

Lehninger

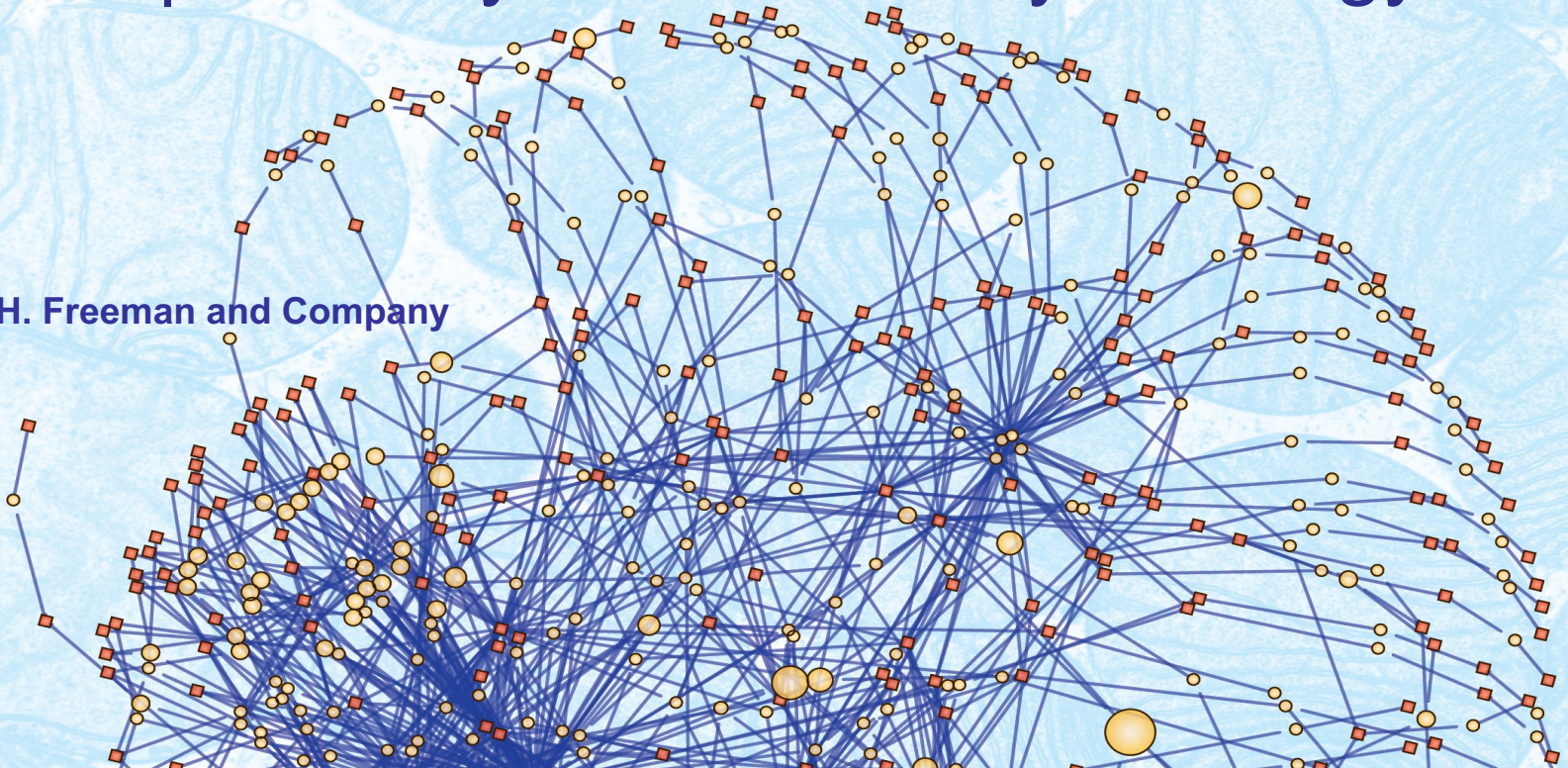
SIXTH EDITION

Principles of Biochemistry

David L. Nelson | Michael M. Cox

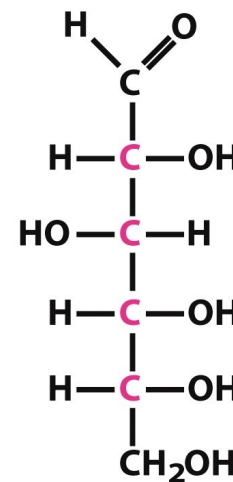
7 | Carbohydrates and Glycobiology

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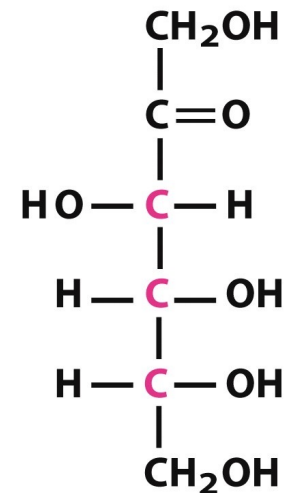


Carbohydrates

- Polyhydroxy aldehydes or ketones
 - Many but **NOT all** have formula $C_n(H_2O)_n$
 - Some also contain N, P or S
- Produced from CO_2 and H_2O via photosynthesis in plants
- Three major classes (many end with **-ose**)
 - Monosaccharide (one-sugar)
 - Disaccharide (two-sugar)
 - Polysaccharide (many-sugar)



D-Glucose



D-Fructose



Week 7 Carbohydrates and Glycobiology

7.1 Monosaccharides and Disaccharides

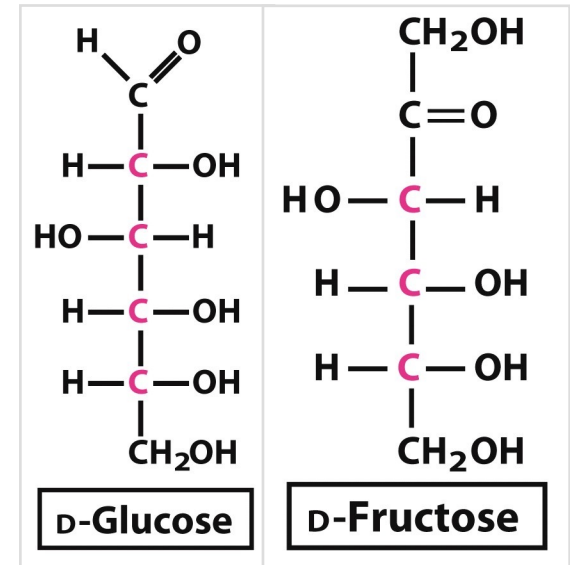
7.2 Polysaccharides

7.3 Glycoconjugates

7.4 Carbohydrates as Informational Molecules

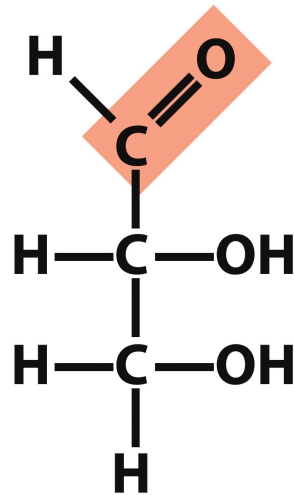
Monosaccharide

- Freely soluble in water (H-bonds).
 - Glucose solubility: 91 g in 100 mL water.
 - Sucrose solubility: 200 g in 100 mL water.
- Unbranched carbon chain.
 - Carbon atoms linked by single bonds.
 - One C double-bonded to O (carbonyl group).
 - Each of the other C atoms has a hydroxyl group (-OH).

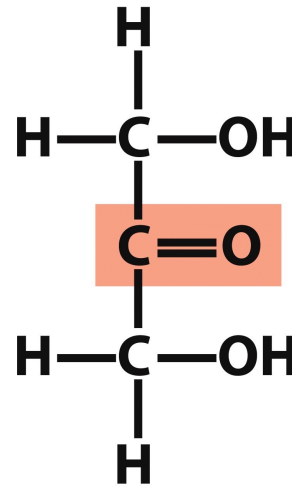


Aldoses and Ketoses

- An **aldose** contains an **aldehyde** functionality
 - **Carbonyl group** at the end of carbon chain.
- A **ketose** contains a **ketone** functionality
 - **Carbonyl group** at any other position.

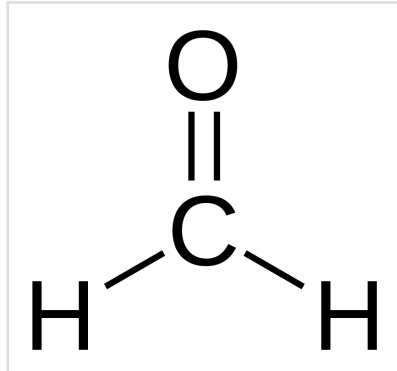


Glyceraldehyde,

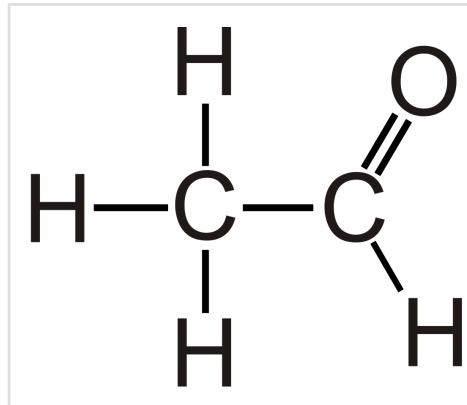


Dihydroxyacetone,

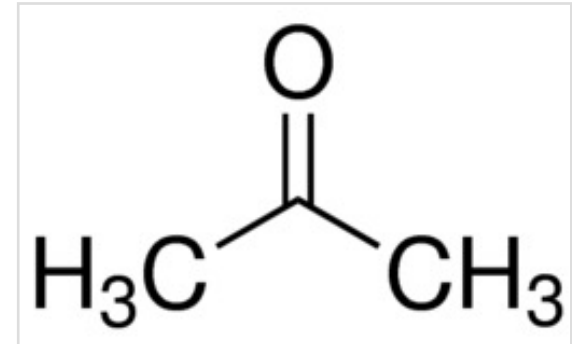
Aldehyde, Ketone and Glycerol



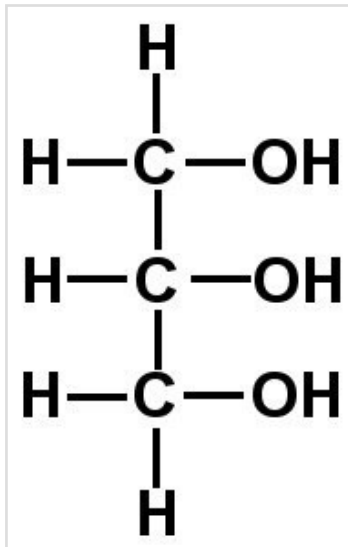
formaldehyde



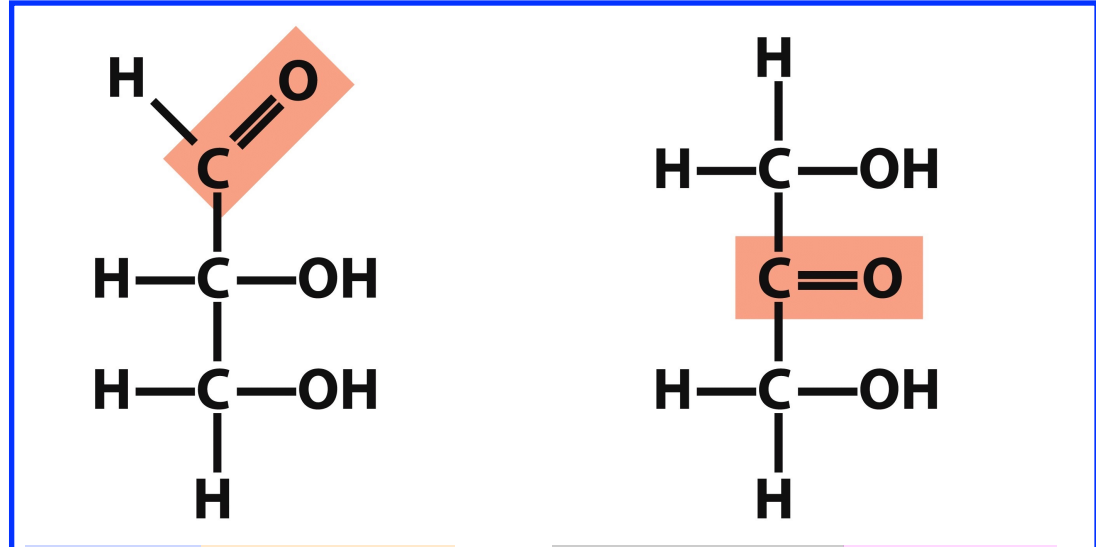
acetaldehyde



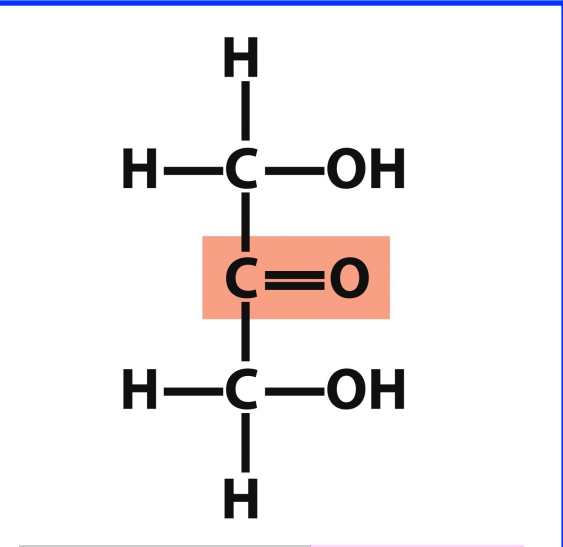
acetone



glycerol



Glyceraldehyde,



Dihydroxyacetone,

Three-Carbon Sugars and More

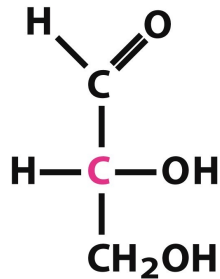
Triose

Tetrose

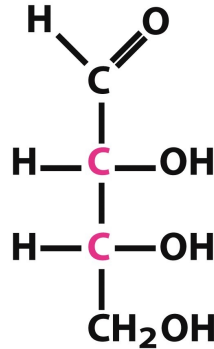
Pentose

Hexose

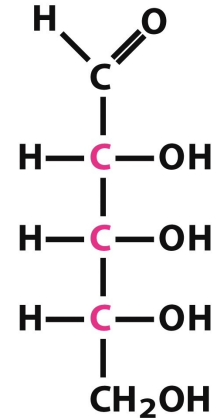
Aldose



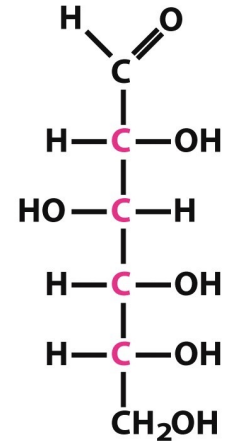
D-Glyceraldehyde



D-Erythrose

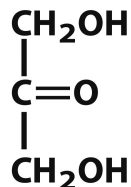


D-Ribose

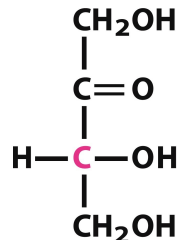


D-Glucose

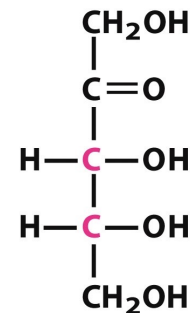
Ketose



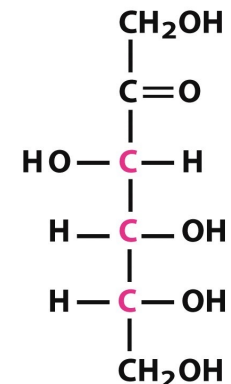
Dihydroxyacetone



D-Erythrulose



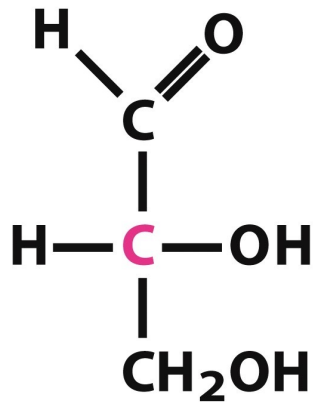
D-Ribulose



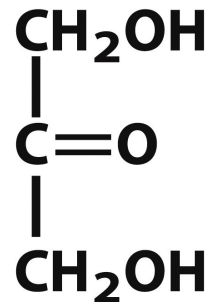
D-Fructose

Monosaccharides Have Chiral Centers

- All monosaccharides **except dihydroxyacetone** have one or more **chiral (asymmetric) carbon** atoms.
- The simplest aldotriose, glyceraldehyde, contains one chiral center.
 - Glyceraldehyde has **two** isomers called **enantiomers**.
 - Enantiomers are mirror images of each other.

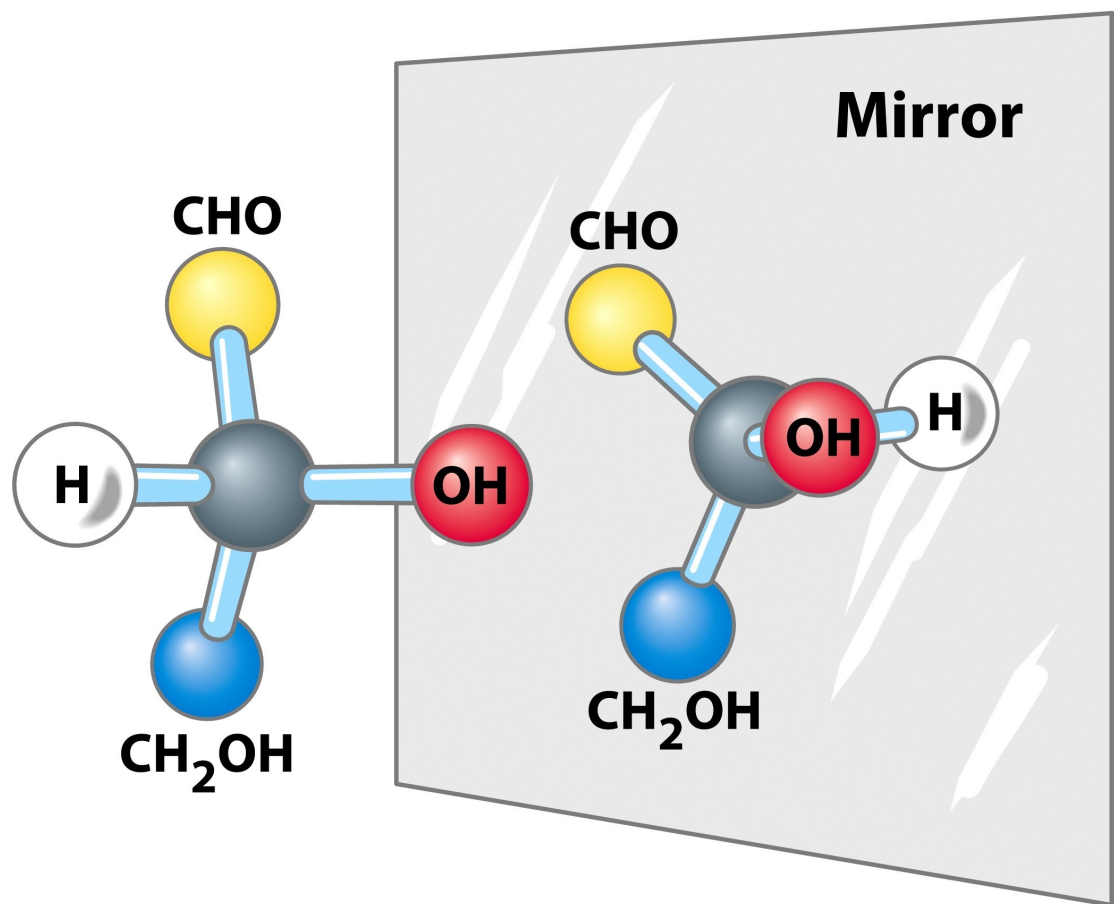


D-Glyceraldehyde



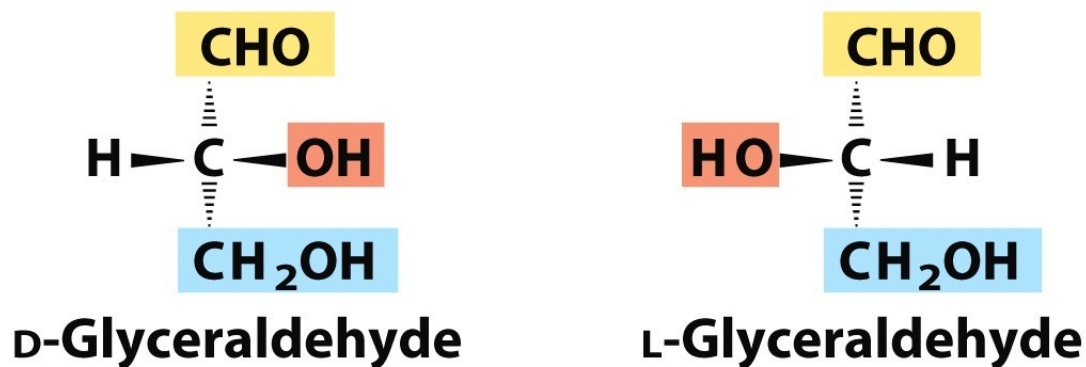
Dihydroxyacetone

Ways to Represent Two Enantiomers 1

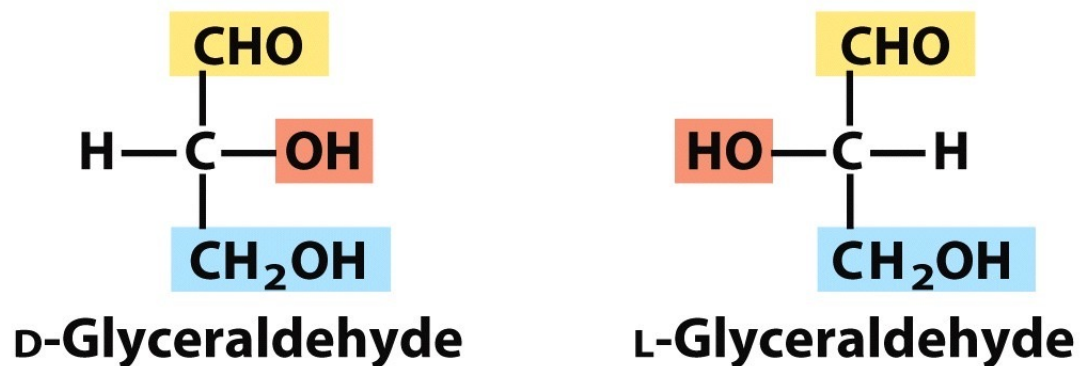


Ball-and-stick models

Ways to Represent Two Enantiomers 2



Perspective formulas



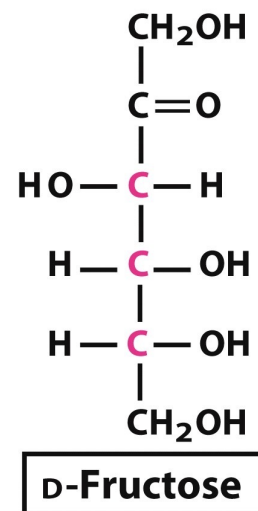
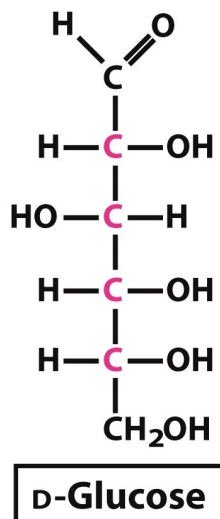
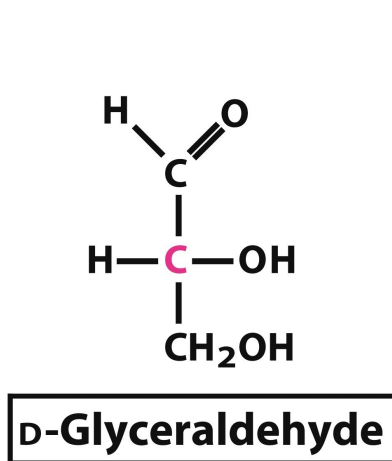
Fischer projection formulas

- Chiral compounds can be drawn using **perspective** formulas.
- However, chiral carbohydrates are usually represented by **Fischer** projections.
- **Horizontal** bonds are pointing **toward you**; vertical bonds are projecting away from you.

Number of Stereoisomers

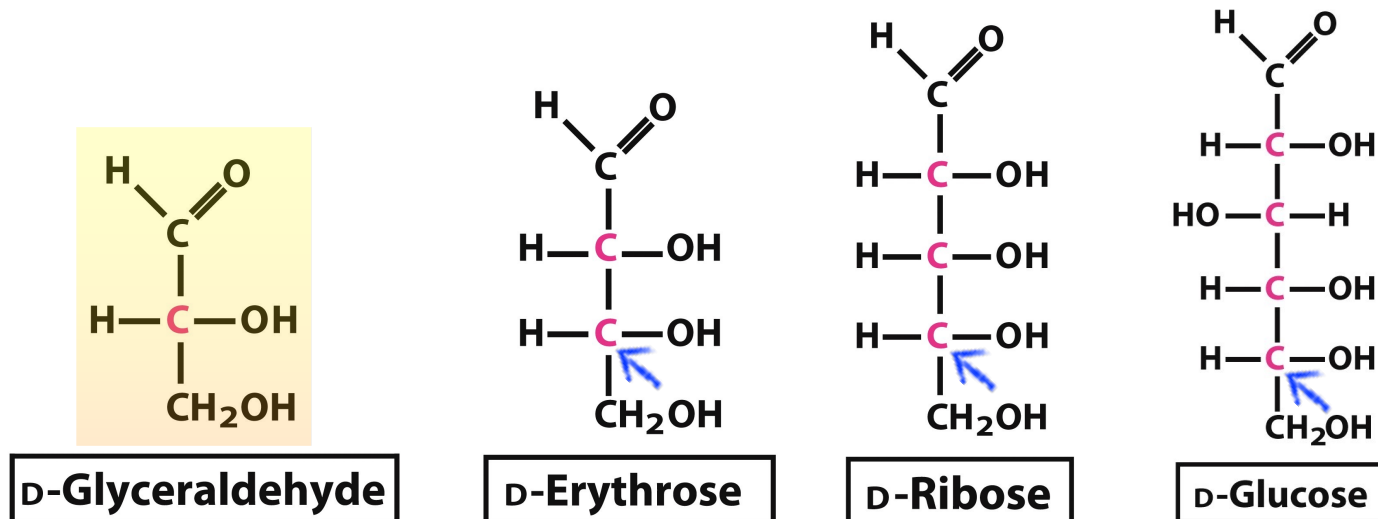
In general, a molecule with n chiral centers can have 2^n different stereoisomers.

- Glyceraldehyde has **1 chiral center**, and therefore 2 stereoisomers (**D-glyceraldehyde** and **L-glyceraldehyde**).
- Aldohexose has **4 chiral centers**, and therefore 16 stereoisomers.
- Ketohexose has **3 chiral centers**, and therefore 8 stereoisomers.



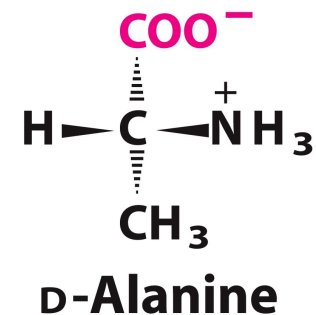
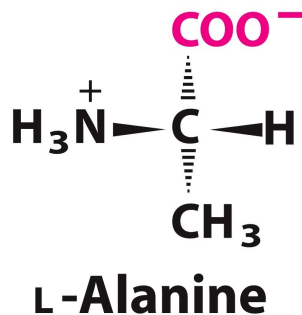
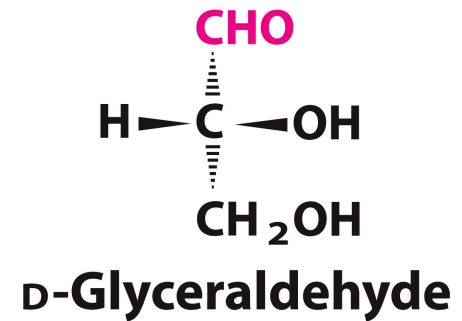
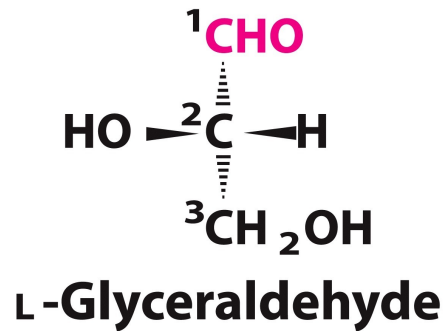
D-Stereoisomer or L-Stereoisomer?

- Reference carbon
 - Chiral center **most distant** from carbonyl carbon.
- Reference molecule
 - D-isomers have the same configuration at the reference carbon as **D-glyceraldehyde** (-OH group on the right).
- Most hexoses in living organisms are **D stereoisomers**.



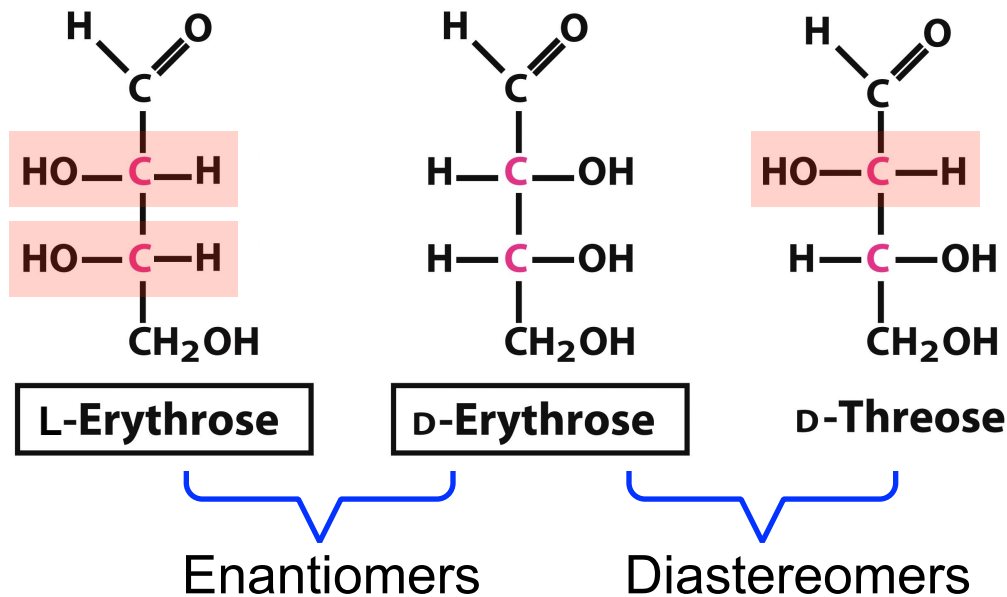
All Amino Acids Are Chiral Except Gly

- DL system.
 - Compare with glyceraldehyde.
 - Absolute configuration only.
 - Not optical properties.
 - Only L isomers found in proteins
- RS system.



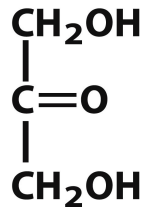
Enantiomer and Diastereomer

- Enantiomers: stereoisomers that are mirror images.
- Diastereomers: stereoisomers that are **NOT mirror images**.
- Enantiomers have similar physical properties.
- Diastereomers have different physical properties.
 - L- and D-erythrose have the same water solubility.
 - Water solubilities of erythrose and threose are different.



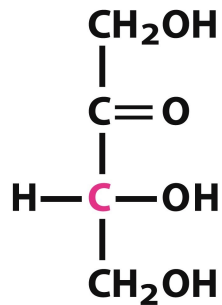
Ketoses

Three carbons



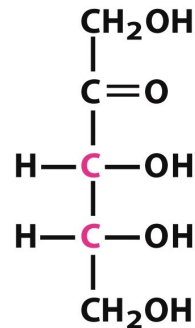
Dihydroxyacetone

Four carbons

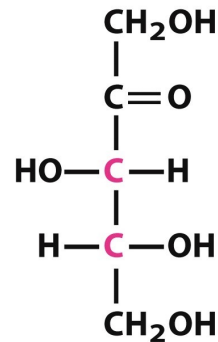


D-Erythrulose

Five carbons

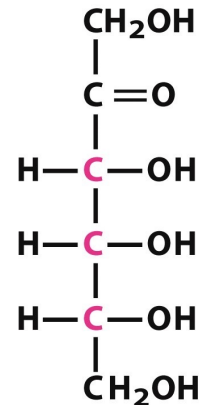


D-Ribulose

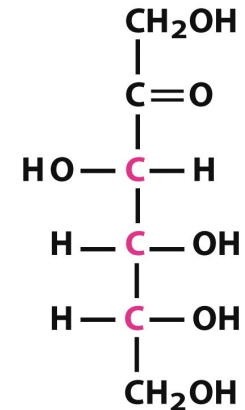


D-Xylulose

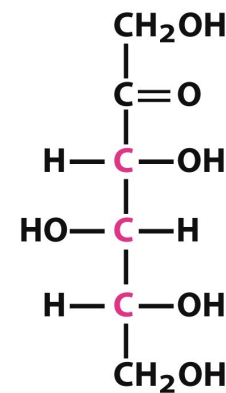
Six carbons



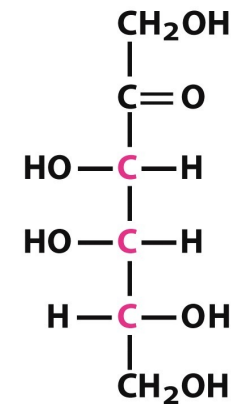
D- Psicose



D-Fructose



D-Sorbose

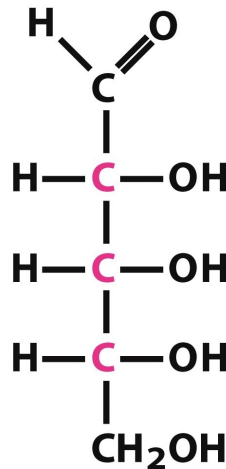


D-Tagatose

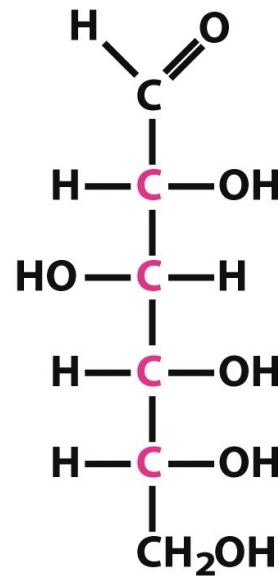
Erythrose->Erythrulose. Ribose->Ribulose. Xylose->Xylulose.

Structures to Know

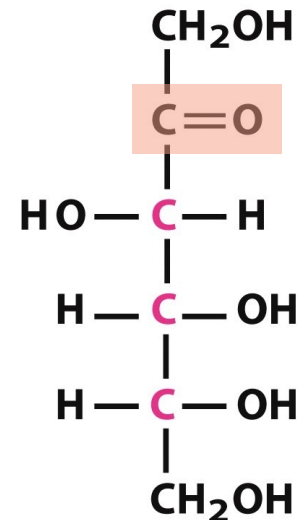
- Ribose is the standard **five-carbon** sugar (pentose).
 - Component of nucleic acid.
- Glucose is the standard **six-carbon** sugar (hexose).
 - Most common aldohexose in nature.
- Fructose is the **ketose form** of glucose.
 - Most common ketohexose in nature.



D-Ribose



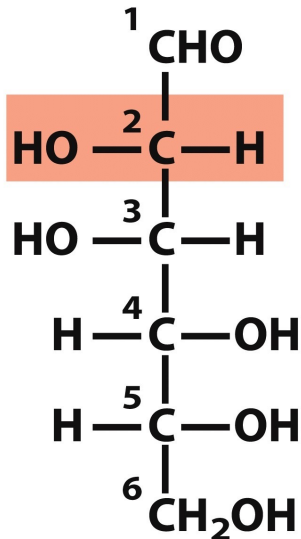
D-Glucose



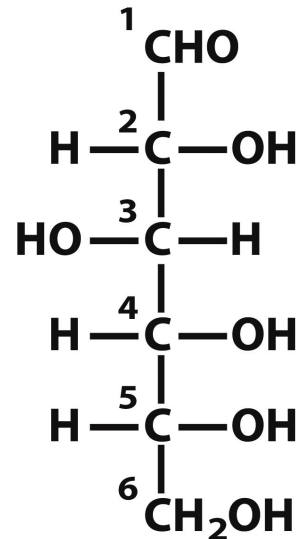
D-Fructose

Epimer

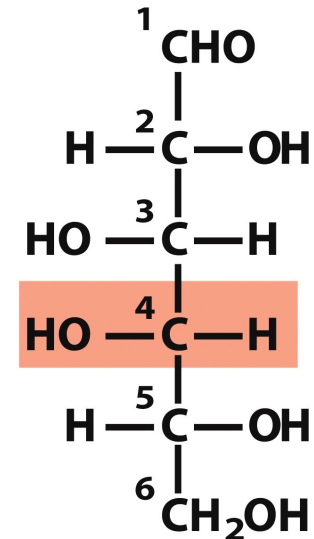
- Epimers are two sugars that differ **only in configuration around one carbon atom.**
- Configurations at all the other chiral centers are identical.



D-Mannose
(epimer at C-2)

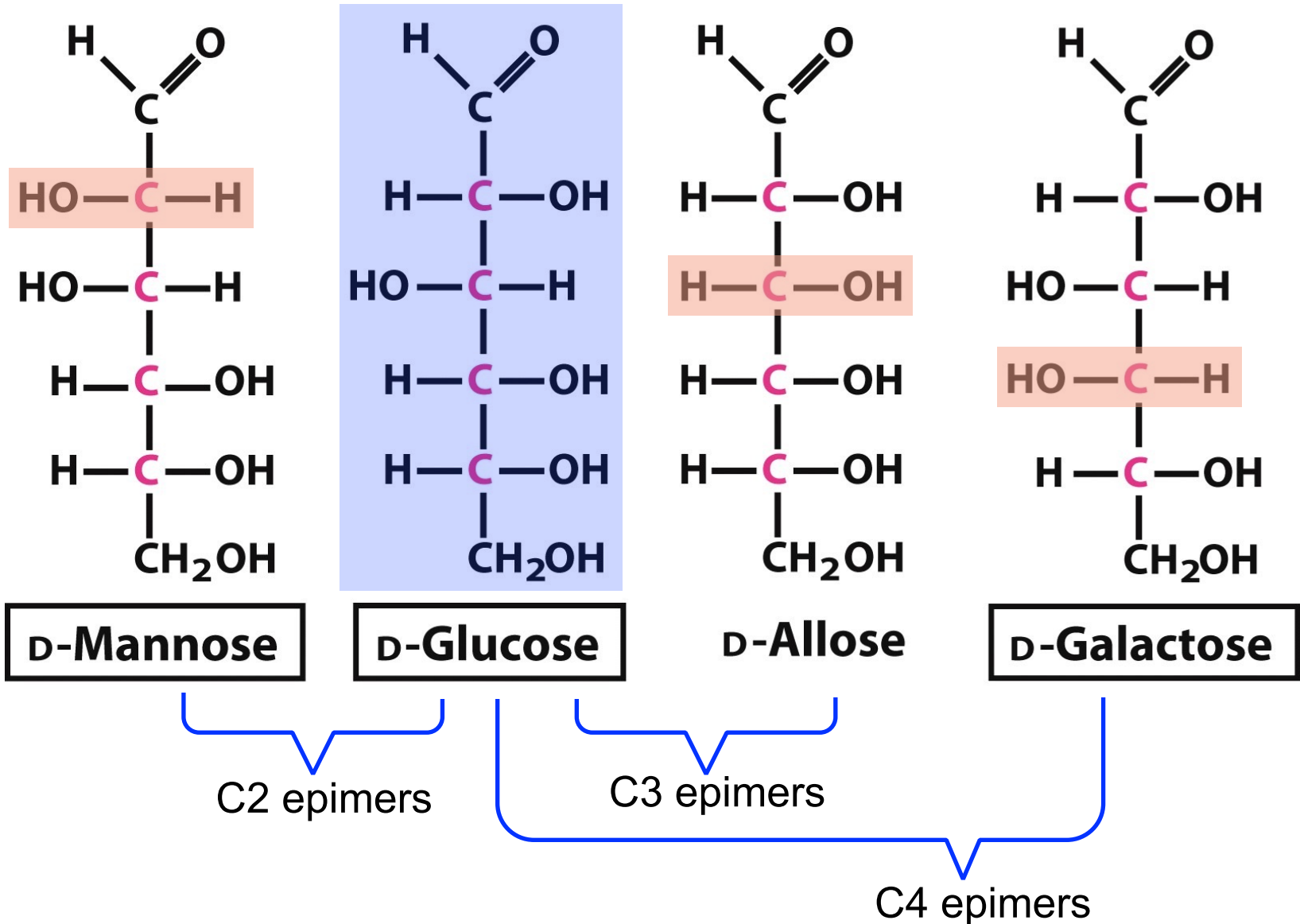


D-Glucose



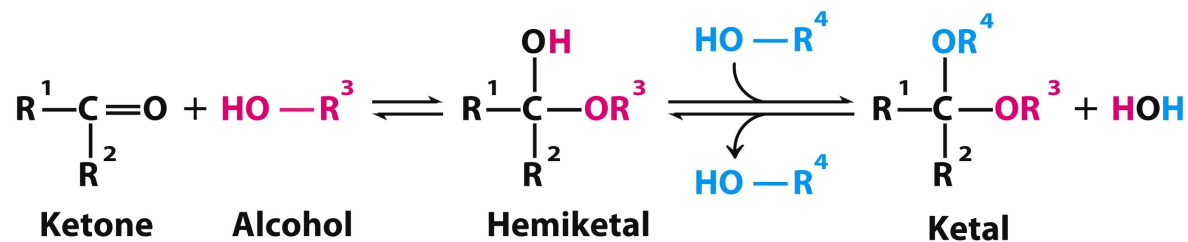
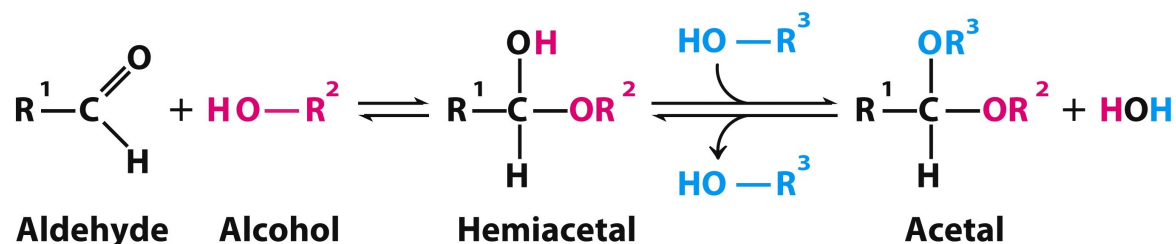
D-Galactose
(epimer at C-4)

Epimers of D-glucose



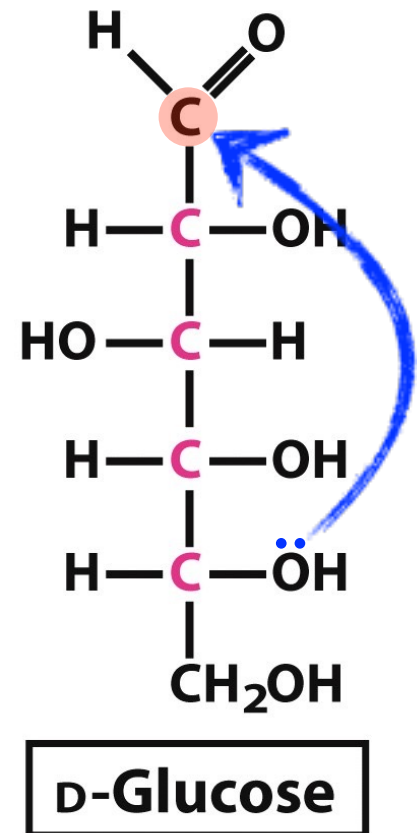
Hemiacetals and Hemiketals

- Aldehyde and ketone carbons are **electrophilic**. Alcohol oxygen atom is **nucleophilic**.
- When **aldehydes** are attacked by **alcohols**, **hemiacetals** form (“hemi-” means “half”).
 - Further attack by alcohols produces acetals.
- When **ketones** are attacked by alcohols, **hemiketals** form.
 - Further attack by alcohols produces ketals.



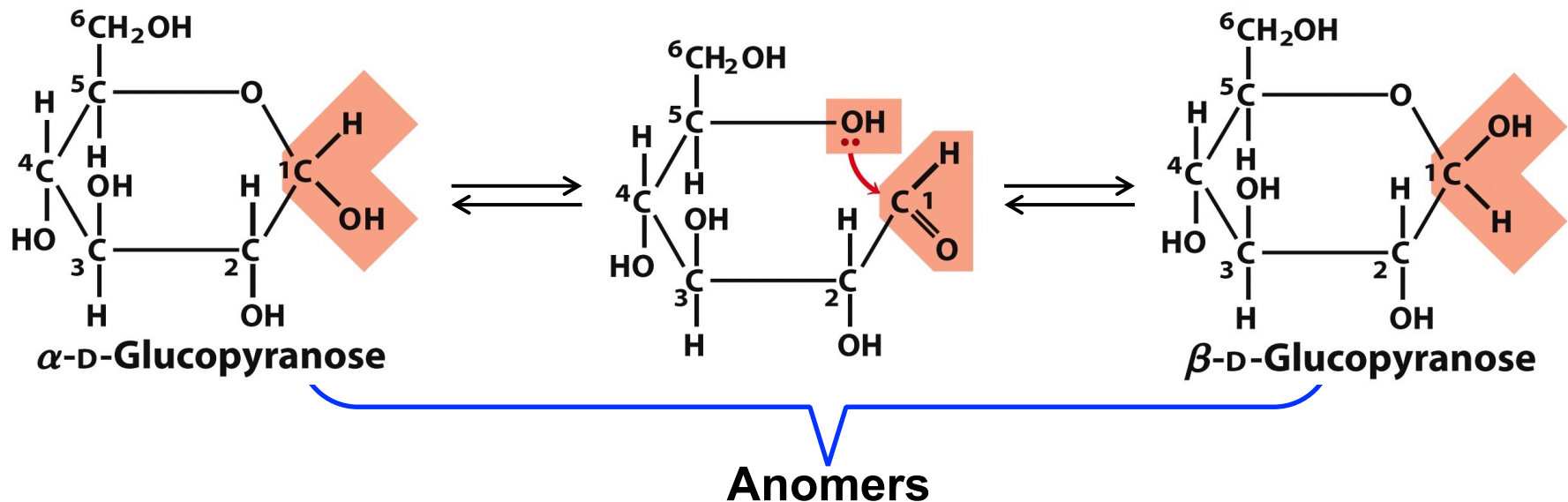
Cyclization of Monosaccharides

- Monosaccharides are polyhydroxy aldehydes or ketones.
 - Have hydroxyl oxygen atoms as nucleophiles.
 - Have carbonyl carbon atoms as electrophiles.
- Pentoses and hexoses readily undergo **intramolecular cyclization**.
- The former carbonyl carbon becomes a new chiral center, called the anomeric carbon (carbon #1 in glucose).



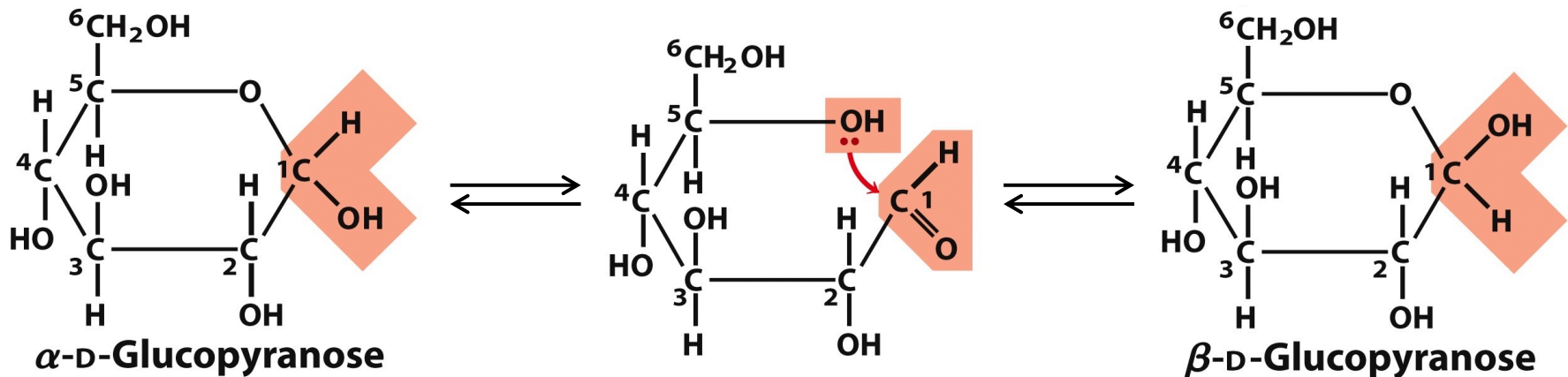
Cyclization of Monosaccharides

- The former carbonyl oxygen becomes a **hydroxyl group**; the position of this group determines if the anomer is α or β .
- If the hydroxyl group is on the opposite side (trans) of the ring as the CH_2OH moiety, the **configuration is α** .
- If the hydroxyl group is on the same side (cis) of the ring as the CH_2OH moiety, the **configuration is β** .



Mutarotation

- The α and β anomers of D-glucose **interconvert** in aqueous solution by a process called **mutarotation**.
 - One ring form opens briefly into linear form.
 - Linear form closes to produce the other ring form.
- At equilibrium.
 - 1/3 α -D-glucose.
 - 2/3 β -D-glucose.
 - Very small amounts of linear form and five-membered ring (glucofuranose) form.



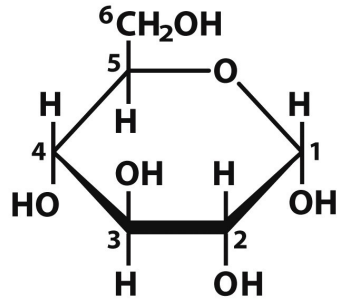
Pyranose and Furanose

- **Pyranose**

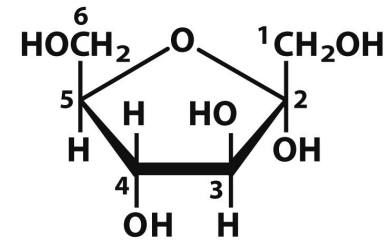
- **Blue**-membered
- Contains oxygen
- Sugar ring

- **Furanose**

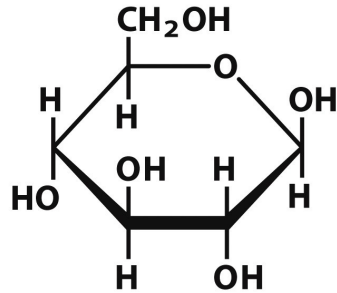
- **Red**-membered
- Contains oxygen
- Sugar ring



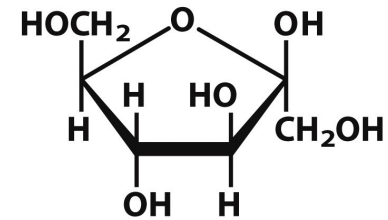
α -D-Glucopyranose



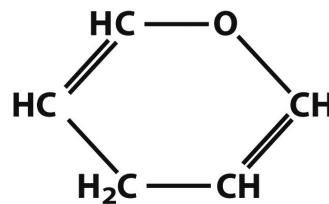
α -D-Fructofuranose



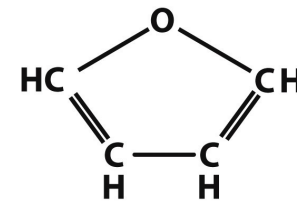
β -D-Glucopyranose



β -D-Fructofuranose

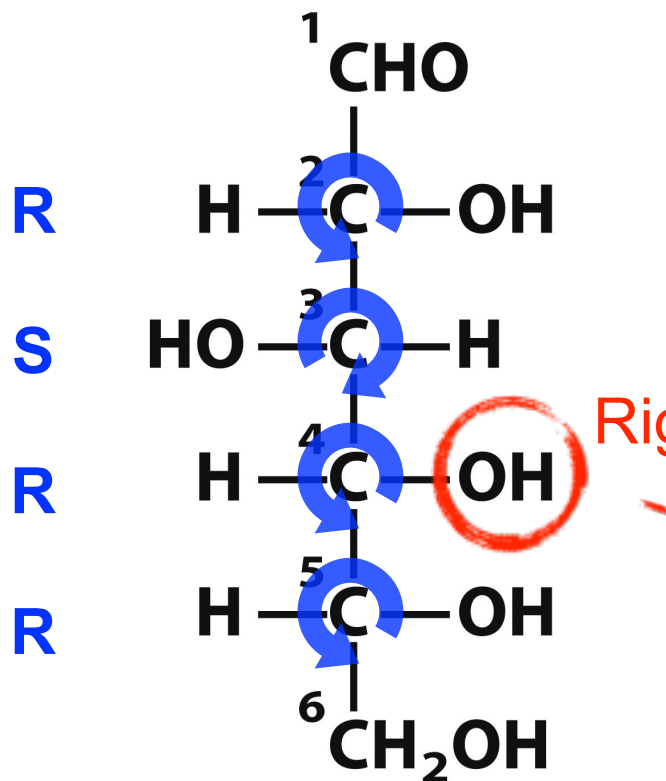


Pyran



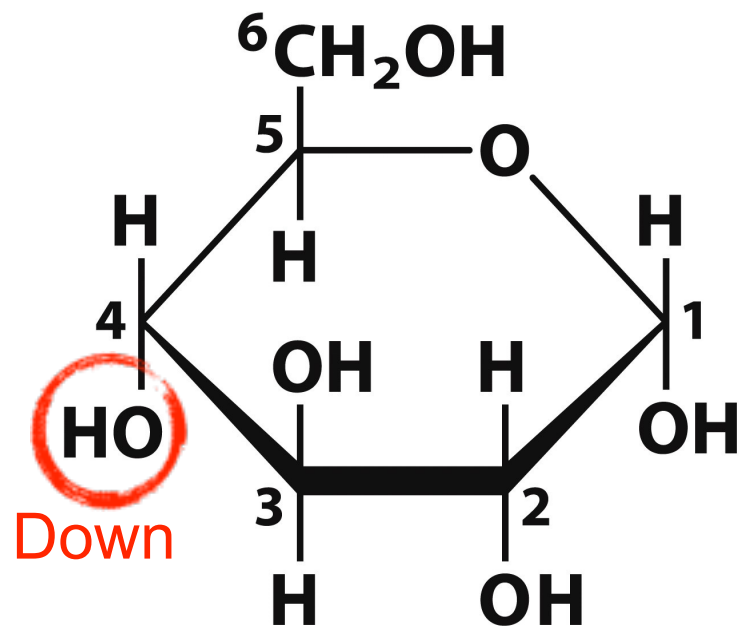
Furan

Fischer Projection vs. Haworth Perspective



D-Glucose
Fischer projection

Linear structure



α -D-Glucopyranose
Haworth perspective

Cyclic structure

Common Prefix and Suffix 1

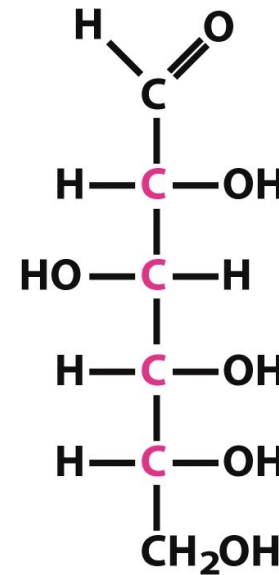
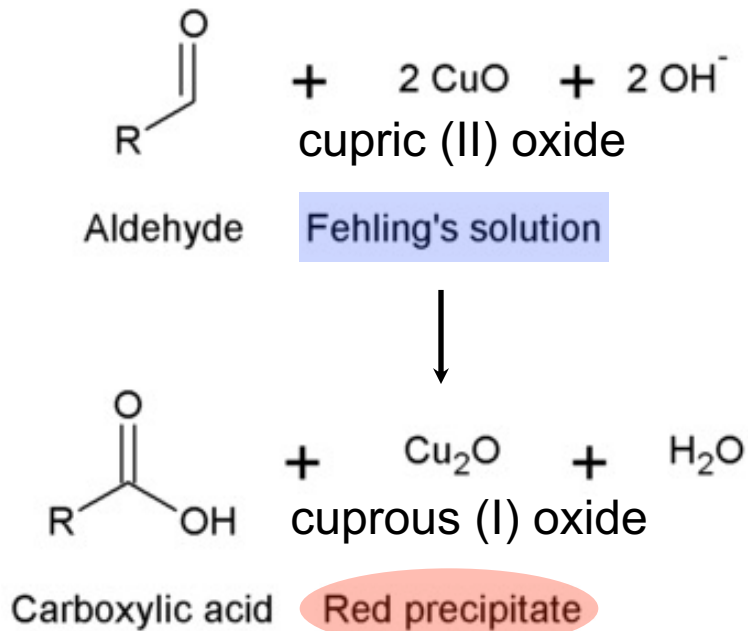
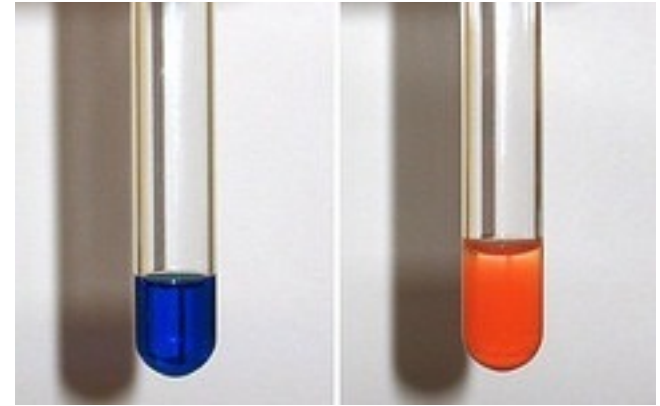
Prefix / Suffix	中文	Example
-ose	糖	gluc ose , fructose, ribose, sucrose, lactose, maltose, cellulose
-ase	酶	polymer ase , kinase, amylase, lipase, protease, lactase
-ate	酸, 盐	acet ate , aspartate, pyruvate, carbonate, nitrate, sulfate
-aldehyde, -al	醛	form aldehyde , acetaldehyde, benzaldehyde, retinal
-one	酮	acet one , testosterone, progesterone
-ol	醇	methan ol , ethanol, glycerol, cholesterol
-amine, -ine	胺	methyl amine , ethanolamine, adenine, guanine
-ane	烷	meth ane , ethane, propane, butane
-ene	烯	ethyl ene , benzene
-yne	炔	ethyl yne , propyne
glyco-	糖	glyco biology, glycomics, glycan, glycoconjugate, glycoprotein, glycopeptide, glycolipid, glycolysis, glycosyltransferase
-saccharide	糖	monos accharide , disaccharide, oligosaccharide, polysaccharide

Common Prefix and Suffix 2

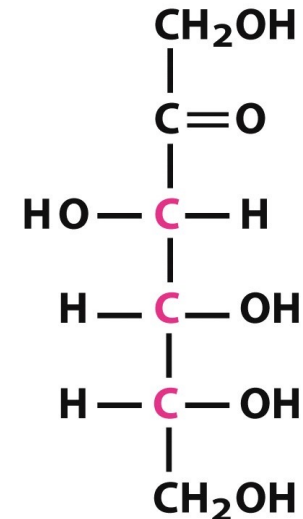
Prefix / Suffix	中文	Example
meth-, mono-, uni-	甲, 单	methane, methionine, monomer, monocyte, carbon monoxide, unicellular
eth-, bi-, di-	乙, 二	ethane, ethanol, bicycle, bilingual, binary, dipeptide, carbon dioxide
prop-, tri-, tert-,	丙, 三	propane, triangle, triose, tricarboxylic acid, tertiary structure, ternary complex
but-, tetra-	丁, 四	butane, butanol, tetrose, tetramer, tetrahydrofolate, tetrahydrofuran, tetrahedron
pent-	戊, 五	pentose, pentagon, pentamer
hex-	己, 六	hexose, hexokinase
hept-	庚, 七	heptose, heptane
oct-	辛, 八	octopus, October
non-	壬, 九	November
dec-	癸, 十	December, decimal, hexadecimal
hemi-, semi-	半	hemiacetal, hemisphere, semiconductor, semifinal
oligo-	寡	oligopeptide, oligonucleotide, oligosaccharide
poly-, multi-	多	polypeptide, polysaccharide, polymer, multicellular, multi-subunit protein

Reducing Sugars

- **Monosaccharides are reducing sugars.**
 - All aldoses, such as glucose.
 - All alpha-hydroxyl ketoses, such as fructose.
 - Positive in Fehling's reaction.



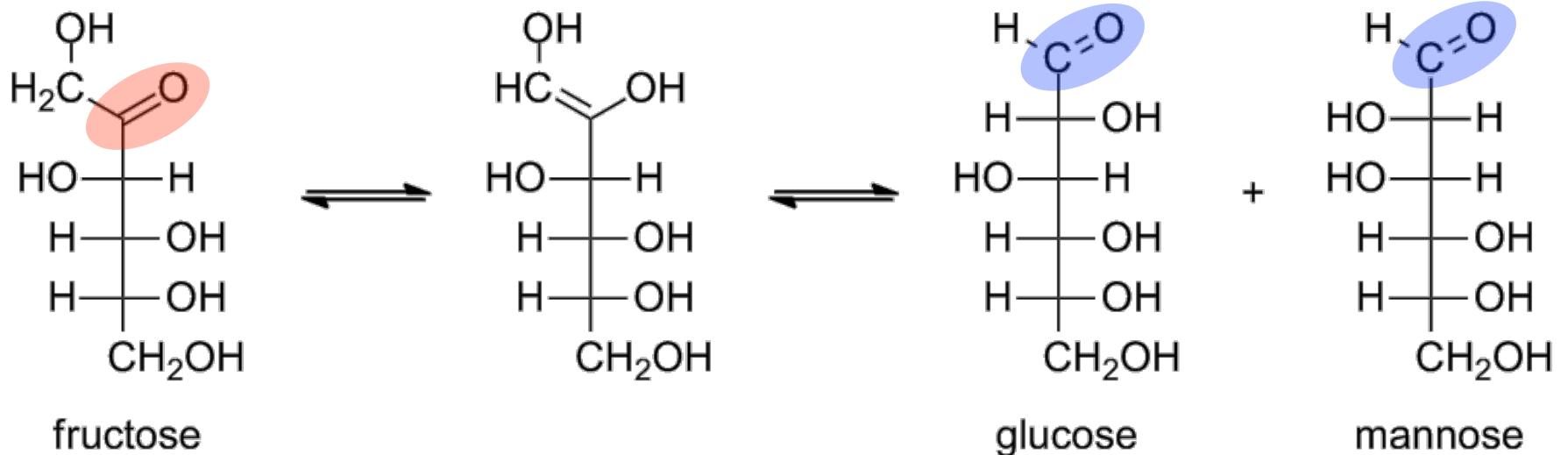
D-Glucose



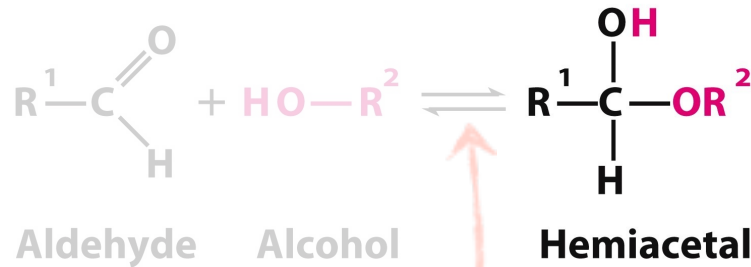
D-Fructose

Why is Fructose a Reducing Sugar?

- Fructose, a **ketose**, is **readily isomerized** to a mixture of **aldoses** (glucose and mannose) under basic conditions.



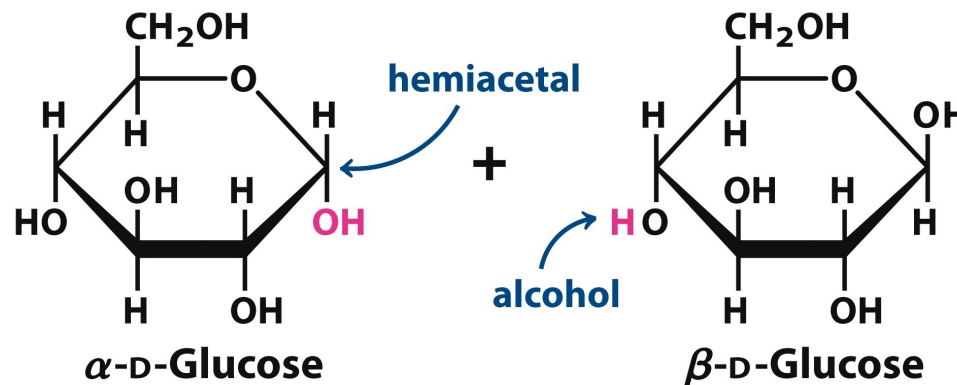
Disaccharides



Monosaccharide Cyclization

Two sugar molecules can be joined.

- One sugar acts as a hemiacetal.
- The other sugar acts as an alcohol.



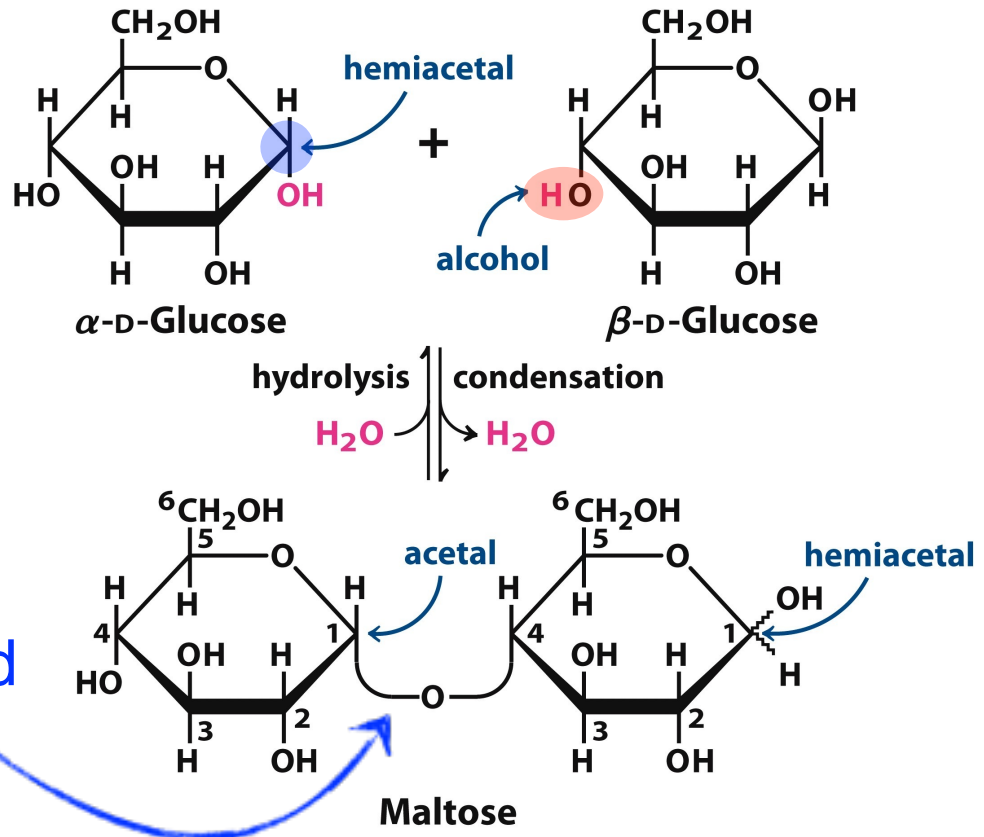
Disaccharides Contain a Glycosidic Bond

- Two sugar molecules can be joined via a **glycosidic bond** between an **anomeric carbon** and a **hydroxyl group**.

- One molecule of **water** is eliminated.

- Hemiacetal** is converted to **acetal**.

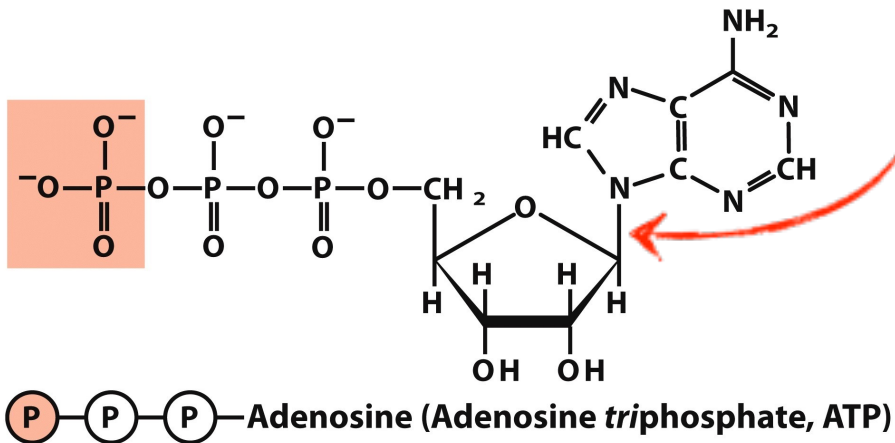
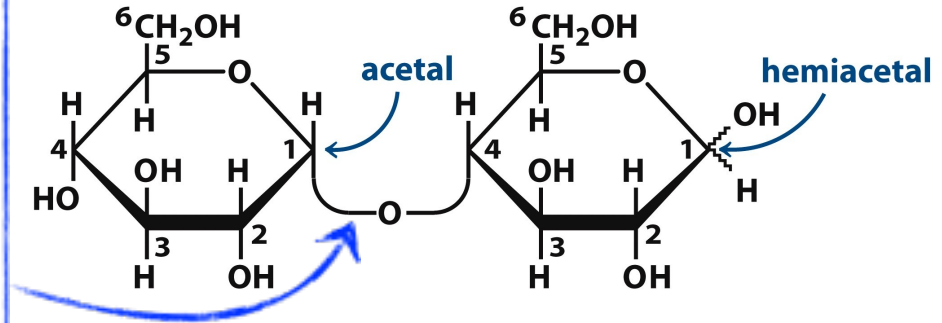
glycosidic bond



Glycosidic Bond

O-glycosidic bond

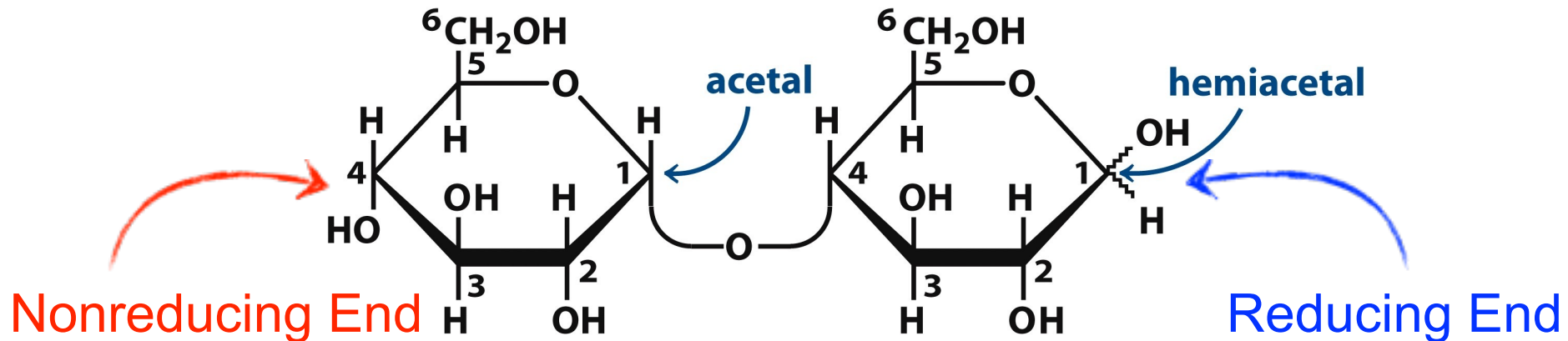
anomeric carbon
connected to an
oxygen atom.



N-glycosidic bond

anomeric carbon
connected to a
nitrogen atom.

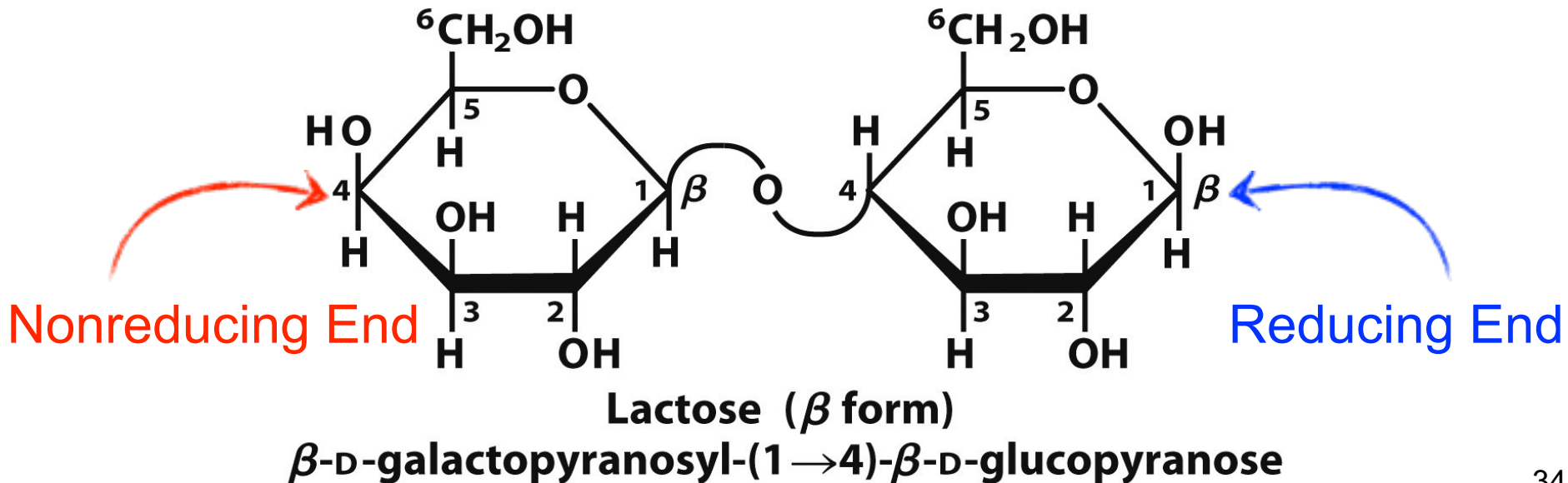
Maltose is a Reducing Disaccharide



- First monomer (glucose) is **nonreducing**.
 - Anomeric carbon involved in the glycosidic linkage (acetal)
 - **Cannot convert** between linear and cyclic form.
- Second monomer (glucose) is **reducing**.
 - Anomeric carbon NOT involved in the glycosidic linkage (hemiacetal)
 - **Can still convert between linear and cyclic form.**
 - Wavy lines indicate structure may be α or β (can be interconverted).

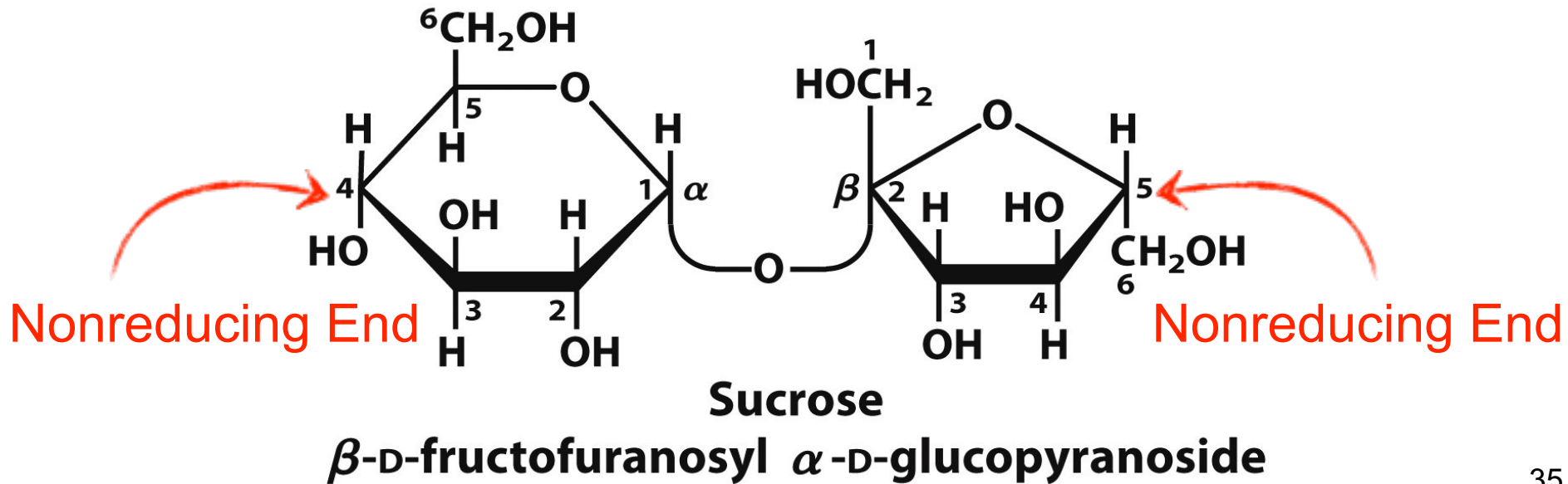
Lactose is a Reducing Disaccharide

- Lactose occurs naturally in milk (gives sweetness).
- Lactose is made of two monosaccharides.
 - Galactose and glucose.
- Lactose is a **reducing** disaccharide.
 - Anomeric carbon in galactose **involved in glycosidic bond**.
 - Anomeric carbon in glucose is **available for oxidation**.

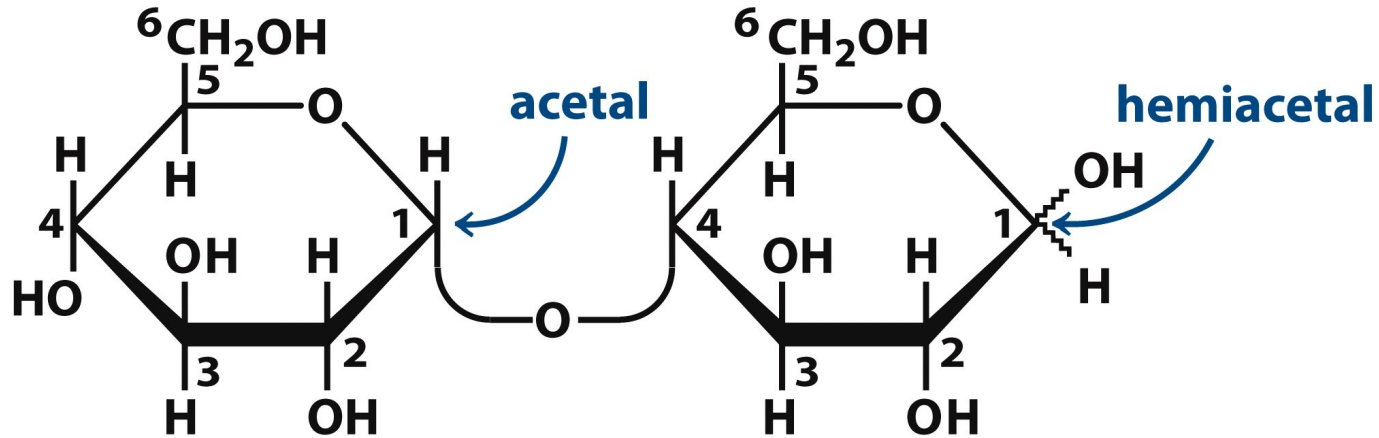


Sucrose is a Nonreducing Disaccharide

- Sucrose is produced by plants but not by animals.
- Sucrose is made of two monosaccharides.
 - Glucose and fructose.
- Sucrose is a **nonreducing** disaccharide.
 - Anomeric carbon (C #1) in glucose involved in glycosidic bond.
 - Anomeric carbon (C #2) in fructose involved in glycosidic bond.



Disaccharide Nomenclature 1

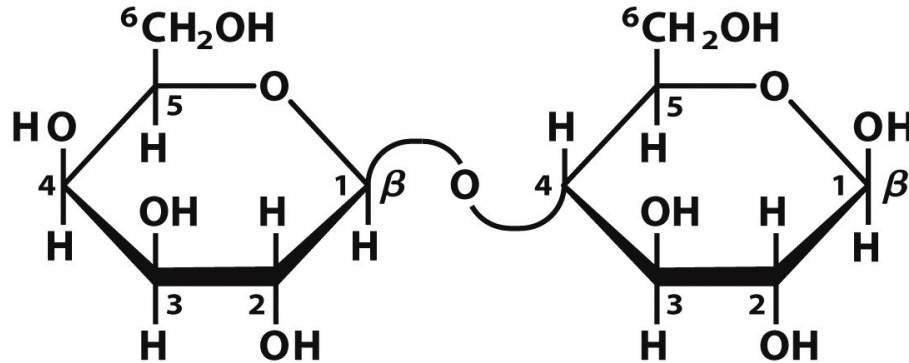


Maltose

α -D-glucopyranosyl-(1 \rightarrow 4)-D-glucopyranose

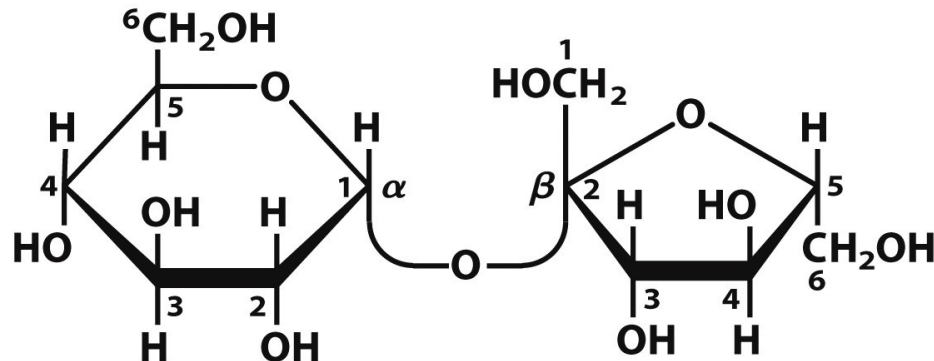
1. Name of 1st monosaccharide. Name of 2nd monosaccharide. \rightarrow Glc Glc
2. Electrophile \rightarrow nucleophile. \rightarrow Glc \rightarrow Glc
3. Carbons involved in glycosidic bond. \rightarrow Glc(1 \rightarrow 4)Glc
4. Configuration of anomeric carbon. \rightarrow Glc(α 1 \rightarrow 4)Glc

Disaccharide Nomenclature 2



Lactose (β form)

1. Gal Glc
2. Gal->Glc
3. Gal(1->4)Glc
4. Gal(β 1->4)Glc



Sucrose

1. Glc Fru
2. Glc<->Fru
3. Glc(1<->2)Fru
4. Glc(α 1<->2 β)Fru

Summary 7.1 Mono- and Disaccharides

- Sugars (saccharides) contain one aldehyde or ketone group and two or more hydroxyl groups.
- Monosaccharides generally contain several **chiral centers**, and exist in different stereochemical forms.
 - Fischer projection. Perspective formula.
 - Enantiomer. Diastereomer. Epimer.
 - Monosaccharide cyclization. Hemiacetal. Hemiketal.
 - Haworth perspective. Anomer. Anomeric carbon. Mutarotation.
 - Reducing sugar.
- Disaccharide. Acetal. Glycoside. Glycosidic bond. Nonreducing sugar. Nomenclature.

Week 7 Carbohydrates and Glycobiology

7.1 Monosaccharides and Disaccharides

7.2 Polysaccharides

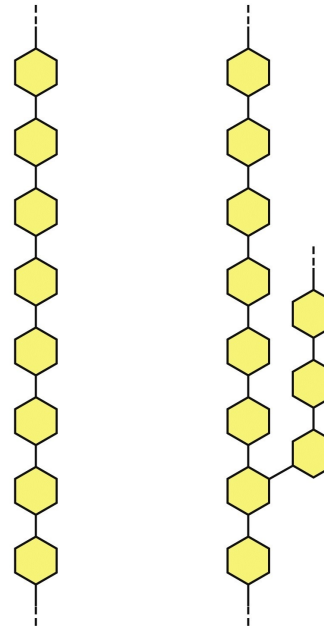
7.3 Glycoconjugates

7.4 Carbohydrates as Informational Molecules

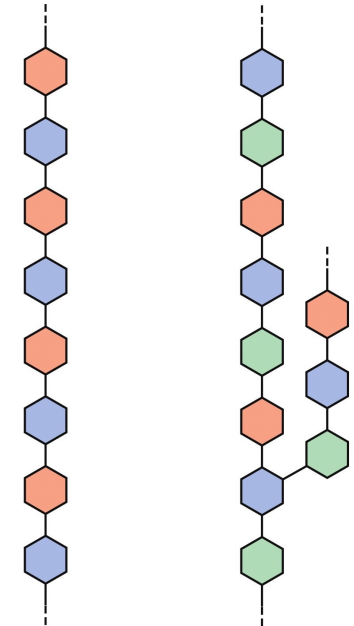
Polysaccharides

- Polysaccharides, also called glycans, are polymers of monosaccharides
- **Homopolysaccharides**
 - Single monomer
 - Linear or branched
- **Heteropolysaccharides**
 - Two or more monomers
 - Linear or branched

Homopolysaccharides
Unbranched Branched

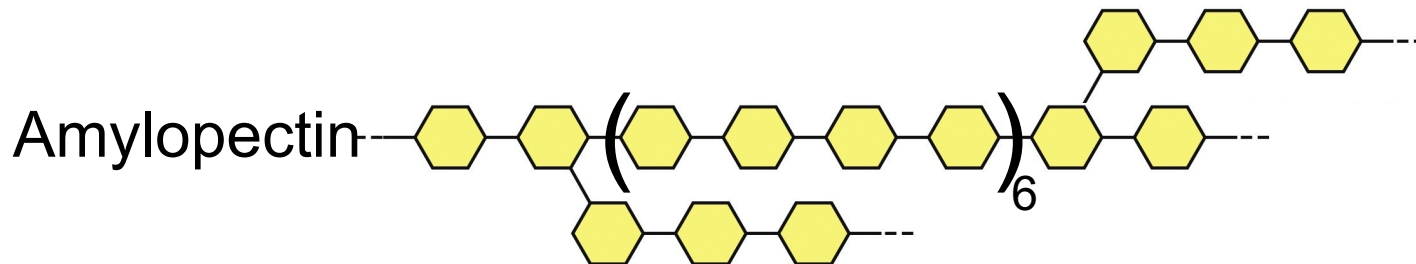
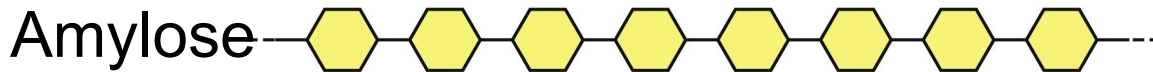


Heteropolysaccharides
Two monomer types, unbranched Multiple monomer types, branched

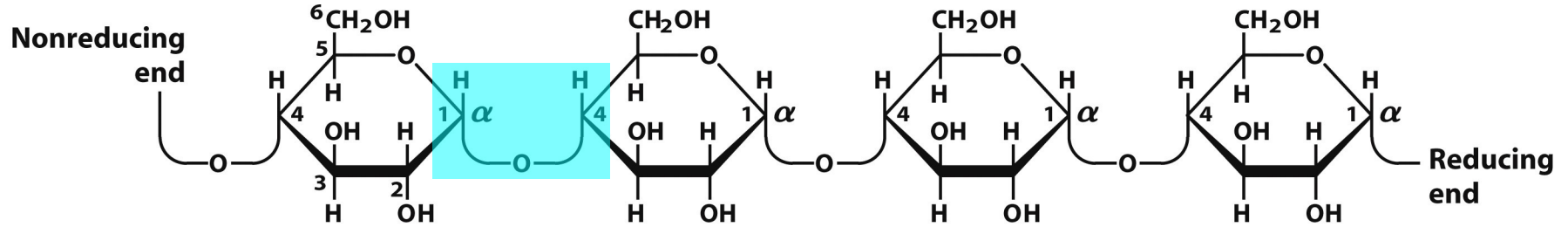


Starch is Homopolysaccharide

- Main **storage** polysaccharide in plants
- A mixture of two homopolysaccharides of **α -D-glucose**
 - **Amylose** is an **unbranched** linear polymer
 - **Amylopectin** is **branched**, and the branch points occur every 24 - 30 residues

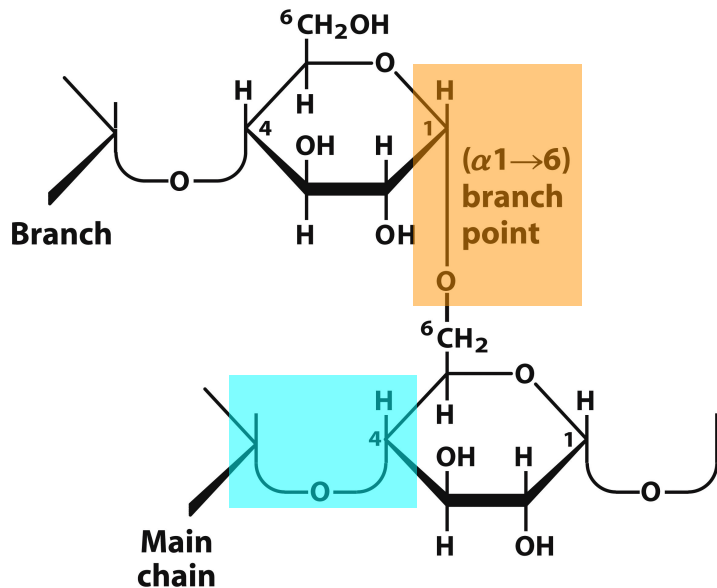


Starch Contains Two Types of Linkages



Amylose

- In **amylose**, glucose residues are connected by **α 1- \rightarrow 4** linkages

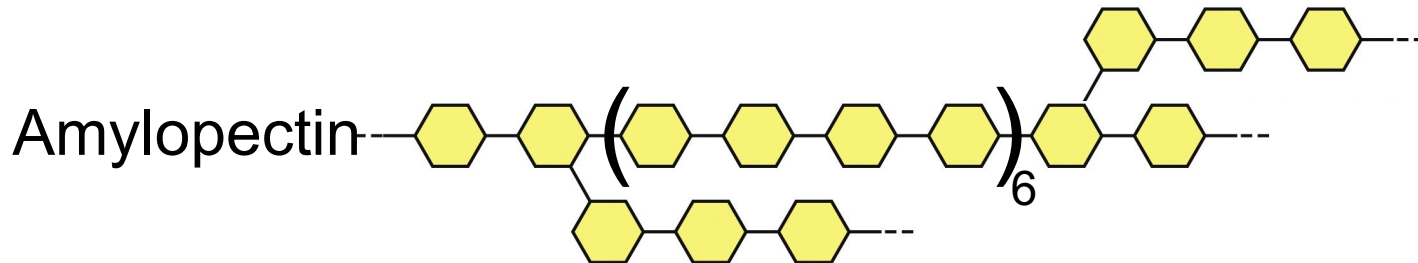
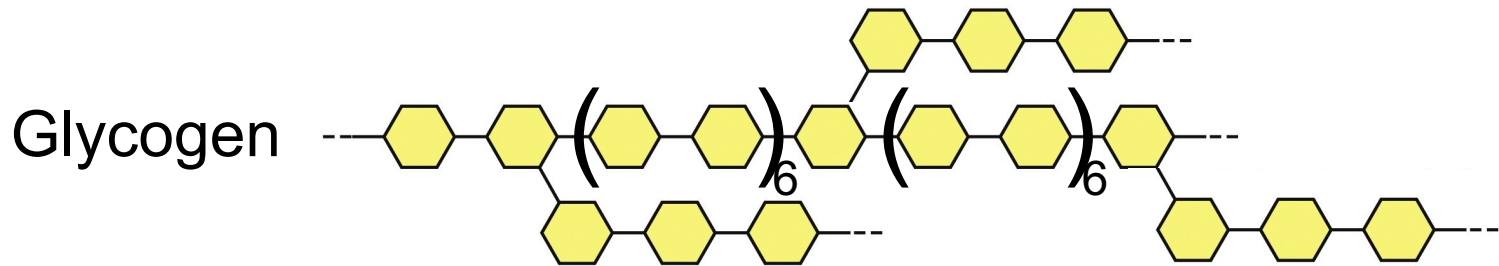


- In **amylopectin**, main chain has **α 1- \rightarrow 4** linkages and branch points have **α 1- \rightarrow 6** linkages

Amylopectin

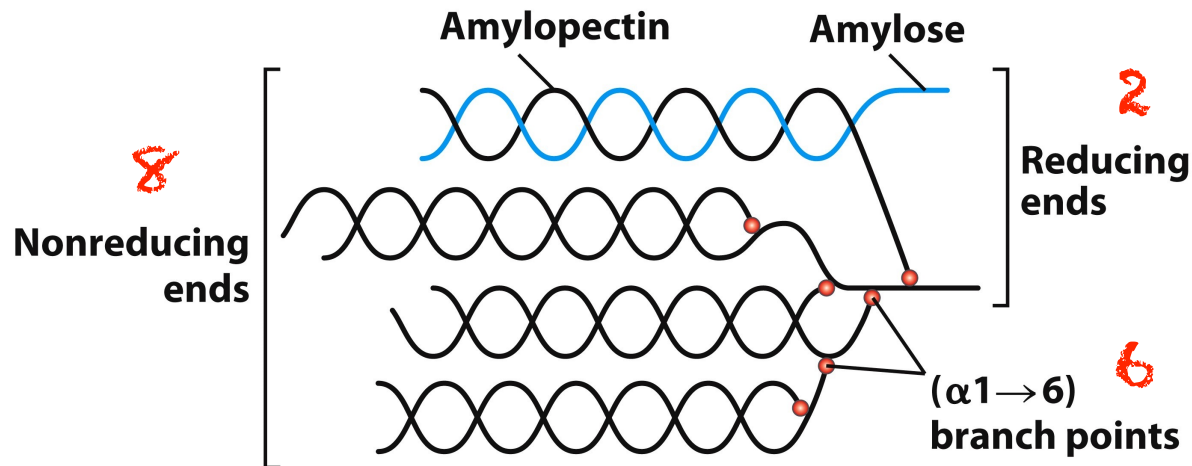
Glycogen is Homopolysaccharide

- Main **storage** polysaccharide in animals.
- Glycogen is similar to amylopectin.
 - Polymer of **α -D-glucose** monomers.
 - (α 1->4)-linked main chain and (α 1->6)-linked branches.
- **More extensively branched** than amylopectin.
 - Branch points every 8 - 12 residues.



Nonreducing Ends in Starch and Glycogen

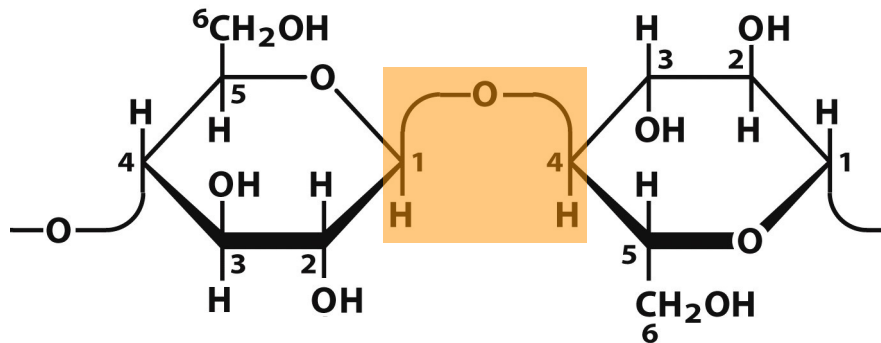
- One amylose molecule has **one reducing end** and **one nonreducing end**.
- One amylopectin or glycogen molecule with n branches has **one reducing end** and **$n + 1$ nonreducing ends**.
- **Digestive enzymes act only at nonreducing ends, and can work simultaneously on many branches.**



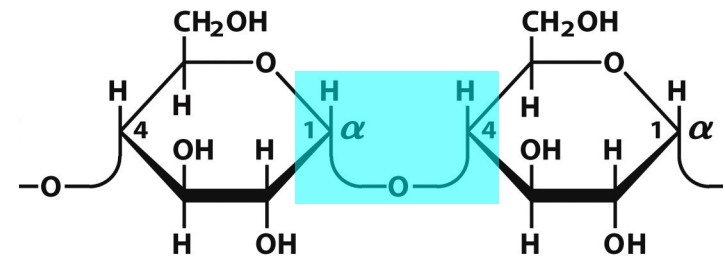
$$\text{Reducing Ends} + \text{Branches} = \text{Nonreducing Ends}$$

Cellulose is Homopolysaccharide

- Found in cell walls of plants.
 - Constitutes much of mass of wood.
 - Cotton is almost pure cellulose.
- Linear, unbranched homopolysaccharide of glucose (like amylose).
 - **(β 1- \rightarrow 4) linkage**
 - For comparison, **(α 1- \rightarrow 4) linkage** in amylose



Cellulose



Amylose

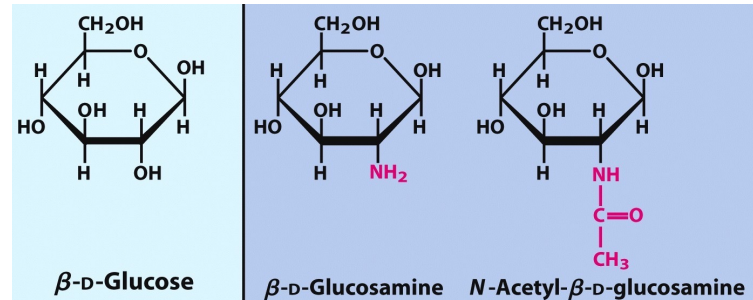
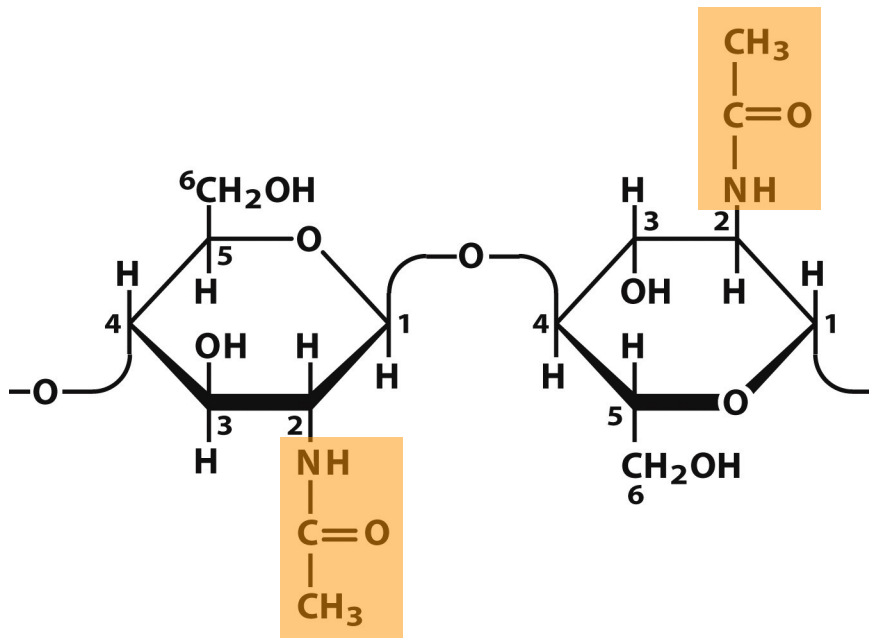
Cellulose Metabolism

- Most animals do **NOT have enzymes** that break (β 1- \rightarrow 4) glycosidic bonds, and so cannot digest cellulose.
 - Have enzymes that break (α 1- \rightarrow 4) glycosidic bonds.
 - Can digest starch and glycogen.
- Fungi and bacteria have **cellulase**, and so they can digest wood.
- Ruminants (cattle, sheep, and goats) and termites live **symbiotically** with microorganisms that produces cellulase.
 - Ruminants can convert cellulose in grass to sugar in milk.
 - Termites can eat wood and so cause damage to buildings.



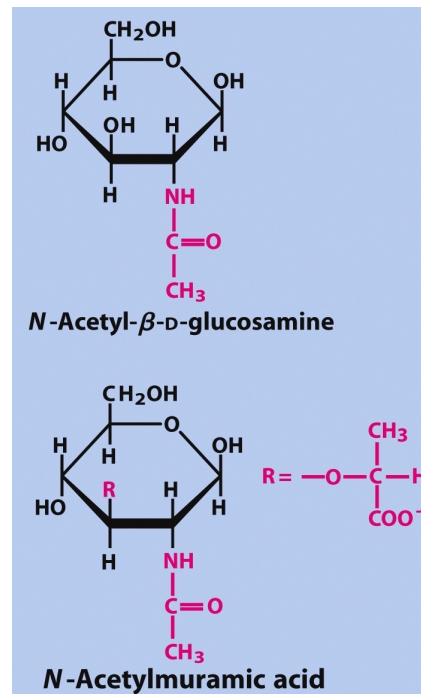
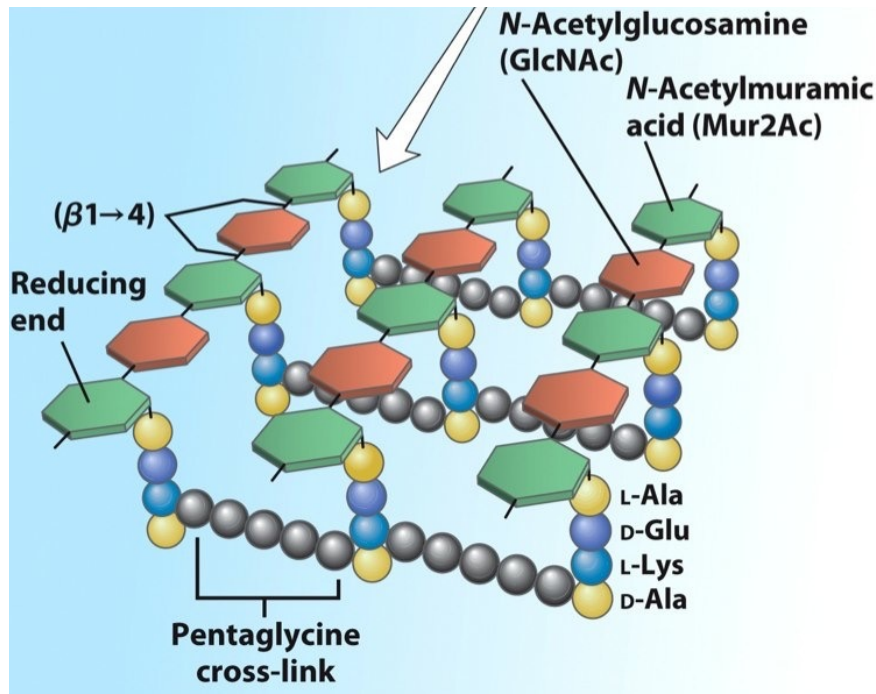
Chitin is Homopolysaccharide

- Linear, unbranched homopolysaccharide.
 - (β 1- \rightarrow 4) linkage.
 - Composed of **N-acetylglucosamine** residues.
- Found in exoskeletons of insects, spiders, and crabs.
 - **Cannot be digested by animals.**



Heteropolysaccharide in Peptidoglycan

- Peptidoglycan contains linear, unbranched heteropolysaccharide.
 - (β 1- \rightarrow 4) linkage.
 - Alternating **N-acetylglucosamine** and **N-acetylmuramic acid** residues.
 - Cross-linked by short peptides.
- Found in **bacterial cell wall**.

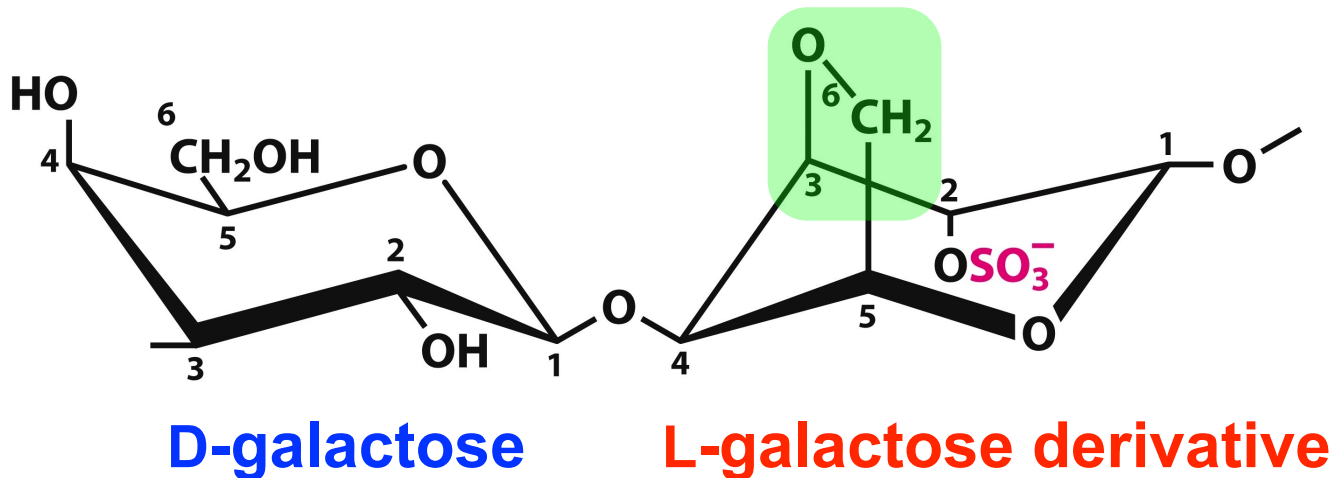


GlcNAc

Mur2Ac

Agarose is Heteropolysaccharide

- Linear, unbranched heteropolysaccharide.
 - (α 1- \rightarrow 3) linkage between disaccharide repeating units.
 - Repeating unit consists of **D-galactose** and **L-galactose derivative**.
 - **Ether bridge** and **sulfate ester**.
 - (β 1- \rightarrow 4) linkage between D-galactose and L-galactose derivative.
- Found in cell walls of red algae, including some seaweeds.



Summary of Some Polysaccharides

Polymer	Type*	Repeating unit [†]	Roles/significance
Starch			Energy storage: in plants
Amylose	Homo-	(α 1→4)Glc, linear	
Amylopectin	Homo-	(α 1→4)Glc, with (α 1→6)Glc branches every 24–30 residues	
Glycogen	Homo-	(α 1→4)Glc, with (α 1→6)Glc branches every 8–12 residues	Energy storage: in bacteria and animal cells
Cellulose	Homo-	(β 1→4)Glc	Structural: in plants, gives rigidity and strength to cell walls
Chitin	Homo-	(β 1→4)GlcNAc	Structural: in insects, spiders, crustaceans, gives rigidity and strength to exoskeletons
Peptidoglycan	Hetero-; peptides attached	4)Mur2Ac(β 1→4) GlcNAc(β 1	Structural: in bacteria, gives rigidity and strength to cell envelope
Agarose	Hetero-	3)D-Gal(β 1→4)3,6- anhydro-L-Gal(α 1	Structural: in algae, cell wall material

Summary 7.2 Polysaccharides

- Polysaccharides serve as stored **fuel** (starch and glycogen) and as **structural** components of cell walls (cellulose, chitin, peptidoglycan, and agarose).
- **Homopolysaccharides** starch and glycogen consist of glucose with ($\alpha 1 \rightarrow 4$) linkages. Homopolysaccharides cellulose and chitin are composed of glucose derivatives with ($\beta 1 \rightarrow 4$) linkages.
- **Heteropolysaccharides** peptidoglycan and agarose contain disaccharide repeating units: glucose derivatives and galactose derivatives.

How Carbohydrates Impact Health

LOTS OF STARCH



LOTS OF FIBER

Week 7 Carbohydrates and Glycobiology

7.1 Monosaccharides and Disaccharides

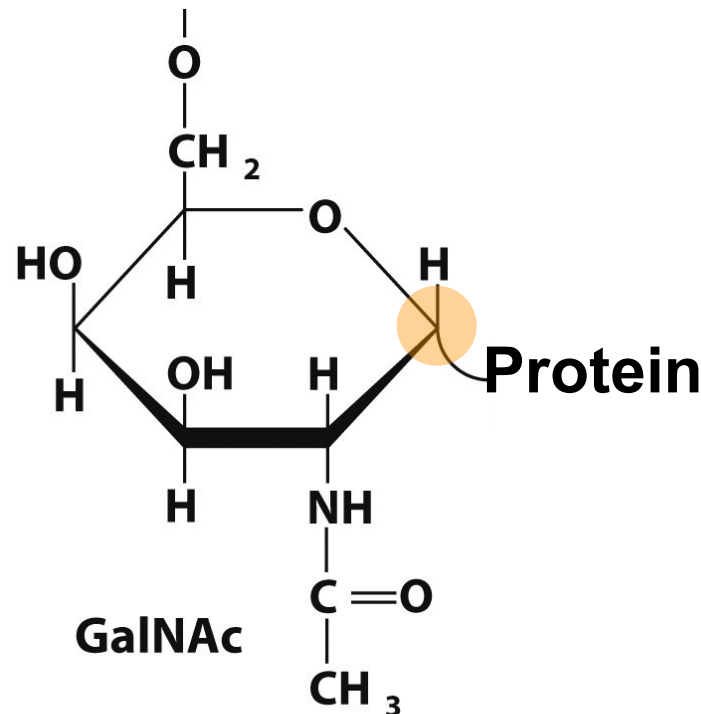
7.2 Polysaccharides

7.3 Glycoconjugates

7.4 Carbohydrates as Informational Molecules

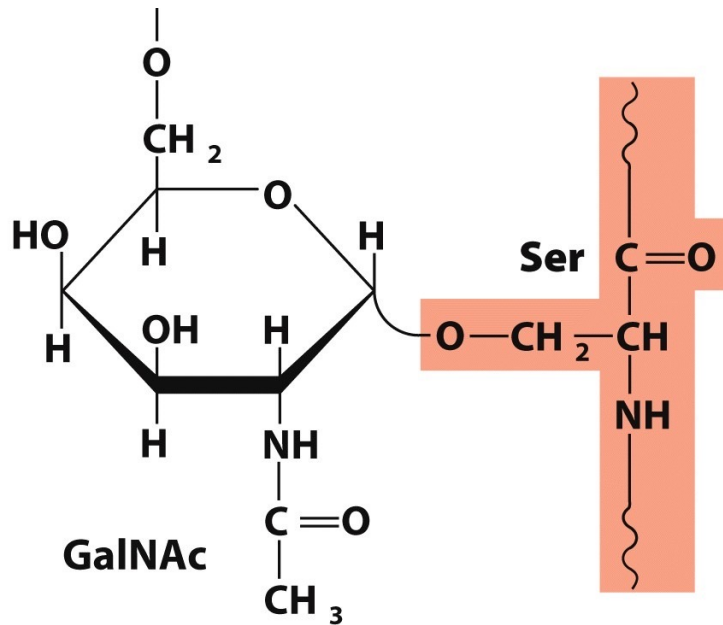
Glycoprotein

- A protein with small oligosaccharides attached
 - Carbohydrate attached via its **anomeric carbon**.
 - Glycosidic bond between carbohydrate and protein.
 - Glycosylation important in regulation of protein activity.

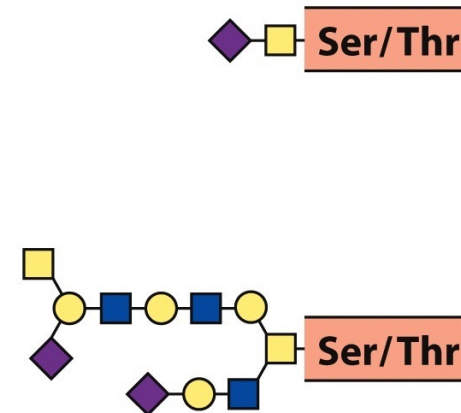


O-Glycosidic Bond

Hydroxyl oxygen (**Ser/Thr**) reacts with anomeric carbon.



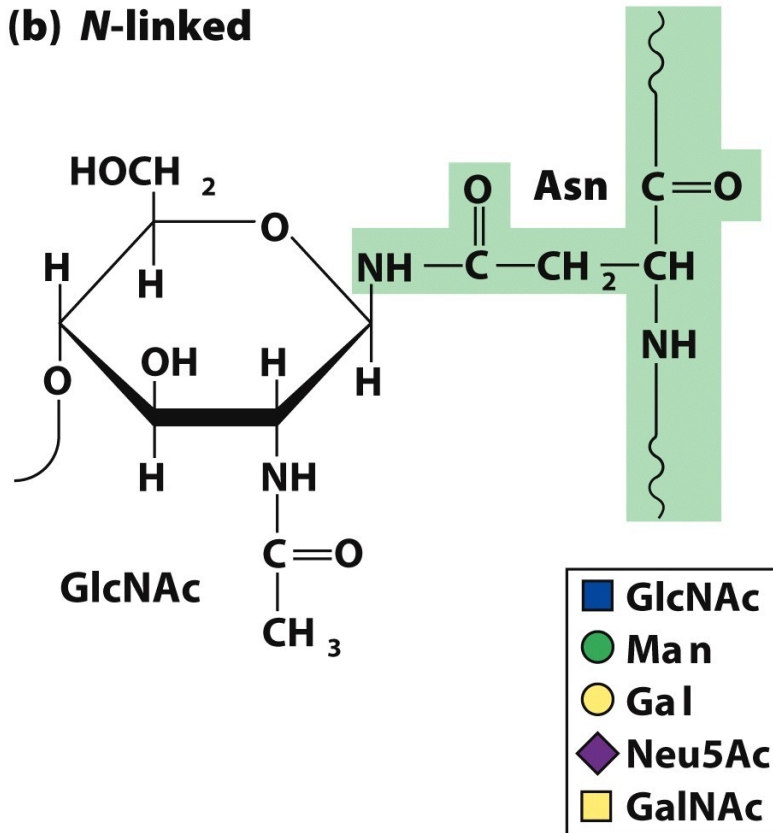
Examples:



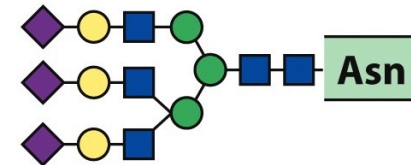
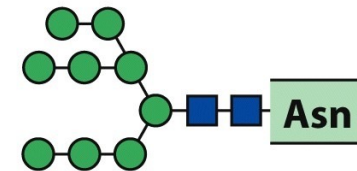
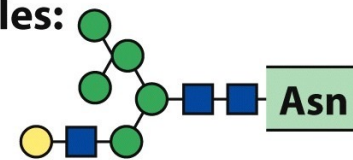
N-Glycosidic Bond

Amide nitrogen (**Asn**) reacts with anomeric carbon.

(b) *N*-linked



Examples:



Example of Glycoprotein: Mucin

- Heavily glycosylated protein.
 - Water-holding capacity.
- Present in most secretions such as saliva and snail slime.
- Give slipperiness.



Beauty Benefits of Snail Slime?

- Keep hydrated.
 - Snails do not like sunlight and appear in rainy days.
- Chemical barrier.
 - Hold water and maintain temperature.
- You never know what the snail has crawled over.
- Snail is the host of many parasites.



Week 7 Carbohydrates and Glycobiology

7.1 Monosaccharides and Disaccharides

7.2 Polysaccharides

7.3 Glycoconjugates

7.4 Carbohydrates as Informational Molecules

Informational Molecule

- A 100-residue polysaccharide vs. a 100-residue polypeptide.
- The number of structurally different polysaccharides is far greater than the number of different polypeptides.
 - All peptides are linear and there is only one way to connect two residues.
 - Polysaccharides can be linear or branched, α - or β -linked, joined 1->4, 1->6, etc.

Common Monosaccharides and derivatives

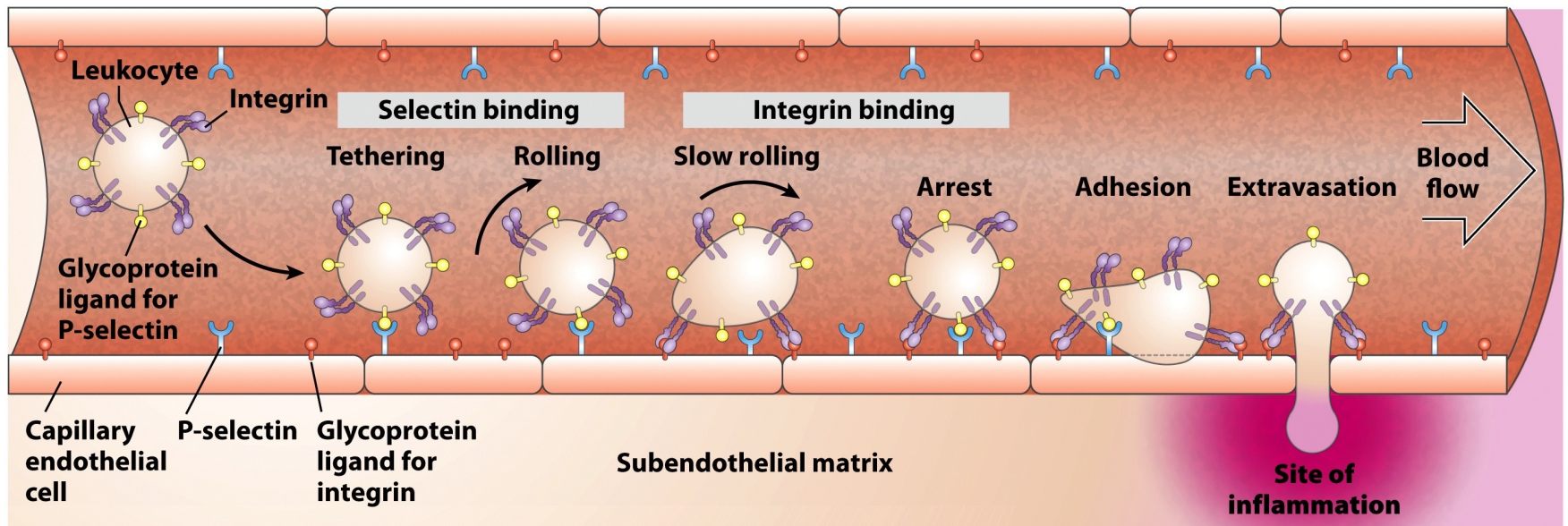
Abequose	Abe	Glucuronic acid	◆ GlcA
Arabinose	Ara	Galactosamine	◻ GalN
Fructose	Fru	Glucosamine	◼ GlcN
Fucose	▲ Fuc	<i>N</i> -Acetylgalactosamine	◻ GalNAc
Galactose	● Gal	<i>N</i> -Acetylglucosamine	■ GlcNAc
Glucose	● Glc	Iduronic acid	◊ IdoA
Mannose	● Man	Muramic acid	Mur
Rhamnose	Rha	<i>N</i> -Acetylmuramic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

Standard Amino Acids

Glycine	Gly G	Serine	Ser S
Alanine	Ala A	Threonine	Thr T
Proline	Pro P	Cysteine¹	Cys C
Valine	Val V	Asparagine	Asn N
Leucine	Leu L	Glutamine	Gln Q
Isoleucine	Ile I	Lysine	Lys K
Methionine	Met M	Histidine	His H
Phenylalanine	Phe F	Arginine	Arg R
Tyrosine	Tyr Y	Aspartate	Asp D
Tryptophan	Trp W	Glutamate	Glu E

Selectins Mediate Cell-Cell Recognition

- Selectins are a family of plasma membrane lectins.
- Mediate movement of leukocytes to site of inflammation.
 - Selectin interacts with a specific oligosaccharide of a glycoprotein.
 - Capillary endothelial cells capture leukocytes.
 - Leukocytes move to infection site and initiate immune attack.



Selectins in Leukocyte Extravasation

- P-Selectin on endothelial cells interacts with a glycoprotein on leukocytes.
 - Red blood cells are carried away at high velocity by a strong blood flow.
 - Leukocytes roll slowly on endothelial cells.
 - Existing interactions are broken and new ones are formed.
- Leukocytes migrate through blood vessel wall into inflamed tissue.
 - These strong interactions immobilize rolling leukocytes at site of inflammation.
 - Profound reorganization of cytoskeleton.
 - The leukocyte insert itself between endothelial cells.



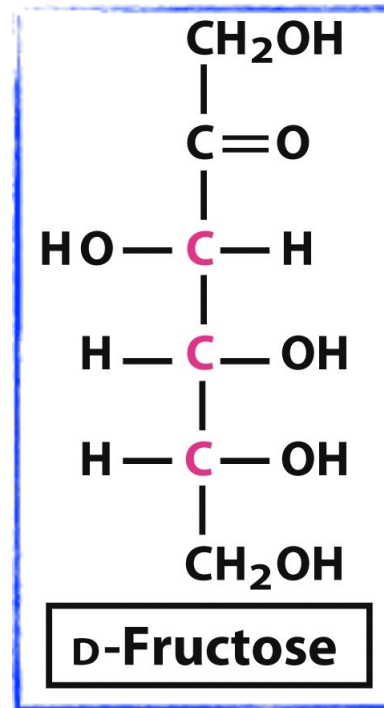
Summary 7.3 and 7.4

- Glycoproteins contain oligosaccharides covalently linked to Ser/Thr or Asn residues. Many cell surface proteins and secreted proteins are glycoproteins.
- The number of ways to assemble a polysaccharide is greater than the number of ways to assemble a protein or nucleic acid. Glycans are more information-dense.
- Lectins are highly specific carbohydrate-binding proteins. Lectins are commonly found on cell surface, and mediate interaction with other cells.

Example Question

Which of the following monosaccharides is *not* an aldose?

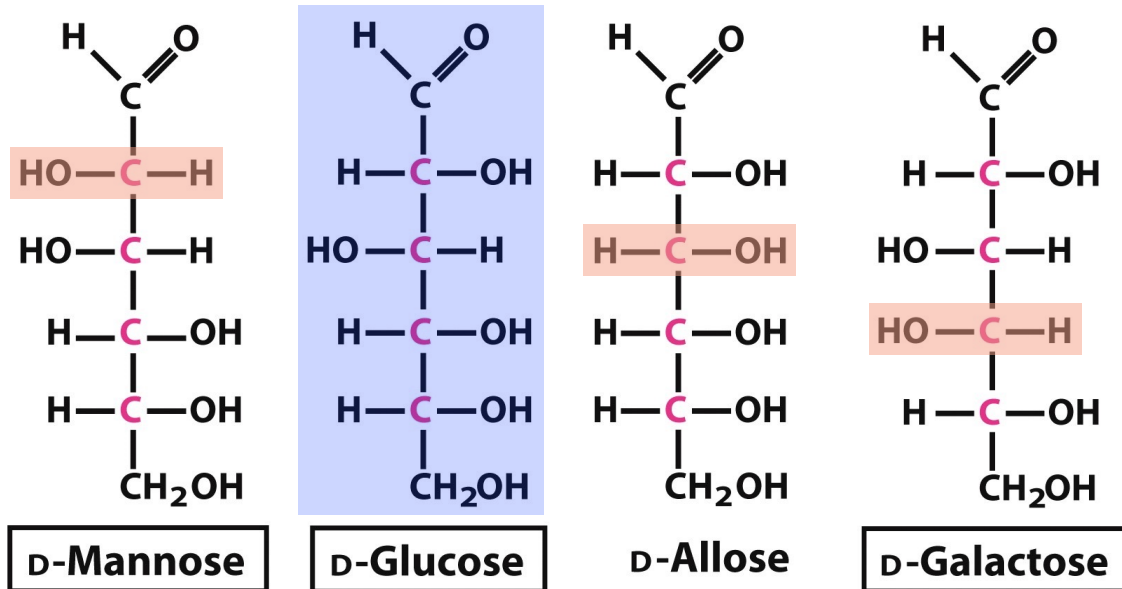
- A) Galactose
- B) Fructose**
- C) Glucose
- D) Glyceraldehyde
- E) Ribose



Example Question

Which of the following is an epimeric pair?

- A) D-glucose and D-glucosamine
- B) D-glucose and D-mannose
- C) D-glucose and L-glucose
- D) D-lactose and D-sucrose
- E) L-mannose and L-fructose



Example Question

When the linear form of glucose cyclizes, the product is a(n):

- A) hemiketal.
- B) glycoside.
- C) hemiacetal.
- D) acetal.
- E) oligosaccharide.

Example Question

Which of the following pairs is interconverted in the process of mutarotation?

- A) D-glucose and D-fructose
- B) D-glucose and D-galactose
- C) D-glucose and D-glucosamine
- D) D-glucose and L-glucose
- E) α -D-glucose and β -D-glucose

Example Question

Following complete hydrolysis of a sample of glycogen and a sample of cellulose, which of the following is *true*?

- A) The cellulose sample has a higher ratio of α -D-glucose than the glycogen sample.
- B) The cellulose sample contains only α -D-glucose.
- C) Both samples consist of a mixture of α -D-glucose and β -D-glucose.
- D) The glycogen sample has a higher ratio of α -D-glucose than the cellulose sample.
- E) The glycogen sample contains only β -D-glucose.

Example Question

Explain why all mono- and disaccharides are soluble in water.

Example Question

Define what enantiomers are (in 20 words or fewer).

Define what epimers are (in 20 words or fewer).

Define what a pyranose is (in 20 words or fewer).

Define what a ketose is (in 20 words or fewer).

Example Question

Match these molecules with their biological roles.

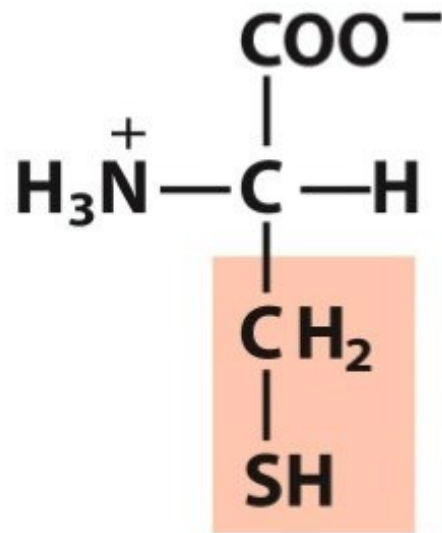
- | | | |
|-------------------|-----|---|
| (a) glycogen | ___ | exoskeleton of insect |
| (b) cellulose | ___ | carbohydrate storage in plant |
| (c) chitin | ___ | carbohydrate storage in animal liver |
| (d) peptidoglycan | ___ | structural component of plant cell wall |
| (e) starch | ___ | structural component of bacterial cell wall |

Example Question

Describe one biological advantage of storing glucose units in branched polymers (glycogen, amylopectin) rather than in linear polymers.

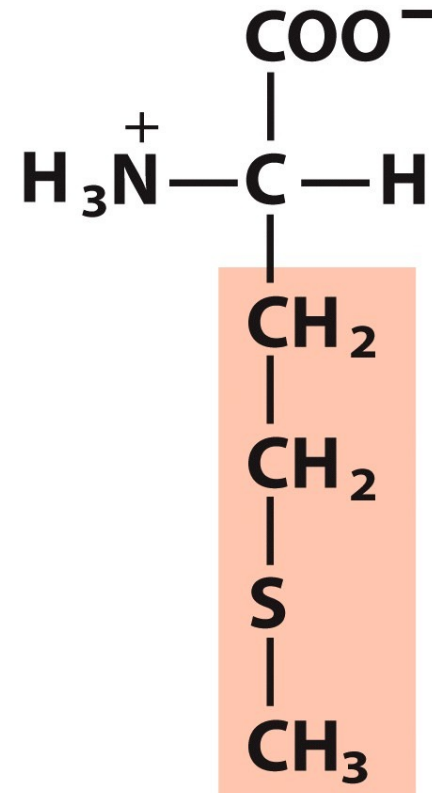
The enzymes that act on these polymers to generate glucose for metabolism **act only on their nonreducing ends**. With extensive branching, there are more such ends for enzymatic attack than would be present in the same quantity of glucose stored in a linear polymer. In effect, **branched polymers increase the substrate concentration for these enzymes**.

Two Sulfur-Containing Amino Acids



Cysteine

Amino acid
for 7th week



Methionine