Topic: Introduction to Carbohydrates

Subject: Biochemistry

Class: F.Y. B. Pharm. (Sem.-1)

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Programme: 2018-2021

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Learning Outcome

- Introduction to Carbohydrates
- Introduction to common monosaccharides ranging from trioses to hexoses
- Introduction to common disaccharides sucrose, cellobiose, maltose, lactose
- Introduction to common polysaccharides starch and glycogen

Mapping of TLO with Course Outcome

Topic	TLO	Bloom Taxonomy	CO
List and identify the commonly occurring carbohydrates	Students will be able to identify structures and functions of various carbohydrate Students will be able to distinguish between monosaccharides . disaccharides and polysaccarides	**L1-Remembering**-(List, Identify, Outline)	2

Introduction to Carbohydrates

Prepared by Dr.Ripudaman

General importance of carbohydrates

Carbohydrates are initially synthesized in plants by photosynthesis.

Carbohydrates are important for:

1- **Provide energy**

2- **Store energy** in the form of:
starch (in plants)
glycogen (in animals and humans)

3- **Supply carbon** for synthesis of other compounds.

4- **Form structural components** in cells and tissues.

Classification carbohydrates

*Carbohydrates are hydrocarbon molecules (Carbon & Hydrogen) that are **classified** into:*

$(CH_2O)_n$

1-Monosaccharides: can **not** be hydrolysed

2-Disaccharides : on hydrolysis give **two** monosaccharides

3-oligosaccharides: on hydrolysis give **3-10** monosccharides

4-Polysaccharides: on hydrolysis give **10 or more** monosaccharides

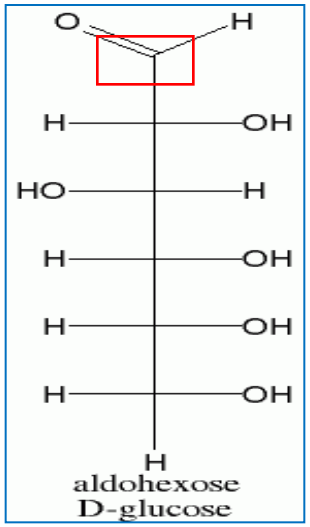
5-Complex sugars: on hydrolysis give a sugar molecule **and** non-sugar molecule

Monosaccharides

Simplest carbohydrate molecule is a monosaccharide : $(C\text{-}H_2\text{-}O)_n$

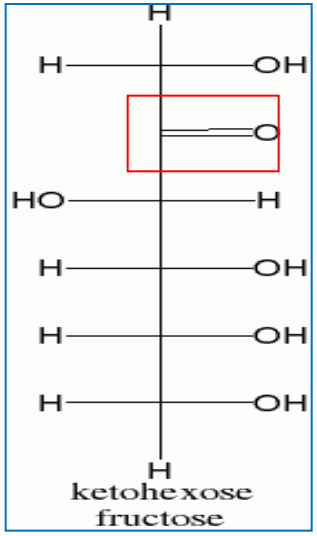
Monosaccharides

- have 3 to 7 carbons
- have either aldehyde group (aldose) or ketone group (ketose)
- have hydroxyl (OH) groups on every carbon (except carbonyl carbon)



Polyhydroxyaldehydes or Polyhydroxyketones

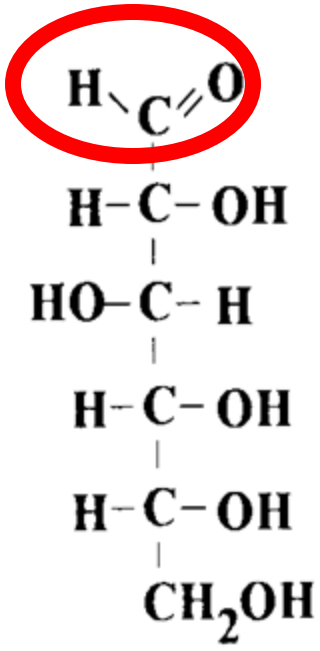
ALDOSEs KETOSEs



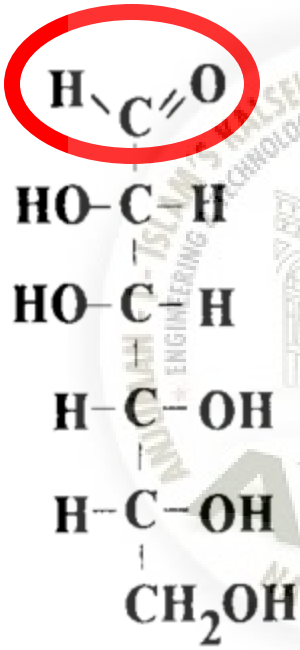
carbonyl group

Aldose

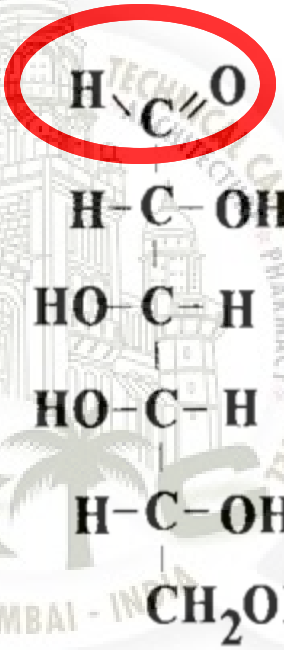
Ketose



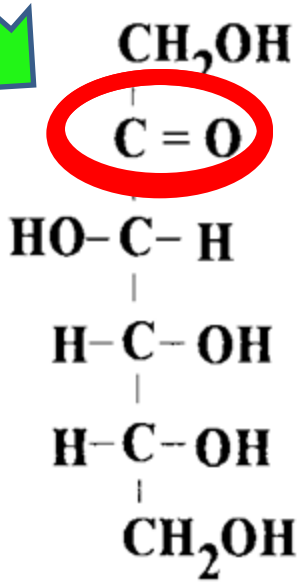
D - Glucose



D - Mannose



D - Galactose



D - Fructose

Classification of monosaccharides

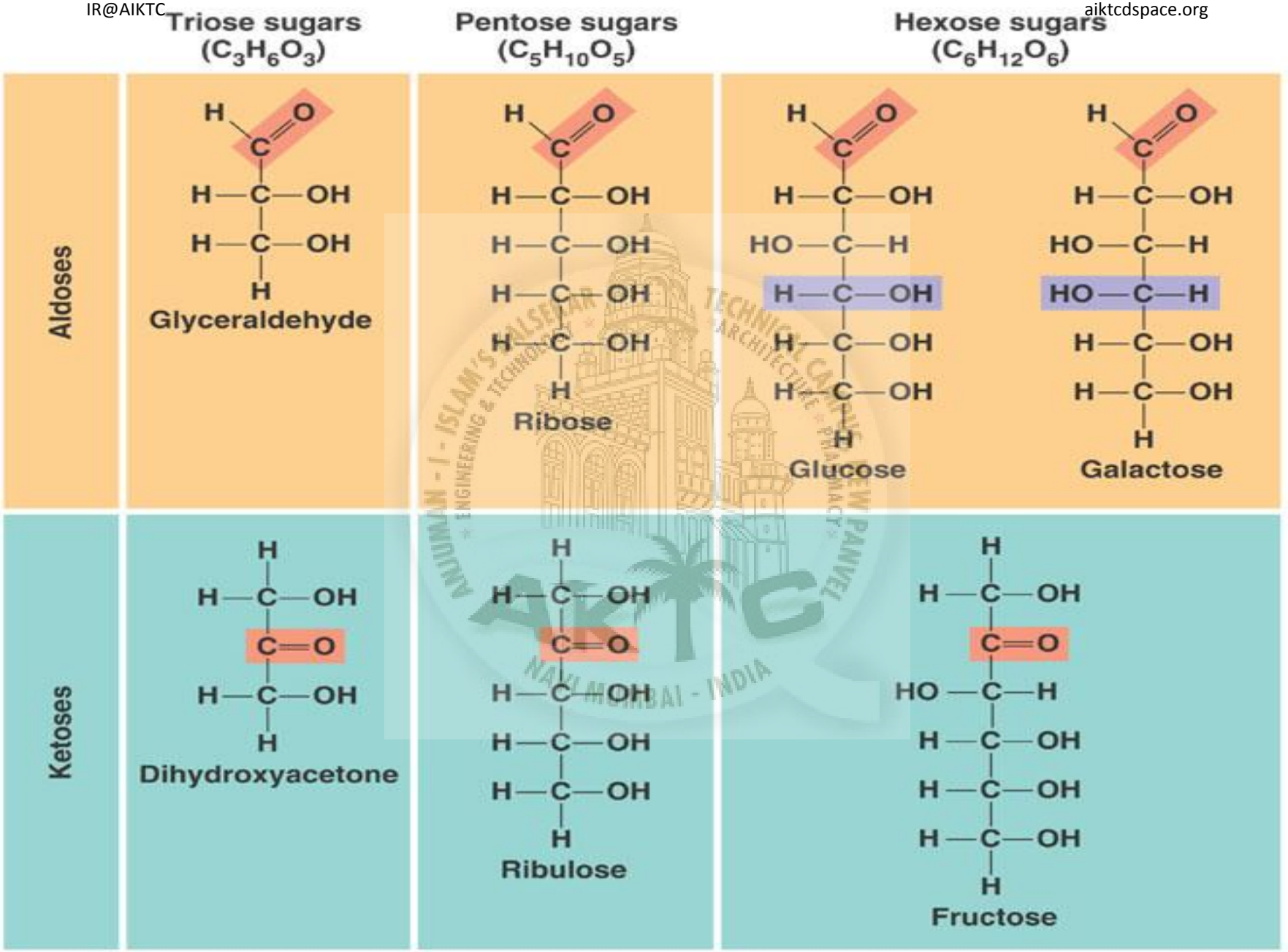
classified according to ***number of carbon atoms (3 -7 carbon atoms) & presence of aldehyde or ketone groups***

Trioses : with **three** carbons e.g. Glyceraldhyde (aldotriose)
& Dihydroxyacetone (ketotriose)

Tetroses: with **four** carbons e.g. Erythrose (aldotetrose)
Erythulose (ketotetrose)

Pentoses: with **five** carbons e.g Ribose (aldopentose)
& Ribulose (ketopentose)

Hexoses : with **six** carbons e.g. Glucose (aldohexose)
Galactose (aldohexose)
Mannose (aldohexose)
& Fructose (ketohexose)



Isomers & Epimers in monosaccharides

Isomers:

Compounds that have the same ***chemical formula*** but ***with different structures***

For example

fructose, **glucose**, **mannose** and **galactose** are all isomers of each other having the same chemical formula **$C_6H_{12}O_6$**

Isomers & Epimers in monosaccharides

epimers:

Carbohydrate isomers that differ in configuration around only specific carbon atom (with the exception of carbonyl carbon) are defined as **epimers** of each other

For example:

glucose and **galactose** are **C-4 epimers** as their structures differ only in the position of –OH at carbon 4

Glucose and **mannose** are **C-2 epimers**

N.B. glucose and fructose are isomers BUT NOT epimers

ALL EPIMERS ARE ISOMERS BUT NOT ALL ISOMERS ARE EPIMERS

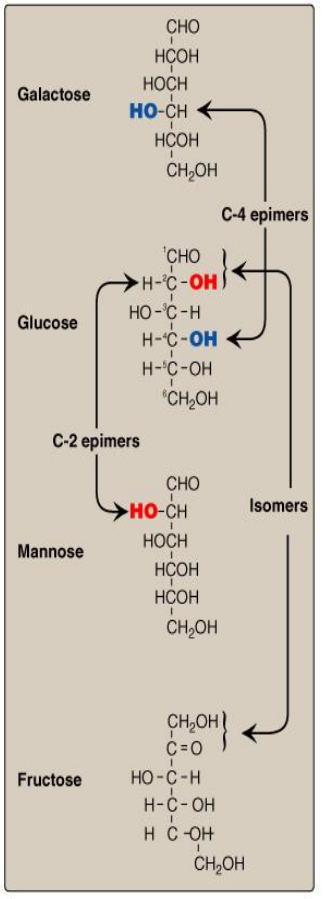
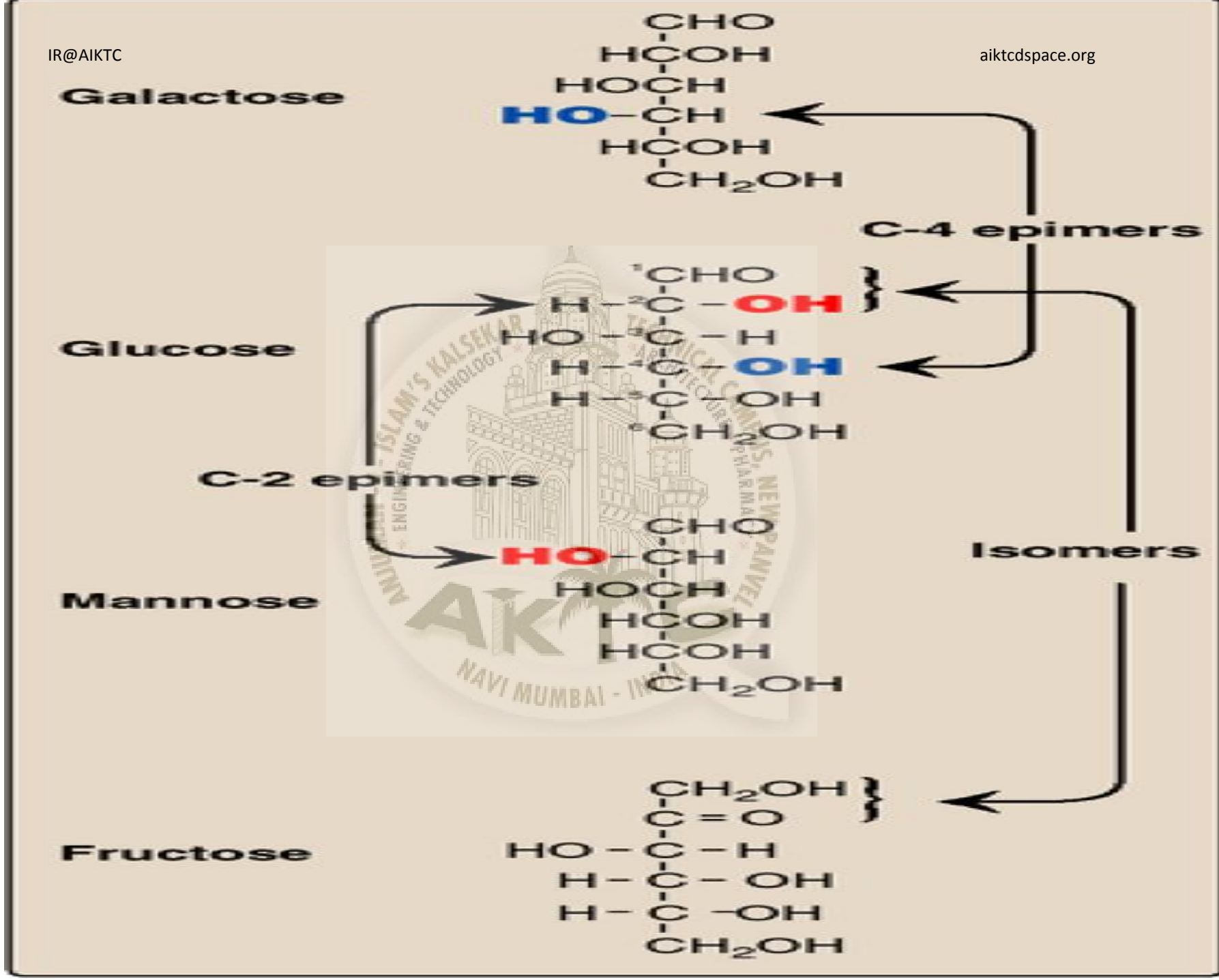


Figure 7.4
C-2 and C-4 epimers and an isomer of glucose.



Enantiomers in monosaccharides

- *A special form of isomerism* is found in pairs of structure that are mirror images of each other.

These mirror images are called ***enantiomers*** & the two members of the pair are designated as a **D- or L- sugar**

- Most sugars are *D sugars*

-In the ***D- isomeric forms***, -OH group on the asymmetric carbon (a carbon linked to four different atoms) farthest from the carbonyl carbon is on the right, while in the ***L-isomeric forms***, it is on the left.

-Enzymes known as ***racemases*** are able to interconvert D- & L- sugars (D- to L & L- to D-)

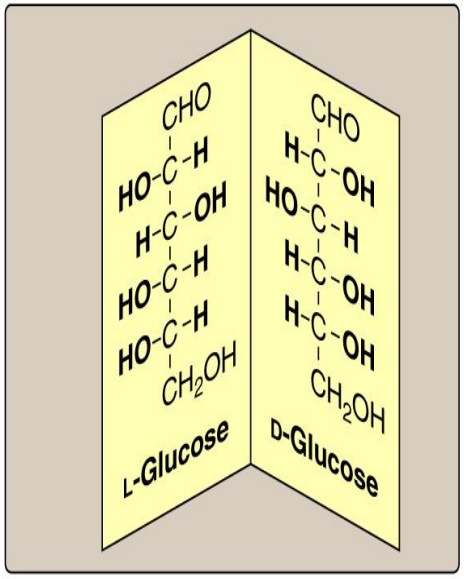


Figure 7.5
Enantiomers (mirror images) of glucose.

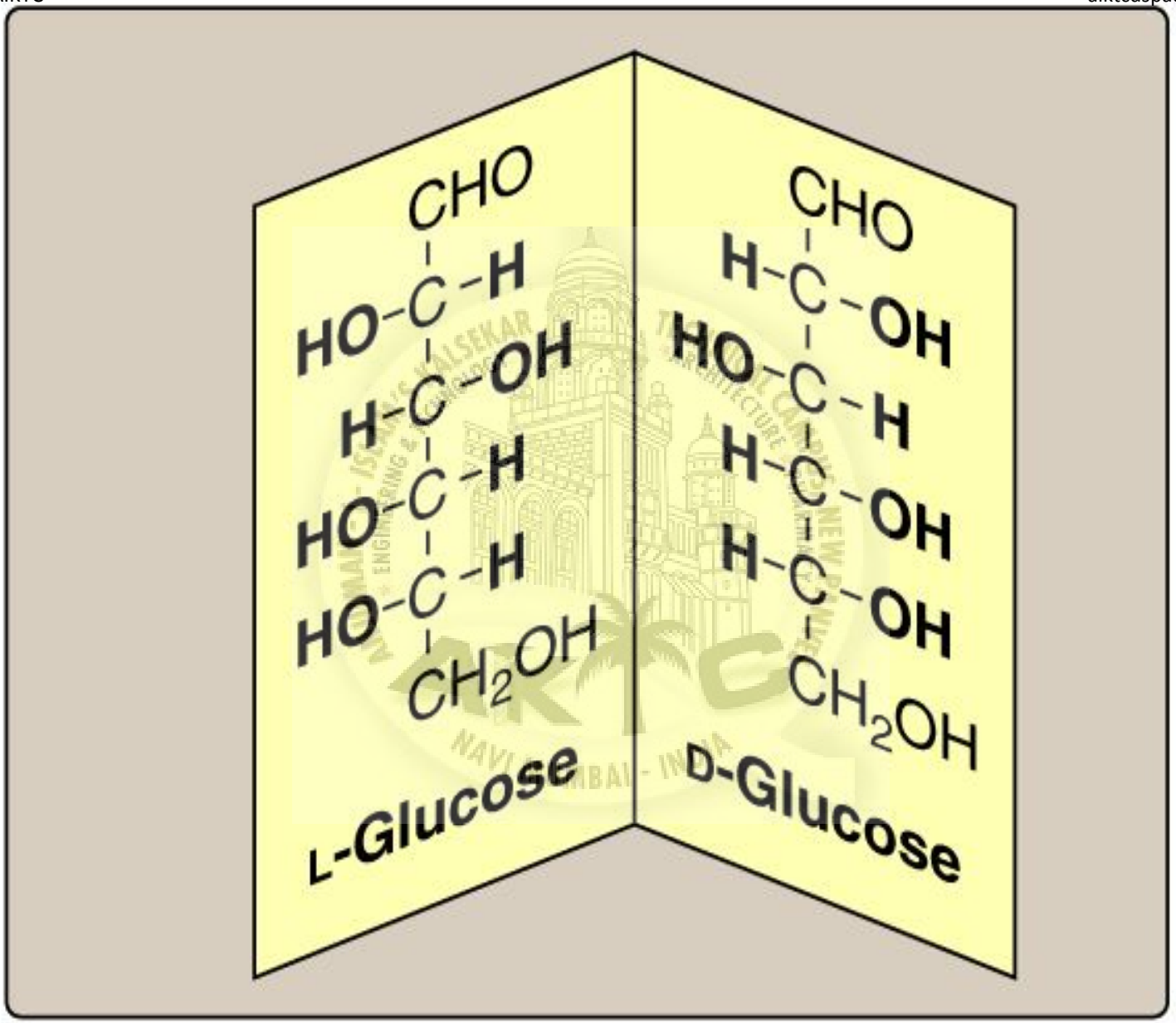

CHO
HO–C–H
H–C–OH
HO–C–H
HO–C–H
CH2OH
L-Glucose
CHO
H–C–OH
HO–C–H
H–C–OH
H–C–OH
CH2OH
D-Glucose

Figure 7.5

Cyclization of monosaccharides

Less than 1% of monosaccharides with five or more carbons exist in the **open-chain (acyclic)** form.

The majority are predominantly found in a **ring (cyclic) form** in which the aldehyde or ketone group reacts with –OH group on the same sugar.

Anomeric carbon:

cyclization creates an anomeric carbon (the former carbonyl carbon) generating the α and β–configuration of the sugar

For example : **α-D-glucose & β–D-glucose**

These two sugars are glucose but are **anomers** to each other

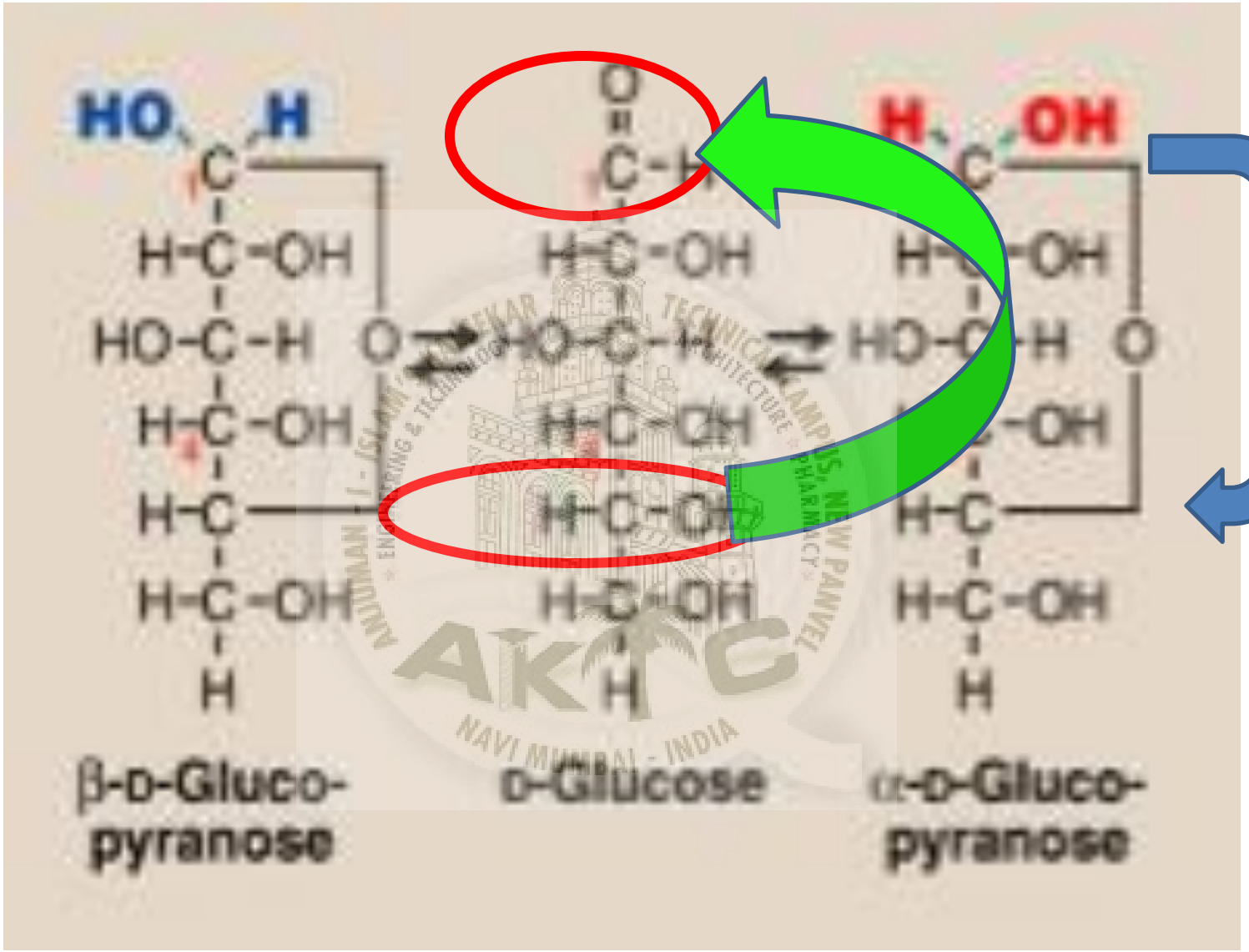
Modified Fischer projection formula:

In α- configuration the, the –OH on the **anomeric carbon** projects to the same side of the ring

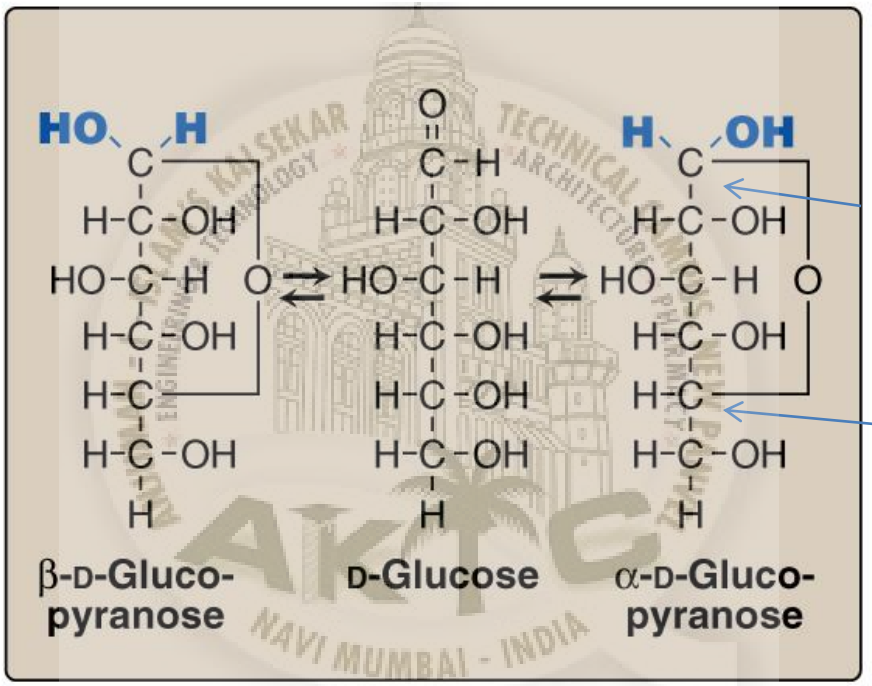
Hawroth projection formula:

In α- configuration, -**OH of anomeric carbon** is trans to **CH2OH** group (different)

& β- configuration, -**OH of anomeric carbon** is cis to **CH2OH** (same)


β-D-Gluco-
pyranose
D-Glucose
α-D-Gluco-
pyranose

Modified Fischer Projection Formula



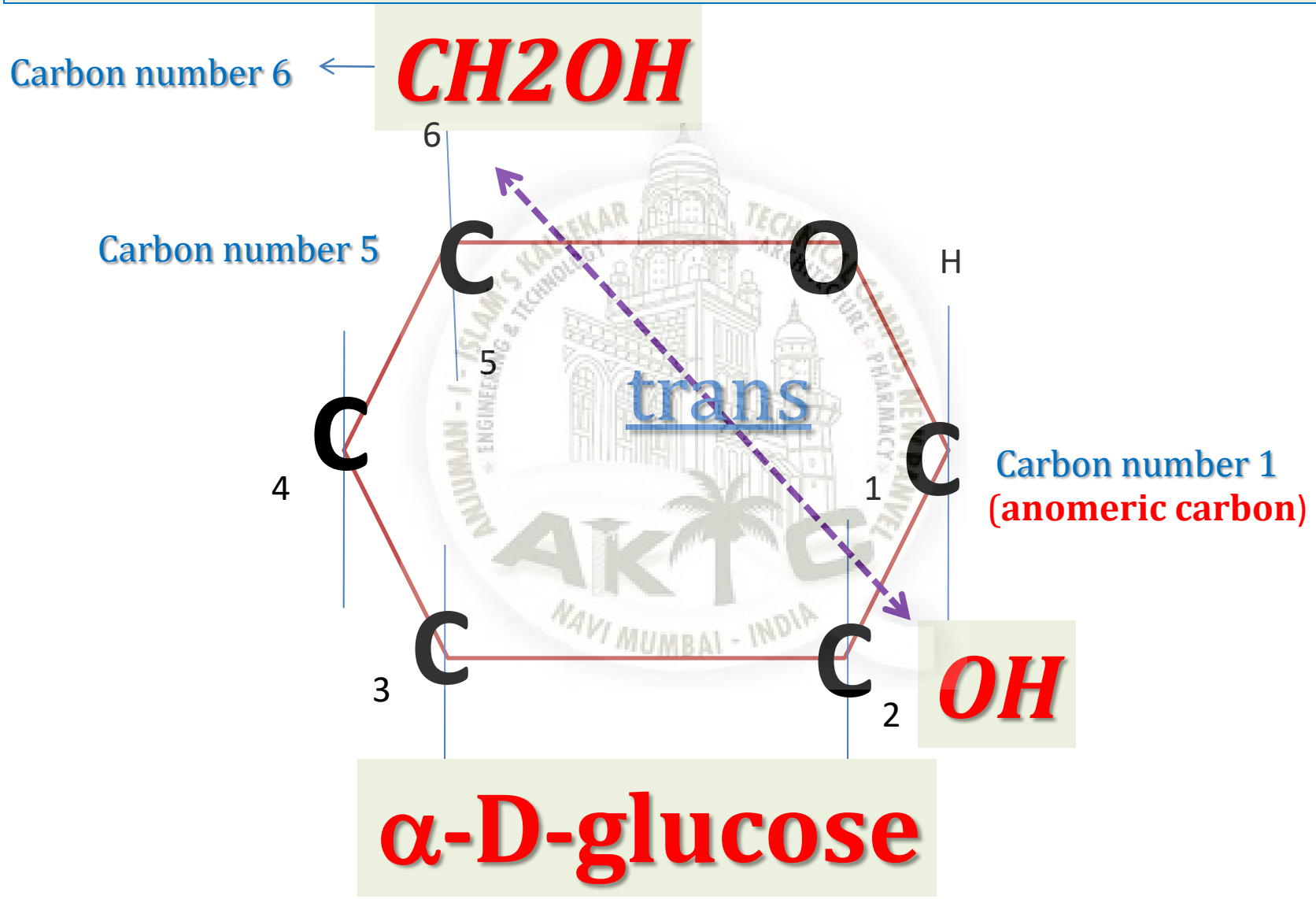
Carbon number 1 (**anomeric carbon**)

Carbon number **5**

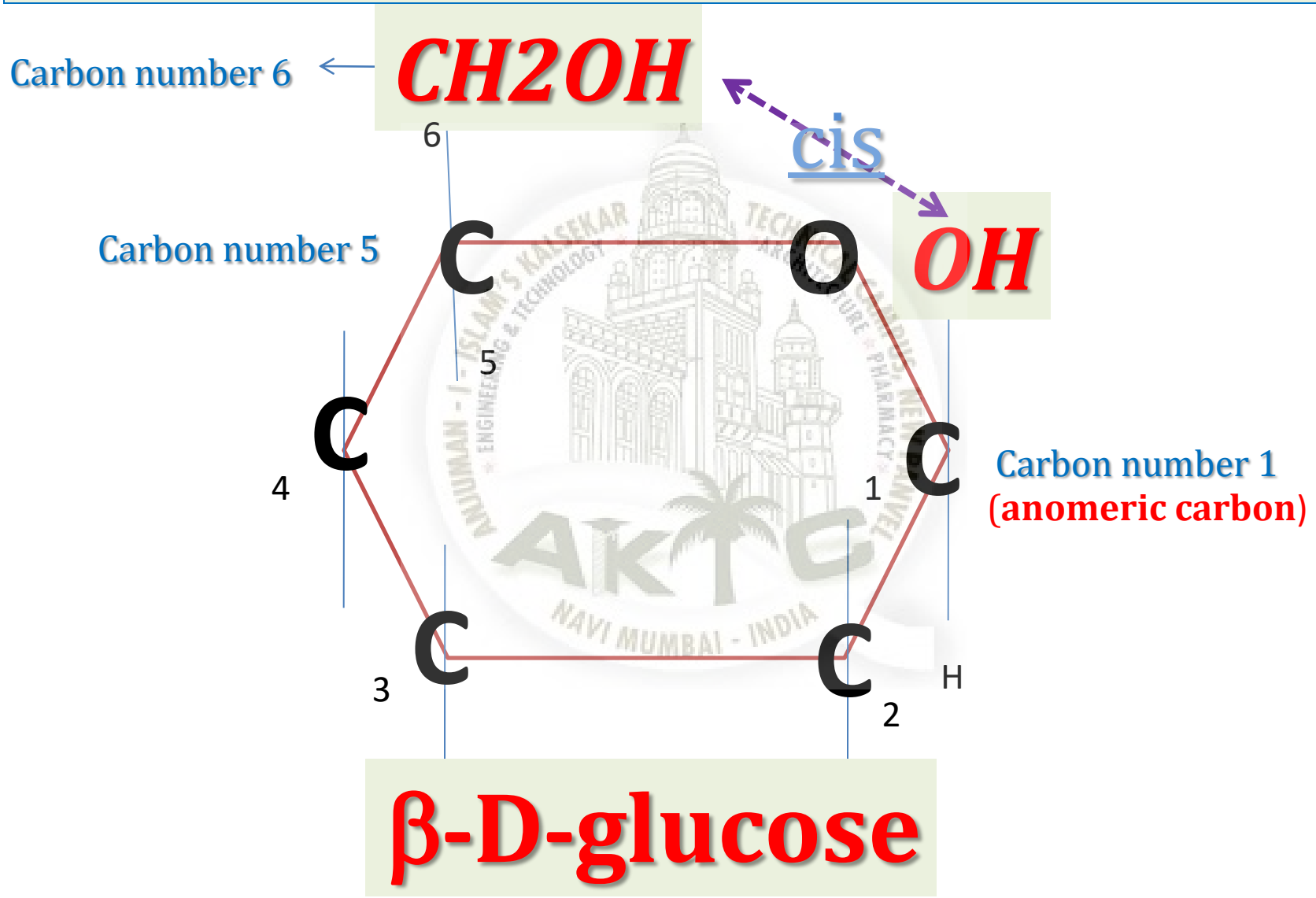
Figure 7.6

The interconversion of the α and β anomeric forms of glucose (mutarotation).

Hawroth Projection Formula



Hawroth Projection Formula



Dissacharides, oligo- & polysaccharides

Monosaccharides can be joined by **glycosidic bonds** to form
disaccharides (two units)
oligosaccharides (3-10 units)
polysaccharides (more than 10 units)

Important Disaccharides:

lactose (glucose + galactose): found in *milk*
sucrose (glucose + fructose): found in *table sugar*
maltose (glucose + glucose): in *malt*

Important Polysaccharides :
glycogen (from animal sources)
starch (from plant sources)
cellulose (plant sources)

The bonds that link monosaccharides are called ***glycosidic bonds***

Polysaccharides

1- Glycogen

- It is a long and branched polysaccharide (glucose polymer) that humans and **animals** store in the **liver** and **skeletal muscles**.

- Main **storage** of carbohydrates in the body

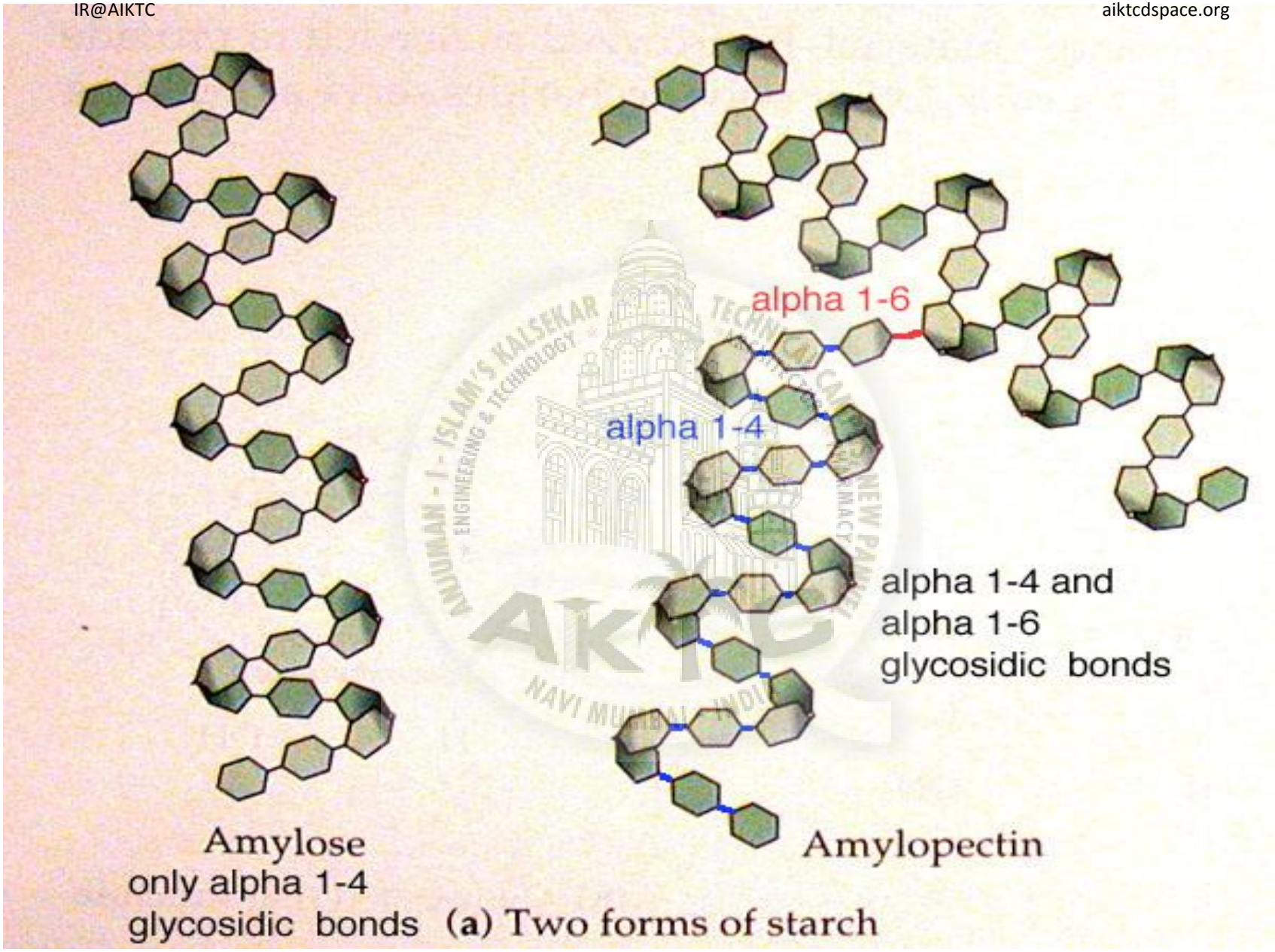
2- Starch

- It is available in **plants.**
- It is the **main carbohydrate of diet** -
  Rich sources of starches: include potatoes, rice and wheat. -

- It is a polysaccharide (glucose polymers) made up of:

1- **amylose** (outer layer of starch granules)
molecules are linear (long but with no branches)
2- **amylopectin** (inner layer of starch granules)
molecules are long and with branches

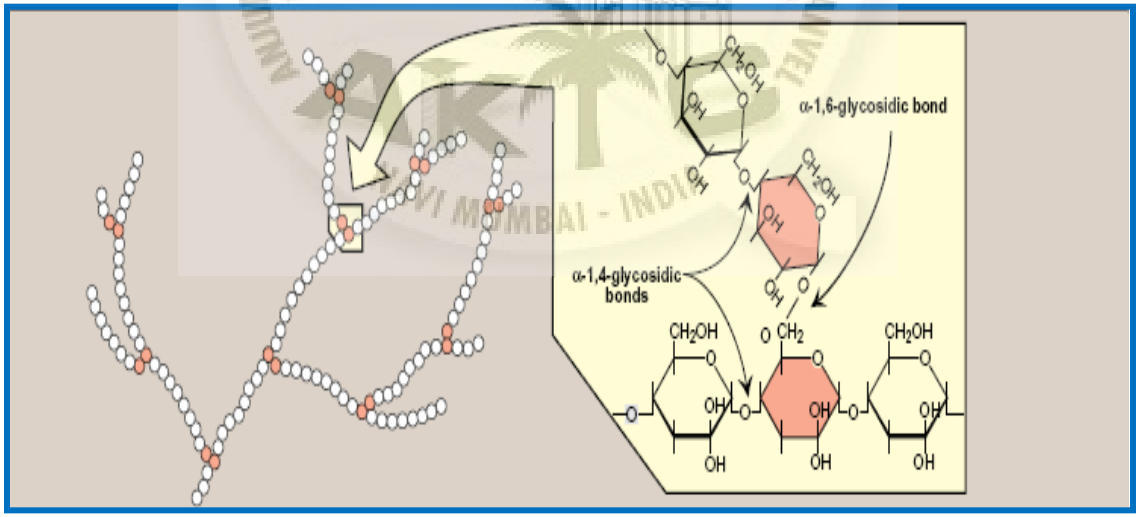
Humans and animals digest starch by hydrolysis by the enzyme amylase

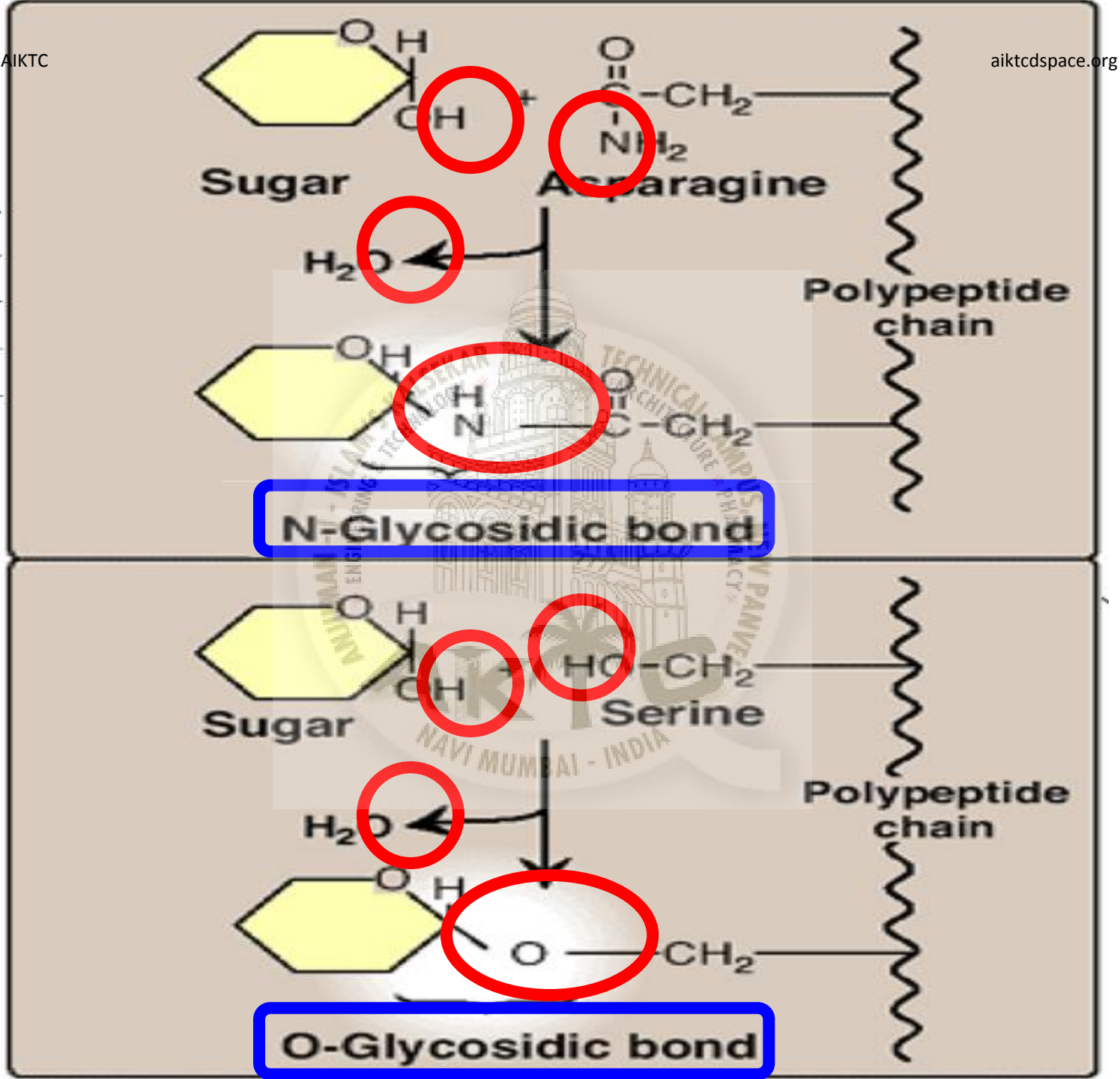


(a) Two forms of starch

structure of glycogen & amylopectin of starch

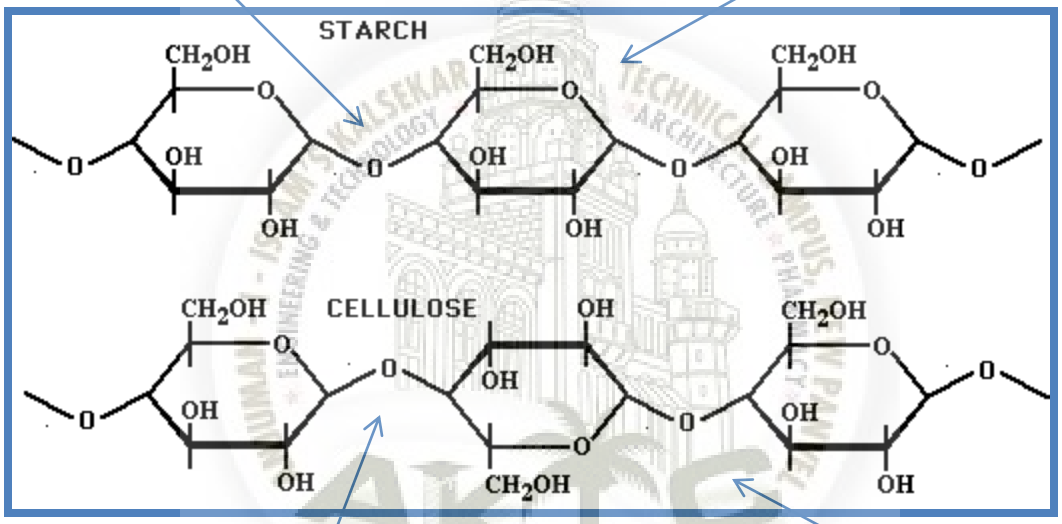
- **Glycogen & Amylopectin of Starch are branched chain polysaccharides made from α- D-glucose.**
- **Glucose molecules are bound by α (1 - 4) linkage**
- **Branches are linked by α(1 - 6) linkage**





α 1-4 glycosidic bond

Amylose of starch (outer layer of starch granules)
Linear (not branched)



β 1-4 glycosidic bond

cellulose

Complex carbohydrates

Carbohydrates can be attached by glycosidic bonds to **non-carbohydrate** molecules including:

1- purines and pyrimidines (in ***nucleic acids***)

2- proteins (in ***glycoproteins***)

3- lipids (***glycolipids***)

Reducing Sugars

If the oxygen on the anomeric carbon of a sugar is not attached to any other structure, the sugar can act as a reducing agent and is termed a reducing sugar.

Medical importance:

These sugars can react with chromogenic reagents as **Benedict's reagent or Fehling's solution** causing the reagent to be reduced and colored

Applications in Medicine: diagnosis of presence glucose in urine

Reducing and non-reducing sugars:

- **All monosaccharides** are **reducing** sugars
- **All disaccharides (EXCEPT sucrose)** are **reducing** sugars
- **Oligo- and polysaccharides** are **non-reducing** sugars

Main ***carbohydrates of diet*** of humans

1- **monosaccharides**:
mainly **glucose, fructose**
ABSORBED with NO DIGESTION

2- **disaccharides**:
sucrose, **lactose** & **maltose**
DIGESTED into monosaccharides

3-**polysaccharides**:
starch (plant source e.g. rice, potato, flour)
& **glycogen** (animal source)
DIGESTED into monosaccharides

cellulose (fibers of vegetables & fruits)
NOT DIGESTED

References

- **Monosaccharides: Their Chemistry and Role in Natural Products" by P M Collins and R J Ferrier**
- **. "Carbohydrates: Structure and Biology" by J Lehmann**

Review Question for attainment of TLOs/CO

- Definitions of carbohydrates and draw structures of common monosaccharides
- Draw structures of sucrose and lactose