Structure and Functions of CARBOHYDRATES

Foundation Block | DR. USMAN GHANI | First Year

Objectives and Overview

Objectives

By the end of the lecture the First Year students will be able to:

- Understand the structure and physiological functions of carbohydrates
- Discuss the main role of carbohydrates in providing and storing energy
- Describe the structure and functions of glycosaminoglycans

Overview

- Carbohydrates
- Classification of carbohydrates:
  - Monosaccharides
  - Disaccharides
  - Polysaccharides
- Isomerism
- Aldo keto isomers
- Isomers
- Enantiomers
- Alpha and beta forms
- Mutarotation
- Reducing sugars
- Complex carbohydrates
- Glycosidic bond
- Glycosaminoglycans (GAGs)

Classification of Carbohydrates

Monosaccharides

Classifications based on:

Thank you very much

Monosaccharides

Types of aldose and ketose sugars

Aldose	Ketose
Glyceraldehyde	Dihydroxyacetone
Ribose	Ribulose
Glucose	Fructose

Isomerism

Compounds with same chemical formula but different structure

Aldo and Keto Isomers

Glucose (Aldose)

Fructose (Ketose)

Disaccharides

Consist of two units of monosaccharides

Enantiomers (D and L Forms)

Epimers

Differ from each other in configuration around only one specific carbon atom

Disaccharides

Alpha and Beta Forms

Cyclization of monosaccharides

Mutarotation

Interconversions of alpha and beta forms

Reducing Sugars

Polysaccharides

Condensation of monosaccharide units

Mutarotation

Reducing Sugars

Examples of reducing sugars:
Monosaccharides, maltose, lactose

Sucrose is NOT a reducing sugar because it has no free anomeric carbon

Mutarotation

Mutarotation

Mutarotation

Complex Carbohydrates

(<10 Units)

Complex Carbohydrates

(Homopolysaccharides >10 Units)

Complex Carbohydrates

(Heteropolysaccharides >10 Units)

Complex carbohydrates

Complex Carbohydrates

(Homopolysaccharides >10 Units)

Complex Carbohydrates

(Heteropolysaccharides >10 Units)

Complex carbohydrates

Examples of >10 Units

Complex carbohydrates

Miscellaneous of >10 Units

Take Home Message

References

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Pages: 83-86, 157-159

Carbohydrates

Defined as hydrates of carbon

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- Disaccharides (two monosaccharide units)
- Oligosaccharides (3-10 monosaccharide units)
- Polysaccharides (>10 monosaccharide units)
  - Homo and heteropolysaccharides

Monosaccharides

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Carbohydrates

Defined as hydrates of carbon

- Compounds of Carbon, Hydrogen and Oxygen (CHO)
- Most abundant organic molecules in nature
- Empirical formula $(CH_2O)_n$
- Major source of dietary energy
- Storage form of energy in the body
- Structural component of cell membranes

A number of disease are associated with abnormal carbhydrate metabolism:

Diabetes mellitus

Galactosemia

Glycogen storage diseases

Lactose intolerance

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Monosaccharides

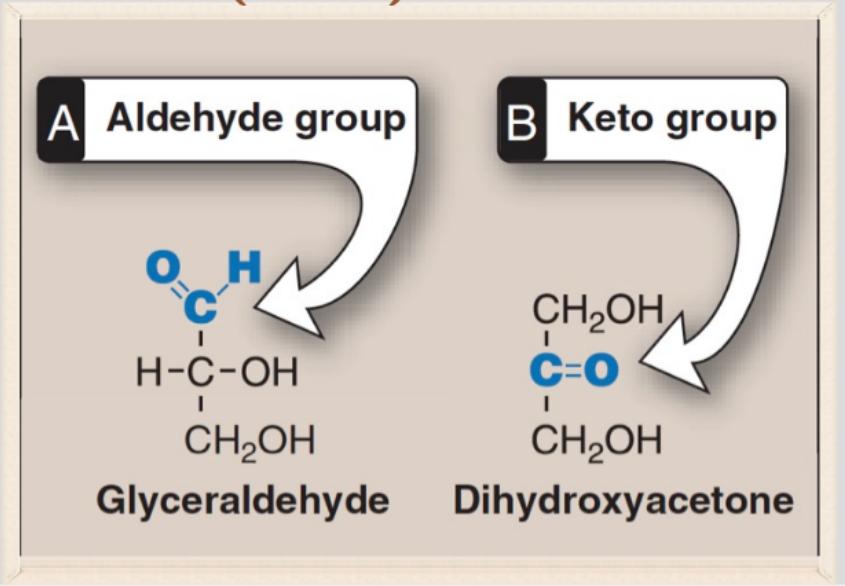
Classification based on:

Number of carbon atoms

Generic names		Examples
3 Carbons:	trioses	Glyceraldehyde
4 Carbons:	tetroses	Erythrose
5 Carbons:	pentoses	Ribose
6 Carbons:	hexoses	Glucose
7 Carbons:	heptoses	Sedoheptulose
9 Carbons:	nonoses	Neuraminic acid

Functional group

- Aldehyde (aldoses)
- Ketone (ketoses)



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6 Carbons: hexoses	Glucose
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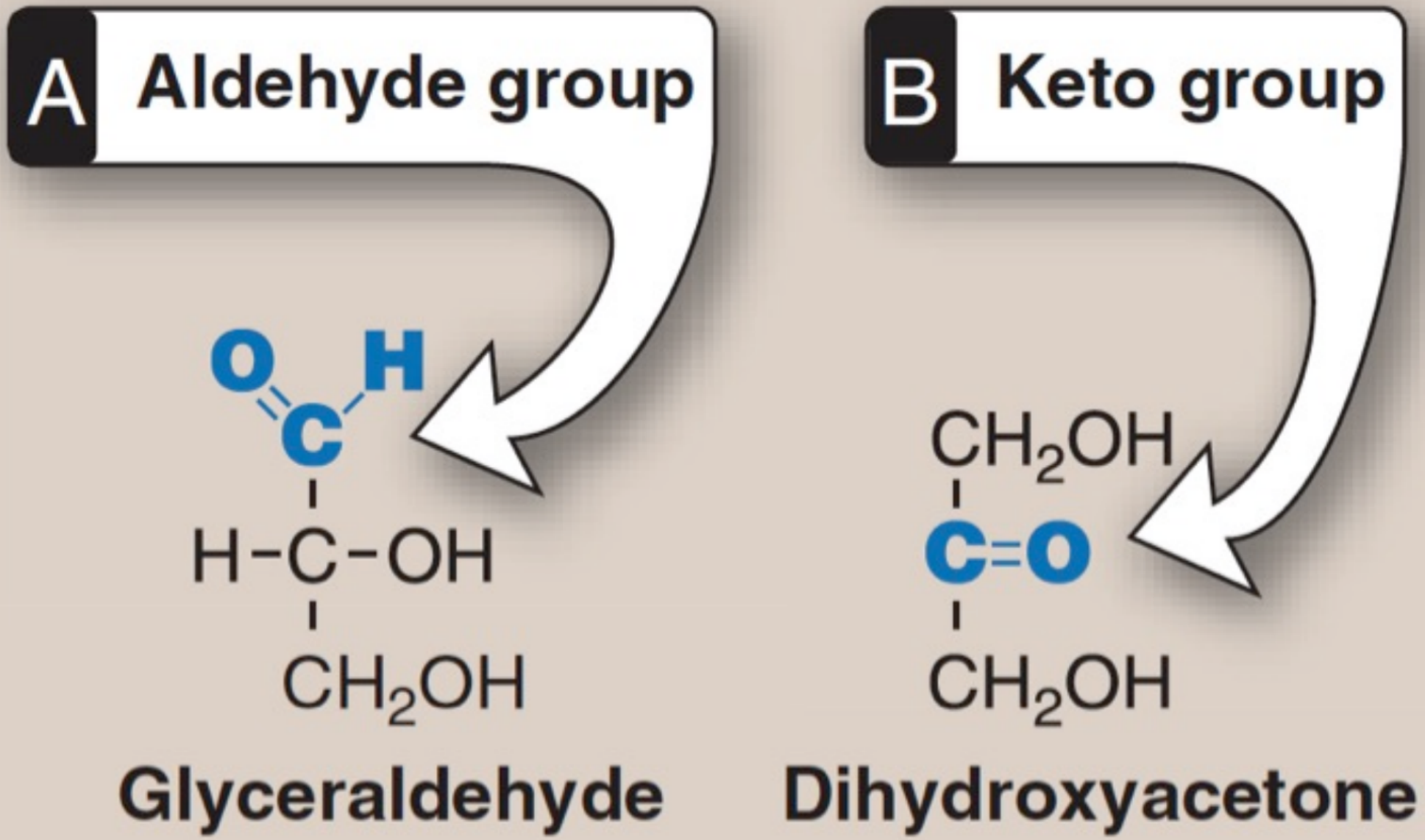
9 Carbons: nonoses	Neuraminic acid

- Ketone (Ketoses)



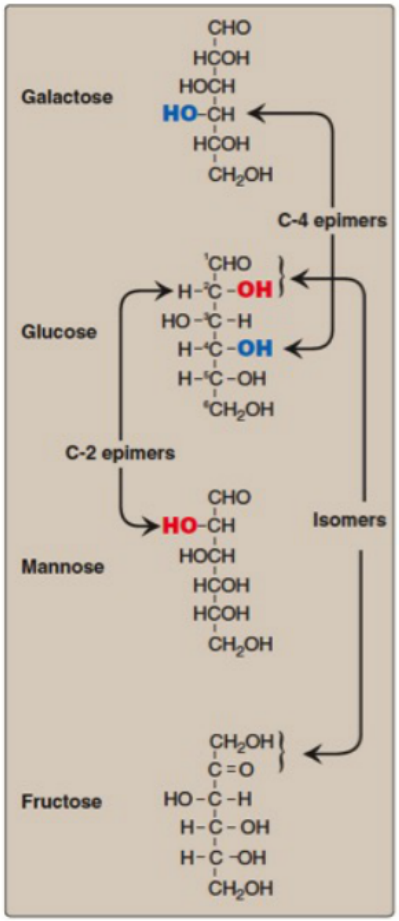
Monosaccharides

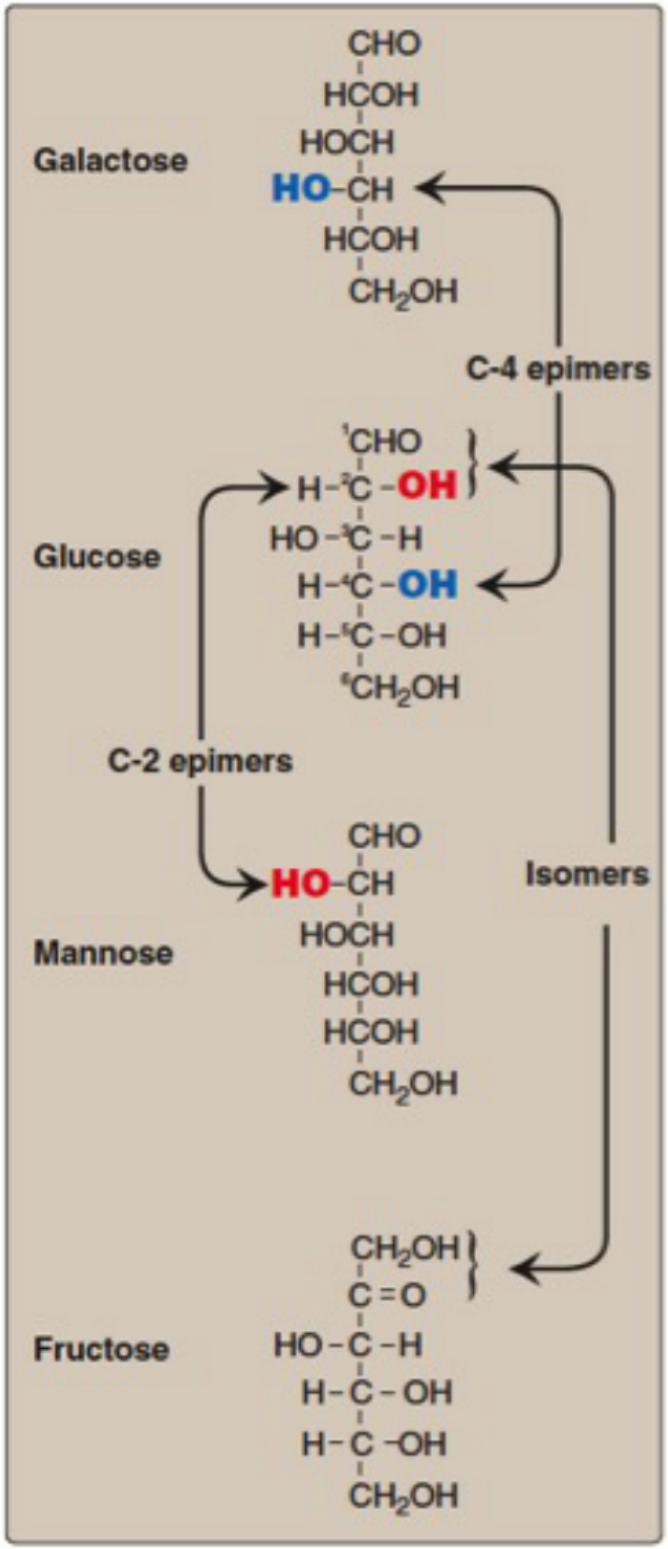
Types of aldose and ketose sugars

	Aldose	Ketose
Triose	Glyceraldehyde	Dihydroxyacetone
Pentose	Ribose	Ribulose
Hexose	Glucose	Fructose

Isomerism

Compounds with same chemical formula but different structure



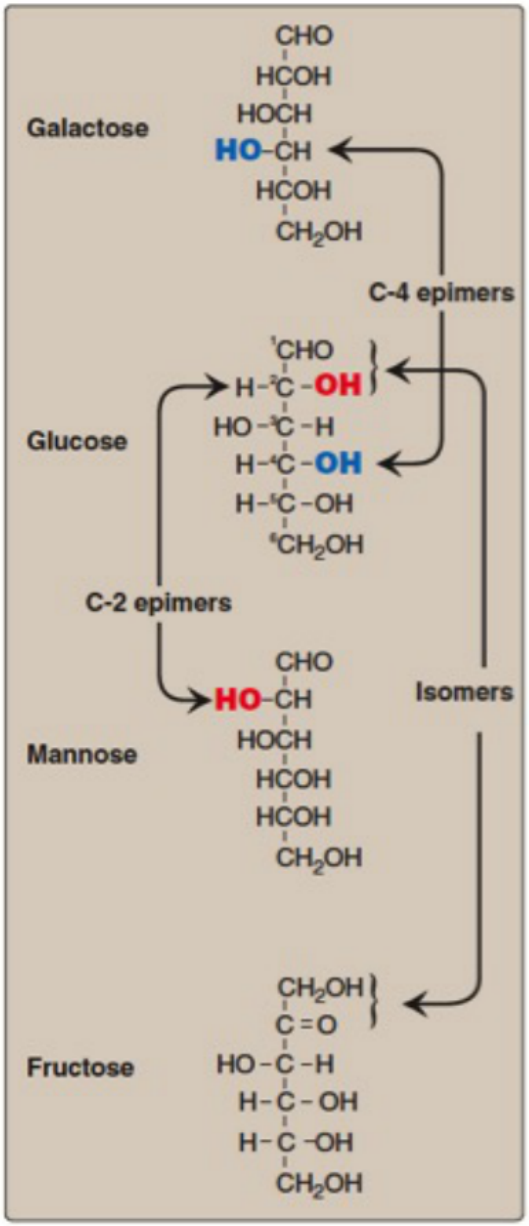

Galactose
Glucose
Mannose
Fructose
C-4 epimers
C-2 epimers
Isomers

Aldo and Keto Isomers

Examples

Glucose (Aldose)

Fructose (Ketose)



o Isomers

ose)

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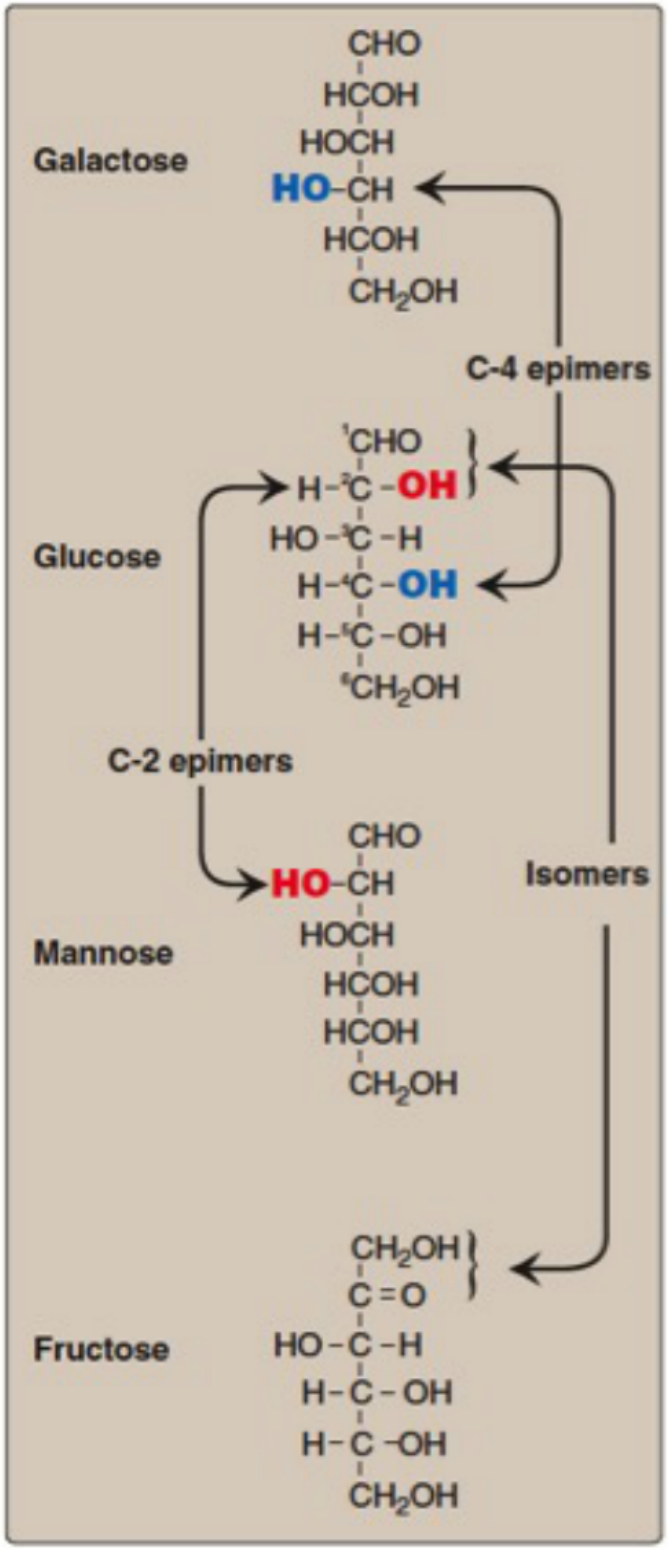


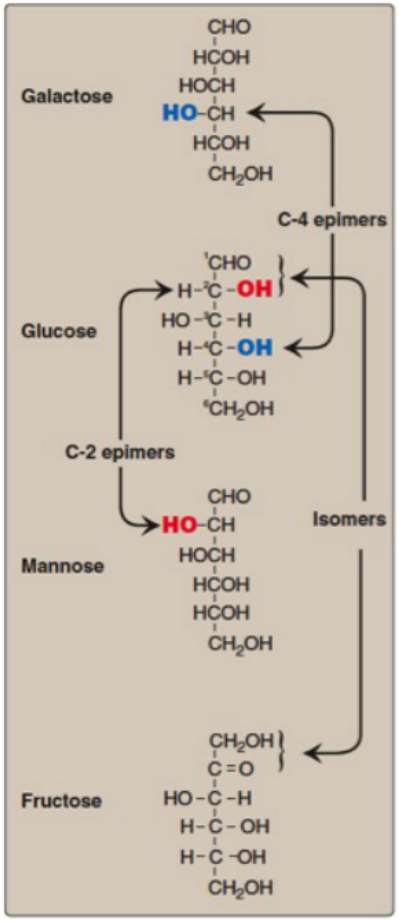
Epimers

CHOs that differ in configuration around only one specific carbon atom

Glucose and galactose are C4 epimers

Glucose and mannose are C2 epimers

Galactose and mannose are NOT epimers



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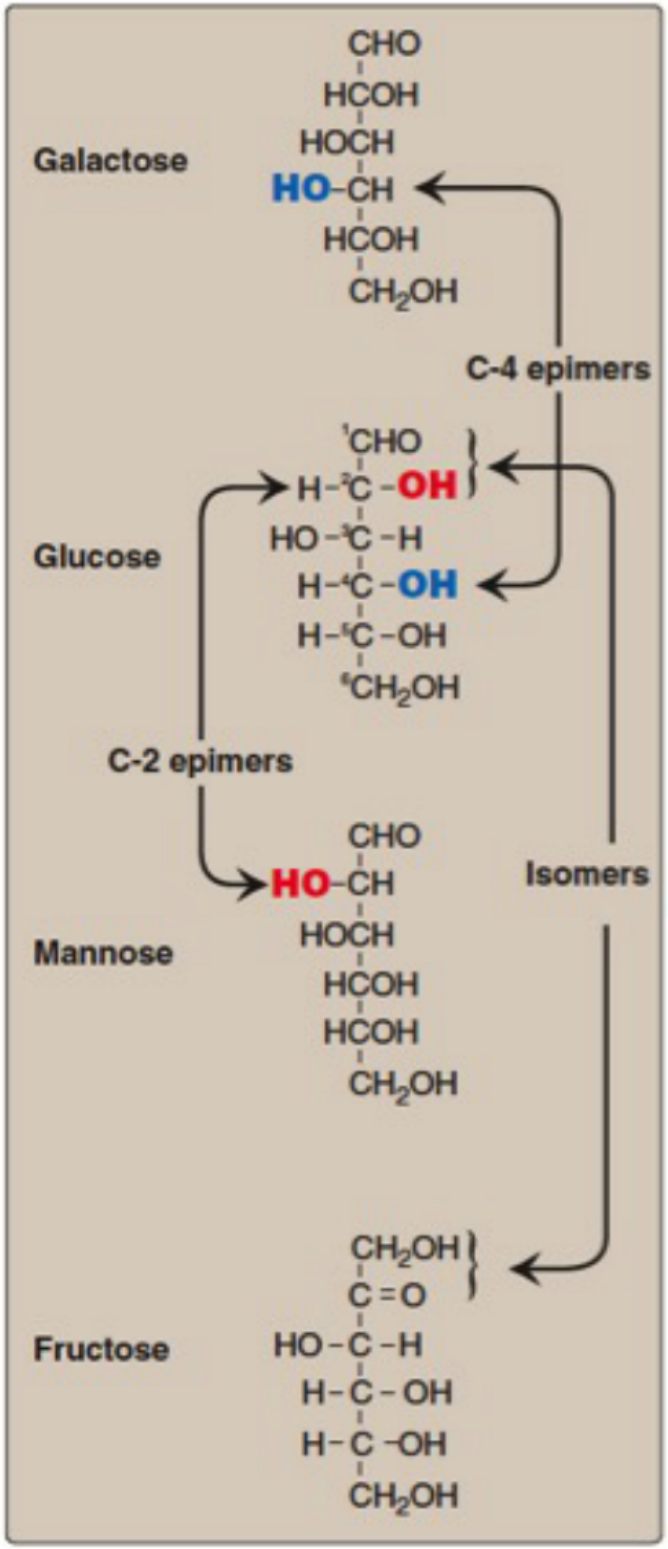

Galactose
Glucose
Mannose
Fructose
C-4 epimers
C-2 epimers
Isomers

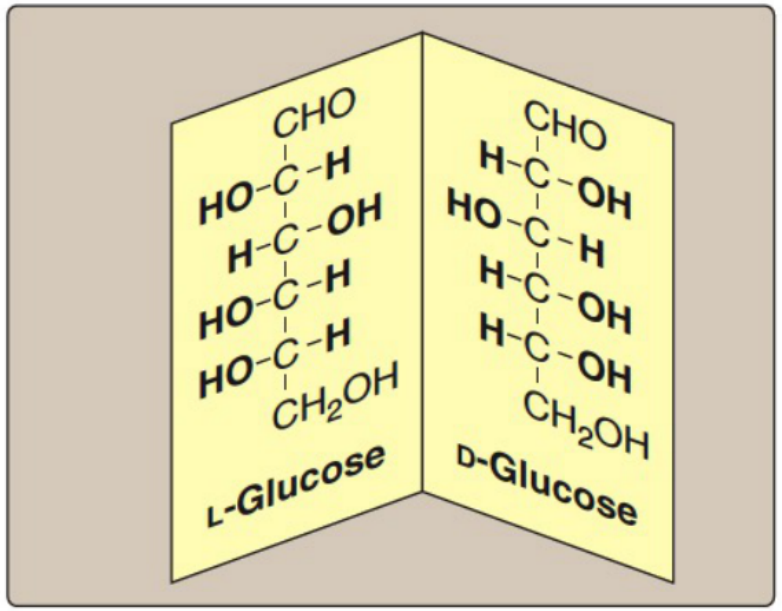
Enantiomers (D and L Forms)

Structures that are mirror images of each other

Designated as D and L sugars

Based on the position of the OH group on the asymmetric carbon farthest from the carbonyl carbon

Majority of sugars in humans are D sugars



Alpha and Beta Forms

Cyclization of monosaccharides

Pyranose: Six-membered ring

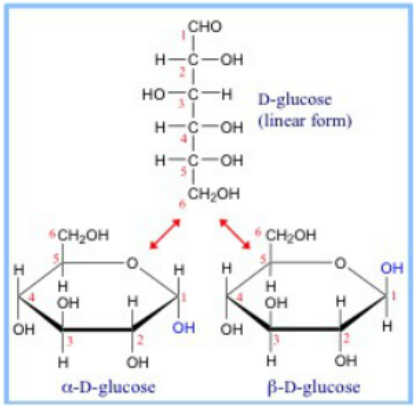
Furanose: Five-membered ring

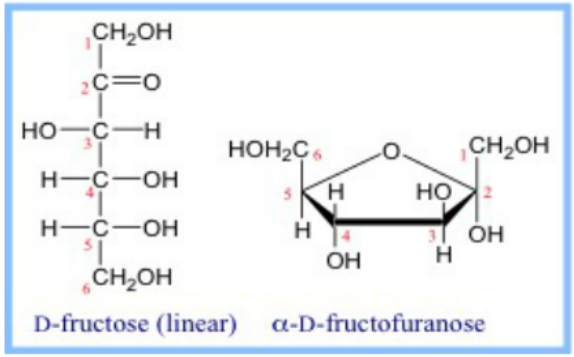
Monosaccharides with 5 or more carbon atoms are found in ring form

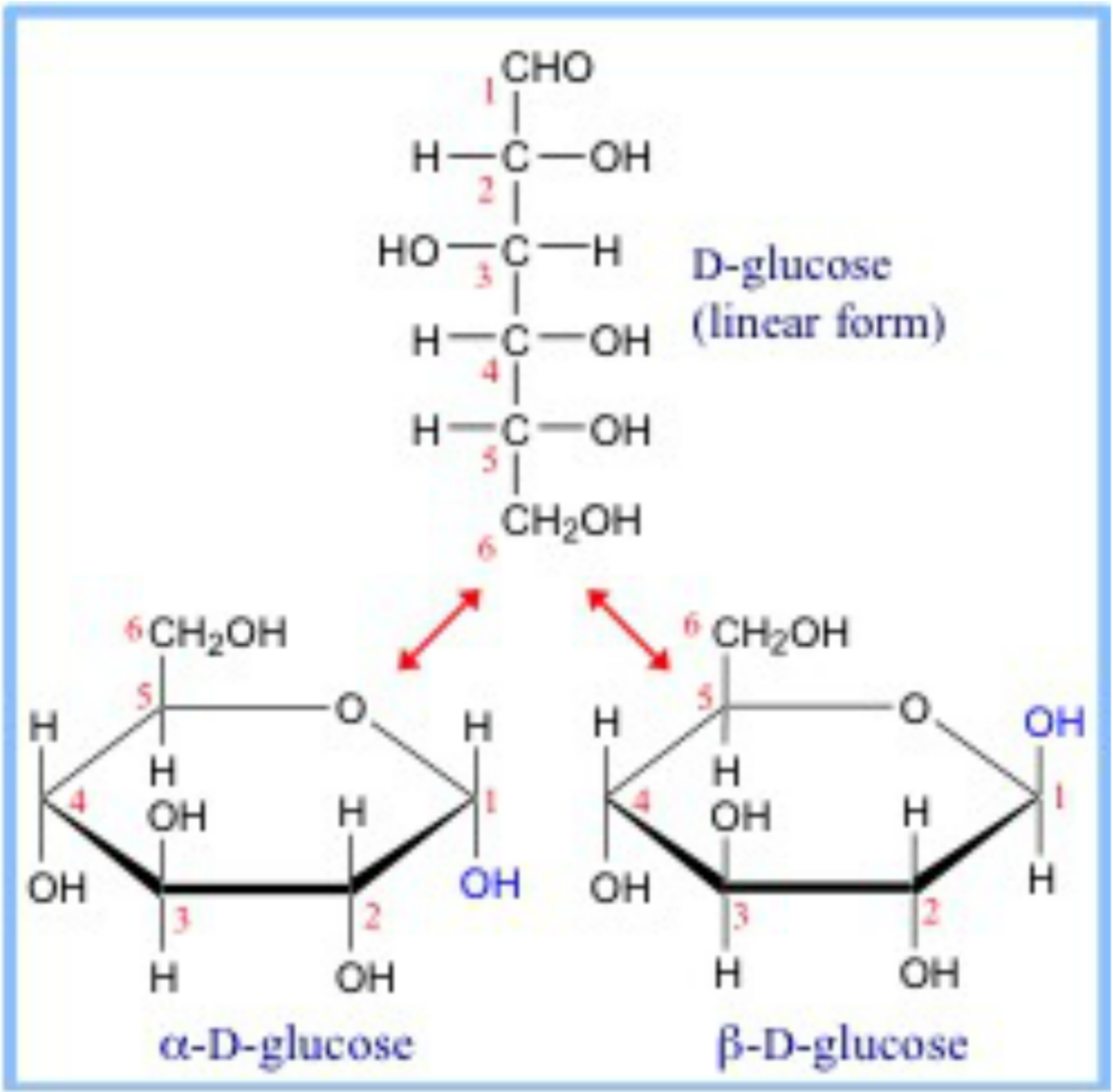
The aldehyde or ketone group reacts with the OH of C5 on the same sugar

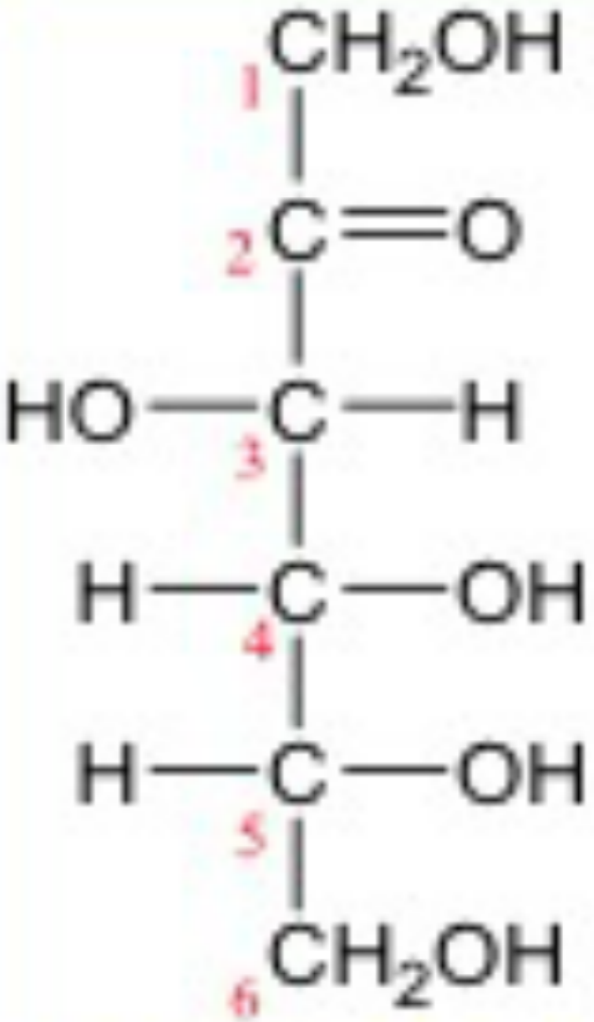
Cyclization creates an anomeric carbon (formerly carbonyl)

Generating alpha and beta configurations

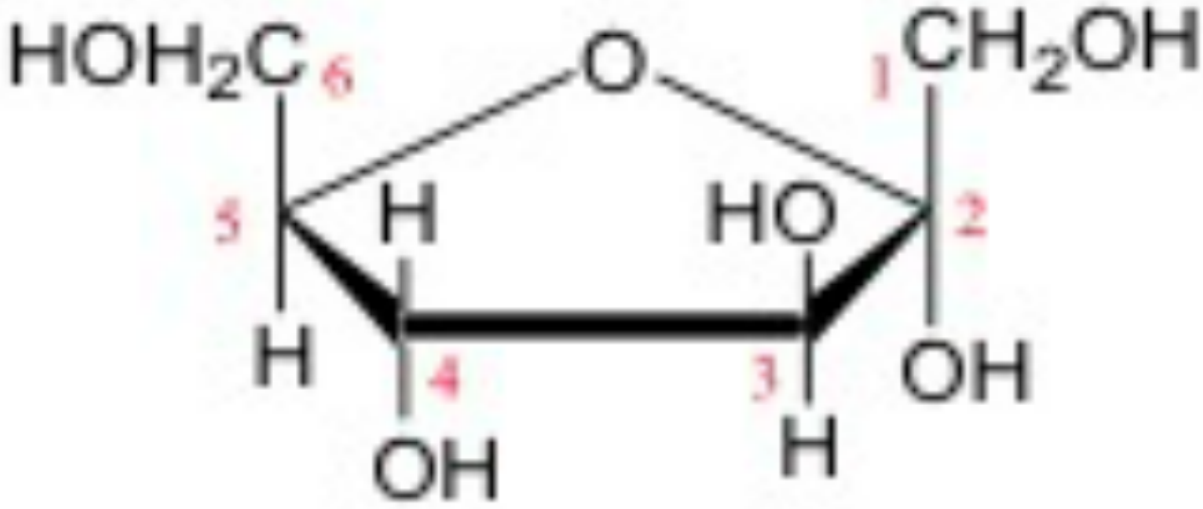





CHO
H—C—OH
HO—C—H
H—C—OH
H—C—OH
CH2OH
D-glucose
(linear form)
α-D-glucose
β-D-glucose



D-fructose (linear)



α-D-fructofuranose

Pyranose: Six-membered ring

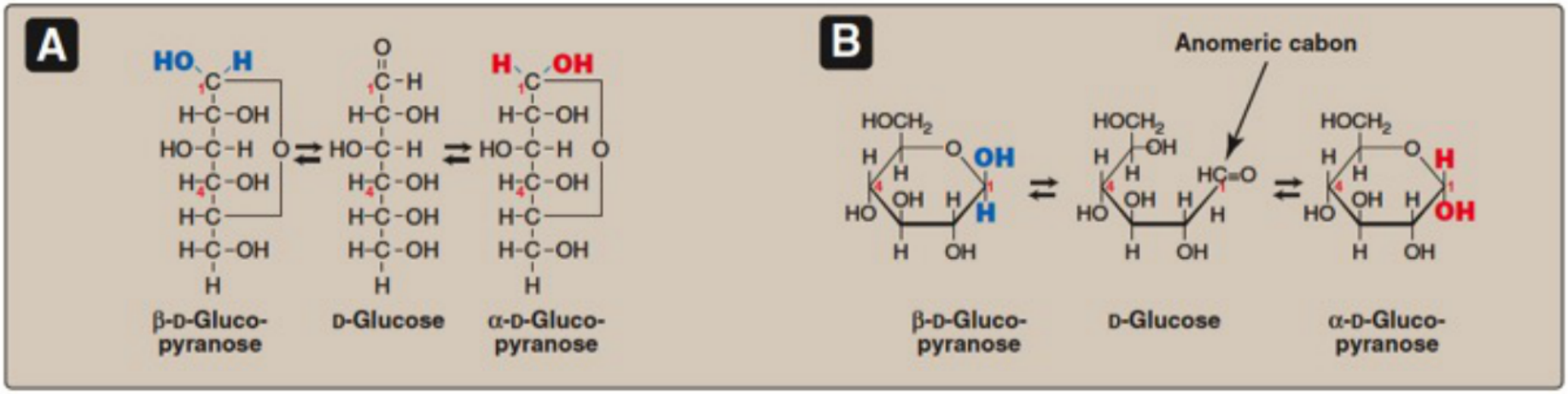
Furanose: Five-membered ring

Mutarotation

Interconversion of alpha and beta forms

The anomeric forms of sugars are in equilibrium

Can be interconverted spontaneously



The anomeric carbon is asymmetric

Asymmetric carbon:
Carbon to which four different groups are bound

Disaccharides

Contain two units of monosaccharides

Joined by o-Glycosidic bond

Examples:

Maltose (alpha 1-4)

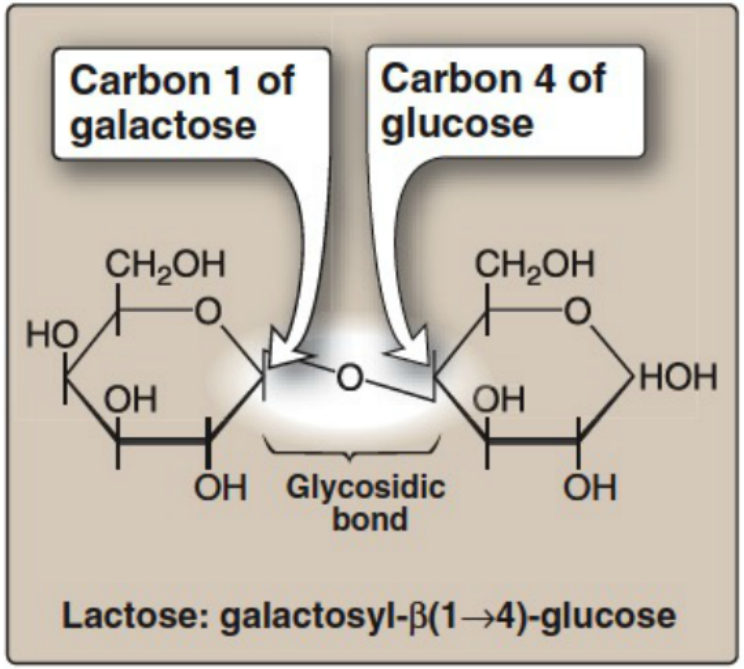
Glucose + Glucose

Sucrose (alpha 1-2)

Glucose + Fructose

Lactose (beta 1-4)

Glucose + Galactose



Polysaccharides

Contain >10 monosaccharide units

Homopolysaccharides (chain of same sugar monomers)
Examples:
Branched: Glycogen and starch (alpha-glycosidic polymer)
Unbranched: Cellulose (beta-glycosidic polymer)

Heteropolysaccharides (chain of different sugar monomers)
Examples: Glycosaminoglycans (GAGs)

Reducing Sugars

Sugar that is not linked to another compound by a glycosidic bond

The hydroxyl group on the anomeric carbon of sugar is not linked to another compound by a glycosidic bond (free aldehyde or ketone group)

It can reduce the chromogenic agents (Benedict's reagent, Fehling's solution) to produce color

Urine is tested for the presence of reducing sugars using these colorimetric tests

Reducing Sugars

Examples of reducing sugars:
Monosaccharides, maltose, lactose

Sucrose is NOT a reducing sugar because:
It has no free anomeric carbon

Complex Carbohydrates

CHOs complexed with non-CHOs

By glycosidic bond (N or O type)

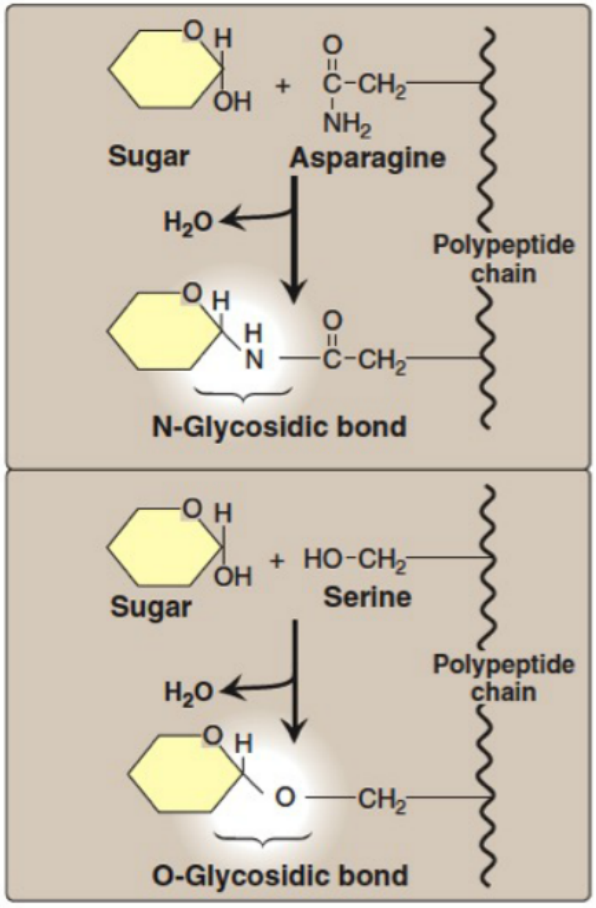
1. Purine and pyrimidine bases
2. Bilirubin
3. Glycoproteins and proteoglycans
4. Glycolipids

Complex Carbohydrates

Glycosidic bond in complex CHOs

N-Glycosidic bond

O-Glycosidic bond



Complex Carbohydrates

Glycosaminoglycans (GAGs)

Large complexes of negatively charged heteropolysaccharide chains

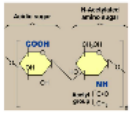
Bound to proteins forming proteoglycans

Bound to water (gel-like matrix)

Mucous secretions are viscous, lubricating because of GAGs (also called mucopolysaccharides)

Complex Carbohydrates

Glycosaminoglycans (GAGs)

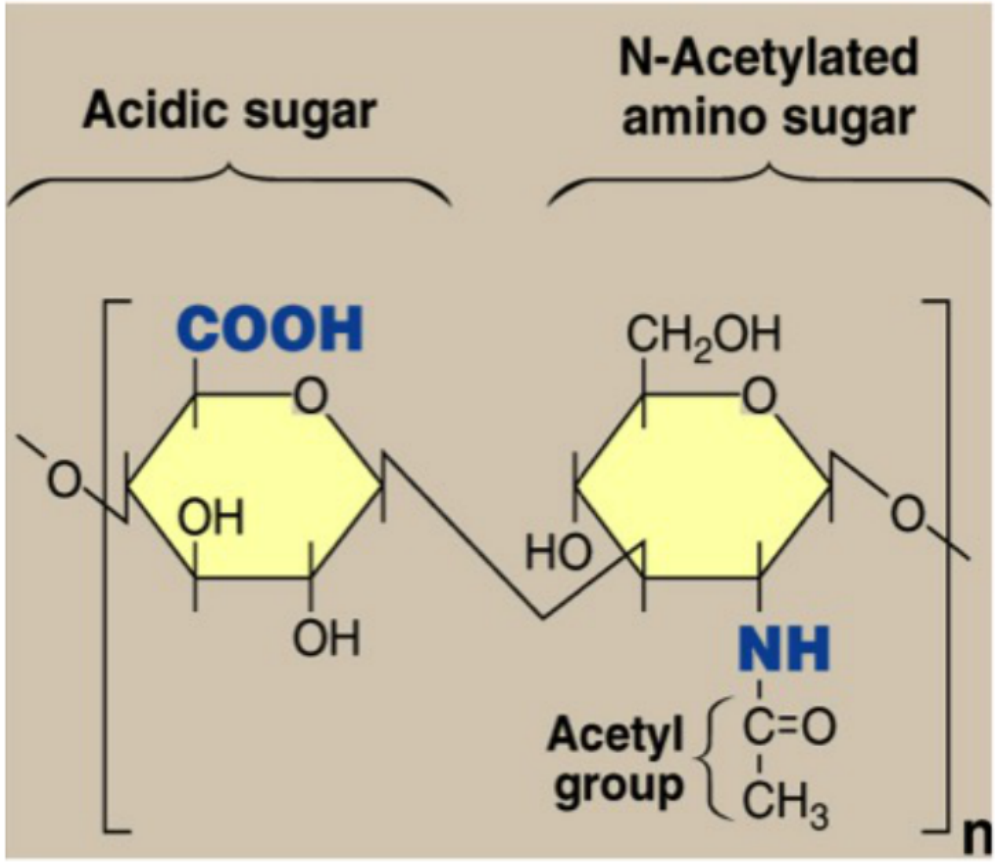


GAGs are linear polymers of repeating disaccharides units [acid sugar-amino sugar]n

The amino sugar (usually sulfated) is either D-glucosamine or D-galactosamine

The acidic sugar is either D-glucuronic acid or L-iduronic acid

GAGs are strongly negatively-charged due to: carboxyl and sulfate groups


Acidic sugar
N-Acetylated amino sugar
COOH
O
OH
OH
O
CH2OH
O
HO
O
NH
Acetyl group
C=O
CH3
n

Complex carbohydrates

Resilience of GAGs

GAGs have negative charges

Their chains repel each other

So they slide past each other

When GAG solution is compressed, the water is squeezed out

This property gives resilience to synovial fluid and vitreous humor of the eye

When decompressed, they go back to their original volume

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So they slide past each other

This causes mucous and synovial fluids to be slippery

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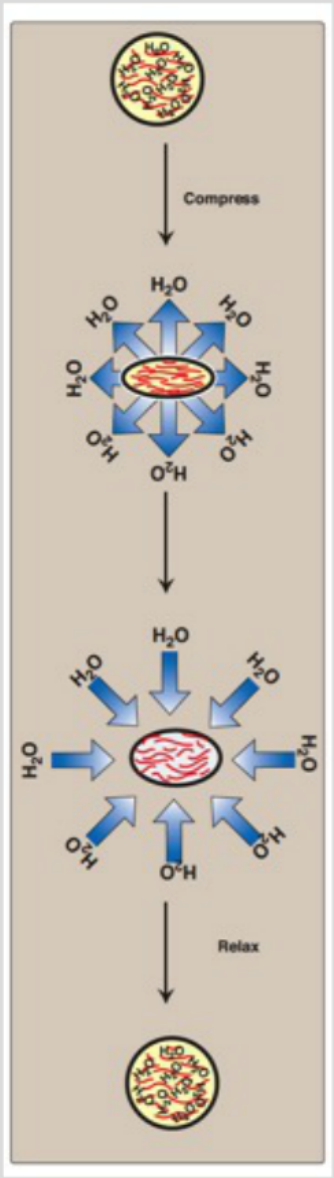
Compress
H_2O
Relax

Complex carbohydrates

Examples of GAGs

Chondroitin sulfates: Most abundant GAG
Keratan sulfates: Most heterogeneous GAGs
Hyaluronic acid: Unsulfated / unbound
Heparin: Intracellular anticoagulant

Take Home Message

- Structure and functions of carbohydrates
- Mono, di and Polysaccharides
- Sugar Isomers

Complex carbohydrates:

- Glycosaminoglycans and proteoglycans
- Structure and function of GAGs
- Examples of GAGs: chondroitin sulfate, keratin sulfate, hyaluronic acid and heparin

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CH_2OH	CH_2OH
Glyceraldehyde	**Dihydroxyacetone**

Thank you very much

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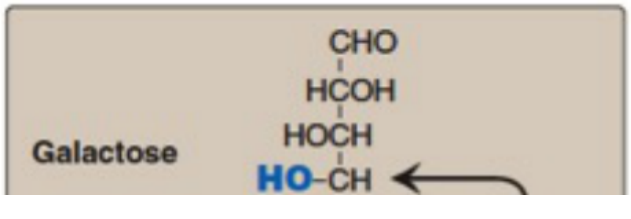

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