

# Carbohydrate

## ❖ Classification

1. Numbers
2. Location of carbonyl group
3. Number of carbon atoms
4. Configuration
5. Reactivity

## ❖ Common hexoses

1. Aldoses
2. Ketoses

## ❖ Stereochemistry

1. Chirality
2. Enantiomers
3. D- & L-sugars
4. Physical properties
5. Fischer projections
6. Haworth formulae
7. Stereo projections
8. Chair presentations

## ❖ Conformation

1. Intramolecular cyclization
2. Anomer
3. Mutarotation
4. Furanose & pyranose

## ❖ Some important monosaccharide

1. D-glyceraldehyde
2. D-glucose
3. D-fructose
4. D-galactose
5. D-ribose

## ❖ Disaccharide

1. Glycosidic bond
2. Disaccharide

## ❖ Oligosaccharide

## ❖ Polysaccharide

# Carbohydrate



## Carbohydrate Can Be Divided up Into 3 Groups



¶ Sugar  
Glucose + Sucrose



· Starch



⌋ Cellulose

### Why do we need carbohydrate?



## Carbohydrate

Compounds contain C, H, O with  
general formula of  $C_m(H_2O)_n$

All have C=O and -OH functional groups

Classified based on

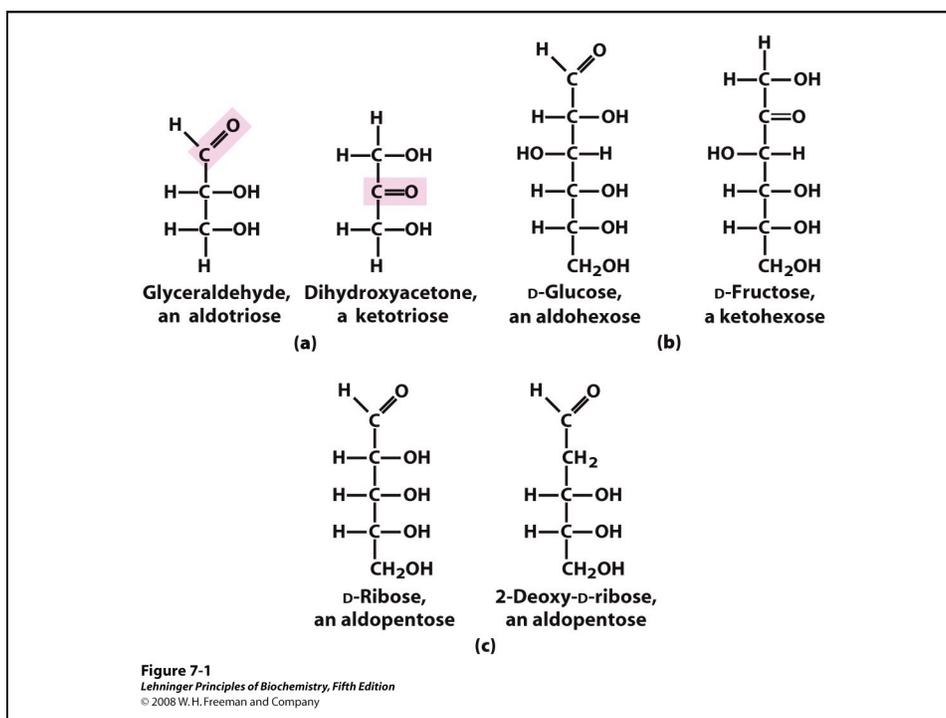
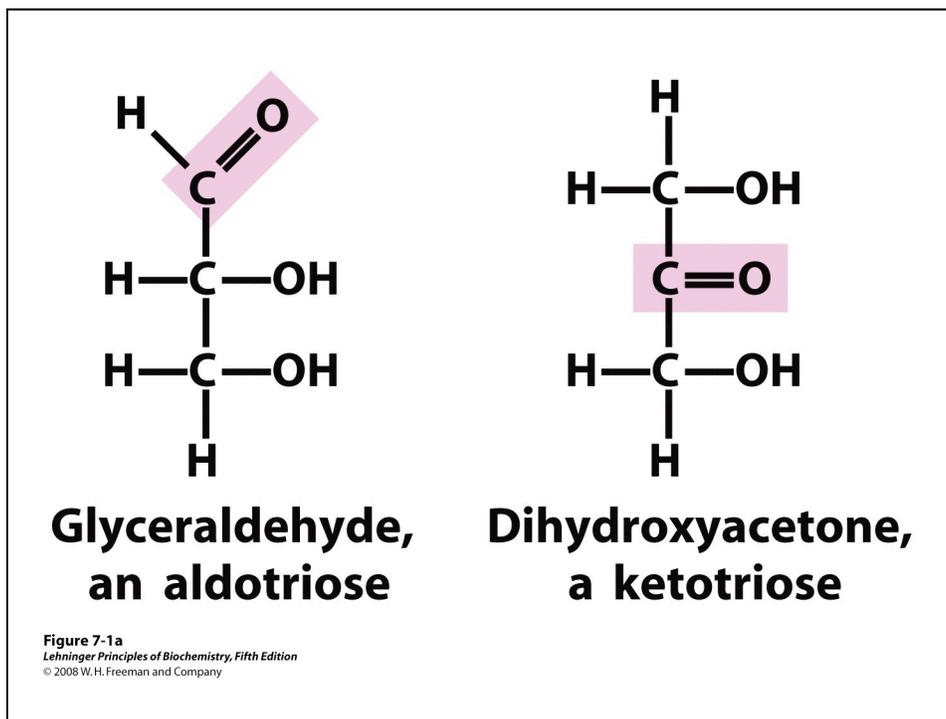
- Size of base carbon chain
- Number of sugar unit
- Location of C=O group
- Stereochemistry

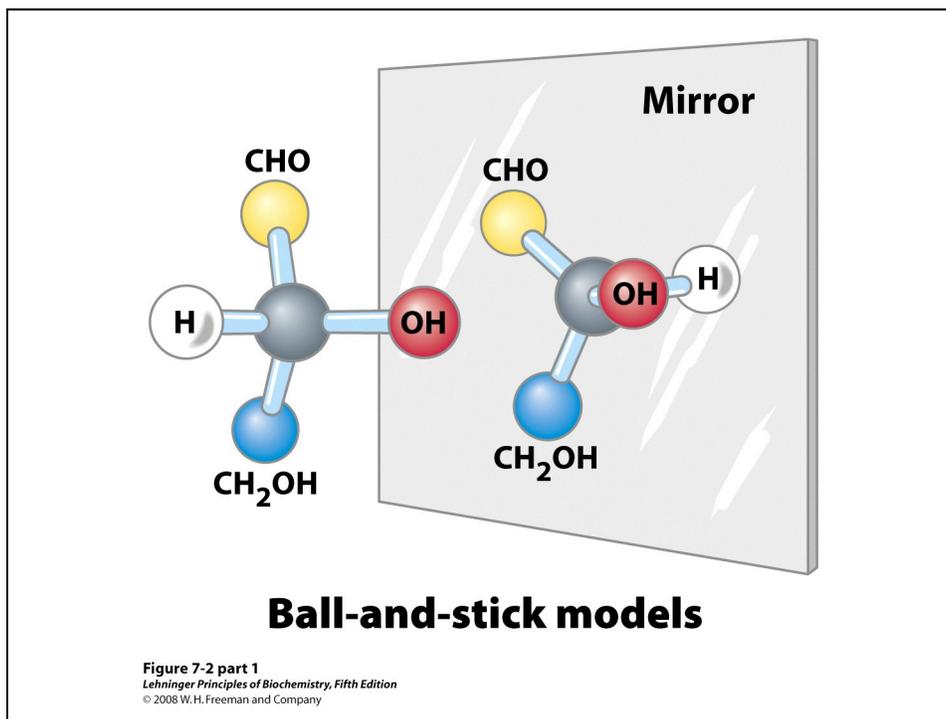
## Types of Carbohydrates

Classification based on the number of sugar units  
in the total chain

Monosachcarides	Single sugar unit
Disaccharides	Two sugar units
Trisachcarides	Three sugar units
Oligosaccharides	up to 10/13/ sugar units
Polysaccharides	> 13 sugar units

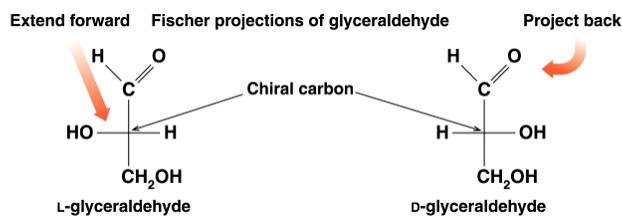
Chaining relies on the glycosidic bonds





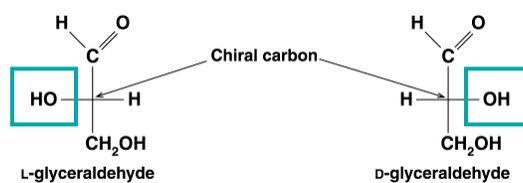
## Fischer Projections

- Used to represent carbohydrates (chiral carbons)
- Places the most oxidized group at the top (C1)
- Uses horizontal lines for bonds that come forward
- Uses vertical lines for bonds that go back



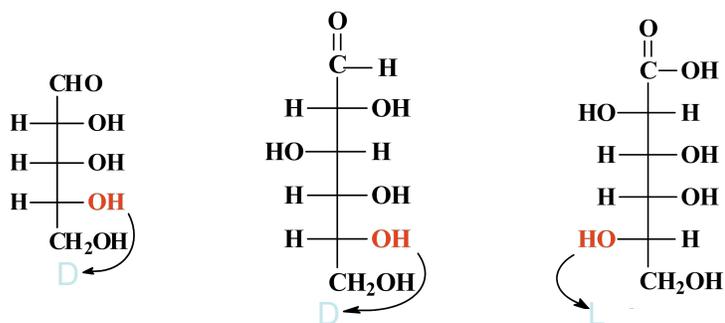
## D and L Notations

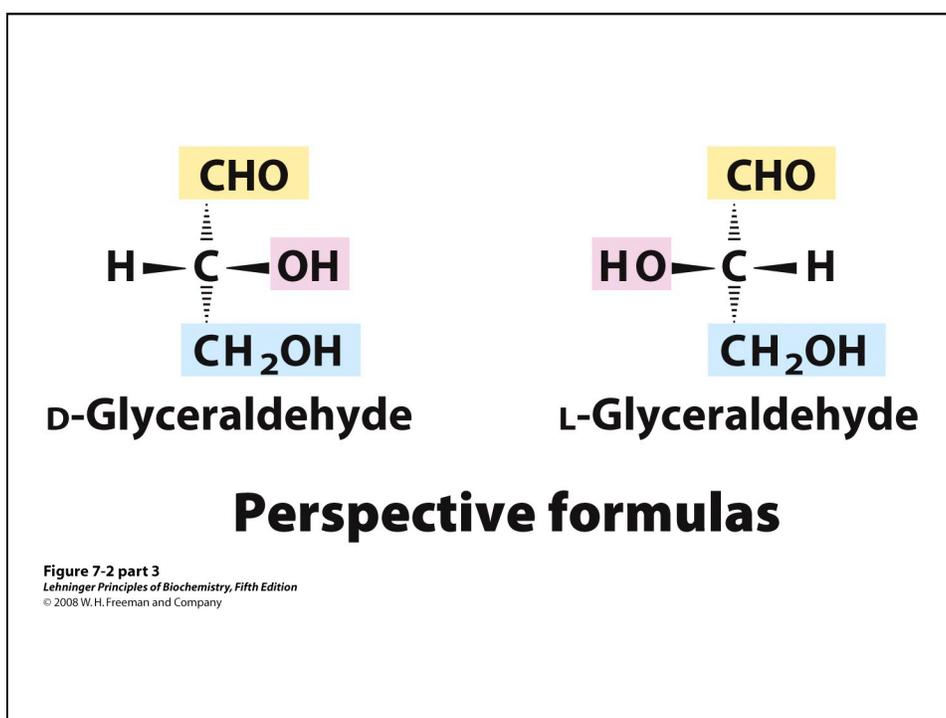
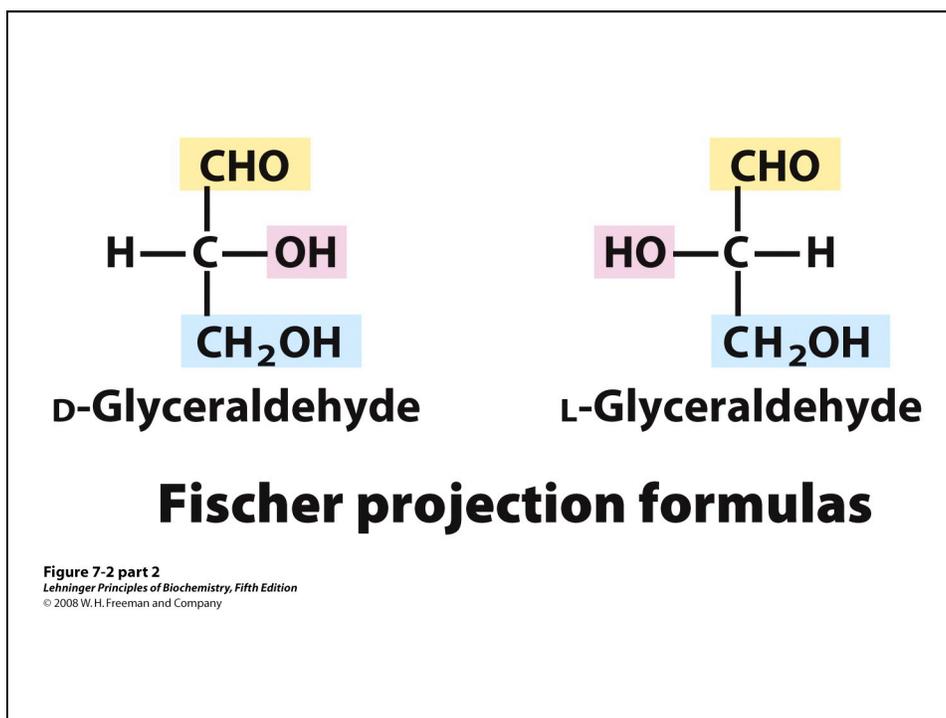
- By convention, the letter **L** is assigned to the structure with the —OH on the left
- The letter **D** is assigned to the structure with —OH on the right



## D and L Monosaccharides

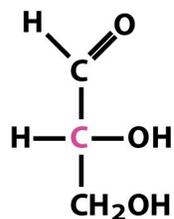
- Stereochemistry determined by the asymmetric center farthest from the carbonyl group
- Most monosaccharides found in living organisms are D





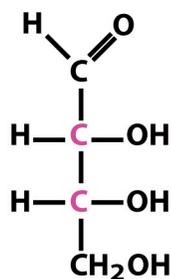
## D-Aldoses

### Three carbons

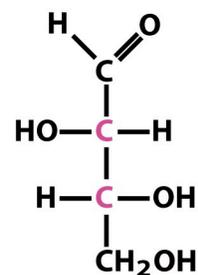


**D-Glyceraldehyde**

### Four carbons



**D-Erythrose**

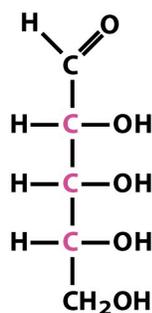


**D-Threose**

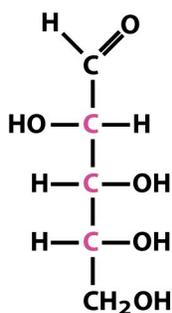
Figure 7-3a part 1  
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## D-Aldoses

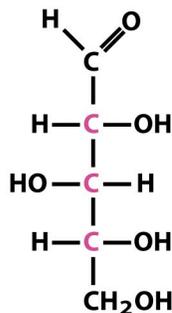
### Five carbons



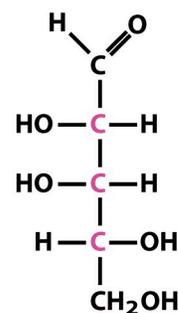
**D-Ribose**



**D-Arabinose**

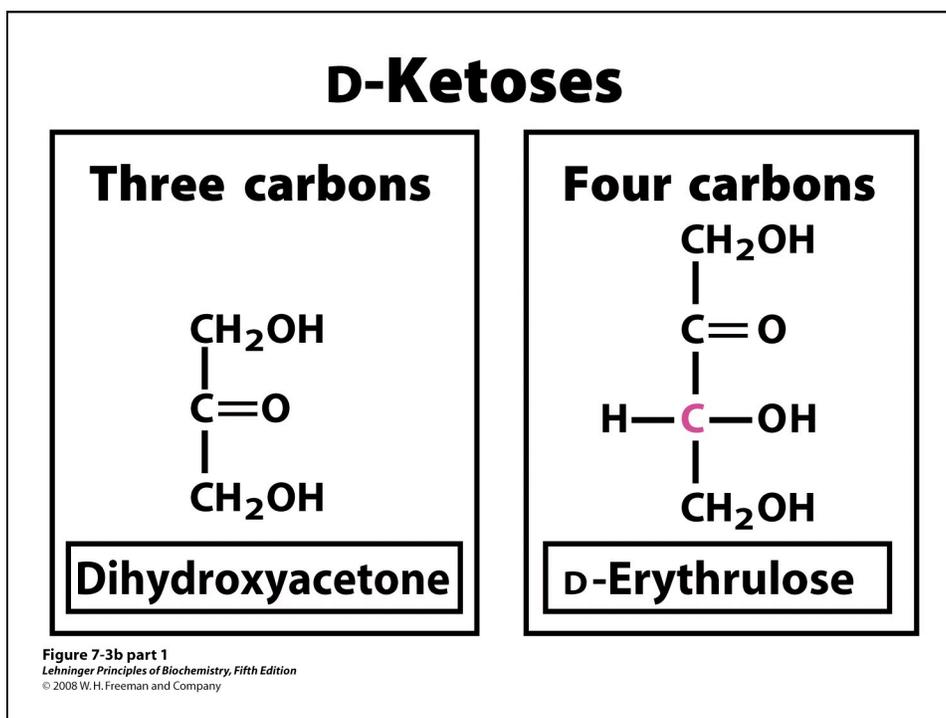
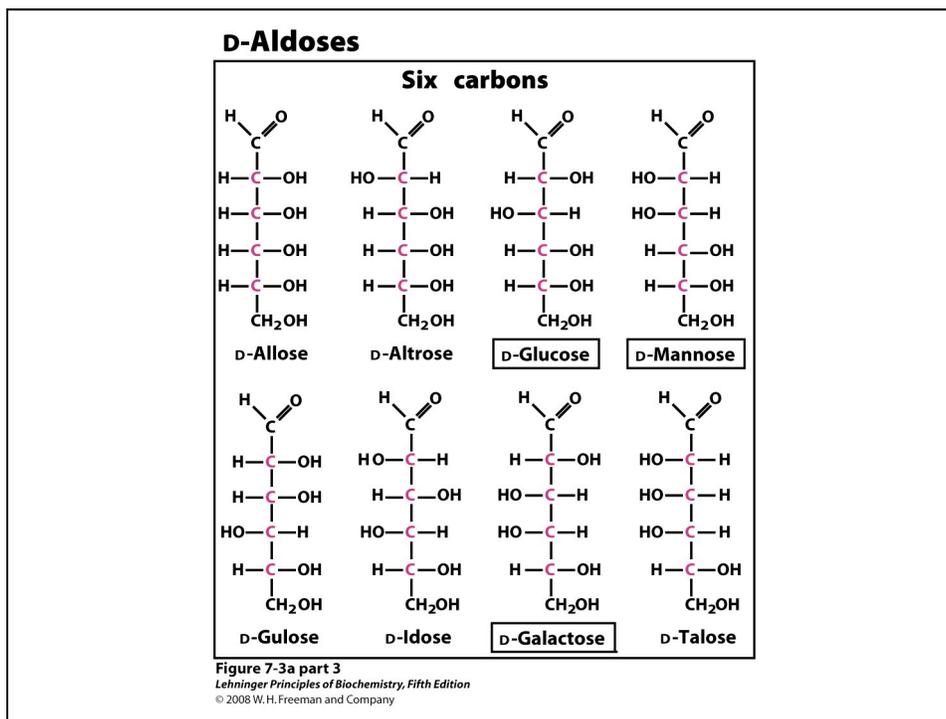


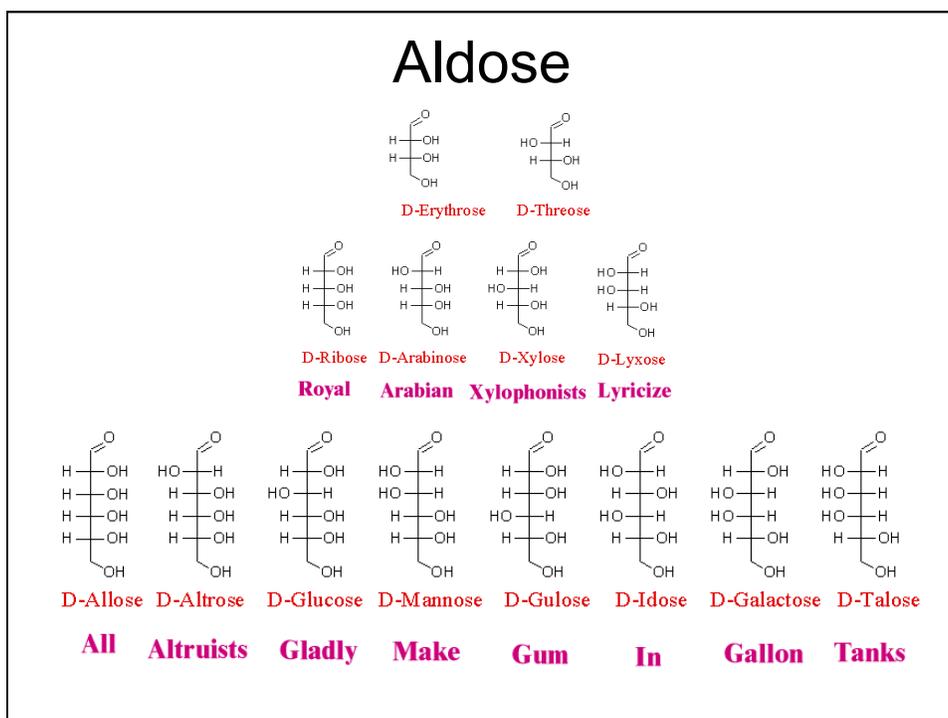
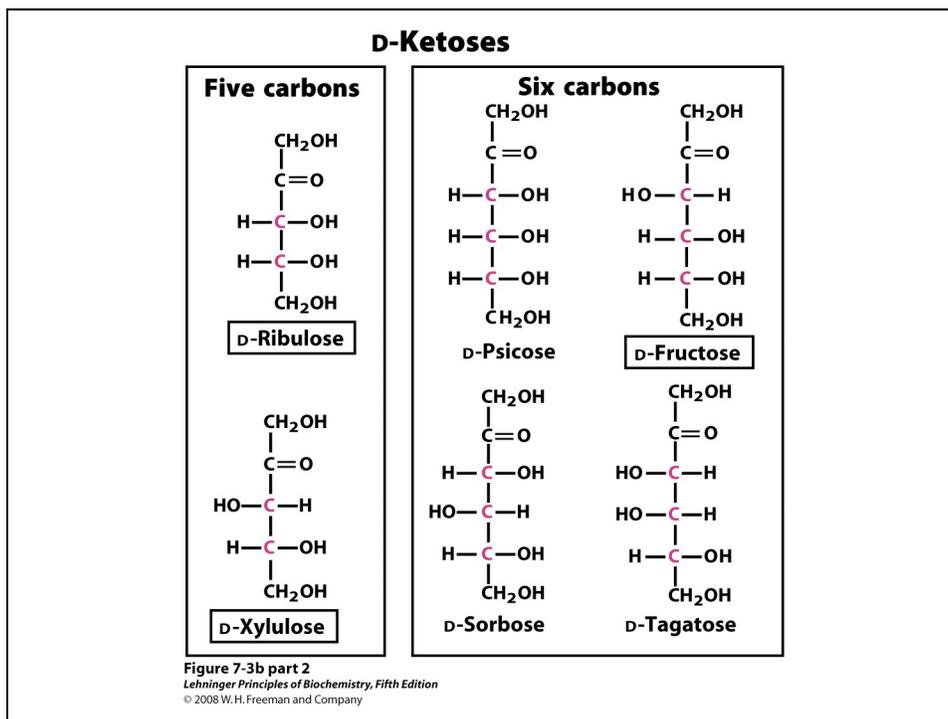
**D-Xylose**



**D-Lyxose**

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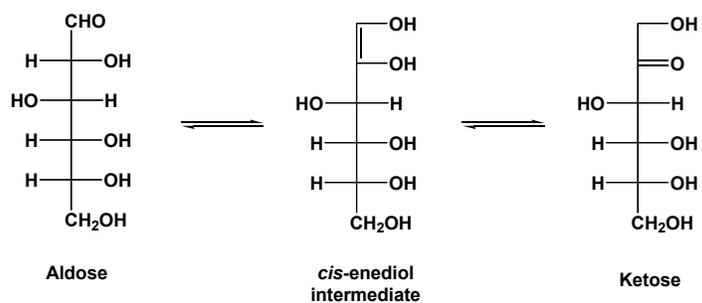




## Ketone Sugars

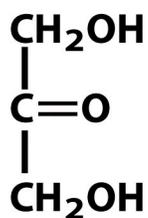
Ketones are not easy to oxidize except for ketoses

**Enediol reaction** -- All monosaccharides are reducing sugars



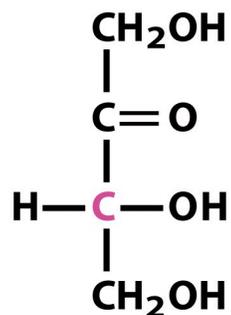
## D-Ketoses

### Three carbons



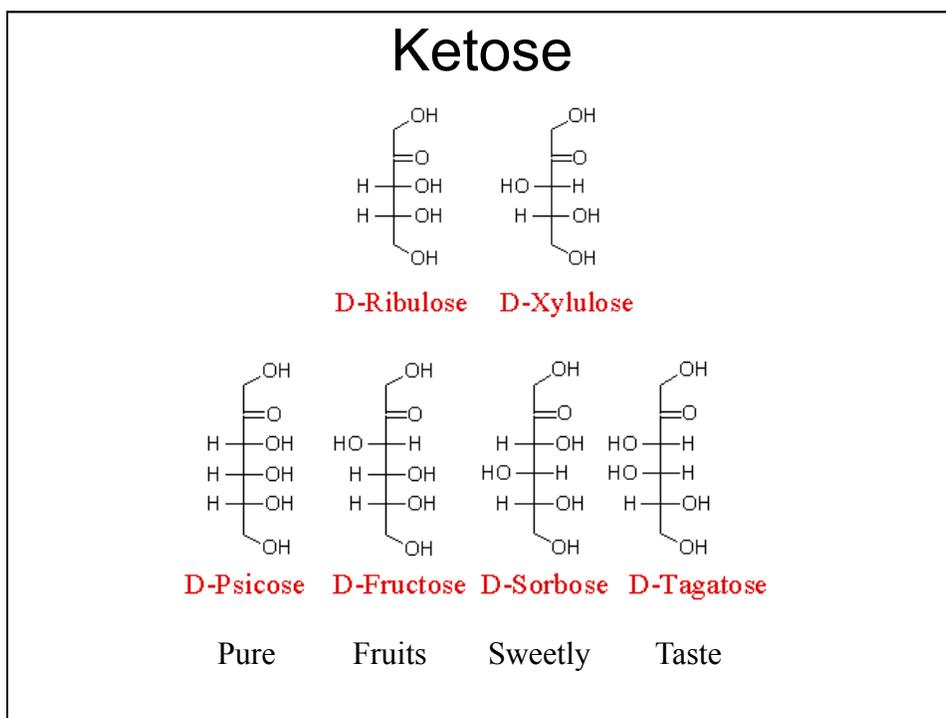
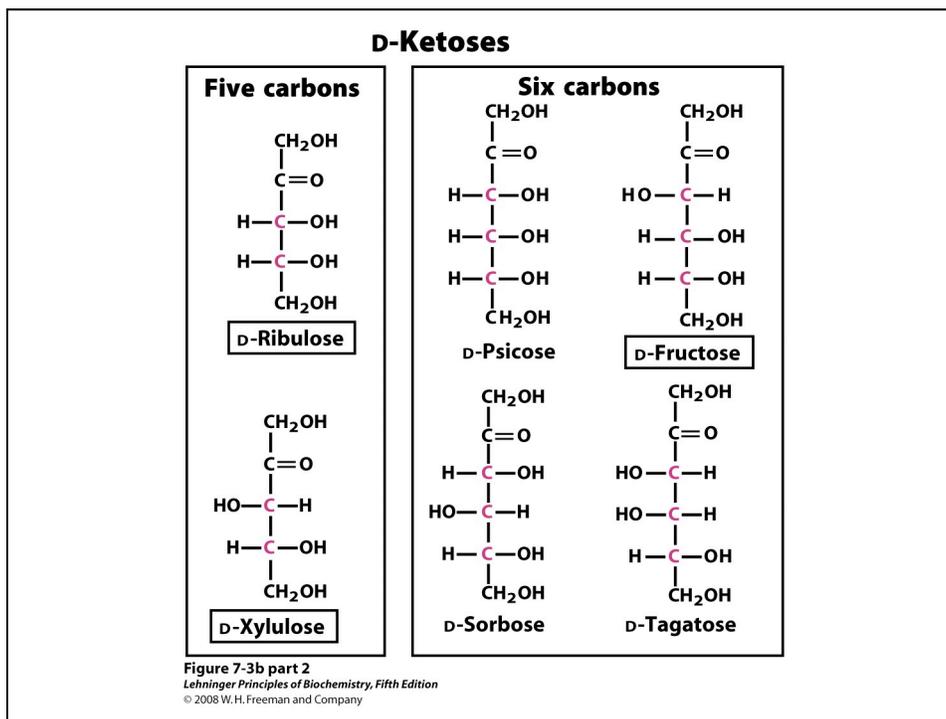
**Dihydroxyacetone**

### Four carbons



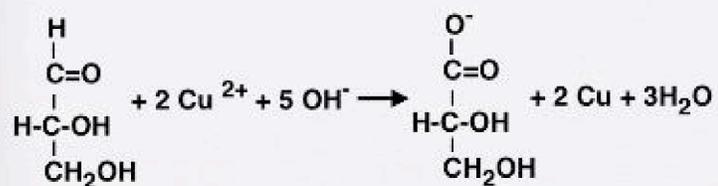
**D-Erythrulose**

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## Reducing sugars

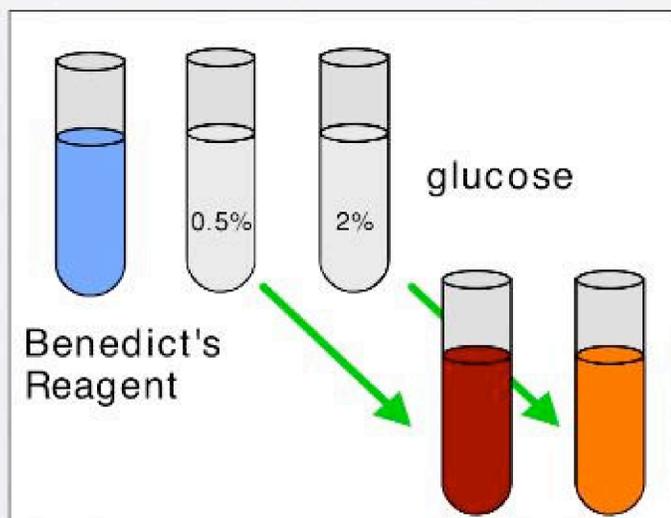
Aldehyde sugars are readily oxidized and will react with Benedict's reagent.



This provides a good test for presence of glucose in urine. You get a red precipitate.

Other tests - Tollen's or Fehling's solutions.

## Benedict's reagent



# Conformation

Intramolecular cyclization

Anomer

Mutaroation

Furanose & pyranose

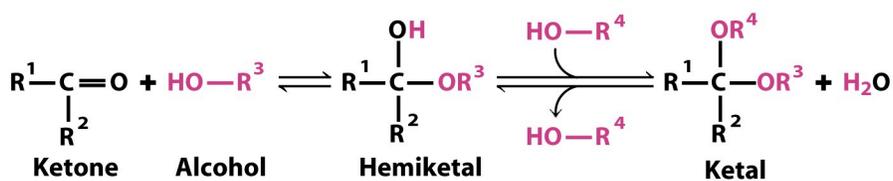
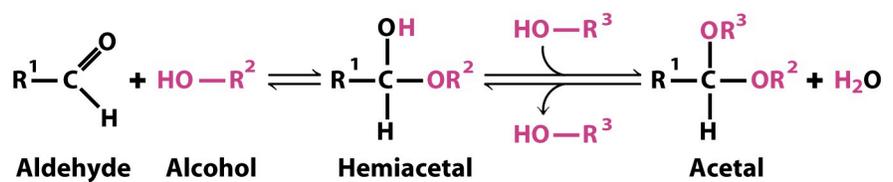
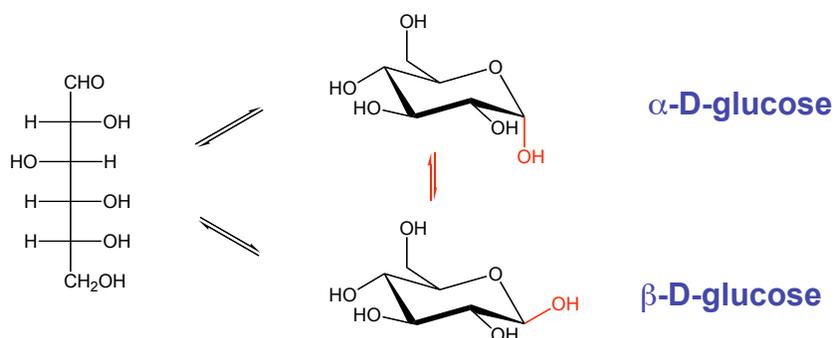


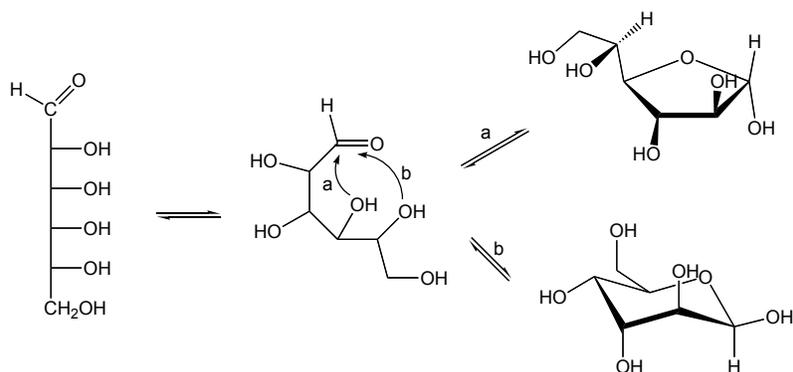
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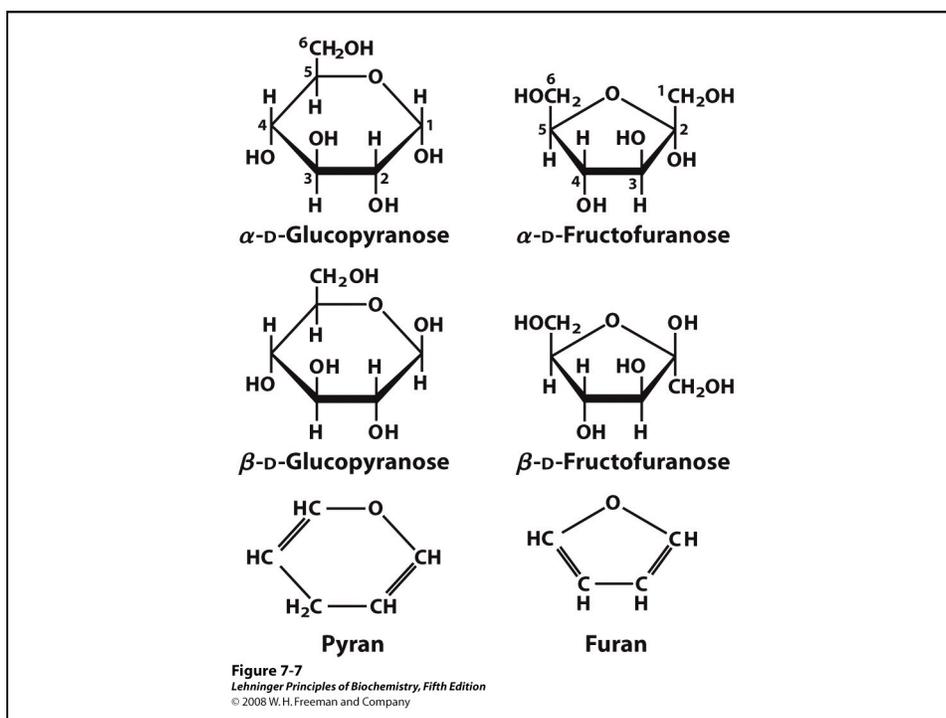
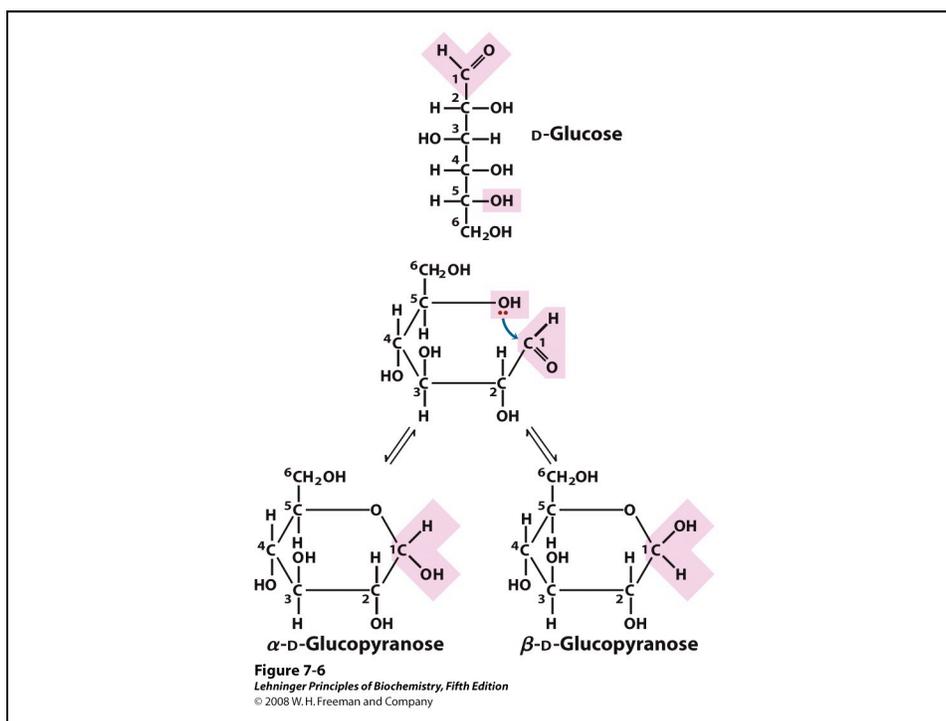
## Cyclization of D-glucose



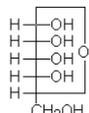
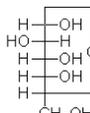
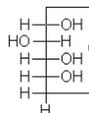
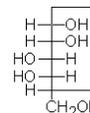
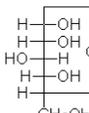
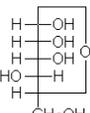
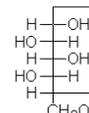
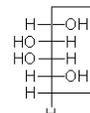
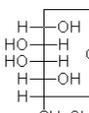
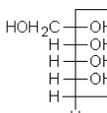
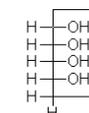
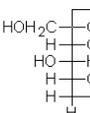
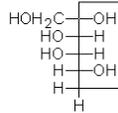
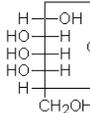
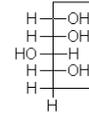
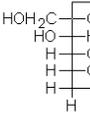
## Intramolecular Cyclization

Chain can bend and rotate

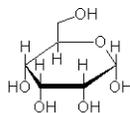
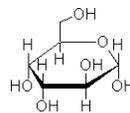
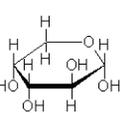
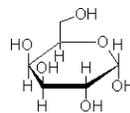
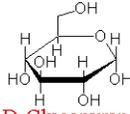
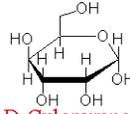
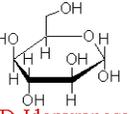
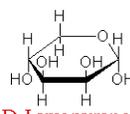
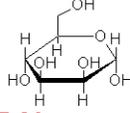
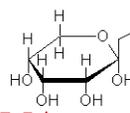
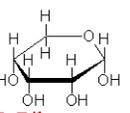
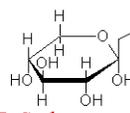
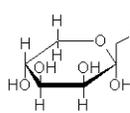
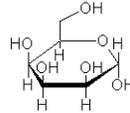
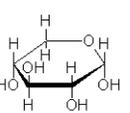
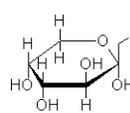




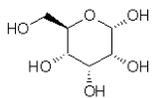
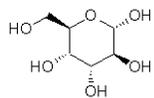
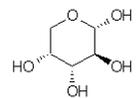
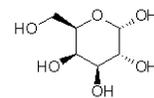
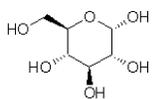
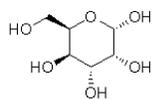
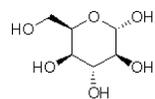
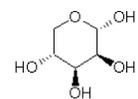
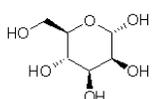
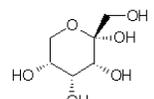
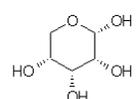
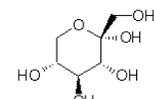
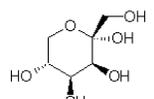
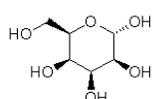
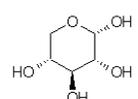
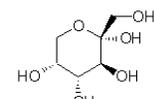
## Fisher Projections

 $\alpha$ -D-Allopyranose $\alpha$ -D-Altropyranose $\alpha$ -D-Arabinopyranose $\alpha$ -D-Galactopyranose $\alpha$ -D-Glucopyranose $\alpha$ -D-Gulopyranose $\alpha$ -D-Idopyranose $\alpha$ -D-Lyxopyranose $\alpha$ -D-Mannopyranose $\alpha$ -D-Psicopyranose $\alpha$ -D-Ribopyranose $\alpha$ -D-Sorbopyranose $\alpha$ -D-Tagatopyranose $\alpha$ -D-Talopyranose $\alpha$ -D-Xylopyranose $\alpha$ -D-Fructopyranose

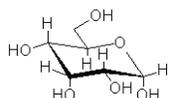
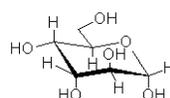
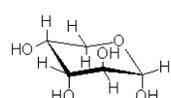
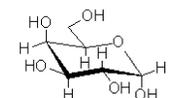
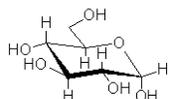
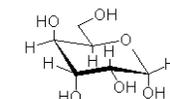
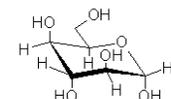
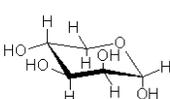
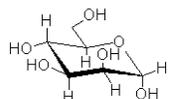
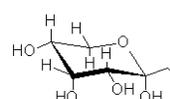
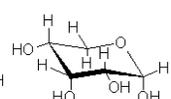
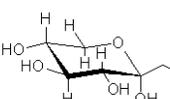
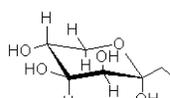
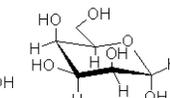
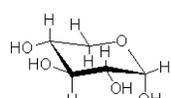
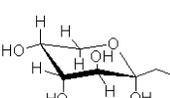
## Haworth Formulae

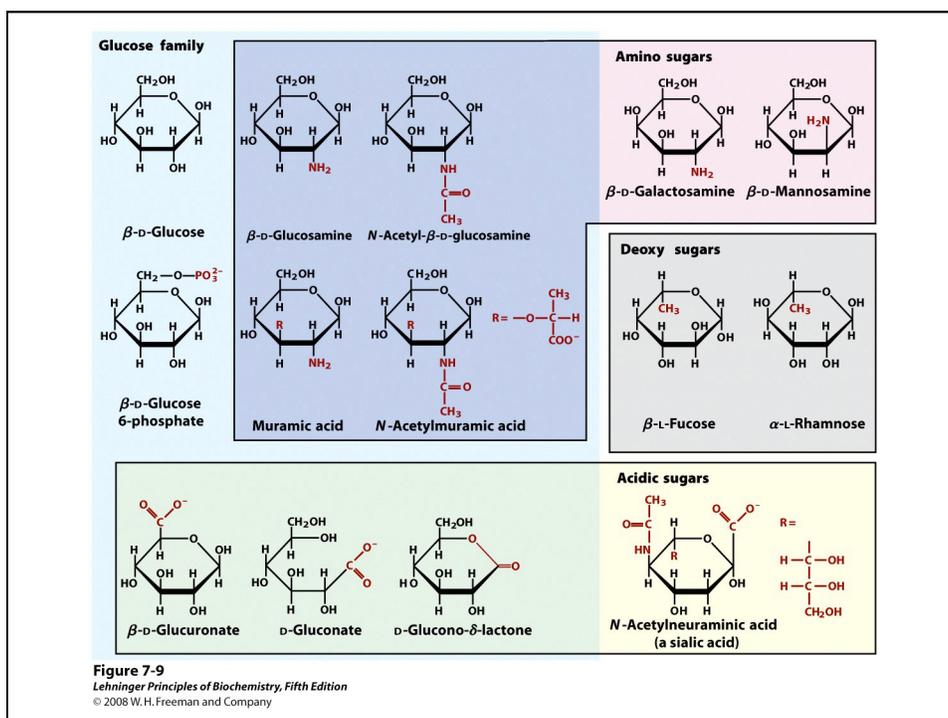
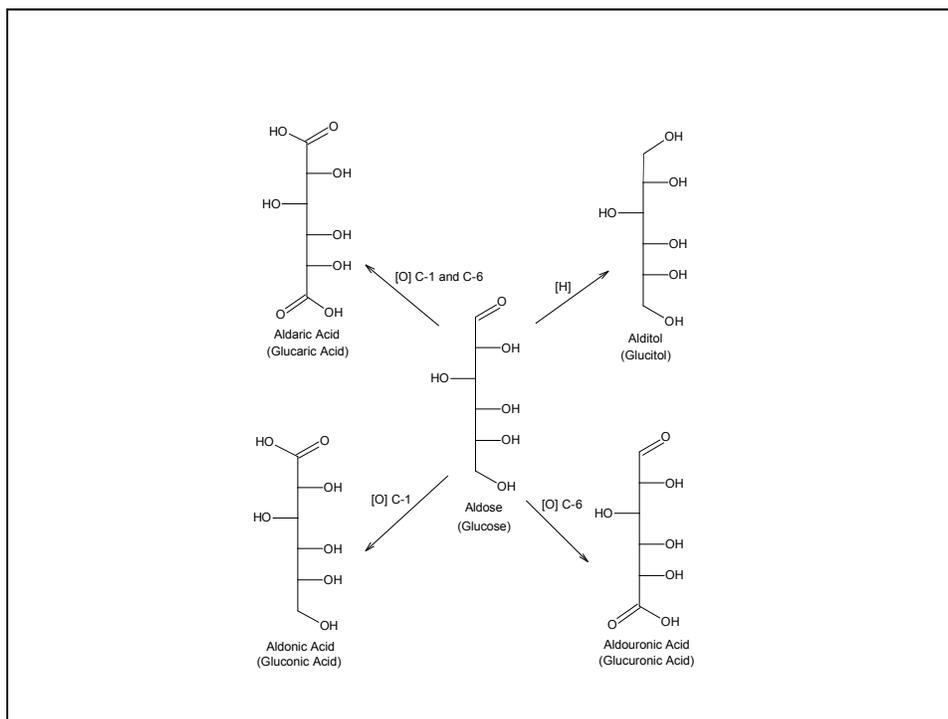
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## Stereo Projections

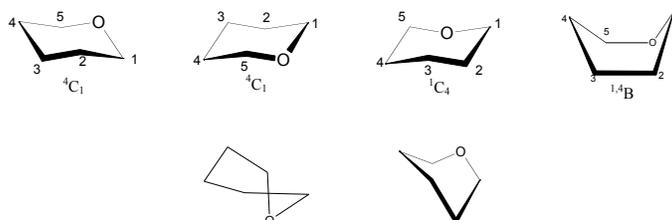
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## Chair Presentations

 $\alpha$ -D-Allopyranose $\alpha$ -D-Altropyranose $\alpha$ -D-Arabinopyranose $\alpha$ -D-Galactopyranose $\alpha$ -D-Glucopyranose $\alpha$ -D-Gulopyranose $\alpha$ -D-Idopyranose $\alpha$ -D-Lyxopyranose $\alpha$ -D-Mannopyranose $\alpha$ -D-Psicopyranose $\alpha$ -D-Ribopyranose $\alpha$ -D-Sorbopyranose $\alpha$ -D-Tagatopyranose $\alpha$ -D-Talopyranose $\alpha$ -D-Xylopyranose $\alpha$ -D-Fructopyranose



Pyranose: *Chair*, *Boat*, *Half-chair*, *Skew*.



Furanose: *Envelope*, *Twist*.

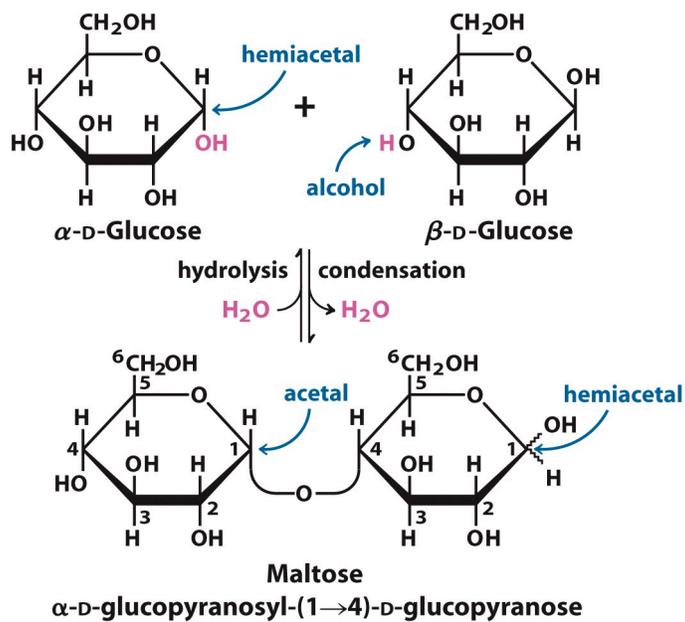


Figure 7-11  
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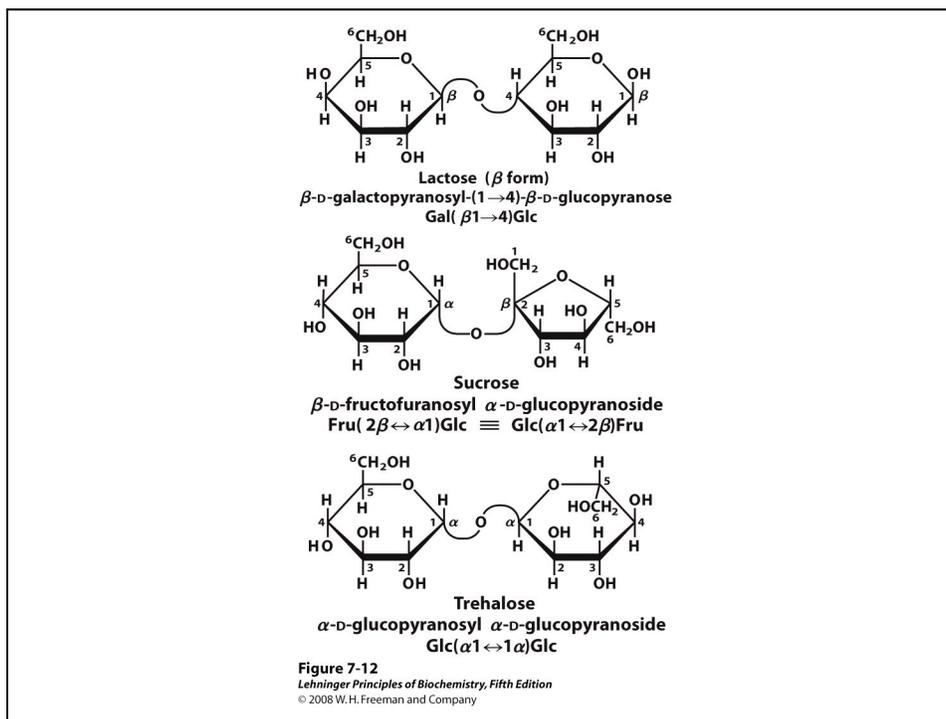


TABLE 7-1

### Symbols and Abbreviations for Common Monosaccharides and Some of Their Derivatives

Abequose	Abe	Glucuronic acid	◆ GlcA
Arabinose	Ara	Galactosamine	◻ GalN
Fructose	Fru	Glucosamine	◻ GlcN
Fucose	Fuc	N-Acetylgalactosamine	◻ GalNAc
Galactose	● Gal	N-Acetylglucosamine	■ GlcNAc
Glucose	● Glc	Iduronic acid	◇ IdoA
Mannose	● Man	Muramic acid	Mur
Rhamnose	Rha	N-Acetylmuramic acid	Mur2Ac
Ribose	Rib	N-Acetylneuraminic acid (a sialic acid)	◆ Neu5Ac
Xylose	★ Xyl		

**Note:** In a commonly used convention, hexoses are represented as circles, N-acetylhexosamines as squares, and hexosamines as squares divided diagonally. All sugars with the "gluco" configuration are blue, those with the "galacto" configuration are yellow, and "manno" sugars are green. Other substituents can be added as needed: sulfate (S), phosphate (P), O-acetyl (OAc), or O-methyl (Ome).

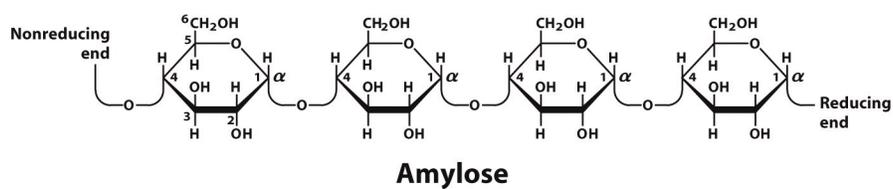
Table 7-1  
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## COMPLICATION OF CARBOHYDRATE

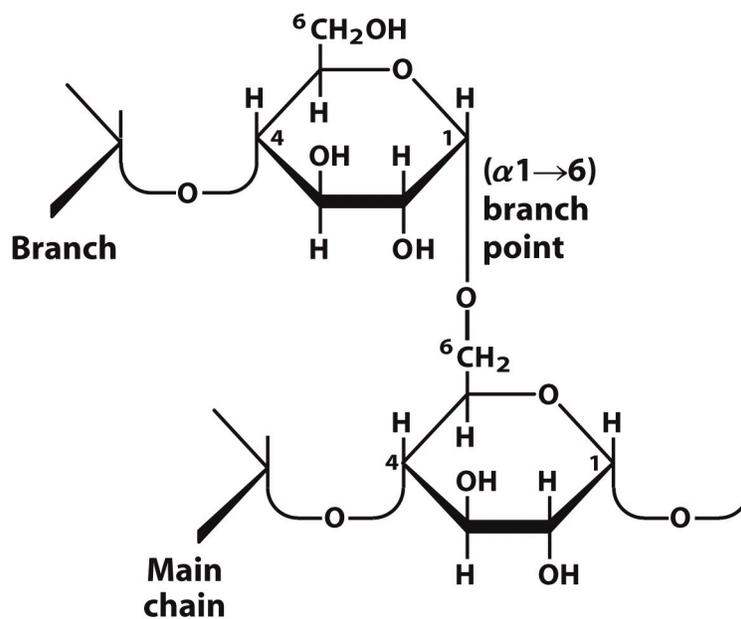
1. Number of Carbon Atoms
2. The Location of Carbonyl Group
3. The Configuration of Sugar (D or L)
4. The Size of Ring (5, 6 or 7)
5. The Configuration at Position 1 (a or b)
6. The Connectivity between Sugar Units
7. Derivatives (oxidation, reduction, deoxy, various group)

## CARBOHYDRATE ISOMERS

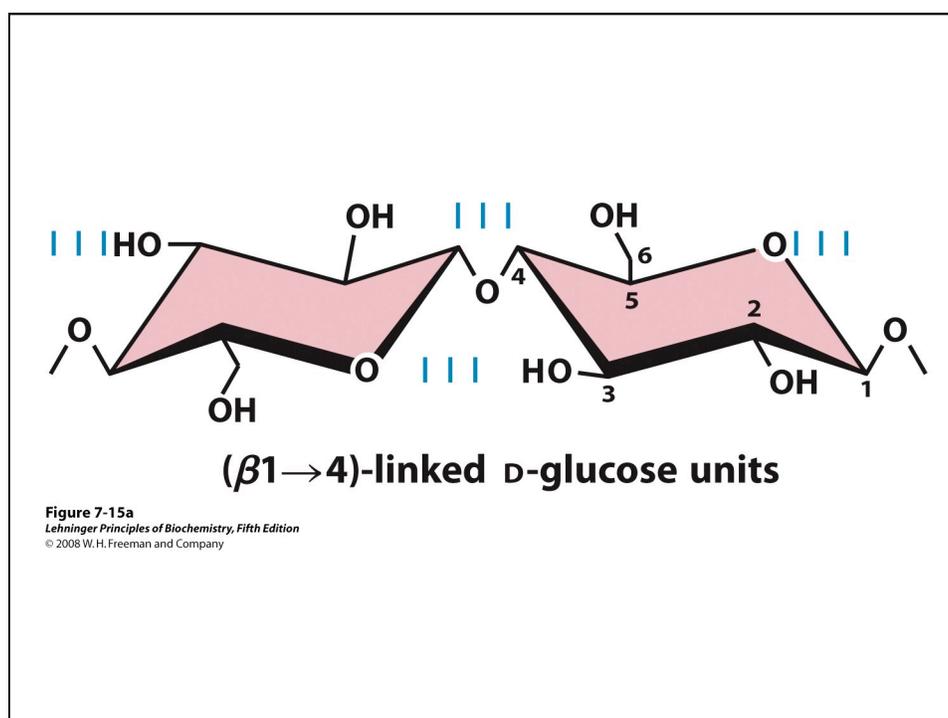
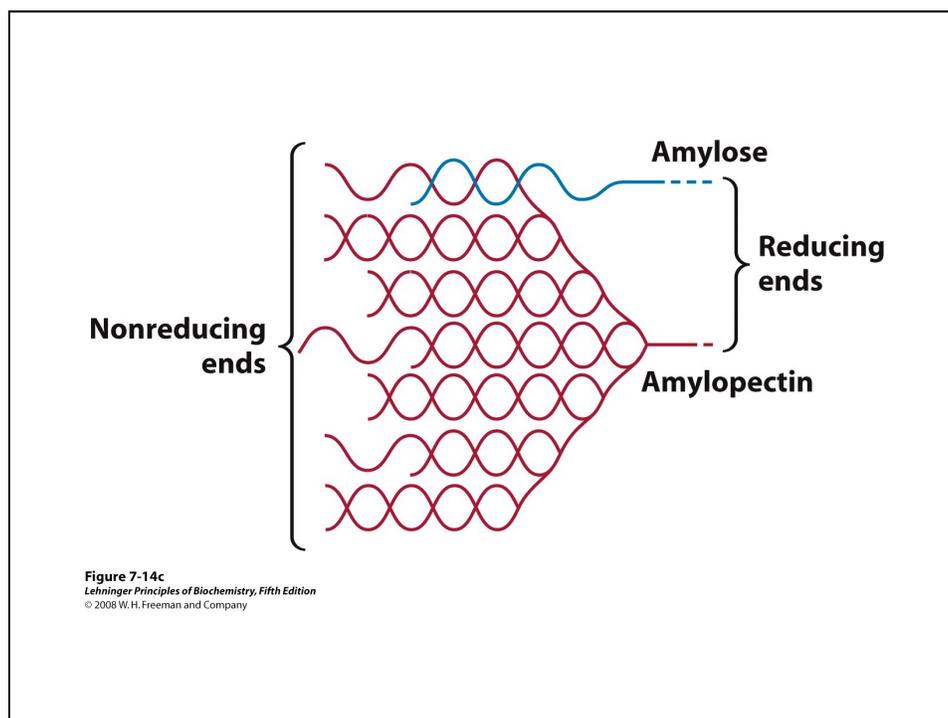
Combination of Individual Units	Number of Carbohydrates
Two identical units, A-A dimer	11
Three identical units, A-A-A trimer	176
Three different units, A-B-C trimer	1,056
Five different units, A-B-C-D-E pentamer	2,144,640

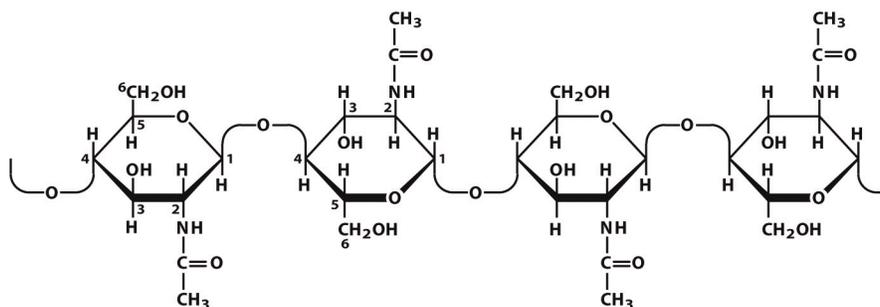


**Figure 7-14a**  
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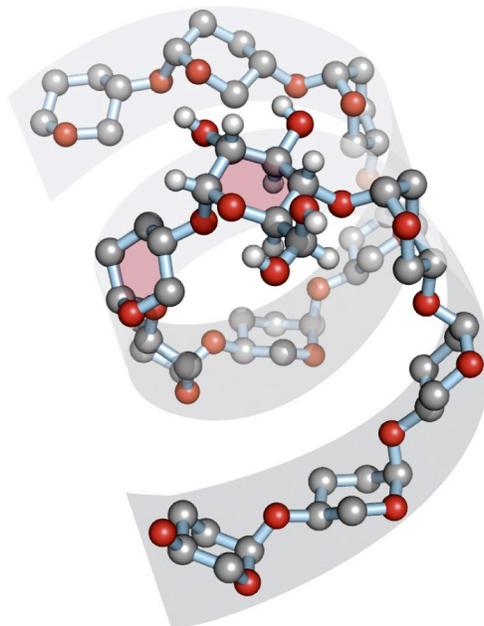


**Figure 7-14b**  
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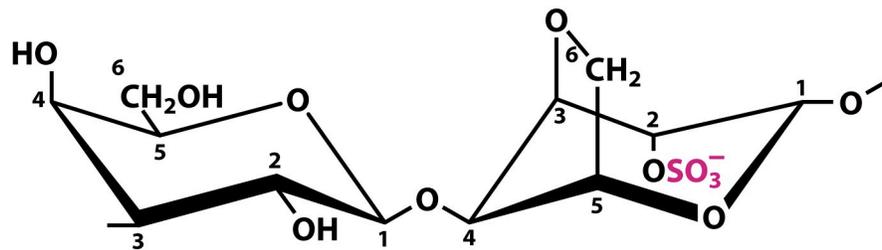




**Figure 7-17a**  
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**Figure 7-20b**  
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### Agarose

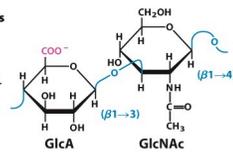
**3)D-Gal( $\beta$ 1  $\rightarrow$ 4)3,6-anhydro-L-Gal $2S(\alpha$ 1 repeating units)**

**Figure 7-21**  
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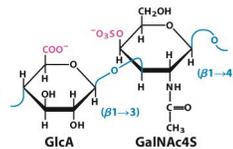
#### Glycosaminoglycan Repeating disaccharide

Number of disaccharides per chain

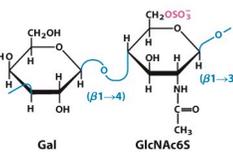
**Hyaluronate**  
~50,000



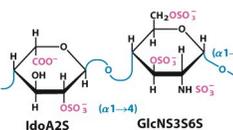
**Chondroitin 4-sulfate**  
20-60



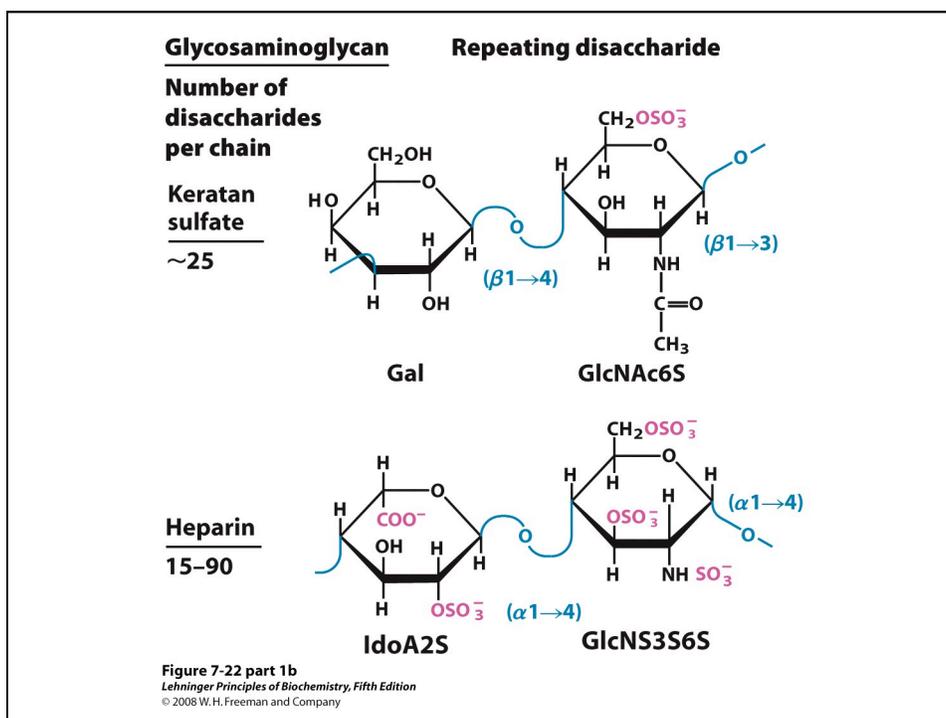
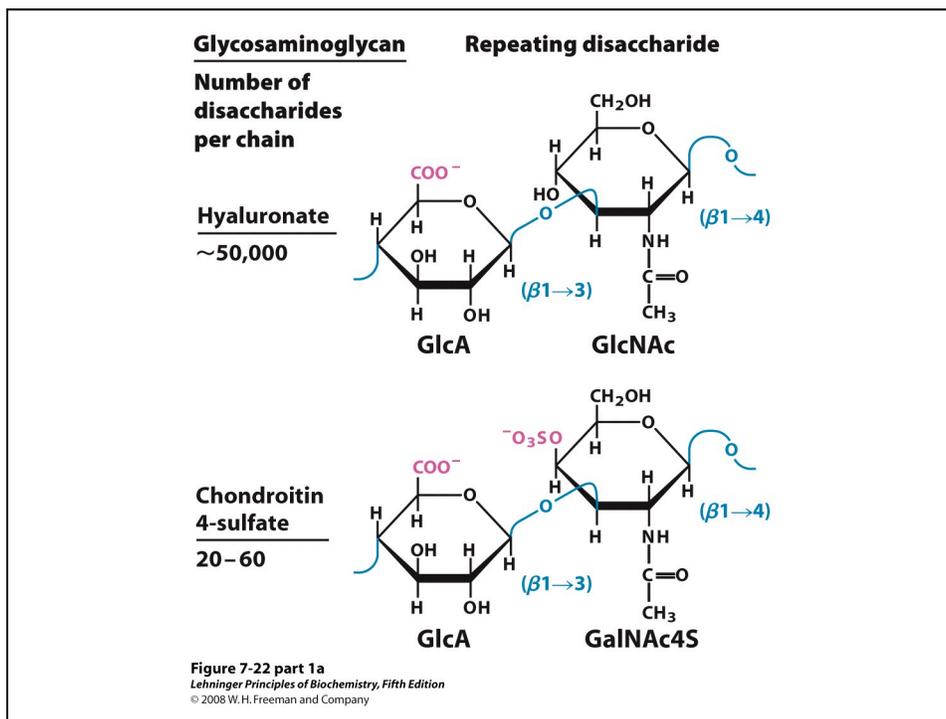
**Keratan sulfate**  
~25

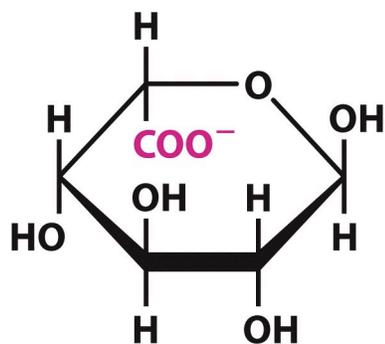


**Heparin**  
15-90

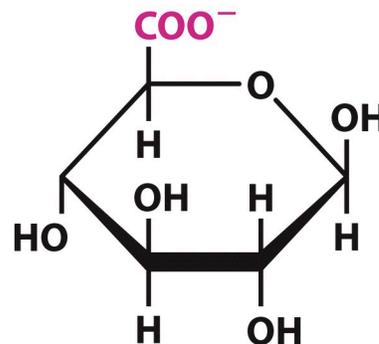


**Figure 7-22 part 1**  
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**$\alpha$ -L-Iduronate  
(IdoA)**



**$\beta$ -D-Glucuronate  
(GlcA)**

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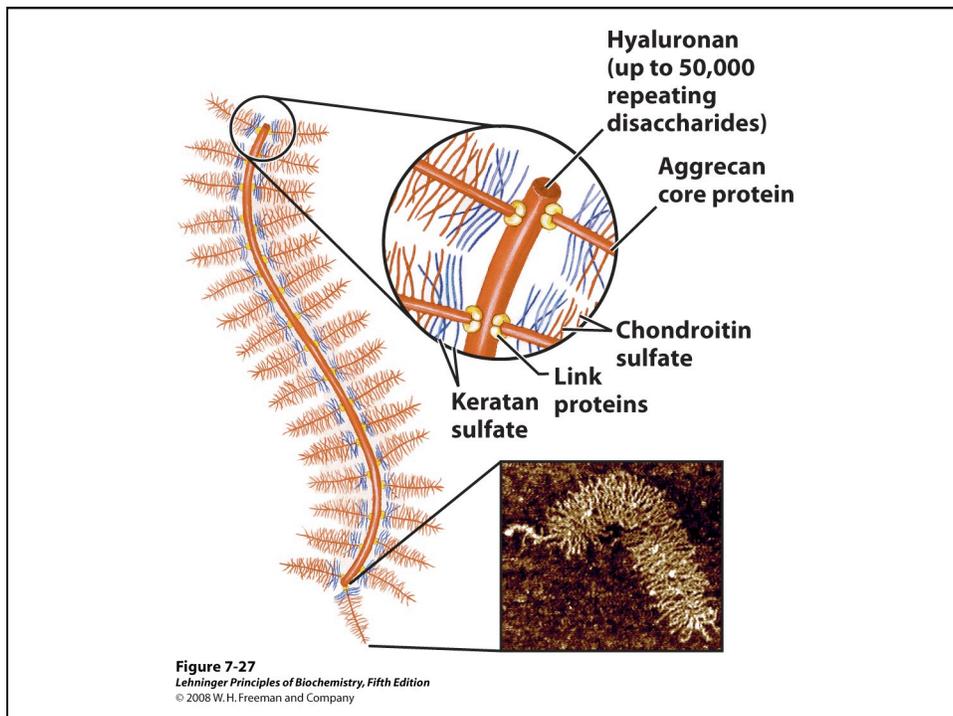
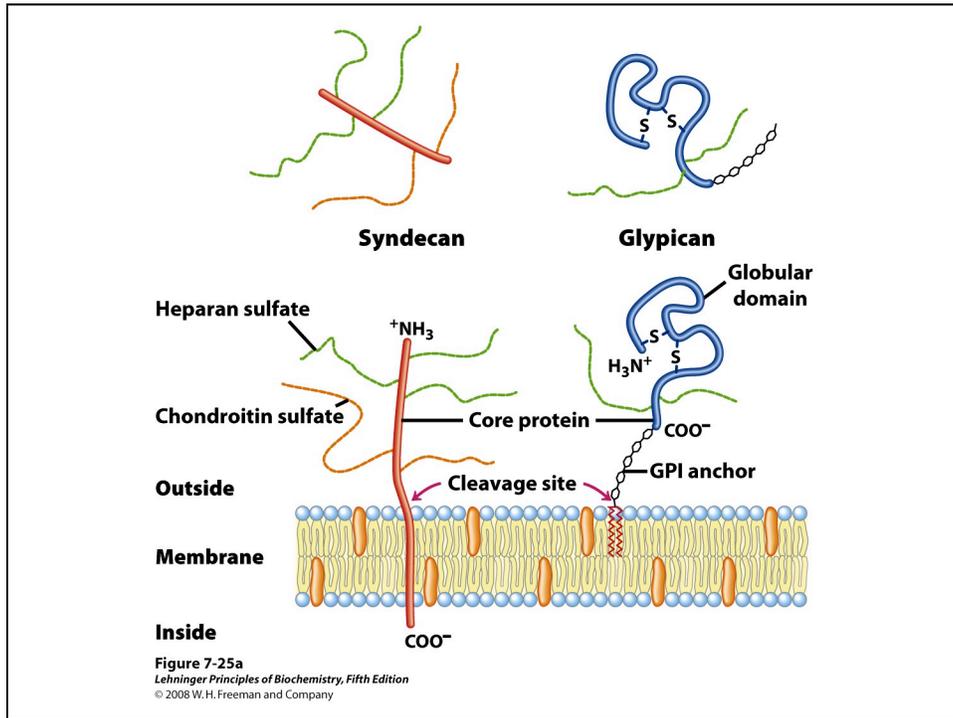
**TABLE 7-2 Structures and Roles of Some Polysaccharides**

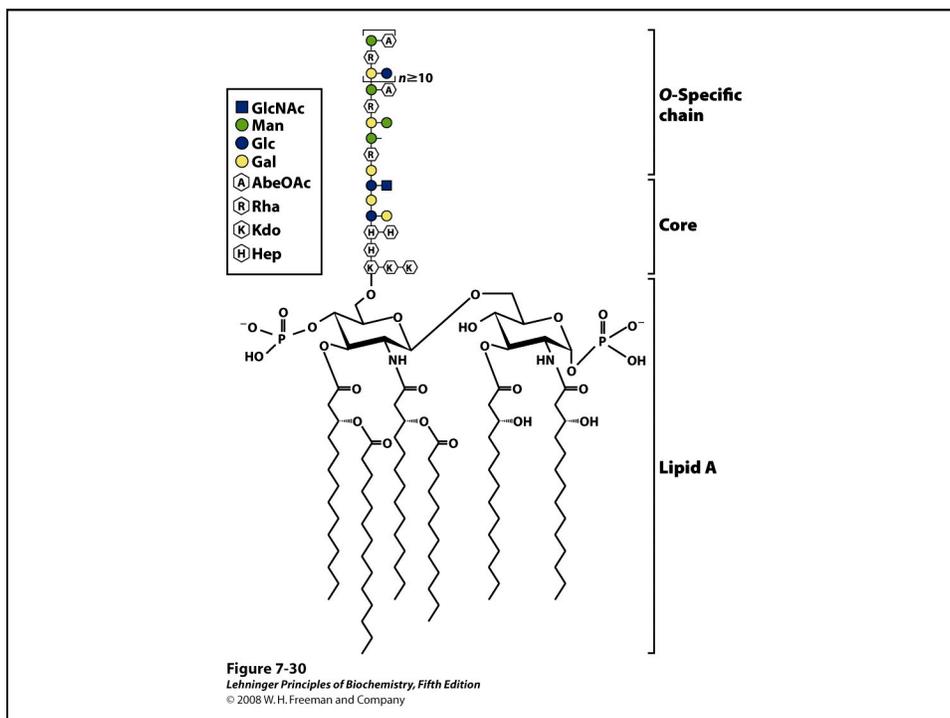
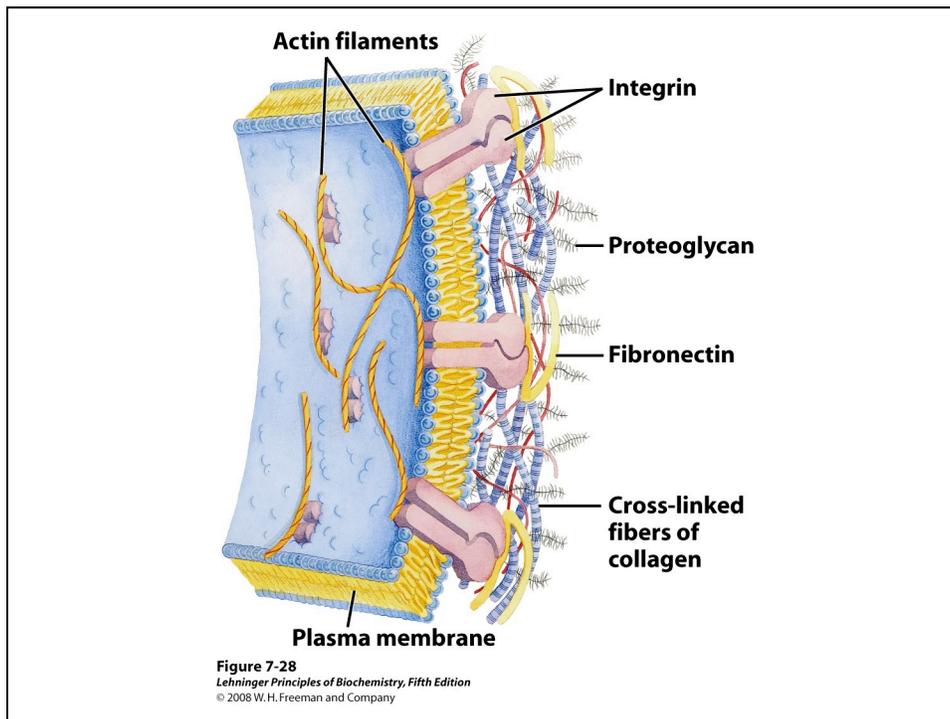
Polymer	Type*	Repeating unit <sup>†</sup>	Size (number of monosaccharide units)	Roles/significance
<b>Starch</b>				<b>Energy storage: in plants</b>
Amylose	Homo-	( $\alpha$ 1 $\rightarrow$ 4)Glc, linear	50–5,000	
Amylopectin	Homo-	( $\alpha$ 1 $\rightarrow$ 4)Glc, with ( $\alpha$ 1 $\rightarrow$ 6)Glc branches every 24–30 residues	Up to $10^6$	
<b>Glycogen</b>	Homo-	( $\alpha$ 1 $\rightarrow$ 4)Glc, with ( $\alpha$ 1 $\rightarrow$ 6)Glc branches every 8–12 residues	Up to 50,000	<b>Energy storage: in bacteria and animal cells</b>
<b>Cellulose</b>	Homo-	( $\beta$ 1 $\rightarrow$ 4)Glc	Up to 15,000	<b>Structural: in plants, gives rigidity and strength to cell walls</b>
<b>Chitin</b>	Homo-	( $\beta$ 1 $\rightarrow$ 4)GlcNAc	Very large	<b>Structural: in insects, spiders, crustaceans, gives rigidity and strength to exoskeletons</b>
<b>Dextran</b>	Homo-	( $\alpha$ 1 $\rightarrow$ 6)Glc, with ( $\alpha$ 1 $\rightarrow$ 3) branches	Wide range	<b>Structural: in bacteria, extracellular adhesive</b>
<b>Peptidoglycan</b>	Hetero-; peptides attached	4)Mur2Ac( $\beta$ 1 $\rightarrow$ 4)GlcNAc( $\beta$ 1)	Very large	<b>Structural: in bacteria, gives rigidity and strength to cell envelope</b>
<b>Agarose</b>	Hetero-	3) $\beta$ -Gal( $\beta$ 1 $\rightarrow$ 4)3,6-anhydro-L-Gal( $\alpha$ 1)	1,000	<b>Structural: in algae, cell wall material</b>
<b>Hyaluronan (a glycosaminoglycan)</b>	Hetero-; acidic	4)GlcA( $\beta$ 1 $\rightarrow$ 3)GlcNAc( $\beta$ 1)	Up to 100,000	<b>Structural: in vertebrates, extracellular matrix of skin and connective tissue; viscosity and lubrication in joints</b>

\*Each polymer is classified as a homopolysaccharide (homo-) or heteropolysaccharide (hetero-).

<sup>†</sup>The abbreviated names for the peptidoglycan, agarose, and hyaluronan repeating units indicate that the polymer contains repeats of this disaccharide unit. For example, in peptidoglycan, the GlcNAc of one disaccharide unit is ( $\beta$ 1 $\rightarrow$ 4)-linked to the first residue of the next disaccharide unit.

Table 7-2  
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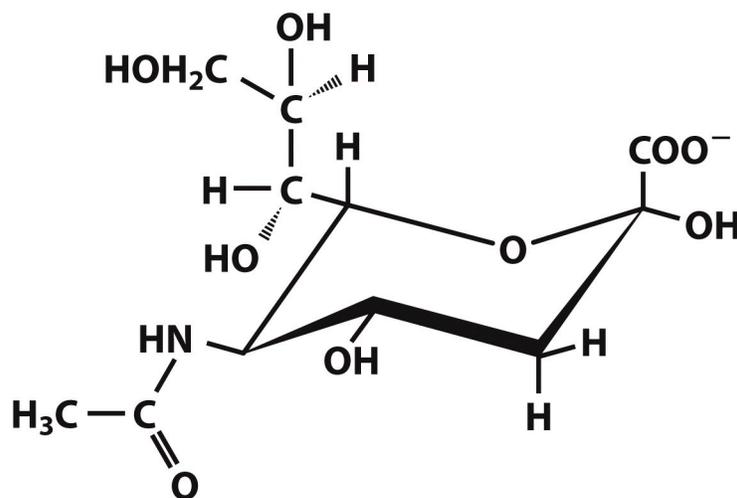
**TABLE 7-3** Some Lectins and the Oligosaccharide Ligands They Bind

Lectin source and lectin	Abbreviation	Ligand(s)
<b>Plant</b>		
Concanavalin A	ConA	Man $\alpha$ 1—OCH <sub>3</sub>
<i>Griffonia simplicifolia</i> lectin 4	GS4	Lewis b (Le <sup>b</sup> ) tetrasaccharide
Wheat germ agglutinin	WGA	Neu5Ac( $\alpha$ 2→3)Gal( $\beta$ 1→4)Glc GlcNAc( $\beta$ 1→4)GlcNAc
Ricin		Gal( $\beta$ 1→4)Glc
<b>Animal</b>		
Galectin-1		Gal( $\beta$ 1→4)Glc
Mannose-binding protein A	MBP-A	High-mannose octasaccharide
<b>Viral</b>		
Influenza virus hemagglutinin	HA	Neu5Ac( $\alpha$ 2→6)Gal( $\beta$ 1→4)Glc
Polyoma virus protein 1	VP1	Neu5Ac( $\alpha$ 2→3)Gal( $\beta$ 1→4)Glc
<b>Bacterial</b>		
Enterotoxin	LT	Gal
Cholera toxin	CT	GM1 pentasaccharide

Source: Weiss, W.I. & Drickamer, K. (1996) Structural basis of lectin-carbohydrate recognition. *Annu. Rev. Biochem.* 65, 441–473.

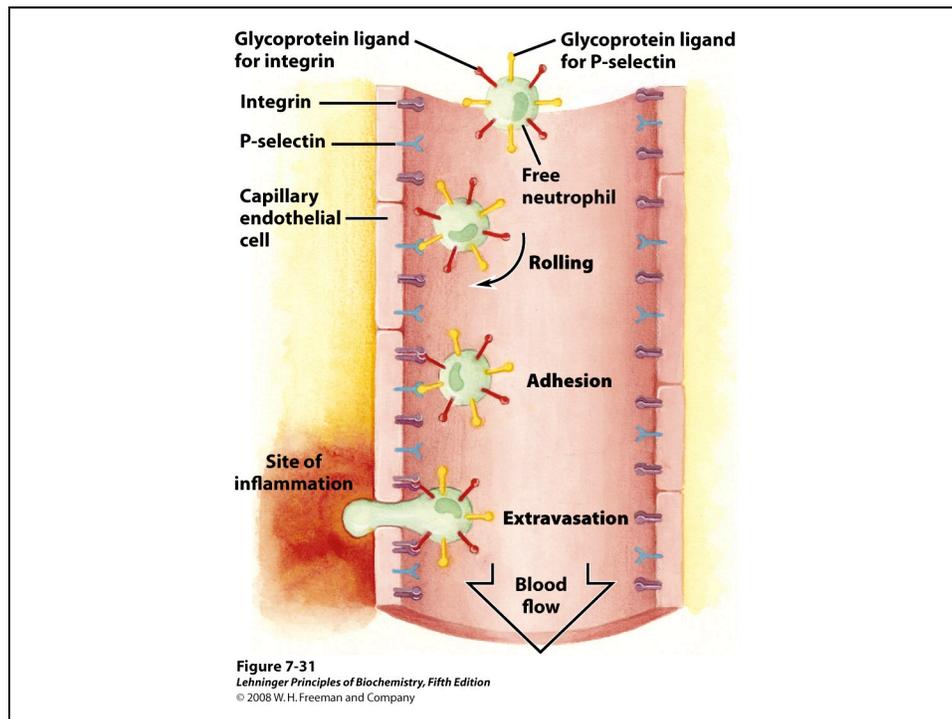
Table 7-3

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**N-Acetylneuraminic acid (Neu5Ac)**  
**(a sialic acid)**

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## How sweet it is!

Sugar	Sweetness
Lactose	0.16
Galactose	0.32
Maltose	0.33
Sucrose	1.00
Fructose	1.73
Aspartame	180
Saccharin	450

Values are relative to sucrose.

## Starch

Energy storage used by plant  
Long repeating chain of  $\alpha$ -D-glucose  
Chain up to 4000 units

### Amylose

Straight chain

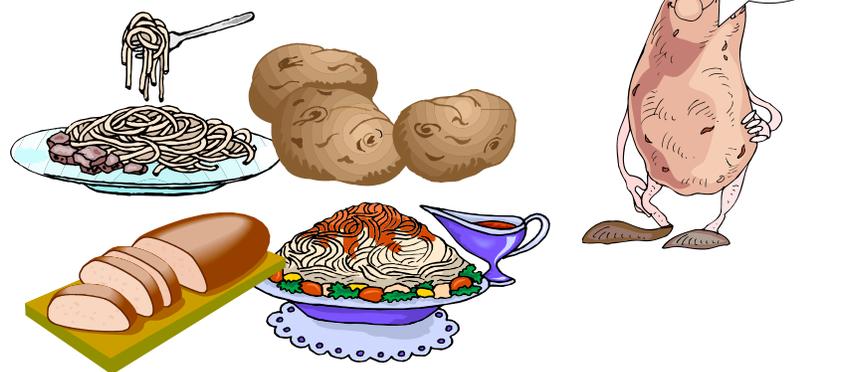
### Amylopectin

Branched structure

Major part of starch

Great for making gravy, jam & jelly

## Starch can be found



**Too much .....**  
Carbohydrate will be converted  
into fat and stored under the  
skin leading to weight gain!

