Chem 352 - Lecture 7
Carbohydrates

Question for the Day: *Unlike amino acids, which owe their diversity to a diverse array of functional groups, monosaccharides feature primarily two functional groups, hydroxyl groups and either a ketone or aldehyde group. What, then, do monosaccharides owe their diversity to?*

1

Introduction to Carbohydrates

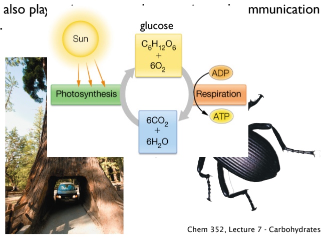
Carbohydrates are one of the four major classes of biological molecules, which include,

- Proteins
- Nucleic acids
- Carbohydrates
- Lipids

2

Introduction to Carbohydrates

- Carbohydrates represent a major source of energy for living organisms.
- They also play ... mmunication roles.



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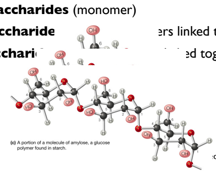
Introduction to Carbohydrates

Carbohydrates are chemically simple, but can be structurally complex

- The simple sugars have the basis stoichiometric empirical formula$(CH_2O)_n$, where n = 3 to 7

Like amino acid, simple sugars (monosaccharides) can combine to form polymers.

- **monosaccharides** (monomer)
- **oligosaccharide** ...ers linked together)
- **polysacchari**... ...ed together



(a) A portion of a molecule of amylose, a glucose polymer found in starch.

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9.1 Monosaccharides

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Monosaccharides

Monosaccharides are

- either **Aldoses**
  - polyhydroxylaldehydes
- or **Ketoses**
  - polyhydroxylketones

Classes based on number of carbons

- triose (3)
- tetrose (4)
- pentose (5)
- hexose (6)
- heptose (7)

Question:

What is the name ending that is typically used to designate a carbohydrate?

A. -ase
B. -ose
C. -ol
D. -al
E. -amine

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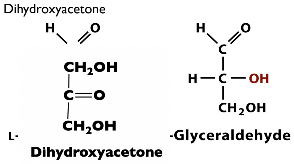
Monosaccharides

Trioses

- L and D Glyceraldehyde
  - Contains a chiral carbon
  - Fischer projections
- Dihydroxyacetone



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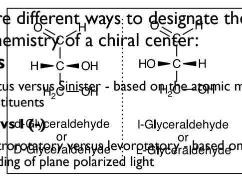
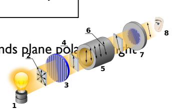
Monosaccharides

There are different ways to designate the stereochemistry of a chiral center:

- **R vs S**
  - Rectus versus Sinister - based on the atomic mass of the substituents
- **d (+) vs l (-)**
  - dextrorotatory versus levorotatory - based on the bending of plane polarized light
- **D vs L**
  - Based on how glyceraldehyde bends plane polarized light





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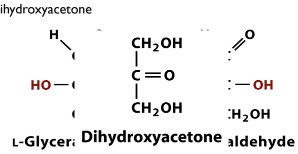
Monosaccharides

Trioses

- L and D Glyceraldehyde enantiomers
  - Contains a chiral carbon
  - Fischer projections
- Dihydroxyacetone



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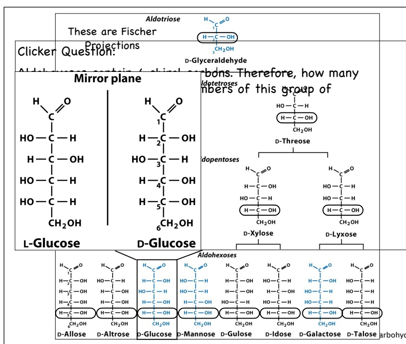

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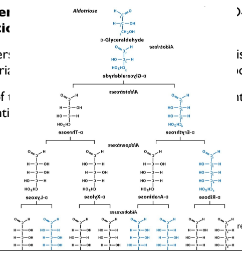
L-enantiomers

Monosaccharides

Trioses through hexoses

- This figure shows only the D–**enantiomers**
- The L-**en**… D-**enantio**…
- Member… …ished using the chira… …bonyl group.
- Most of … …ater are the D-enanti…



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Monosaccharides

Types of optical isomers

- **Enantiomers** are st… …ers that are mirror images of one another
- **Epimer** are stereois… …al carbon that differ fro… carbon.

Question:

Which of following monosaccharides is an epimer of glucose:

Question:

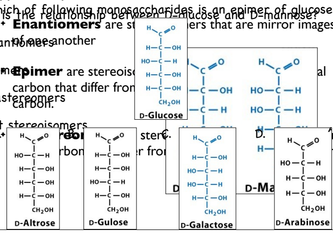
What is the relationship between D-glucose and D-mannose?

A. Enantiomers

B. Epimers

C. Diastereomers

D. Not stereoisomers



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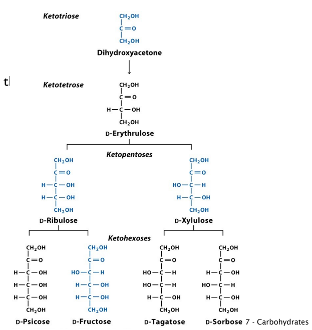
Ketoses

- Trioses t…



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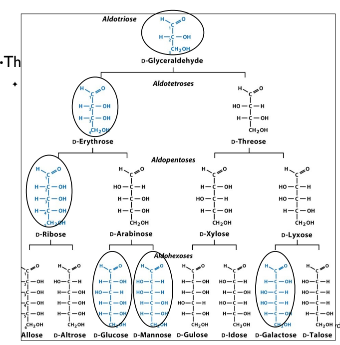
•Th…



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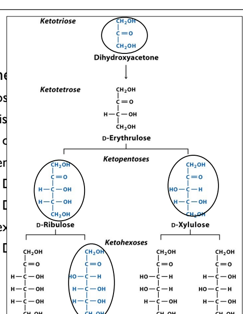
•The one…

- Ketos…
  - tris…
  - pen…
  - hex…



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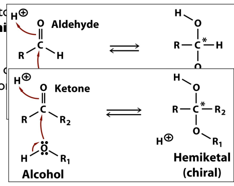
Monosaccharides

•Cyclization of aldoses and ketoses

- An aldehyde can react spontaneously with an alcohol to form a **hemiacetal**.
- A keto... hol to form a **hemi**...
- Both ... hat lead to the fo...



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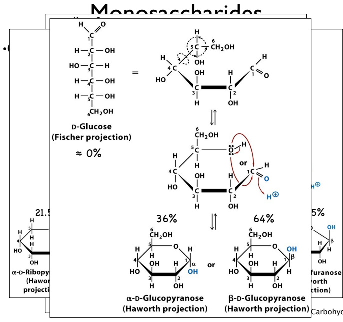
Monosaccharides



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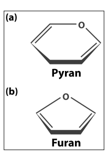
Monosaccharides

•Cyclization of aldoses and ketoses

- The six-member rings are called **pyranose** rings
- The five-member rings are called **furanose** rings.



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Monosaccharides

•Cyclization of aldoses and ketoses

- **pyranose** rings
  - D-glucopyranose (aldohexose)
  - D-mannopyranose (aldohexose)
  - D-galactopyranose (aldohexose)
- **furanose** rings
  - D-fructofuranose (ketohexose)
  - D-ribofuranose (aldopentose)

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Monosaccharides

Clicker Question:

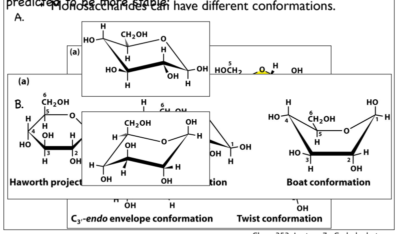
•Conformations of Monosaccharides

Which of following conformations for β-D-glucosopyranose is predicted to be more stable?

- Monosaccharides can have different conformations.

A.

B.



9.2 Derivatives of the Monosaccharides

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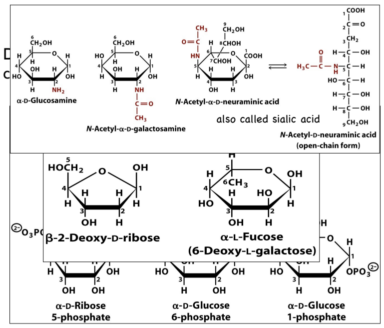

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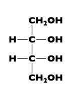
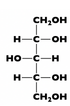
Monosaccharides

Sugar alcohols

- The aldehyde or ketone group is reduced to an alcohol.
- Some are used as natural artificial sweeteners.



erythritol



xylitol

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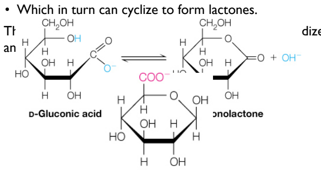
Monosaccharides

Sugar acids

- The aldehyde can be oxidized to an acid to produce **aldonic acids.**
  - Which in turn can cyclize to form lactones.
- Th... dized to an...



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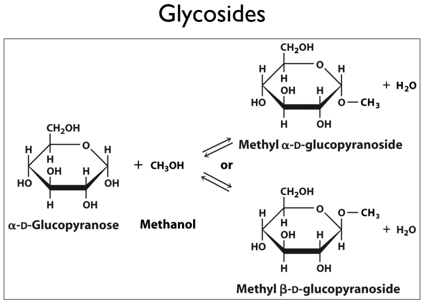
Glycosides



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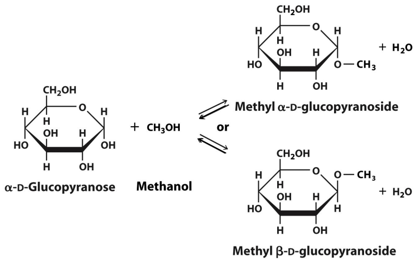
Glycosides



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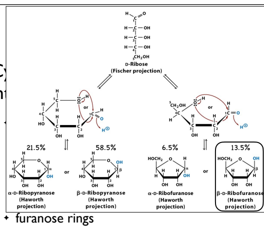
C... to get locked in... s



- furanose rings
  - D-fructofuranose (ketohexose)
  - D-ribofuranose (aldopentose)

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9.3 Oligosaccharides

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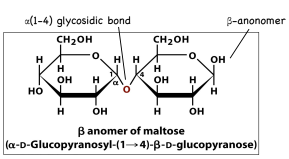
Disaccharides

The glycosidic bond can be used to connect two monosaccharides together to form **disaccharides**.

Important disaccharides include:

- **Maltose** (obtained from starch)



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Disaccharides

The glycosidic bond can be used to connect two monosaccharides together to form disaccharides.

Important disaccharides include:

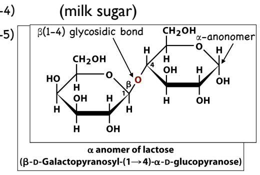
- **Lactose** (milk sugar)

A. α(1-4)

B. β(1-6)

C. β(1-4)

D. α(1-5)



Disaccharides

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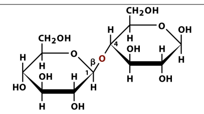
The glycosidic bond can be used to connect two monosaccharides together to form **disaccharides**.

Important disaccharides include:

- **Cellobiose** (obtained from cellulose)



β anomer of cellobiose
(β-D-Glucopyranosyl-(1→4)-β-D-glucopyranose)

Disaccharides

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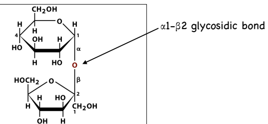
The glycosidic bond can be used to connect two monosaccharides together to form **disaccharides**.

Important disaccharides include:

- **Sucrose** (table sugar)



Sucrose
(α-D-Glucopyranosyl-(1→2)-β-D-fructofuranoside)

Disaccharides

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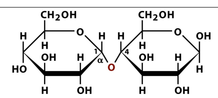
Question:
Which end of the disaccharide maltose is the reducing end?

Because a hemiacetal or hemiketal can easily open to expose either an aldehyde or α-hydroxy ketone, they can still serve as reducing agents for the Cu^{2+} ions found in Fehling's and Benedict's reagents.

A. B.



β anomer of maltose
(α-D-Glucopyranosyl-(1→4)-β-D-glucopyranose)

- Thi… mo…ng and the **nonreducing** ends.

Disaccharides

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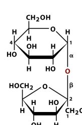
Not all disaccharides have a reducing end

- For example, the disaccharide sucrose contains both and acetal and a ketal, but no hemiacetal or hemiketal.



Sucrose
(α-D-Glucopyranosyl-(1→2)-β-D-fructofuranoside)

Glycosides

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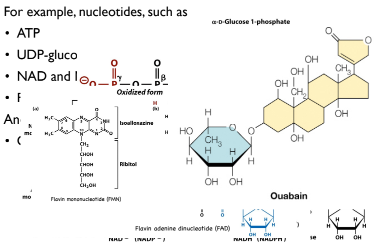
Monosaccharides also form glycosidic bonds to non-sugar.

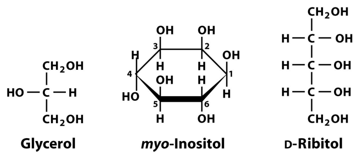
- For example, nucleotides, such as
  - ATP
  - UDP-gluco
  - NAD and I
  - F
- An
  - (



Glycosides

Ribitol is another example of a **sugar alcohol**.

- Where the aldehyde or ketone is reduced to an alcohol.



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9.4 Polysaccharides

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Polysaccharides

TABLE 8.2 Structures of some common polysaccharides

Polysaccharide[a]	Component(s)[b]	Linkage(s)
Storage homoglycans		
Starch		
Amylose	Glc	α-(1 → 4)
Amylopectin	Glc	α-(1 → 4), α-(1 → 6) (branches)
Glycogen	Glc	α-(1 → 4), α-(1 → 6) (branches)
Structural homoglycans		
Cellulose	Glc	β(1 → 4)
Chitin	GlcNAc	β(1 → 4)
Heteroglycans		
Glycosaminoglycans	Disaccharides (amino sugars, sugar acids)	Various
Hyaluronic acid	GlcUA and GlcNAc	β(1 → 3), β(1 → 4)

[a]Polysaccharides are unbranched unless otherwise indicated.
[b]Glc, Glucose; GlcNAc, *N*-acetylglucosamine; GlcUA, D-glucuronate.

Question:
What appears to distinguish the glycosidic bonds used in storage homoglycans from the glycosidic bonds used in structural homoglycans?

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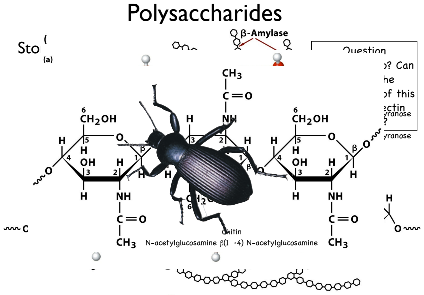
Polysaccharides



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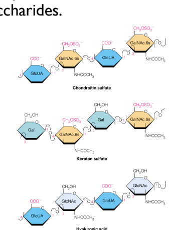
Glycosaminoglycans

Are heteropolysaccarides which are also called mucopolysaccharides.



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9.4 Glycoconjugates

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Glycocongugates

Oligo saccharides are often attached to biological molecules

- To proteins and peptides
  - **Proteoglycans (connective tissue)**
  - **Peptidoglycans (bacterial cell walls)**
  - **Glycoproteins**
- To lipids
  - **Glycolipids**

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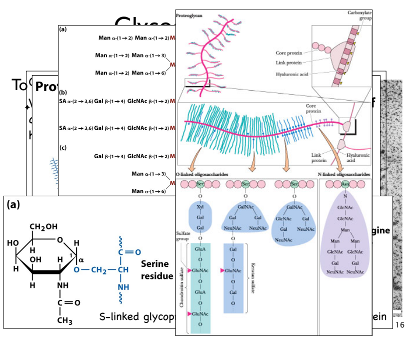

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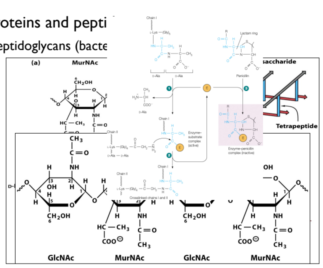
Glycocongugates

To proteins and pepti

- Peptidoglycans (bacte



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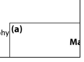
Glycocongugates

Oligo saccharides are often attached to biological molecules

- To proteins and peptides
  - **Proteoglycans (connective tissue)**
  - **Peptidoglycans (bacterial cell walls)**
  - **Glycoproteins**
- To lipids
  - **Glycolipids**



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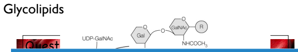
Glycocongugates

To lipids

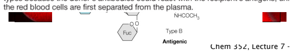
- Glycolipids



Person Has Blood Type:	Makes Antibodies Against:	Can Safely Receive Blood from:	Can Safely Donate Blood to:
O	A, B	O	O, A, B, AB
A	B	O, A	A, AB
B	A	O, B	B, AB
AB	None	O, A, B, AB[a]	AB

TABLE 9.3 Transfusion relationships among ABO blood types

[a]In principle, this relationship is true. However, ABs are not given donations from other types because the donor's antibodies could react with the recipient's antigens, unless the red blood cells are first separated from the plasma.



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Which Structures Do I Need to Know?

- Monosaccharide
  - D-glucose
  - D-galactose
  - D-mannose
  - D-fructose
  - D-ribose
- Disaccharides
  - D-lactose
  - D-maltose
  - D-cellobiose
  - D-sucrose

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Which Structures Do I Need to Know?

- Monosaccharide Derivatives
  - D-glucosamine
  - N-acetyl-D-glucosamine
  - D-gluconic acid
  - D-glucuronic acid
  - D-ribitol
- Polysaccharides
  - amylose
  - amylopectin
  - glycogen
  - cellulose
  - chitin

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Questions

Question:

Indicate which of the following terms best describes the relationship between the following isomers:

D-glyceraldehyde and dihydroxyacetone

A. anomers
B. epimers
C. diastereomers
D. constitutional isomers

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Questions

Question:

Indicate which of the following terms best describes the relationship between the following isomers:

α-D-glucose and β-D-glucose

A. anomers
B. epimers
C. diastereomers
D. constitutional isomers

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Questions

Question:

Indicate which of the following terms best describes the relationship between the following isomers:

D-glucose and D-galactose

A. anomers
B. epimers
C. diastereomers
D. constitutional isomers

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Questions

Question:

D-Lactose comprises D-glucose and D-galactose connected to one another by a β(1→4) glycosidic bond. Draw the structural formula for the α-anomer of D-lactose.

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Questions

Question:

α-D-Lactose has how many stereoisomers?

A. 2
B. 32
C. 256
D. 512
E. 1023

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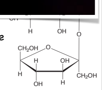
Questions

Questions:

Raffinose is a trisaccharide tha in beans and cabbage. When ea passes undigested through the to the upper intestine, where g producing bacteria break it dow consequences of this physiologi of affairs have been immortaliz movie "Blazing Saddles".) The st for raffinose is shown to the ri

Raffinose



A. What three monosaccharides the combine to form raffinose ?

B. What the glycoside linkages that connect the three monosaccharides?

C. Is raffinose a reducing sugar?