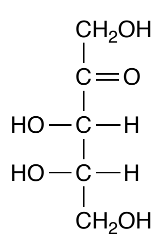


F

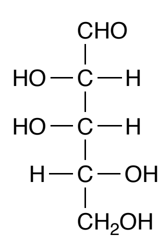
b. **D** and **E** (or **F** and **E**) are constitutional isomers.



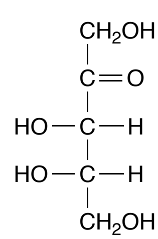
D
aldehyde



E
ketone

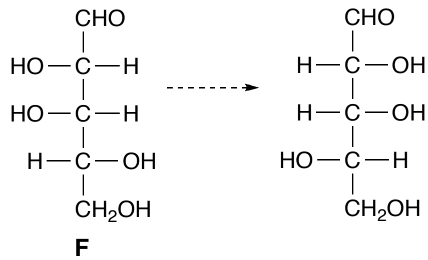


F
aldehyde

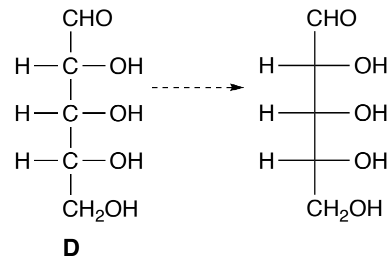


E
ketone

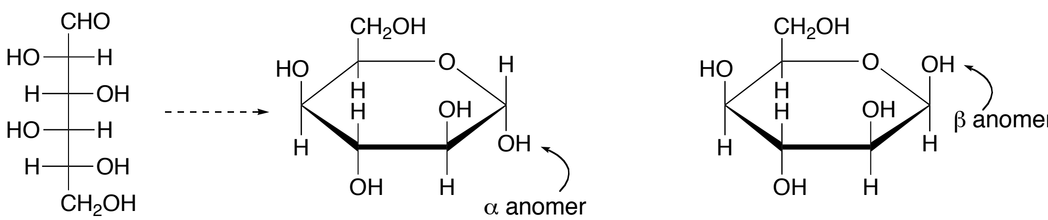
c. Enantiomer of **F**:



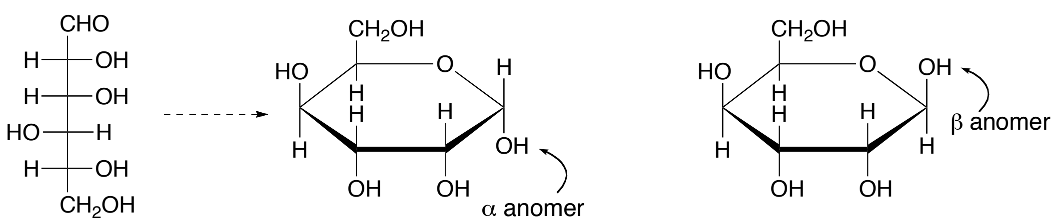
d. Fischer projection of **D**:



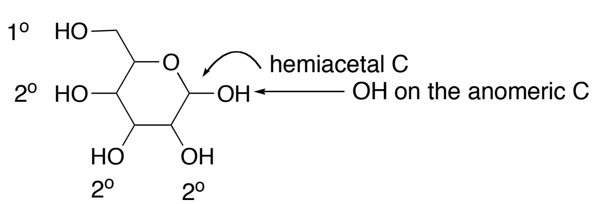
20.41 Convert the monosaccharide to both anomers as in Example 20.3.



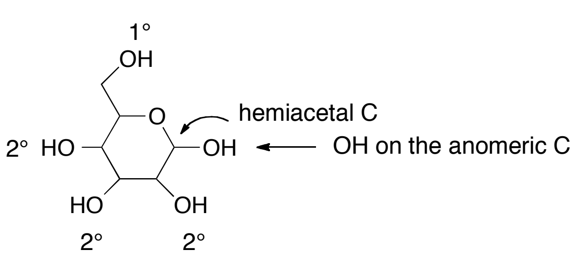
20.42 Convert the monosaccharide to both anomers as in Example 20.3.



20.43 Answer each question about the cyclic monosaccharide, drawn in a skeletal structure.

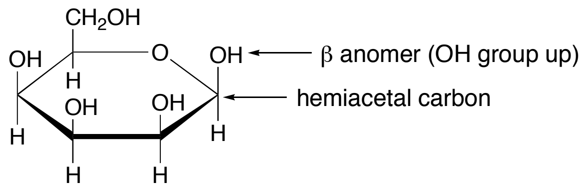


20.44 Answer each question about the cyclic monosaccharide, drawn in a skeletal structure.

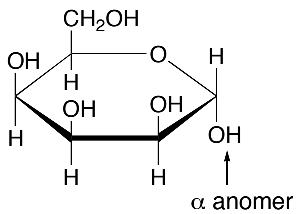


20.45 Answer each question about the cyclic monosaccharide.

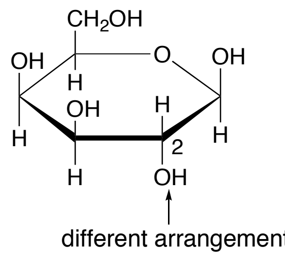
a. and b.



c.

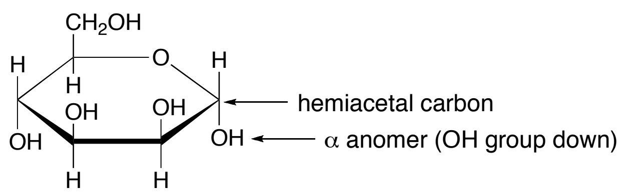


d. stereoisomer:

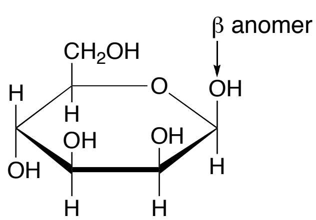


20.46 Answer each question about the cyclic monosaccharide.

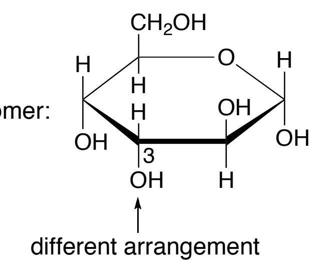
a. and b.



c.

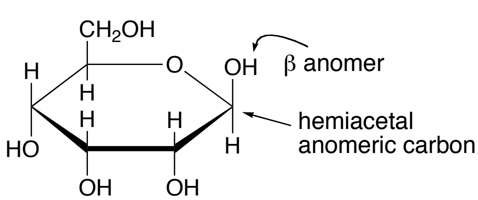


d. stereoisomer:

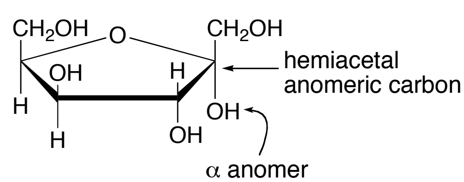


20.47 Answer the questions for each cyclic monosaccharide.

a.

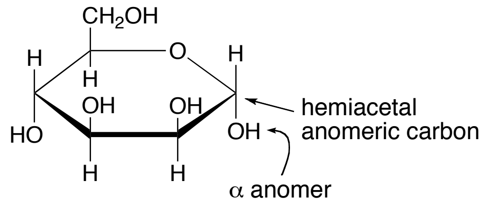


b.

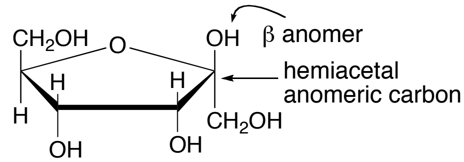


20.48 Answer the questions for each cyclic monosaccharide.

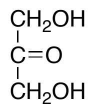
a.



b.



20.49 A ketotriose has no chirality centers and no stereoisomers, so the D or L classification is not needed. The only ketotriose is dihydroxyacetone.



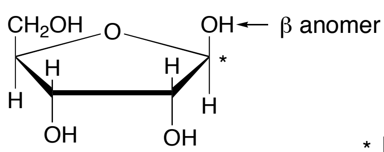
dihydroxyacetone
ketotriose

20.50 A monosaccharide with three chirality centers is labeled a D monosaccharide if the OH group on the chirality center farthest from the carbonyl is on the right. The L monosaccharide has the OH group on the chirality center farthest from the carbonyl on the left.

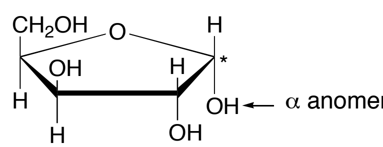
20.51 The hemiacetal carbon is the carbon bonded to an OH and an OR group.

- The α anomer has the OH group drawn down, below the ring.
- The β anomer has the OH group drawn up, above the ring.

a.



b.

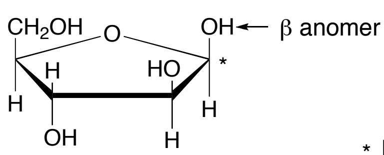


* hemiacetal C

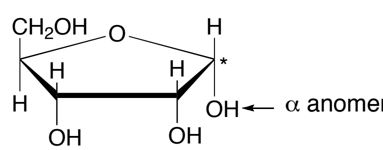
20.52 The hemiacetal carbon is the carbon bonded to an OH and an OR group.

- The α anomer has the OH group drawn down, below the ring.
- The β anomer has the OH group drawn up, above the ring.

a.

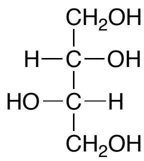


b.

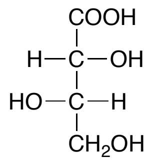


* hemiacetal C

20.53 Draw the structures of an alditol and an aldonic acid that contain four carbons.

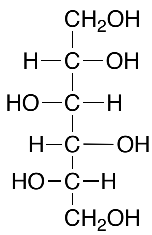


alditol

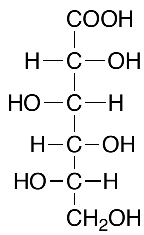


aldonic acid

20.54 Draw the structures of an alditol and an aldonic acid that contain six carbons.



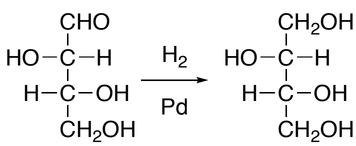
alditol

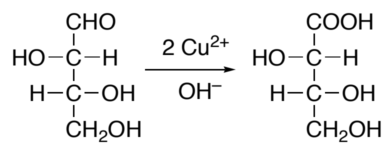


aldonic acid

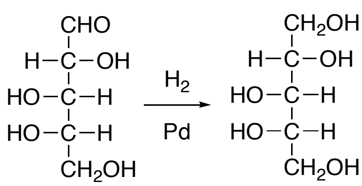
20.55 Draw the products of each reaction.

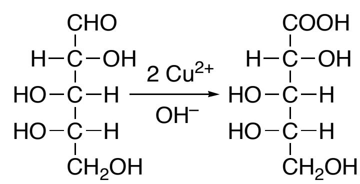
a.



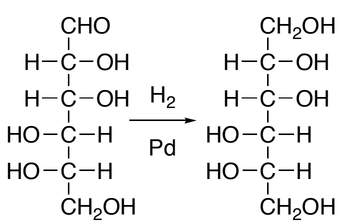


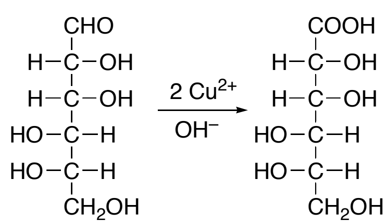
b.





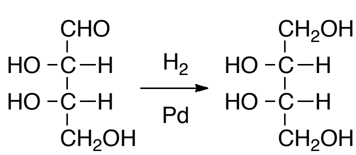
c.

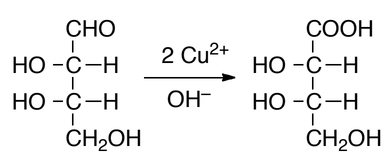




20.56 Draw the products of each reaction.

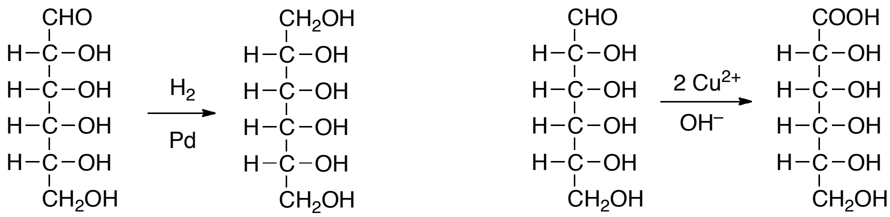
a.





b.

c.



20.57 Draw the products of the oxidation of each monosaccharide as in Example 20.5.

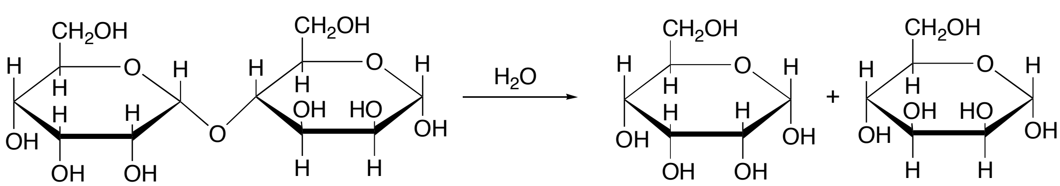
20.58 Draw the products of the oxidation of each monosaccharide as in Example 20.5.

20.59 Reducing sugars are carbohydrates that are oxidized with Benedict's reagent (Cu^{2+}). Glucose, an aldohexose, is a reducing sugar.

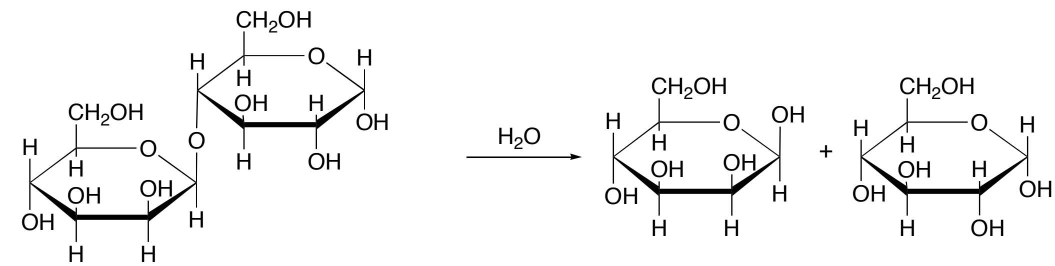
20.60 Monosaccharides exist in three different forms (an acylic aldehyde and two cyclic hemiacetals) in equilibrium. When in solution, an equilibrium mixture of all three forms results via mutarotation.

20.61 Draw the products of the hydrolysis of the disaccharides as in Example 20.7.

a.

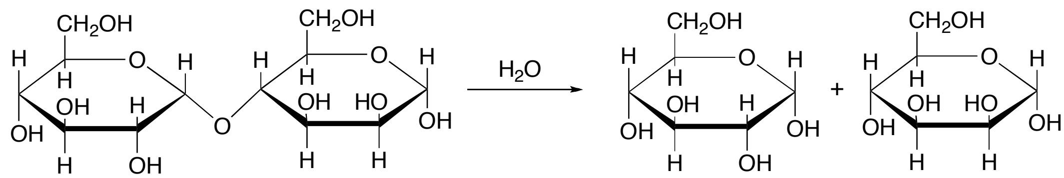


b.

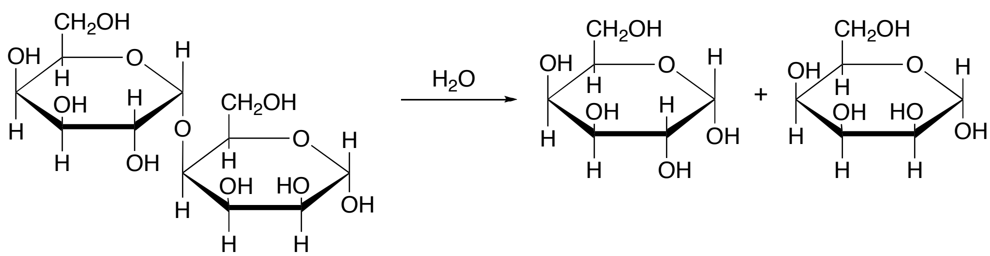


20.62 Draw the products of the hydrolysis of the disaccharides as in Example 20.7.

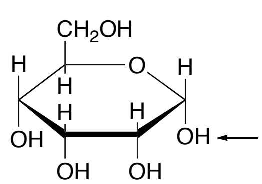
a.



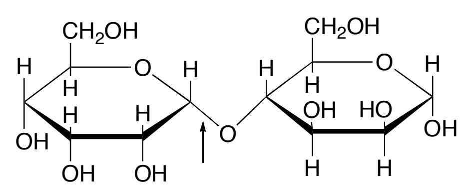
b.



20.63 An α anomer has a hydroxyl at C1, the hemiacetal C, in the down position. An α glycoside has the glycosidic linkage in the down position.

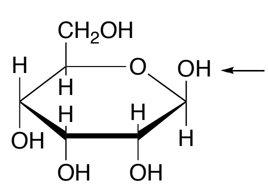


α anomer

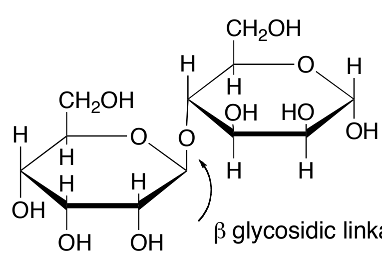


α glycosidic linkage

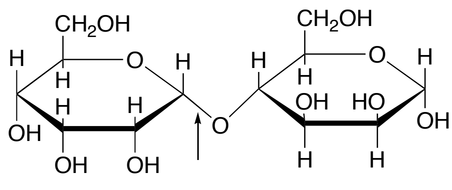
20.64 A β anomer has a hydroxyl at C1, the hemiacetal C, in the up position. A β glycoside has the glycosidic linkage in the up position.



β anomer

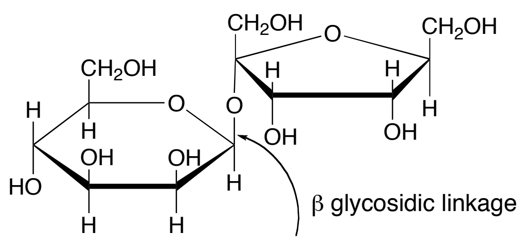


20.65 Draw the disaccharide with an α glycosidic linkage.



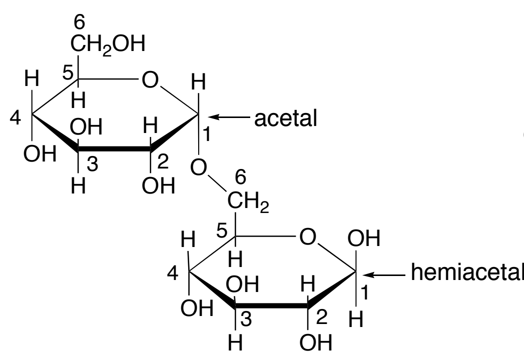
α glycosidic linkage

20.66 Draw the disaccharide with a β glycosidic linkage.

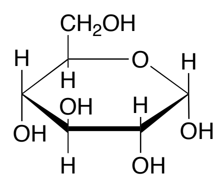


20.67 Answer each question about isomaltose.

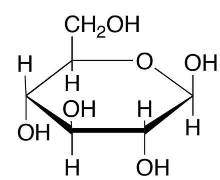
a. and b.



e.



α anomer



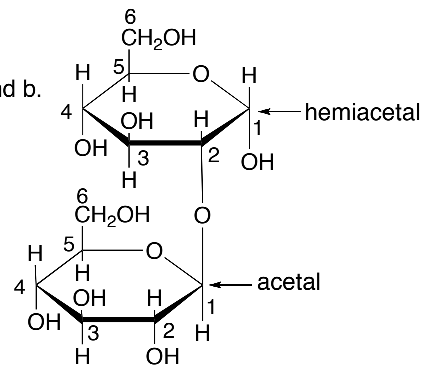
β anomer

c. 1→6-α-glycosidic linkage

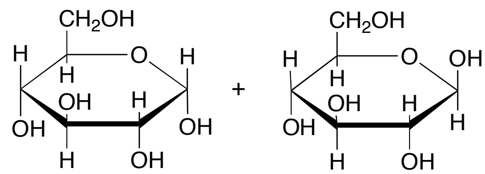
d. β anomer (hemiacetal OH group up)

20.68 Answer each question about sophorose.

a. and b.



e.

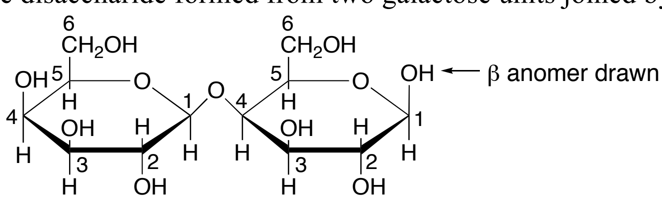


α anomer β anomer

c. 1→2-β-glycosidic linkage

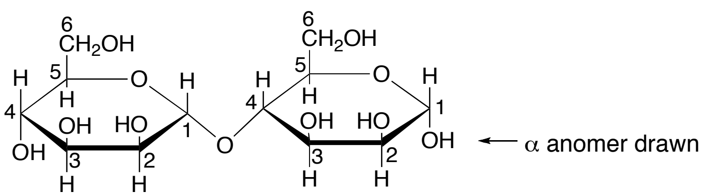
d. α anomer (hemiacetal OH group down)

20.69 Draw the disaccharide formed from two galactose units joined by a 1→4-β-glycosidic linkage.



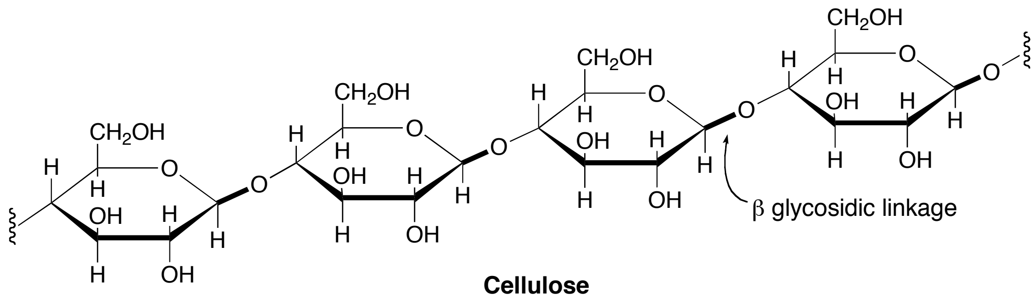
1→4-β-glycosidic linkage

20.70 Draw the disaccharide formed from two mannose units joined by a 1→4-α-glycosidic linkage.

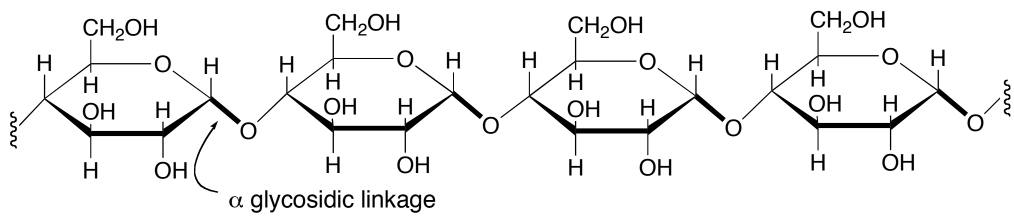


1→4-α-glycosidic linkage

20.71 Cellulose and amylose are both composed of repeating glucose units. In cellulose the glucose units are joined by a 1→4-β-glycosidic linkage, but in amylose they are joined by a 1→4-α-glycosidic linkage. This leads to very different three-dimensional shapes, with cellulose forming sheets and amylose forming helices.



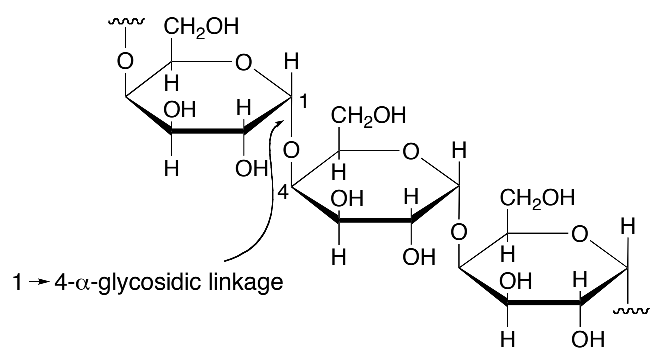
Cellulose
forms sheets.



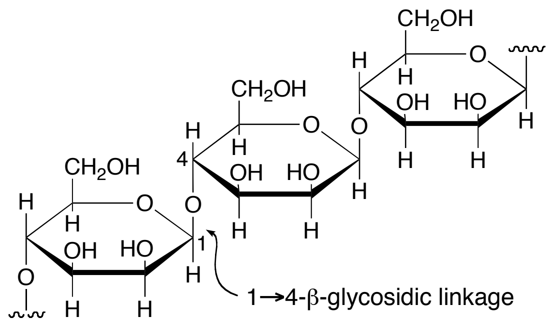
Amylose
forms helices.

20.72 Amylopectin consists of a backbone of glucose units joined in α glycosidic bonds, but it also contains considerable branching along the chain. The linkages of amylopectin are formed by 1→4-α-glycosidic bonds. Glycogen is also a polymer of glucose and contains α glyclosidic bonds like amylopectin, but the branching is more extensive in glycogen than in amylopectin.

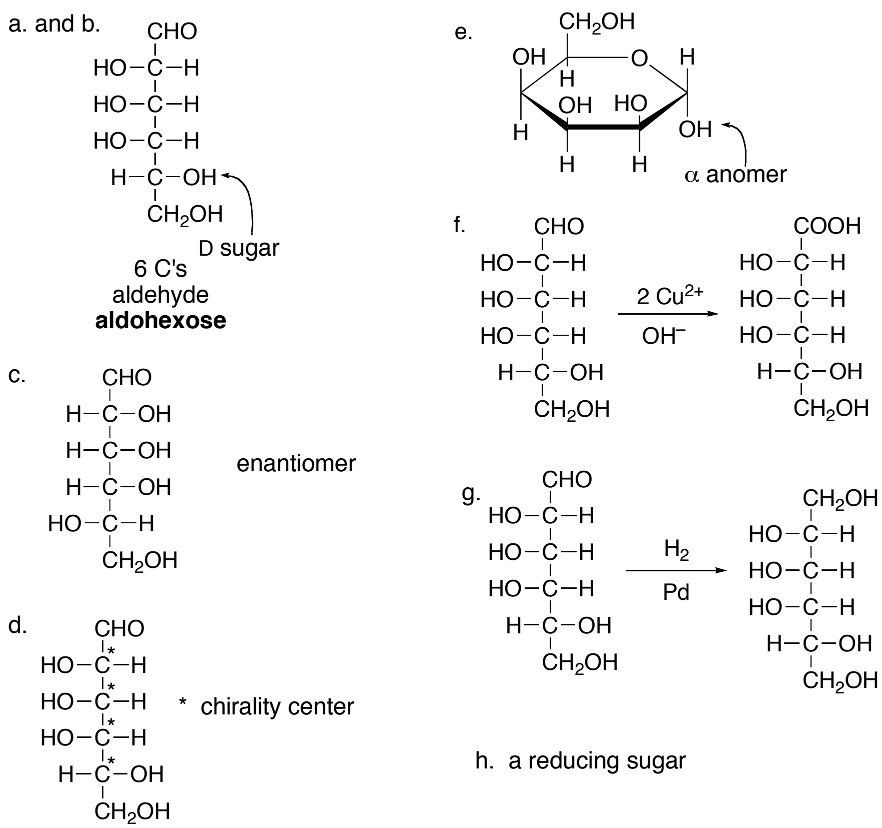
20.73 Draw a short segment of a polysaccharide that contains three galactose units joined together in 1→4-α-glycosidic linkages.



20.74 Draw a short segment of a polysaccharide that contains three mannose units joined together in 1→4-β-glycosidic linkages.

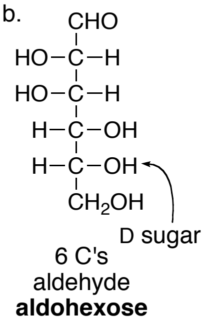


20.75 Answer each question about the monosaccharide.

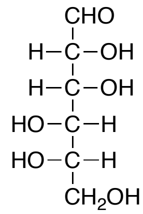


20.76 Answer each question about the monosaccharide.

a. and b.

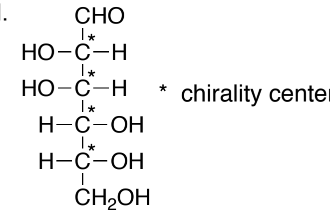


c.

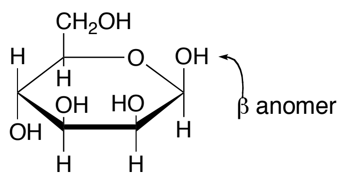


enantiomer

d.



e.



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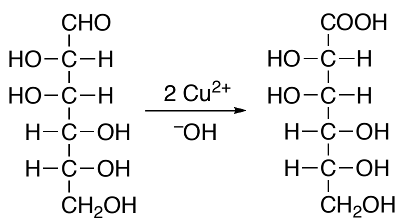
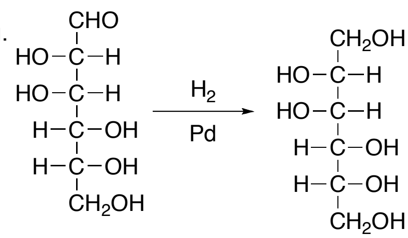


g.



h. a reducing sugar

20.77 Lactose intolerance results from a lack of the enzyme lactase. It results in abdominal cramping and diarrhea. Galactosemia results from the inability to metabolize galactose. As a result, galactose accumulates in the liver, causing cirrhosis, and in the brain, leading to mental retardation.

20.78 Cellulose is a necessary component of our diet even though we don't digest it, because it is the main source of insoluble fiber in our diet. Fiber adds bulk to solid waste so that it is eliminated more readily.

20.79 Fructose is a naturally occurring sugar with more perceived sweetness per gram than sucrose, and so fructose provides the same amount of sweetness in fewer grams and fewer calories. Sucralose is a synthetic sweetener; that is, it is not naturally occurring and is therefore labeled artificial.

20.80 Oxidation reactions help an individual with diabetes monitor blood glucose levels, because a common method for measuring the concentration of glucose measures the amount of oxidizing agent that reacts with a known amount of blood. This value is correlated with blood glucose concentration.

20.81 An individual with type A blood can receive only blood types A and O, because he or she will produce antibodies and an immune response to B or AB blood. He or she can donate to individuals with either type A or AB blood, however, because the type A polysaccharides are common to both and no immune response will be generated.

20.82 An individual with type B blood can receive only blood types B and O because type B blood does not produce antibodies to type O blood, but type A blood produces antibodies to type B blood. An individual with type B blood can donate to individuals with type B or AB blood because AB blood does not contain antibodies to type B blood.

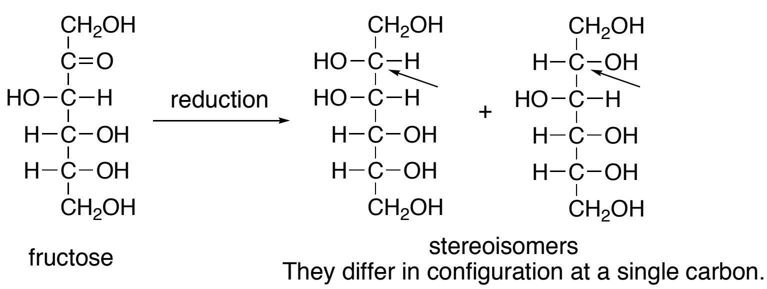
20.83 The long sheets of polysaccharides in chitin are similar to cellulose in that they have β glycosidic linkages and are not digestible by humans.

20.84 Horses derive nutritional value from eating grass but humans cannot because horses have bacteria containing the enzyme β-glycosidase which cleaves all of the β glycoside bonds, whereas humans do not.

20.85 Hyaluronate is a glycosaminoglycan found in the extracellular fluid that lubricates joints and the vitreous humor of the eye. Chondroitin is a component of cartilage and tendons. Heparin is a glycosaminoglycan stored in the mast cells of the liver and other organs and prevents blood clotting.

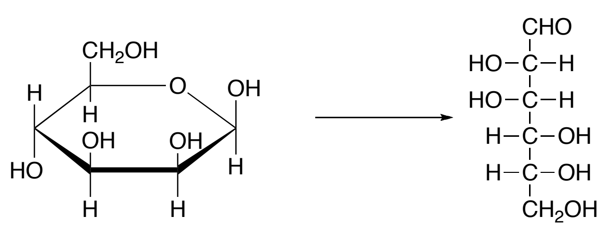
20.86 Chitin is water insoluble but the *N*-acetyl-D-glucosamine from which it is made is water soluble. Chitin is a polysaccharide formed from *N*-acetyl-D-glucosamine units joined together by 1→4-β-glycosidic bonds with the OH group at C2 replaced by $NHCOCH_3$ groups. The chitin chains are held together by an extensive network of hydrogen bonds that causes chitin to be insoluble in water. *N*-Acetyl-D-glucosamine is water soluble because of the number of OH groups on the molecule that can hydrogen bond to water.

20.87 Answer the questions about fructose.



20.88 Convert each cyclic form to an acyclic monosaccharide.

a.



b.