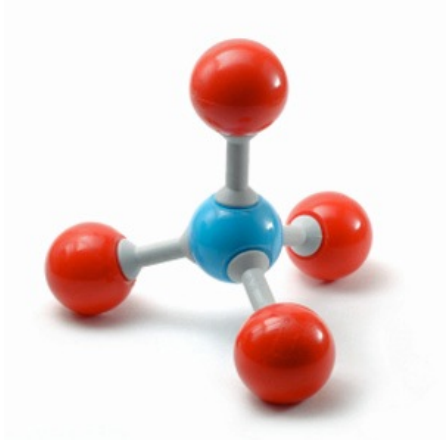
Ch13

Sugars

What biology does with monosaccharides…

disaccharides and polysaccharides.



version 1.0

Ch13

Sugars

- Haworth Structures
  - Saccharides can form rings.
    - That creates a new chiral center.
      - Alpha & Beta isomers
  - Sketching them (Haworth structures)
    - drawing the closed form of saccharides
      - 5-6 carbon rings more stable than open chains
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      - utility of sugar alcohols
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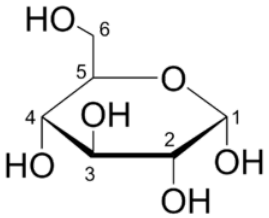

- Disaccharides, building blocks of food
  - General Structure
    - Formation
      - classifying glycosidic bonds
    - Alpha & Beta isomers
  - Maltose
    - ‘malt sugar’ used in fermentation of ethanol and cereals; α 1,4 bond; reducing sugar
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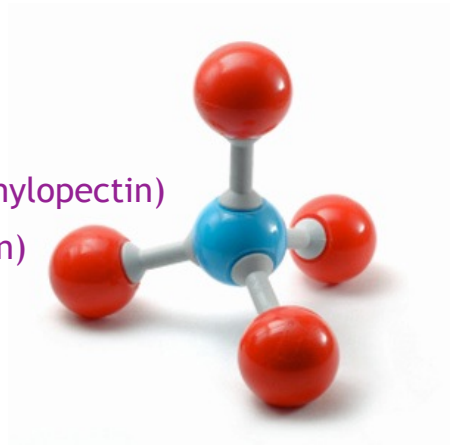
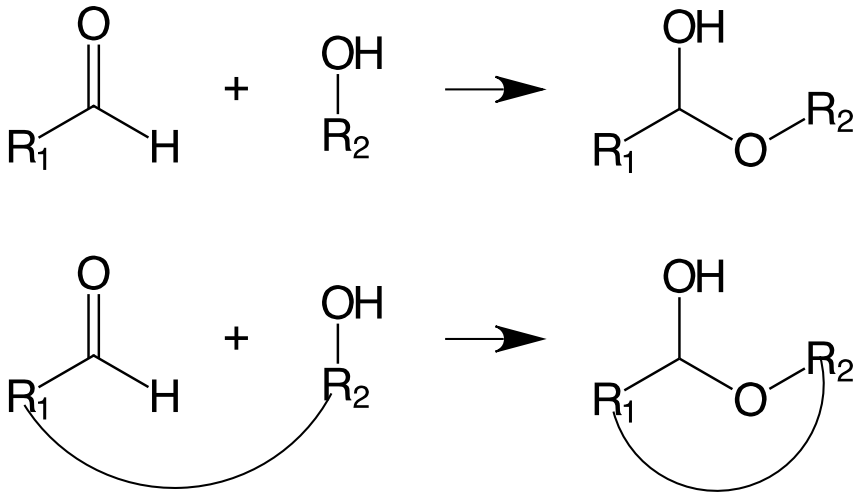
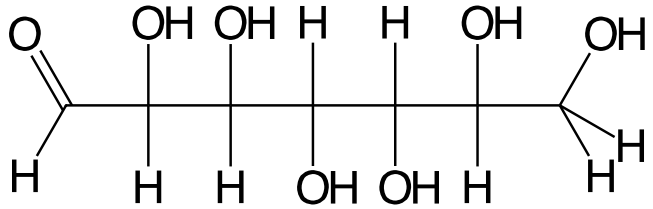
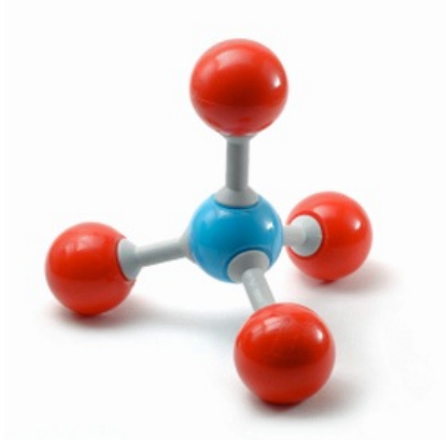


Haworth Structures

- Hydroxyl groups react with carbonyls to form bonds.
- Aldoses have carbonyls and hydroxyl groups.
- They form rings (of 5-6 carbons).







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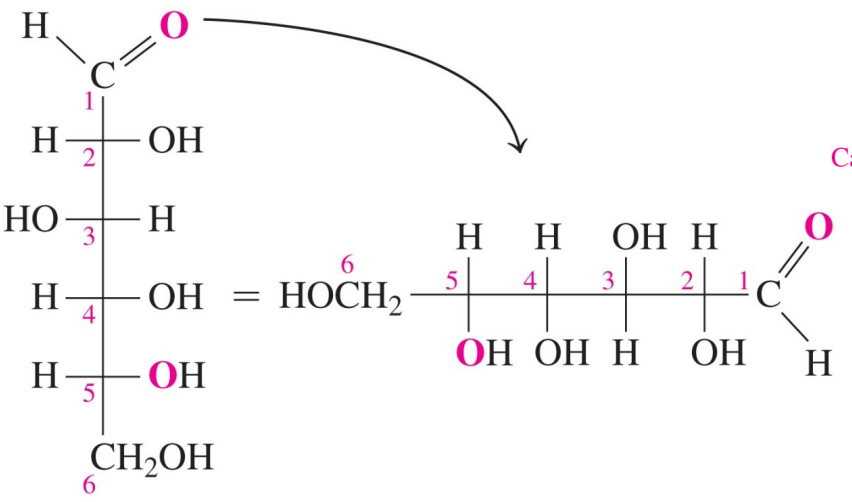
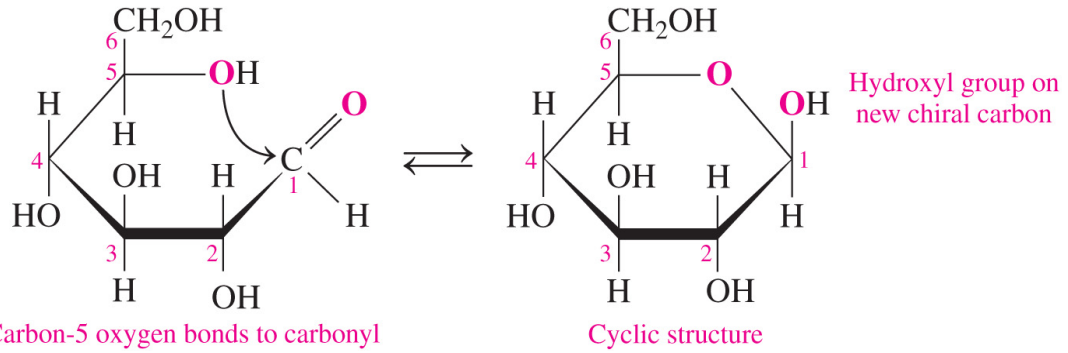
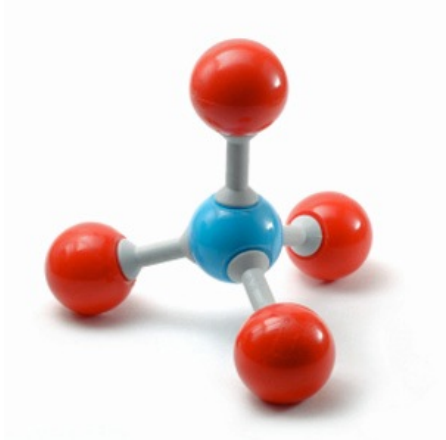


D-Glucose (open chain)





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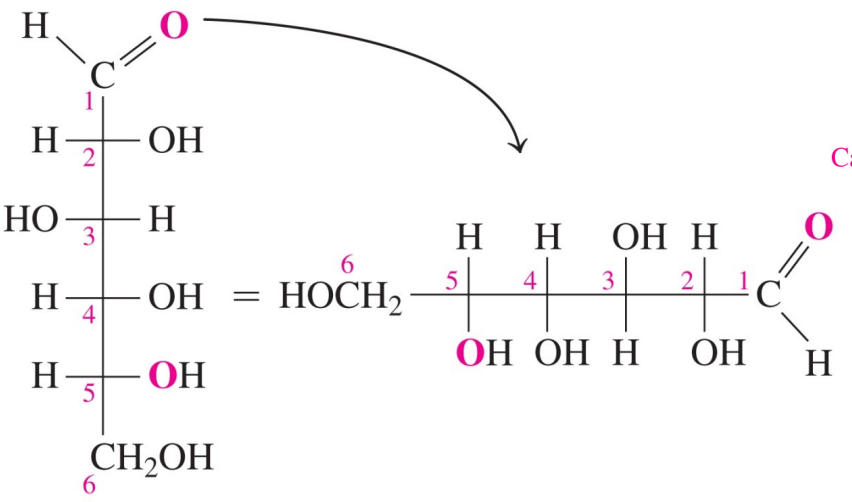

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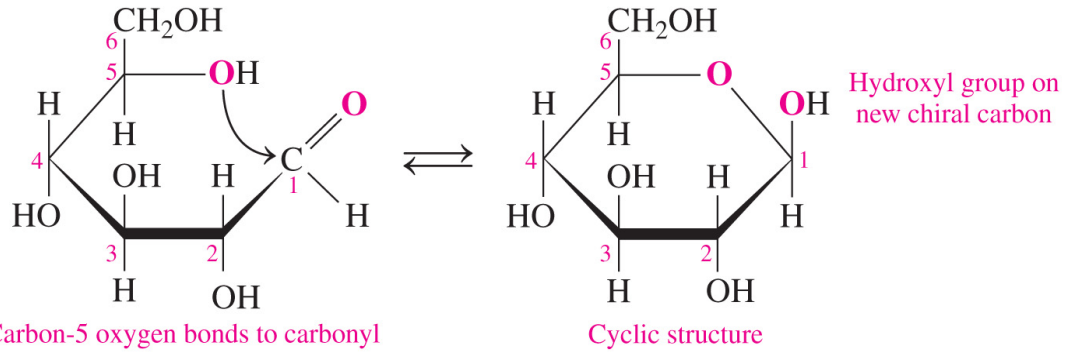
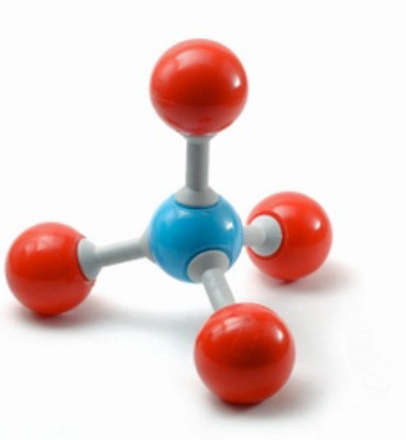


Go Slow with Carbon #5 — it's the hard part!



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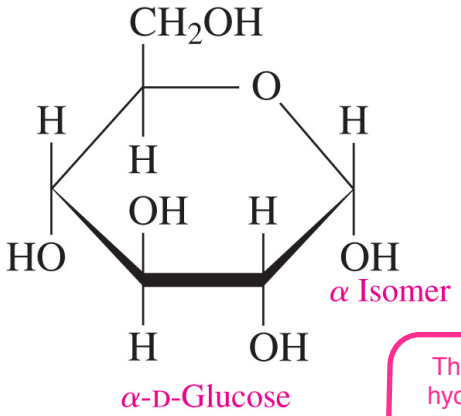
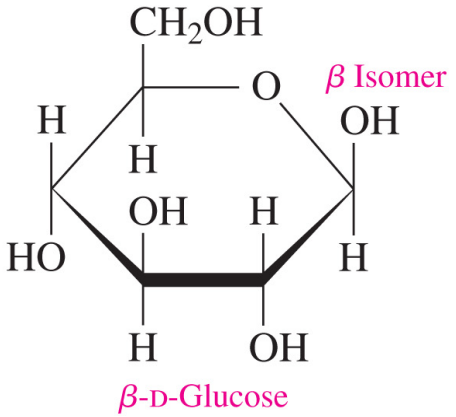
- Monosaccharides in water will interconvert between these two isomers.
  - This interconversion between alpha and beta isomers is called mutarotation.



α Isomer

α-D-Glucose

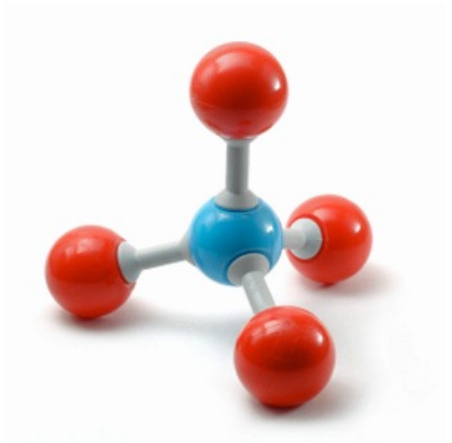
The isomer with the new hydroxyl below the ring is called the alpha isomer.



β Isomer

β-D-Glucose

The isomer with the new hydroxyl above the ring is called the beta isomer.



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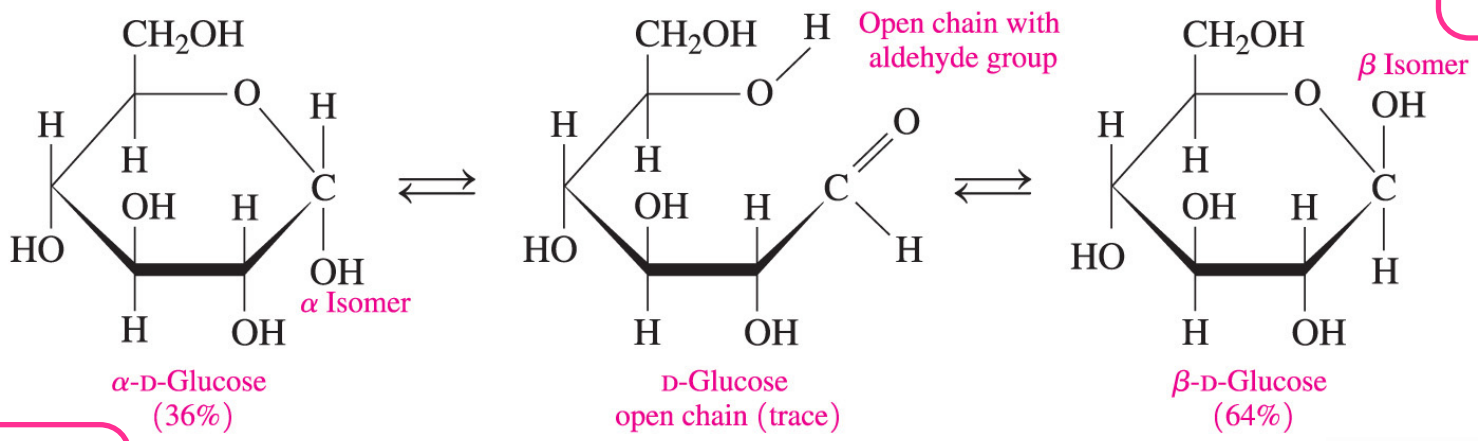
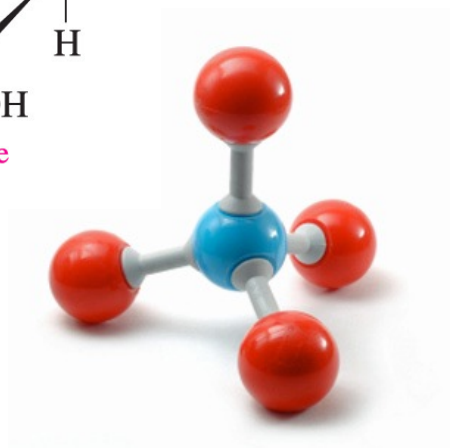
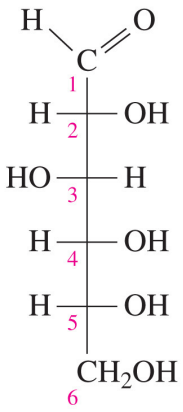


The isomer with the new hydroxyl below the ring is called the alpha isomer.



Haworth Structures

- Ketoses also have a carbonyl.
- Fructose for example can also form Hayworth structures.
- D-Fructose forms a 5 membered ring.



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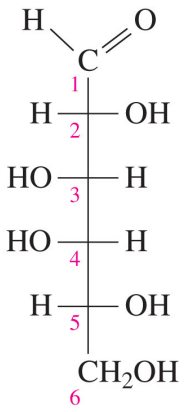
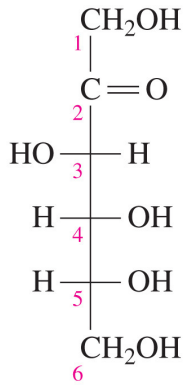
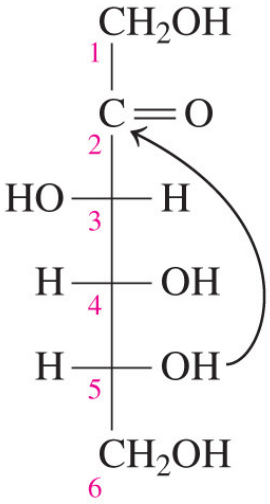


D-Galactose



D-Fructose



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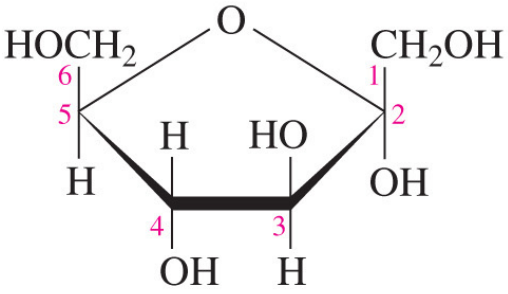
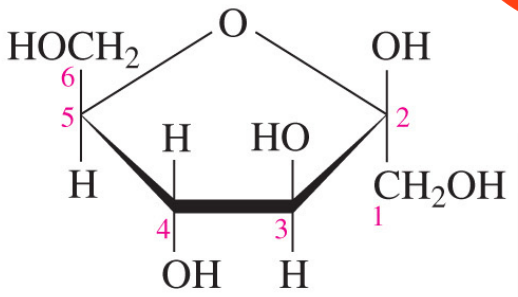


α-D-Fructose



β-D-Fructose

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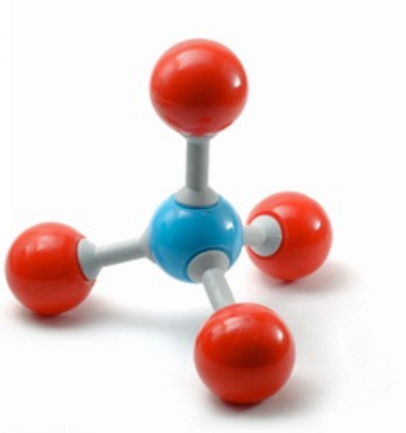
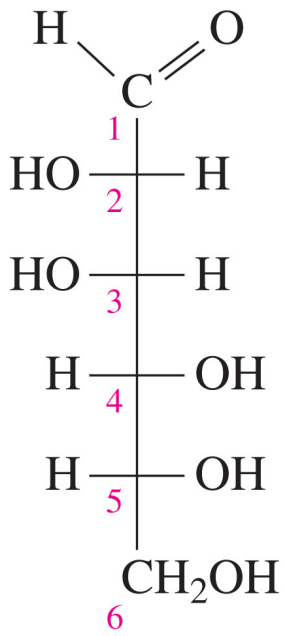


Try it.

- The most stable form of D-Mannose is it's Haworth structure. Draw the Haworth structure of beta-D-Mannose.
- Does this hexose form a five membered or six membered ring?



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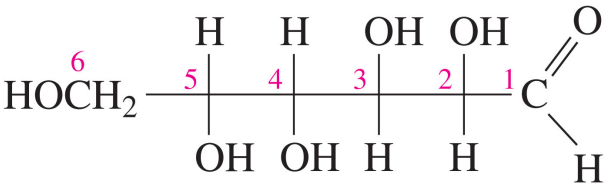

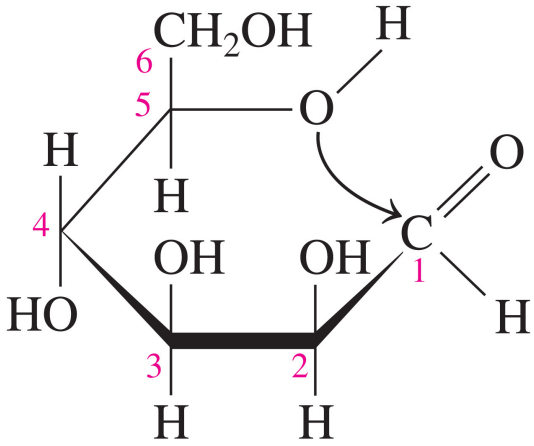

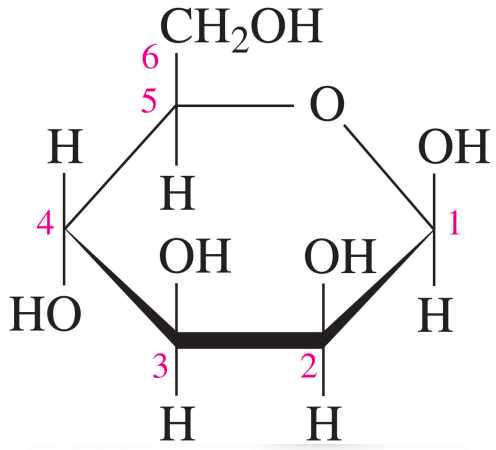

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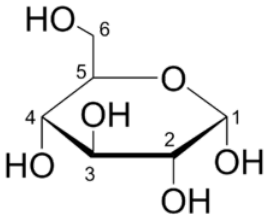

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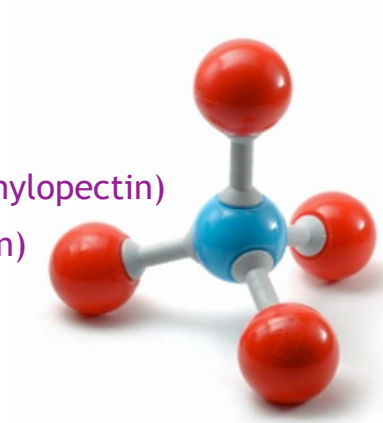
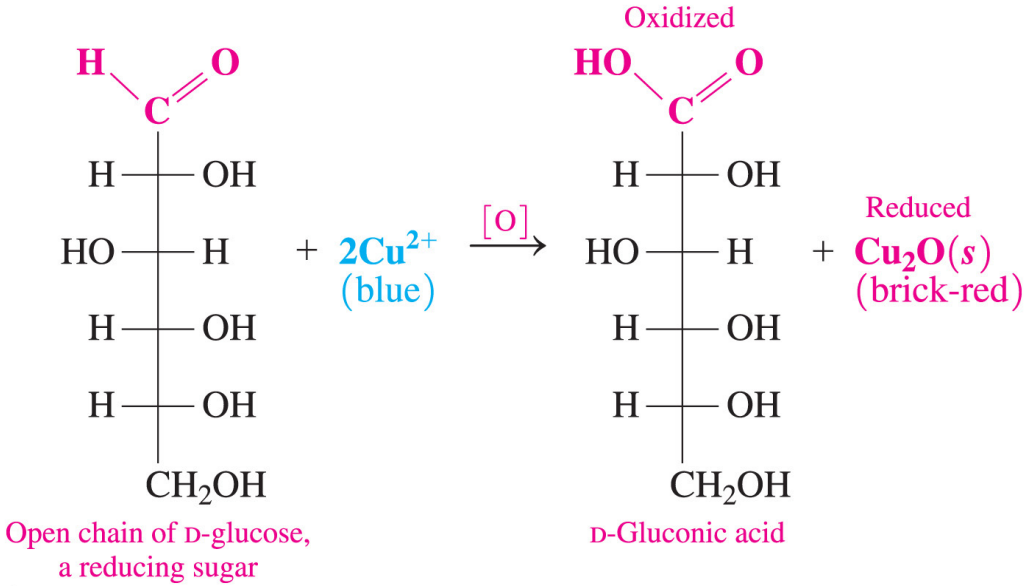
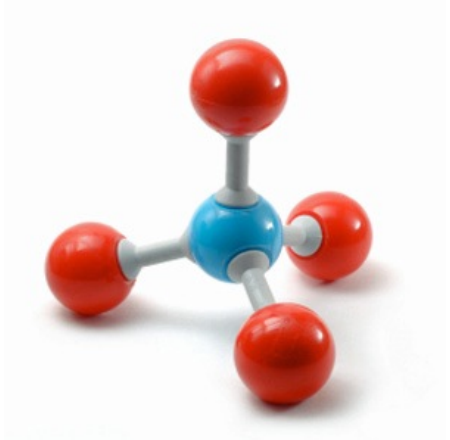


Reactions of Monosaccharides

- Aldoses can be oxidized to acids with copper or silver metal salts.
- These sugars which reduce those salts while being oxidized, are called reducing sugars.
- Acids produced this way are named after their source sugars, by replacing the -ose suffix with -onic acid.
- Gluconic acid is produces from glucose.





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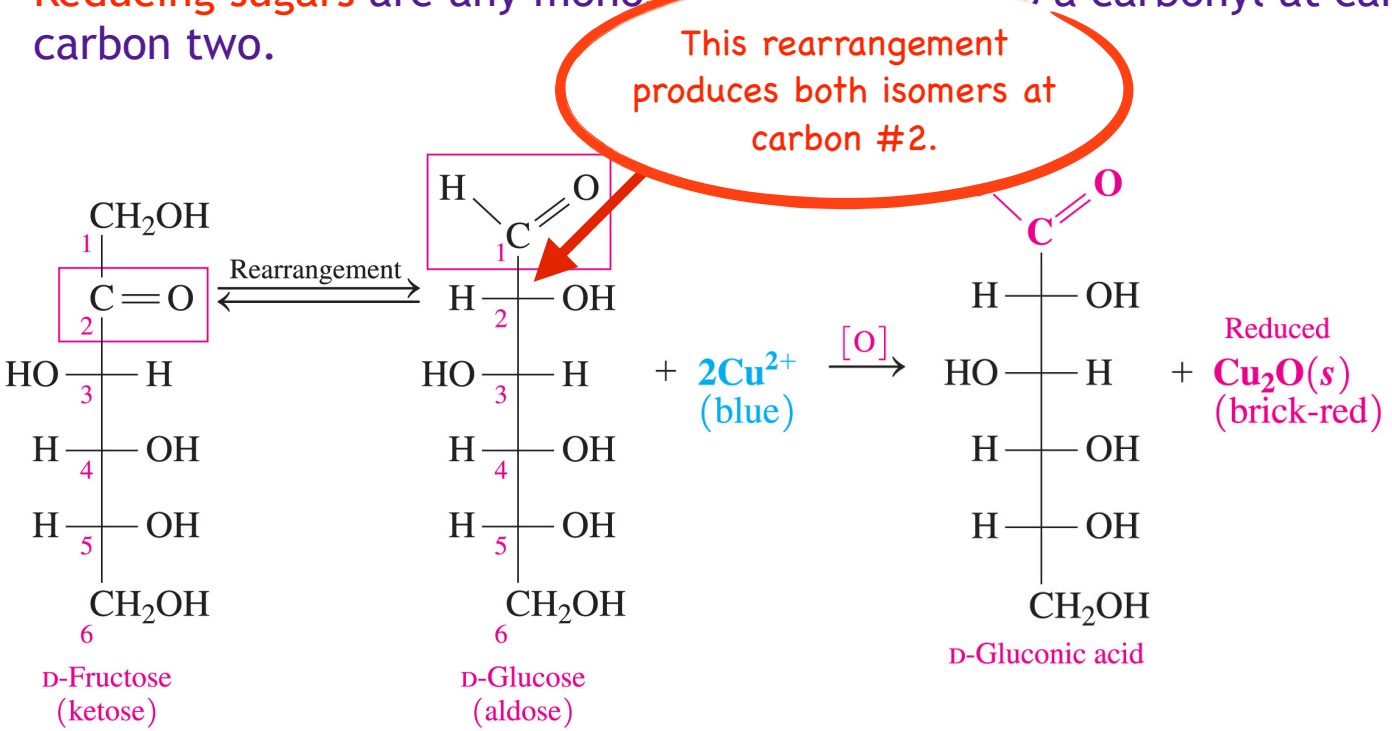
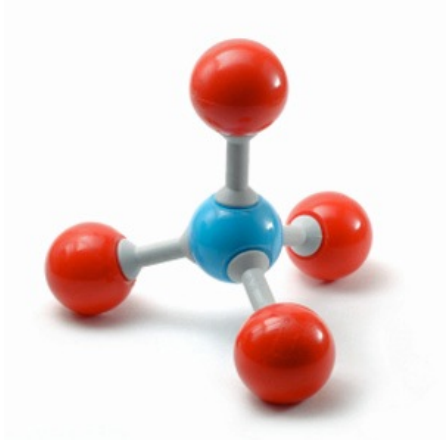
- Aldoses can be oxidized to acids with copper or silver metal salts.
- These sugars which reduce those salts while being oxidized, are called reducing sugars.
- Some ketoses are also reducing sugars. Any ketoses at carbon #2, like D-Fructose, can rearrange to form D-Glucose, and be reduced to D-Gluconic Acid.
- Reducing sugars are any monosac[illegible] has a carbonyl at carbon one or carbon two.





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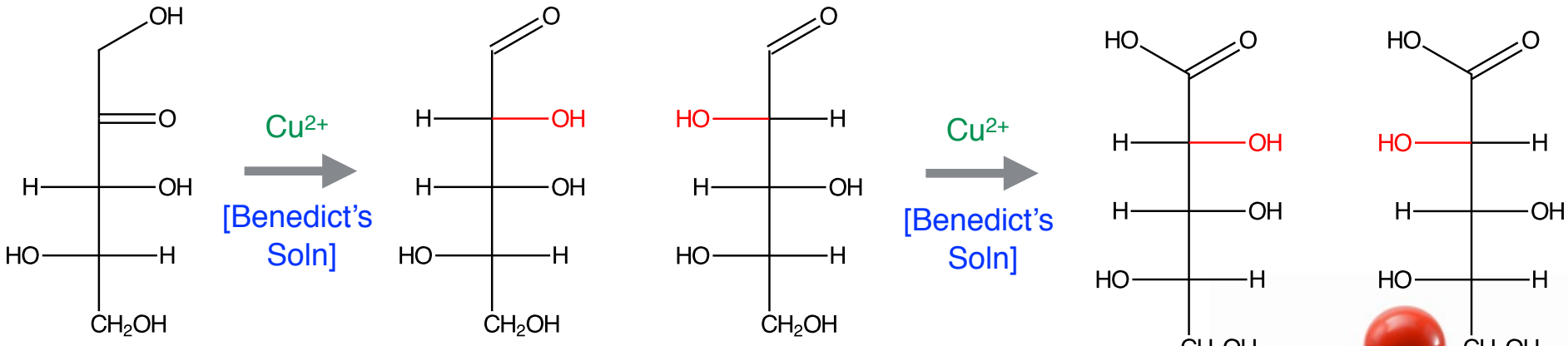
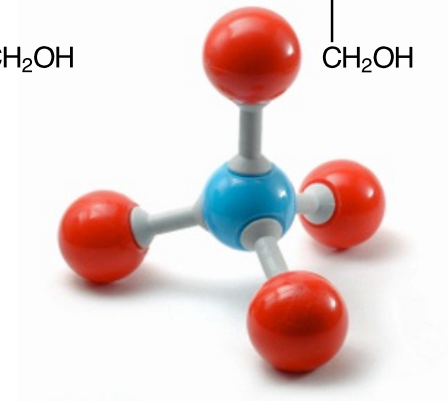
- Some ketoses are also reducing sugars. Any ketoses at carbon #2, like D-Fructose, can rearrange and be reduced.
- When ketoses at carbon #2 are reduced
  - they form two stereoisomers at carbon #2.
- Reducing sugars are any monosaccharide that has a carbonyl at carbon one or carbon two.



This rearrangement produces both isomers at carbon #2.



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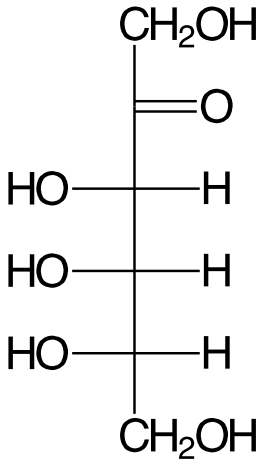
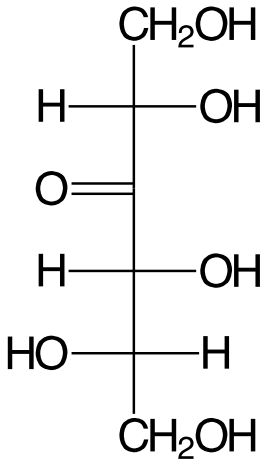
- Which of the following are reducing sugars?

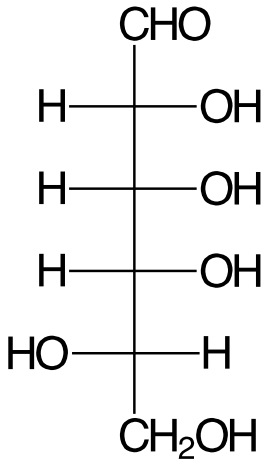
  (in other words, which of the following will react with Benedict's reagent)



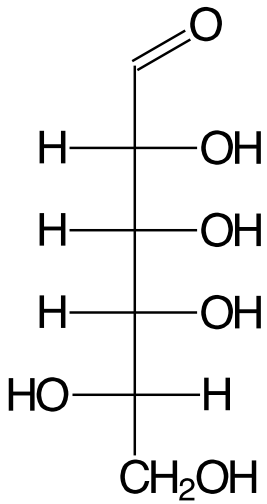
YES



NO



YES



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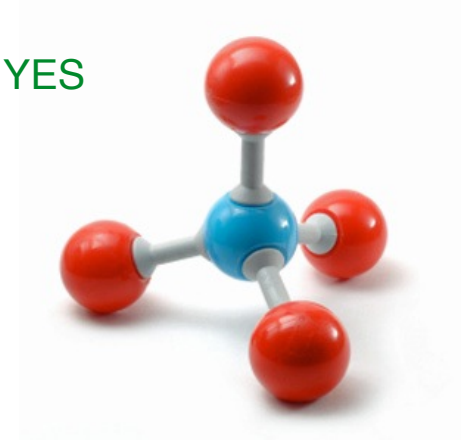

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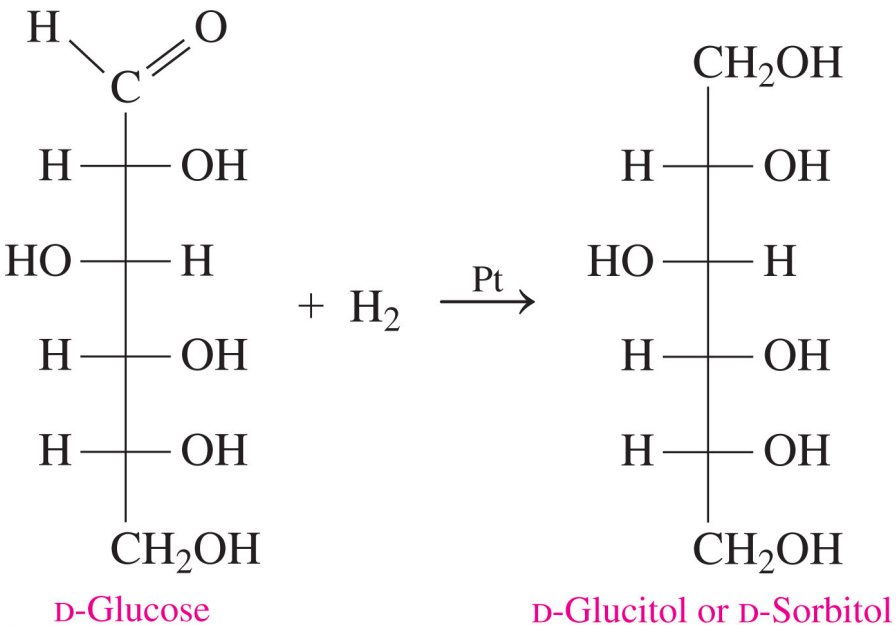
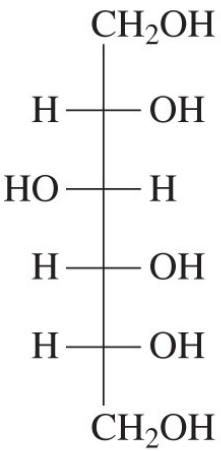
- Sugars can be reduced with catalyzed hydrogenation.
- The sugar substitute D-Sorbitol is produced in this way.



D-Glucose

D-Glucitol or D-Sorbitol



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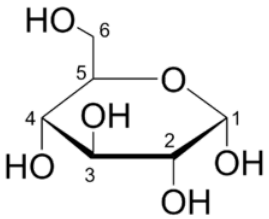

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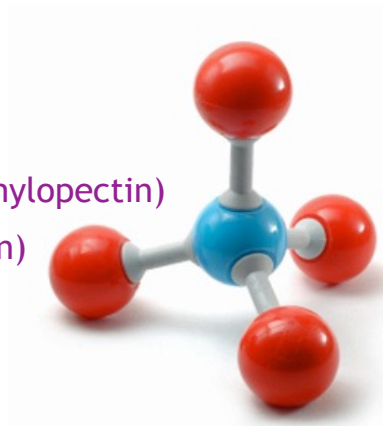
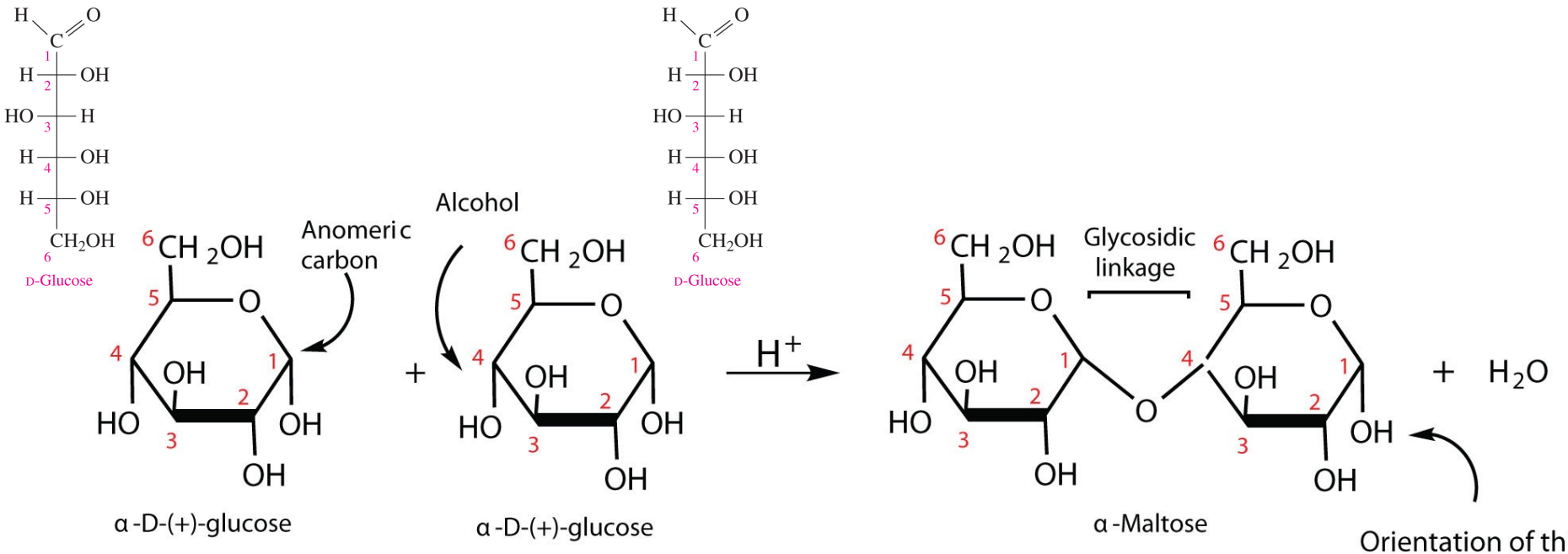
  - Cellulose



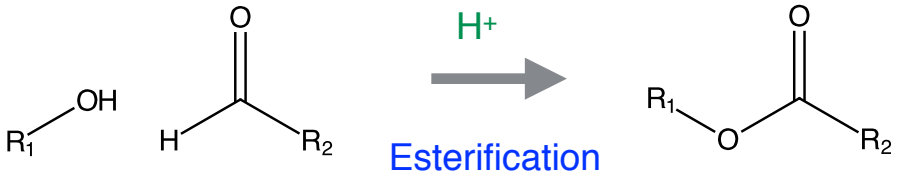
Disaccharides

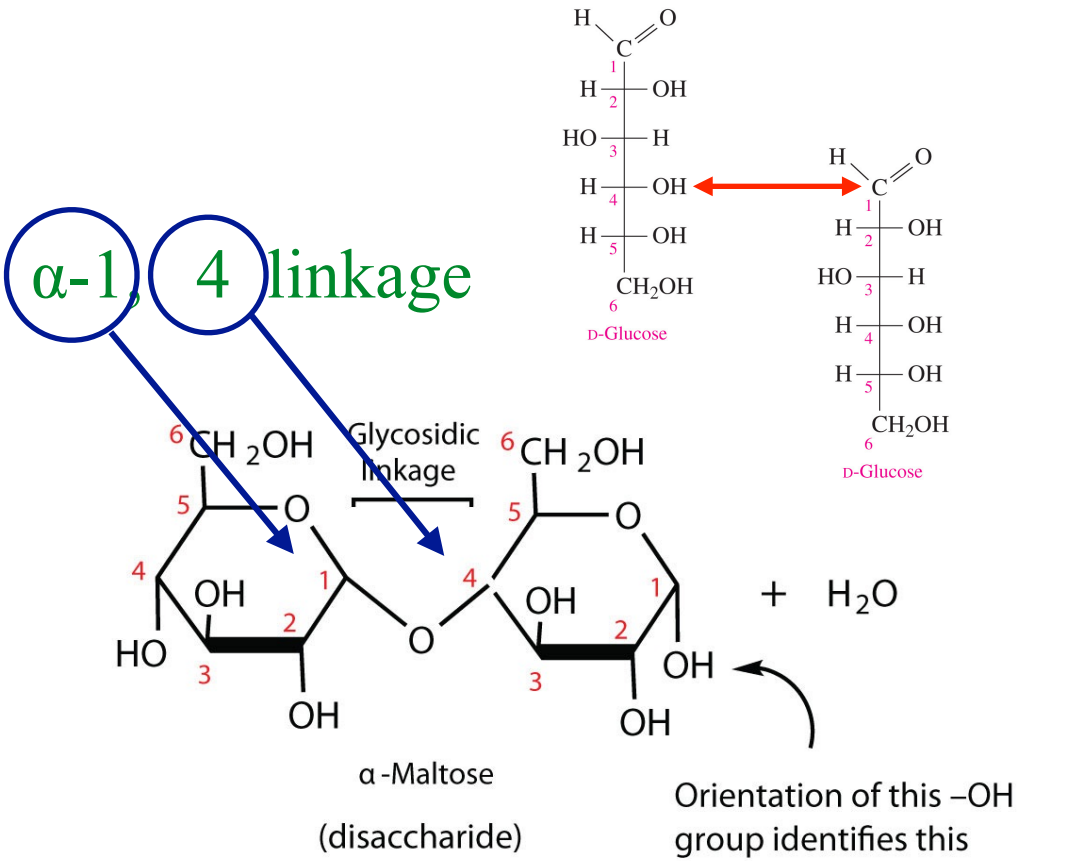
- A disaccharide
  - consists of two monosaccharides linked together
  - is formed when two monosaccharides combine in a dehydration reaction
- The most common disaccharides are maltose, lactose, and sucrose.
- Maltose (a disaccharide) is formed by the condensation of two glucose (two monosaccharide molecules).



Disaccharides

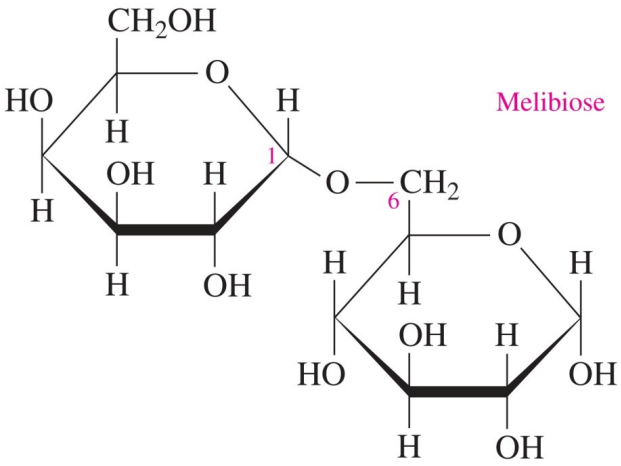
- The bonds between saccharides that form disaccharides are glycosid linkages.
- Forming a glycosid linkage is basically an esterification reaction, between a hidden aldehyde and an alcohol.
  - We describe the linkage by the address of the carbons bonded.
  - We indicate the alpha or beta isomer of the saccharide locked into it's Haworth structure.
  - Maltose has an α-1, 4 linkage.





Disaccharides

- Describe the glycosidic bond in the disaccharide melibiose:

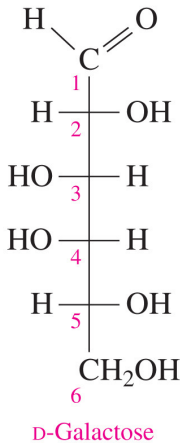


Melibiose

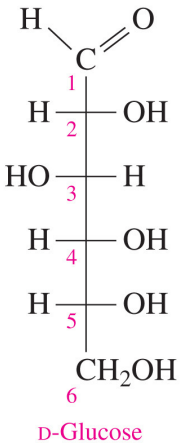
α 1, 6

Go Slow with Carbon #5 — it's the hard part!

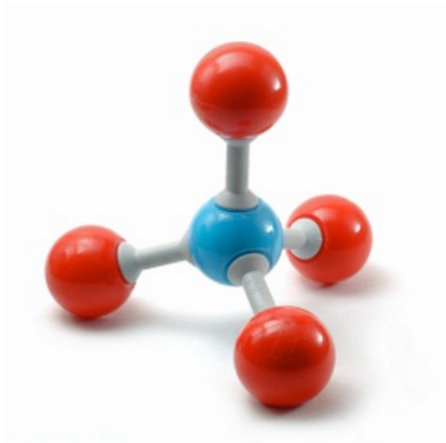
- Draw the Fisher projections of the monosaccharides produced by hydrolysis of melibiose:



D-Galactose

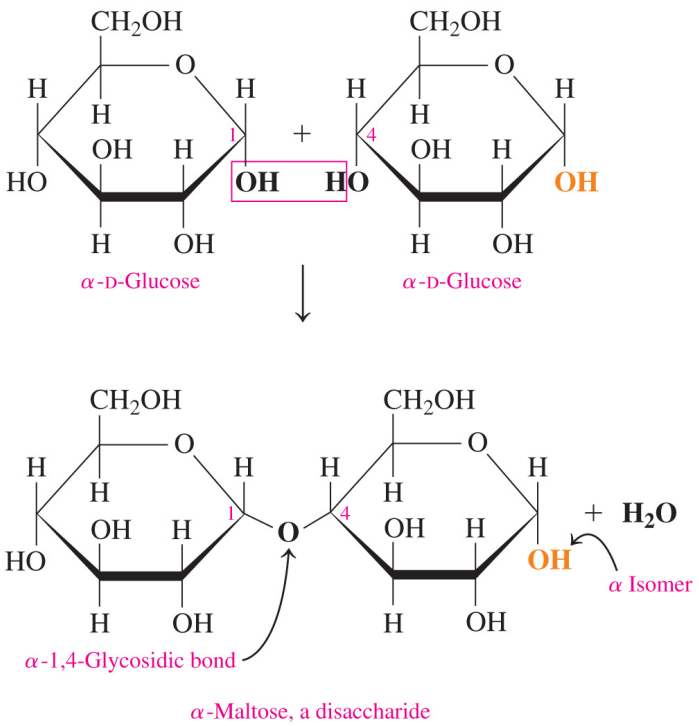


D-Glucose



Disaccharides

- Maltose ("Malt Sugar") is
  - a disaccharide found in malt, barley, grain
    - composed of two D-glucose molecules
  - obtained from the hydrolysis of starch
  - used in cereals, candies, and brewing
    - yeast is used to break down the glocosid before fermenting to form ethanol
  - an aldose (reducing sugar).
  - found in both the α and ß forms
- has an α 1,4 linkage.
- "sweet" & "maple" taste



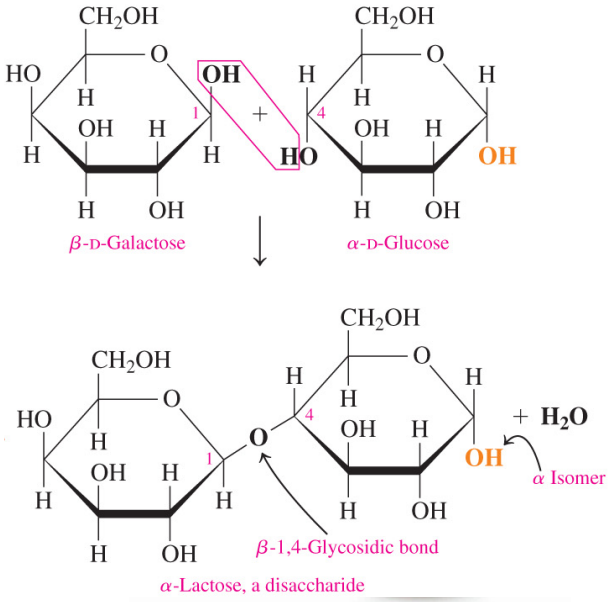
yeast → fermentation

maltose → glucose → beer

Disaccharides

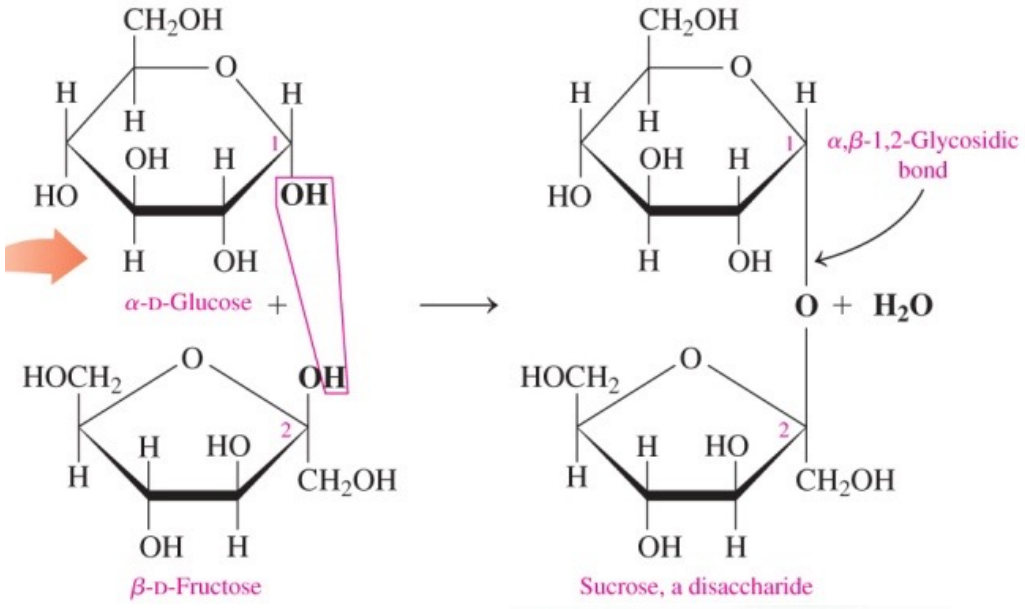
- Lactose ("Milk Sugar") is
  - a disaccharide found in milk and milk products
    - composed of ß-D-galactose and α- or ß-D-glucose.
  - makes up 6–8% of human milk and about 4–5% of cow's milk
- Our body relies on the enzyme lactase to break the glcosidic bond in lactose.
- If people have deficiencies in this enzyme, lactose has to be fermented in the intestinal track
  - producing bloating, methane, and cramps
- Lactose is an aldose and a reducing sugar.
- Lactose is "creamy" and "sweet"

The bond in lactose is a β-1,4-glycosidic bond because the — OH group on carbon 1 of β-D-galactose forms a glycosidic bond with the — OH group on carbon 4 of a D-glucose molecule.



Disaccharides

- Sucrose ("Cane Sugar") is
  - composed of D-Glucose and D-Fructose
  - a disaccharide found in sugar cane (20% by mass) and beets (15% by mass)
  - has a α, β 1,2 linkage
    - both carbonyls are used in this bond!
  - because both carbonyls are locked in this bond, this is not a reducing sugar.
- In the U.S., we estimate people consume about 68 kg a year of sucrose.
- Our body breaks this down into
  - Every cell in your body burns glucose.
  - Fructose can only be consumed by your liver.
    - When the liver is operating at capacity, excess fructose is stored as body fat.
- Sucrose tastes "sweet"



Ch13

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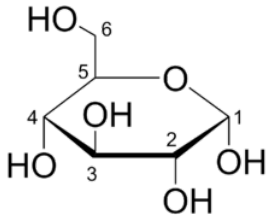

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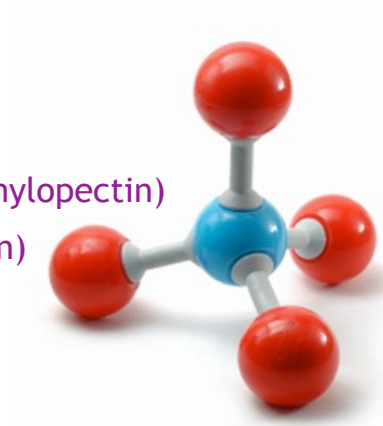
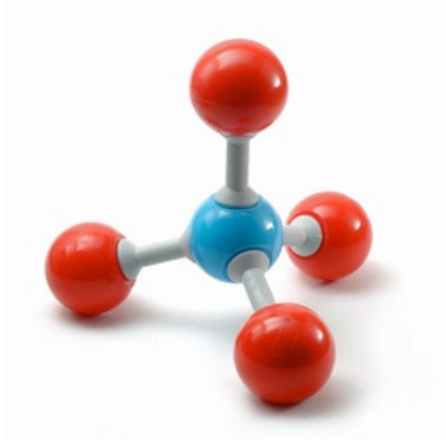


Sweetness

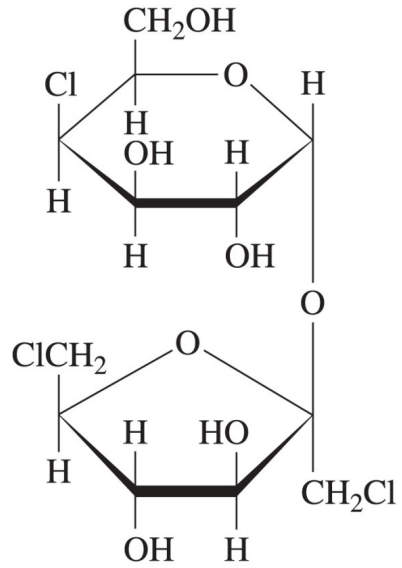
- The defining property of saccharides is sweetness.
- The english word saccharine means sweet.
- The property sweetness is based on the taste of sucrose:
  - sucrose is the zero point on our scale, with a measure of 100
  - everything else is defined relative to it
- Artificial sweeteners have been constructed to produce sweetness based on the structure of sucrose

	Sweetness Relative to Sucrose (=100)
Monosaccharides	
Galactose	30
Glucose	75
Fructose	175
Disaccharides	
Lactose	16
Maltose	33
Sucrose	100
Sugar Alcohols	
Sorbitol	60
Maltitol	80
Xylitol	100
Artificial Sweeteners (Noncarbohydrate)	
Aspartame	18 000
Saccharin	45 000
Sucralose	60 000
Neotame	1 000 000



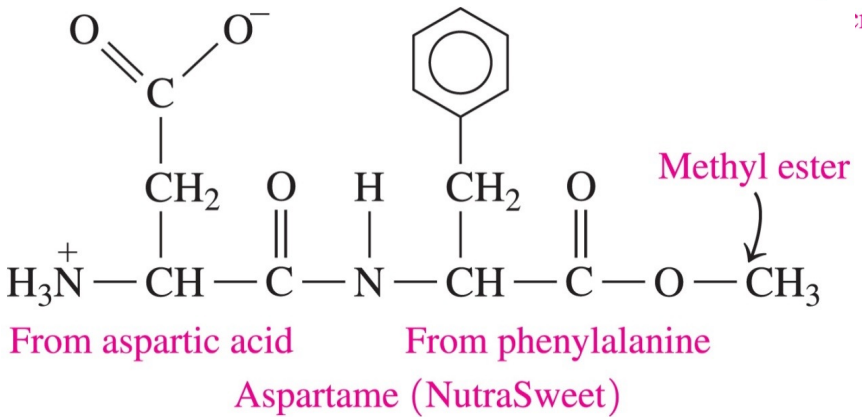
Sweetness

- Splenda is similar to sucrose, but with alcohol groups replaced with chlorine atoms:



ralose (Splenda)

- Aspartame is marketed as NutraSweet or Equal
  - a noncarbohydrate sweetener made from aspartic acid and a methyl ester of the amino acid phenylalanine



Aspartame (NutraSweet)

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Glucose	75
Fructose	175
Disaccharides	
Lactose	16
Maltose	33
Sucrose	100
Sugar Alcohols	
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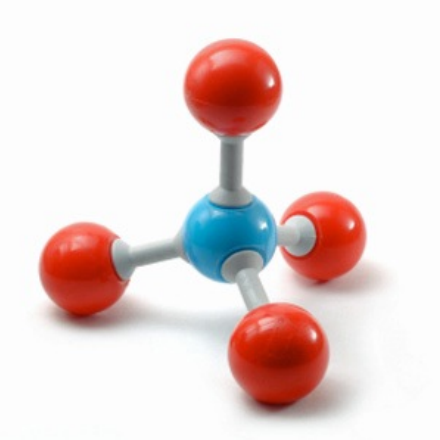
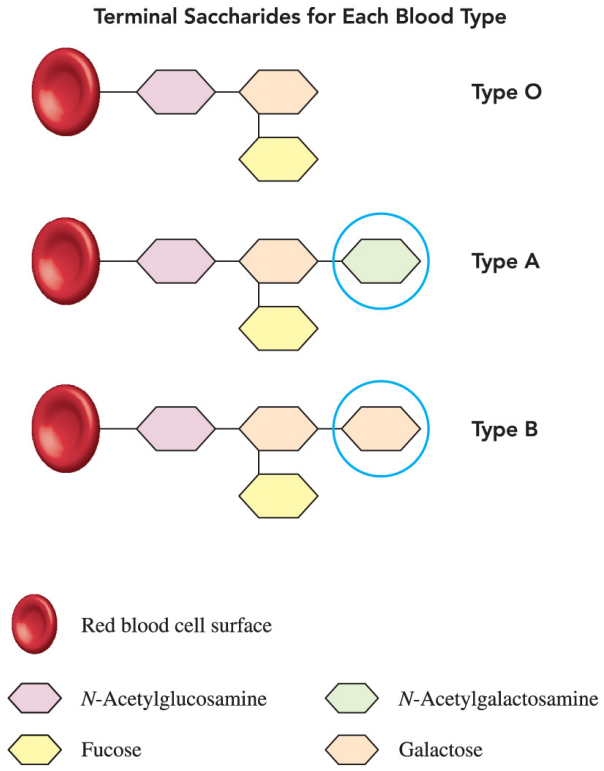
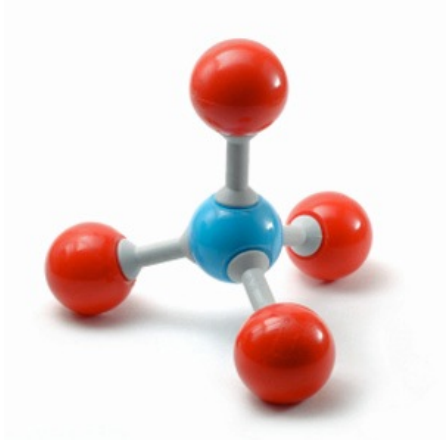


Saccharides in Blood Types

- Blood types A, B, AB, and O are determined by terminal saccharides attached to the surface of red blood cells.
  - O has three common terminal monosaccharides: N-acetylglucosamine, galactose, and fucose
  - A contains the same three monosaccharides, but in addition, a molecule of N-acetylgalactosamine is attached to galactose in the saccharide chain
  - B also contains the same three monosaccharides, but in addition, a second molecule of galactose is attached to the saccharide chain
  - AB consists of the same monosaccharides found in blood types A and B
- Persons with
  - type O blood
    - contains the three common monosaccharides, produce antibodies against blood types A, B, and AB—they are universal donors
  - blood types A, B, and AB can receive type O blood
  - type AB blood
    - contains all the terminal monosaccharides, produce no antibodies to type A, B, or O blood—they are universal recipients





Ch13

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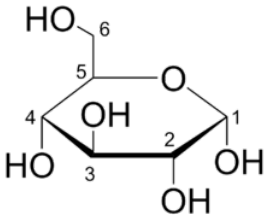

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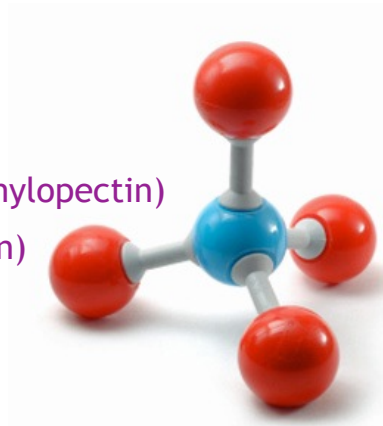
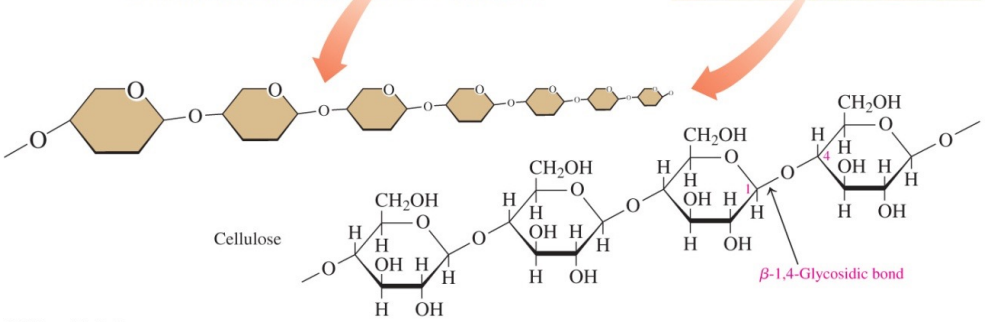
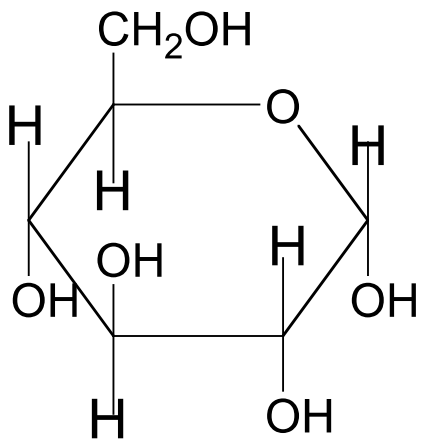
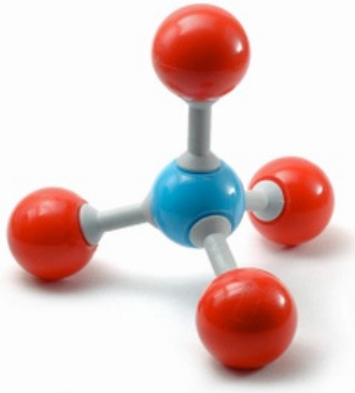


Polysaccharides

- Polysaccharides
  - are formed when monosaccharides are joined together
  - include amylose, amylopectin, and cellulose, which are polymers of α-D-glucose
- The polysaccharide cellulose is composed of glucose units connected by ß-1,4-glycosidic bonds.
  - Cellulose is a long chain of linked sugar molecules that gives wood its remarkable strength.
  - It is the main component of plant cell walls, and the basic building block for many textiles and for paper.
    - Cotton is the purest natural form of cellulose.
  - cannot be digested by humans because humans cannot break down ß-1,4-glycosidic bonds
  - It is the main component of plant cell walls, and the basic building block for many textiles and for paper.







Polysaccharides

- The polysaccharide cellulose is composed of glucose units connected by ß-1,4-glycosidic bonds.
  - Cellulose, the major structural unit of wood,
  - is a polysaccharide of glucose units in unbranched chains with ß-1,4-glycosidic bonds
  - cannot form hydrogen bonds with water; thus, it is insoluble in water
  - gives a rigid structure to the cell walls in wood and fiber
  - is more resistant to hydrolysis than are the starches
  - cannot be digested by humans because humans cannot break down ß-1,4-glycosidic bonds
  - Cellulose is a long chain of linked sugar molecules that gives wood its remarkable strength.
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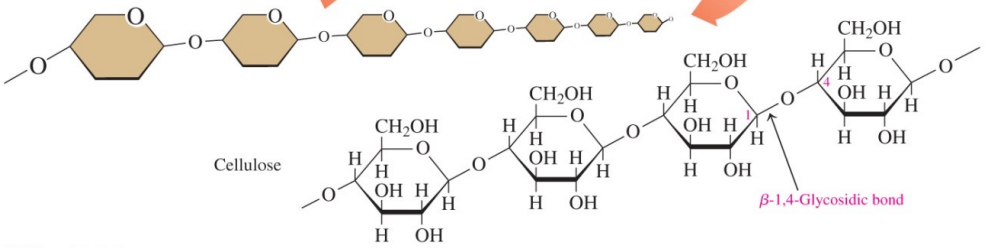

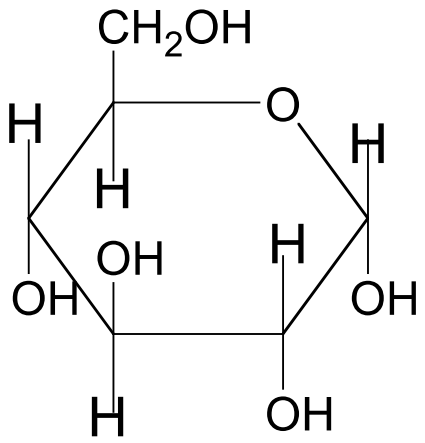

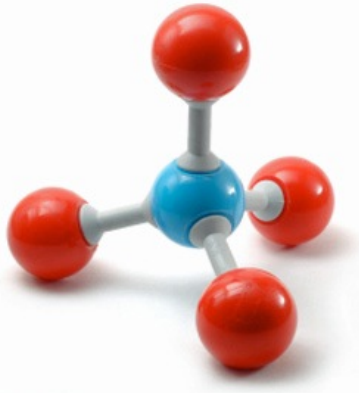

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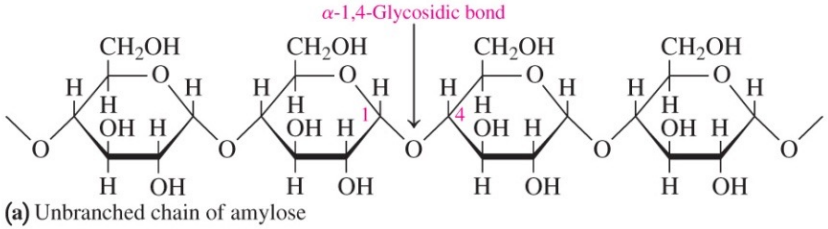
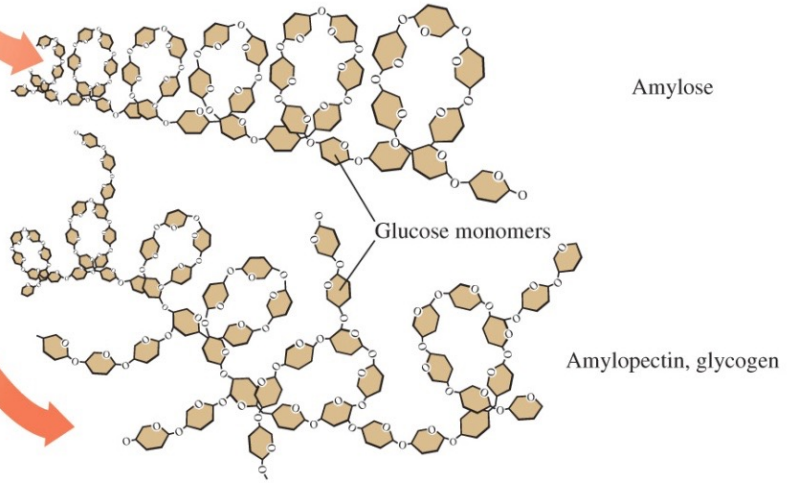
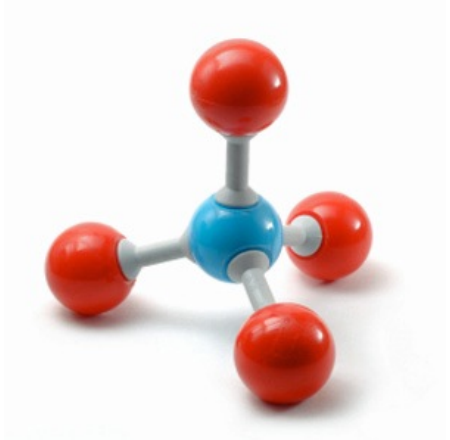




- The structure of amylose is a straight-chain polysaccharide of glucose units.
- Amylose makes up about 20% of starch
  - consists of 250 to 4000 α-D-glucose molecules connected by α-1,4-glycosidic bonds in a continuous chain
  - is called a straight-chain polymer even though the polymers of amylose are actually coiled in helical fashion



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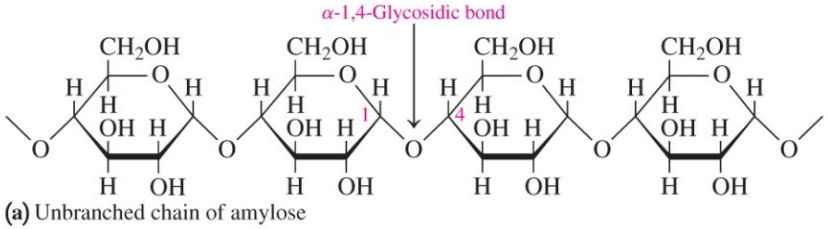
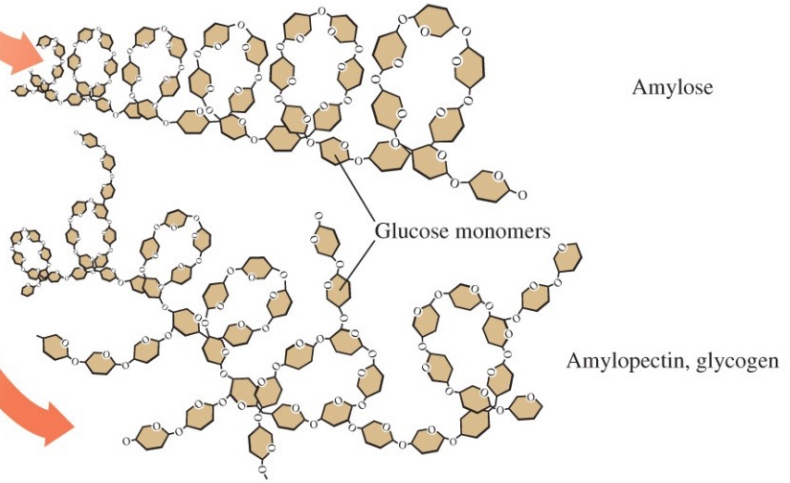
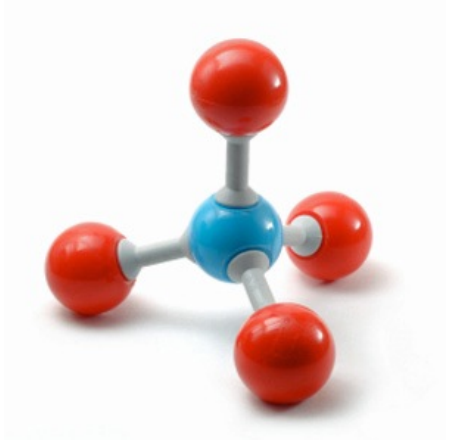




- The structure of amylopectin is a branched chain of glucose.
  - Amylopectin is a soluble polysaccharide and highly branched polymer of glucose found in plants.
  - It is one of the two components of starch, the other being amylose.
  - Glucose units are linked in a linear way with α glycosidic bonds.



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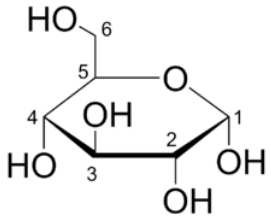

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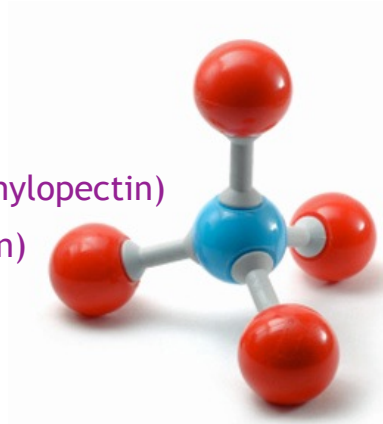

Questions?