CARBOHYDRATE CHEMISTRY

(DISACCHARIDES & HOMOPOLYSACCHARIDES)

BY

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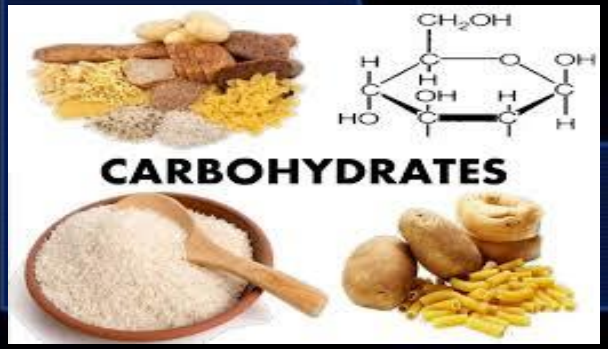

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Classification and Nomenclature

Carbohydrates

1 monosaccharide unit

Monosaccharides

- Functional group
  - Aldoses e.g Glucose
  - Ketoses e.g Fructose
- Number of carbon atoms
  - Trioses
  - Tetroses
  - Pentoses
  - Hexoses
  - Heptoses

2 units

Disaccharides

- Maltose
- Lactose
- Sucrose

3-10 units

Oligosaccharides

- Tri-saccharide
  - Raffinose
- Tetra-saccharide
  - Stachyose

>10 units

Polysaccharides

- Homopoly-saccharide
  - Starch
  - Dextrin
  - Glycogen
  - Cellulose
  - Inulin
- Hetropoly-saccharide
  - Hyaluronic acid
  - Heparin
  - Chondroitin sulfate
  - Dermatan Sulfate
  - Keratan Sulfate

Disaccharides

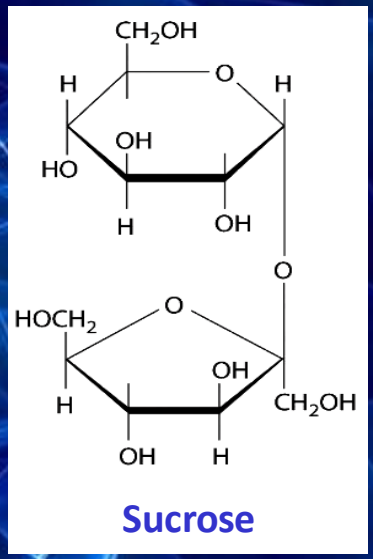
Definition:

- **Disaccharides are sugars which contain 2 monosaccharide two molecules bound by glycosidic bond.**
- **They are present either in α– or β-form, if the second monosaccharide residue contains a free anomeric carbon atom which has the ability to be in α or β-form.**

The most important disaccharides:

1. **Sucrose (α-glucose & β-fructose) by α-1, β-2 glycosidic linkage**
2. **Lactose (β-galactose & glucose) by β-1, 4 glycosidic bond**
3. **Maltose & isomaltose (α-glucose & another glucose) by α-1, 4 glycosidic bond**
4. **Cellobiose (β-glucose & another glucose) by β-1, 4 glycosidic bond**

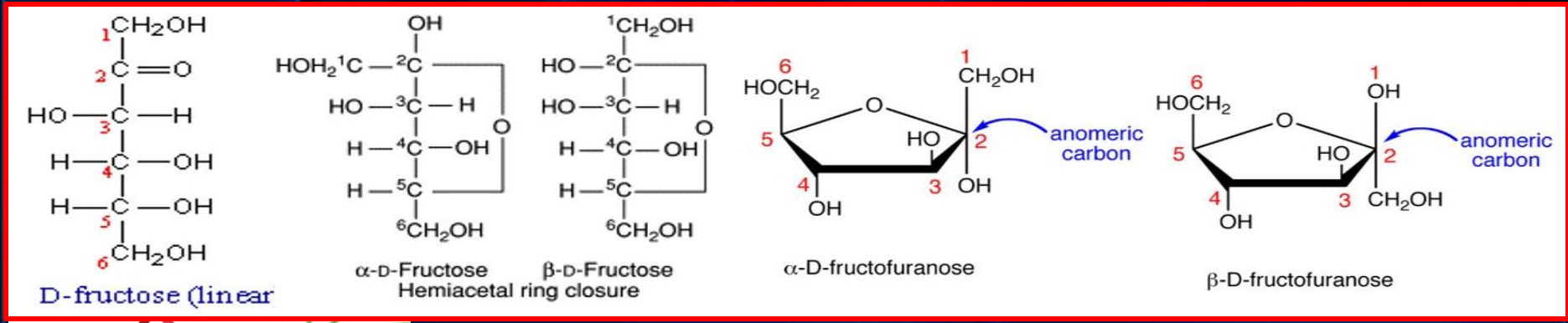
1. Sucrose (Cane or beat sugar)



- **It is called table sugar.**
- **It is formed of α-glucose & β-fructose linked together by α-1, β-2 glucosidic linkage.**
- **It cannot form osazone or exhibit mutarotation.**

N.B.

- **Osazone** (condensation with phenyl hydrazine)
- **Mutarotation** (change in optical rotation by α & β anomeric interconversion)
- **Anomeric carbon** is the carbon derived from the carbonyl carbon compound (ketone or aldehyde functional group) of open-chain form of carbohydrate molecule. **Anomeric carbon is present in the ring structure or Haworth formula.**



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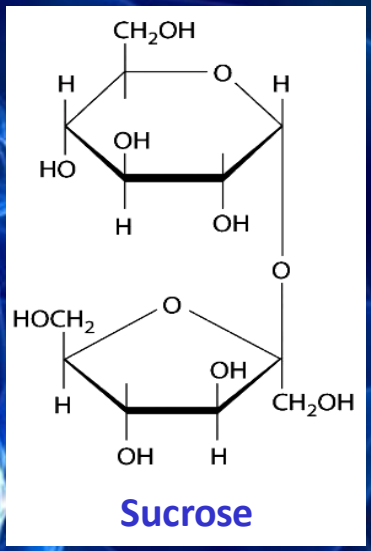


Sucrose

It is characterized by:

a. **Non-reducing sugar:** reducing groups of glucose & fructose are involved in the link between them:

- They cancel the action of each other
- Sucrose cannot form osazone & no mutarotation

b. **It is fermentable sugar.**

c. **Inversion from dextro- to levorotation by hydrolysis:**

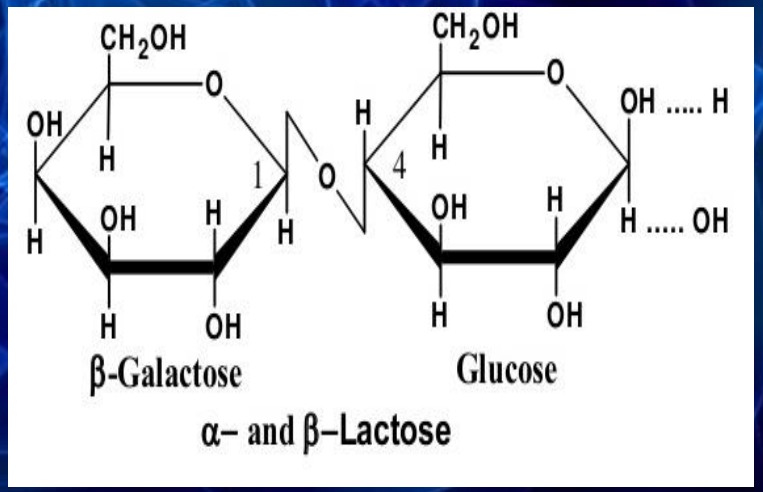
Hydrolysis by sucrase (invertase)

Sucrose ($\alpha = +66.5^{\circ}$) (Dextrorotatory) → (Inversion) → D-glucose ($\alpha = +52.5^{\circ}$) + D-fructose ($\alpha = -92^{\circ}$) (The sum is levorotatory)

- Invert sugar is sweeter than sucrose e.g. honey is a chiefly invert sugar.

2. Lactose (milk sugar)

- Formed of one **D- glucose** & one **β- galactose** linked by **β-1, 4** glycosidic bond. Present in 2 forms α- and β- lactose.
- α- lactose (**α- glucose** + β-galactose)
- β- lactose (**β- glucose** + β-galactose)
- **Reducing → osazone & mutarotation**
- Appears in urine of pregnant females
- **Less sweaty → not block the appetite**
- **Not fermented → no distension**
- **It can be digested (hydrolyzed) by *lactase enzyme*.**
- **Lactase deficiency** → lactose intolerance (distension & diarrhea)
- Milk is used to alleviate the epigastric pain, gastritis & ulcer.
- Many micro-organisms convert lactose to lactic acid → souring of milk.



α– and β–Lactose

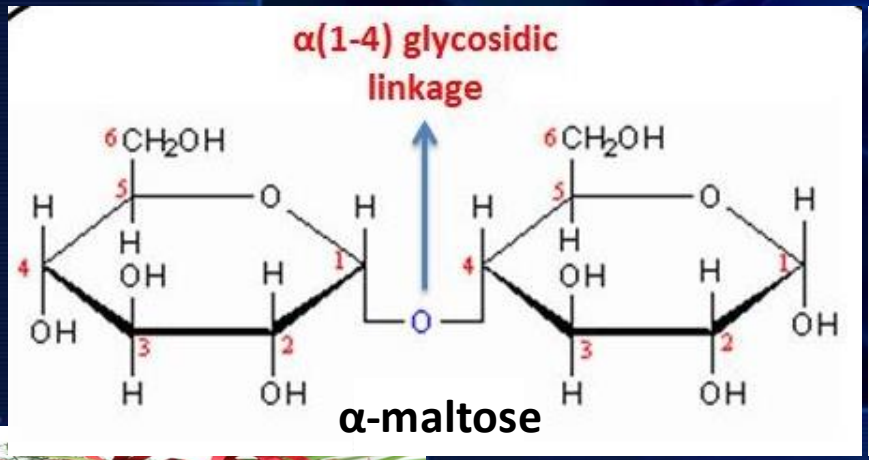
3. Maltose (Malt sugar)

- Not found in nature but produced during starch hydrolysis.
- It is formed of 2 glucose units (one α-glucose & another glucose) linked by α-1, 4 glycosidic bond (α & β-maltose)

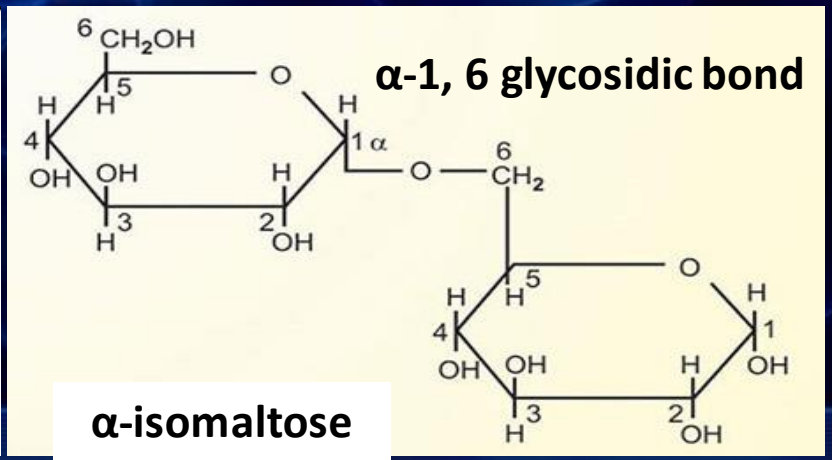
α- Maltose —(Hydrolysis by maltase)→ α-glucose + α-glucose

β- Maltose —(Hydrolysis by maltase)→ α-glucose + β-glucose

- It is a reducing sugar, shows osazone & mutarotation



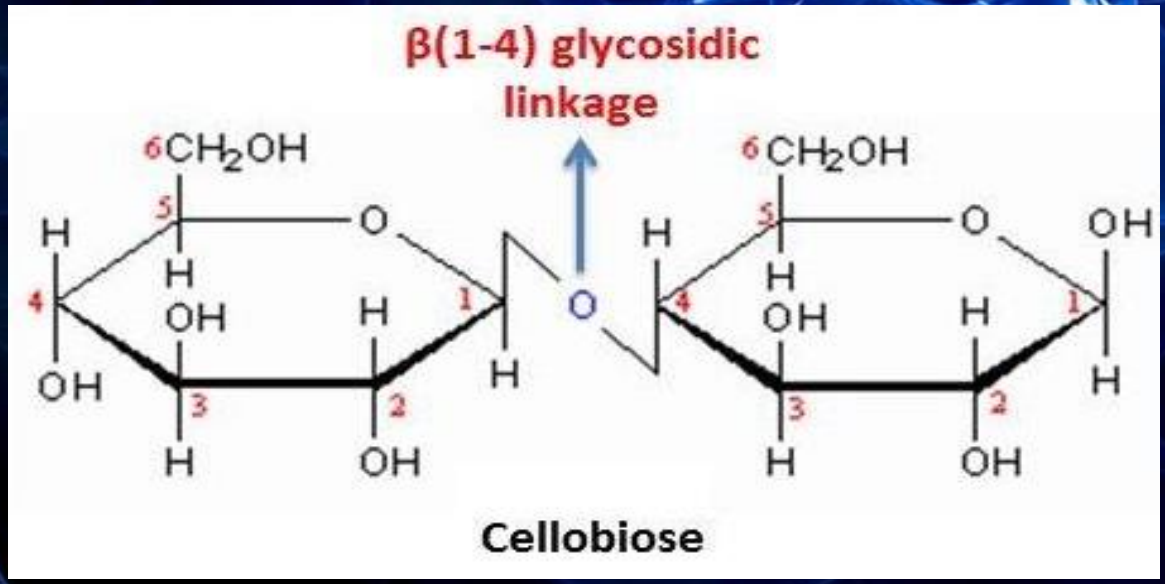
α-maltose



α-isomaltose

4. Cellobiose

- It is formed of 2 D glucose units (β glucose & another glucose) linked by β-1,4 glycosidic bond
- It has 2 forms (α & β)
- It is reducing, forms osazone & shows mutarotation
- It is obtained by partial hydrolysis of cellulose in plant



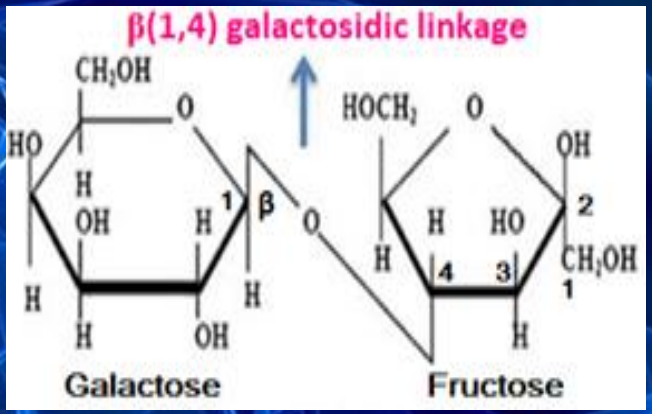
N. B: **Lactulose is a synthetic disaccharide**

It is formed of: β-D-Galactose & D-Fructose

It is linked by β 1→4 galactosidic linkage.

It is not digested nor absorbed.

It is reducing; C2 (anomeric) of fructose is free.



Importance of lactulose

1. Treatment of constipation:

- It acts as **osmotic** substance causing diarrheal effect.

2. ↓ plasma ammonia level (NH_3) in hepatic encephalopathy

- It acts as **osmotic** substance causing diarrheal effect.
- It lowers the PH of the colon, thus converting ammonia (NH_3) to ammonium ion (NH_4^+).

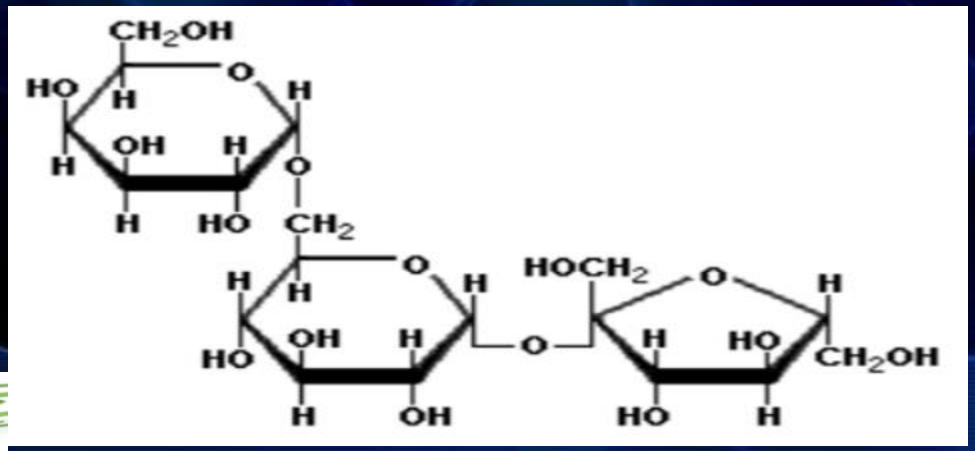
Oligosaccharides

It is formed of 3-10 monosaccharide units:

(trisaccharide, tetrasaccharide, pentasaccharide, ……)

Raffinose is a trisaccharide:

- formed of galactose, glucose & fructose
- Non-reducing (all carbonyl groups are included in the bonds)
- Found in cotton seeds
- Also, it is present in molasses obtained from beet sugar.



POLYSACCHARIDES

Def.: Carbohydrates of high molecular weight.

(>10 monosaccharide sugar units)

Linkage: glycosidic; 1,2 - 1,3 - **1,4 or 1,6.**

Hydrolysis:

Hydrolysis —(acid or specific enz.)→ **Monosaccharides or its derivatives**

Polysaccharides

chemically & functionally

Homogeneous

Hydrolysis

Single sugar type

(e.g. glucose units only)

Heterogeneous

Hydrolysis

Different sugar types associated with other subs.

Homogeneous		Heterogeneous (mucopolysaccharides)		
Glucosans	Fructosans	Neutral	Acidic	
Starch	Inulin	NANA	Non-sulfated	Hyaluronic a.
Dextrin		Bl. gp subs.	sulfated	Heparin
Glycogen		Gonadotrophins, thyrotrophic H		Heparan sulphate
Cellulose		α1 & α2 globulins		Chondoritin sulfate
Dextrans		Ovalbumin		Keratan sulphate
Chitin		Fibrinogen		Dermatan sulphate

Polysaccharides of biological importance

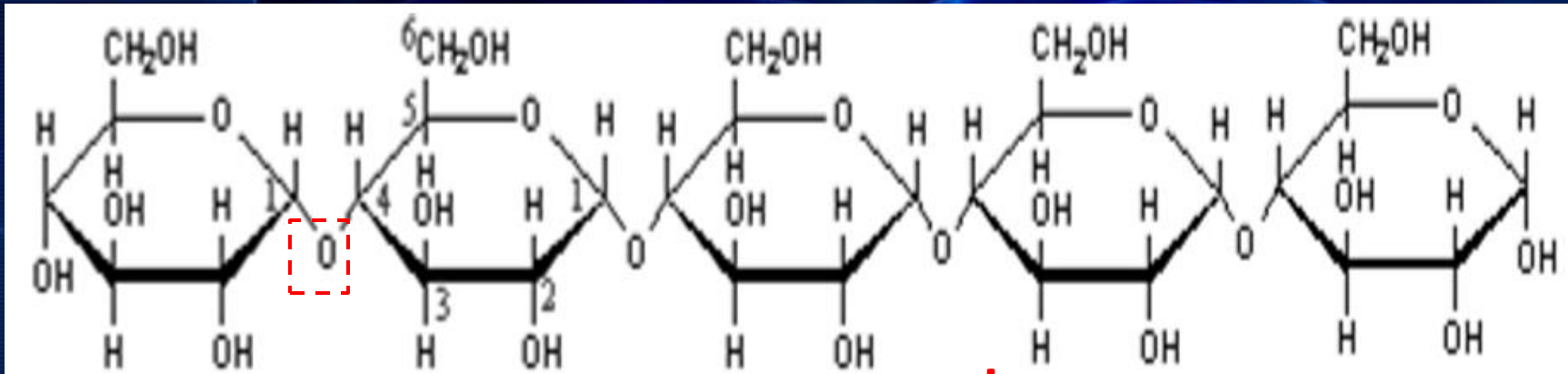
1- Starch: (Glucosans, α-D-glucose units)

- It is found in cereals, legumes & others.
- The most important food source of CHO (60%)
- **Insoluble** in water → a **suspension**

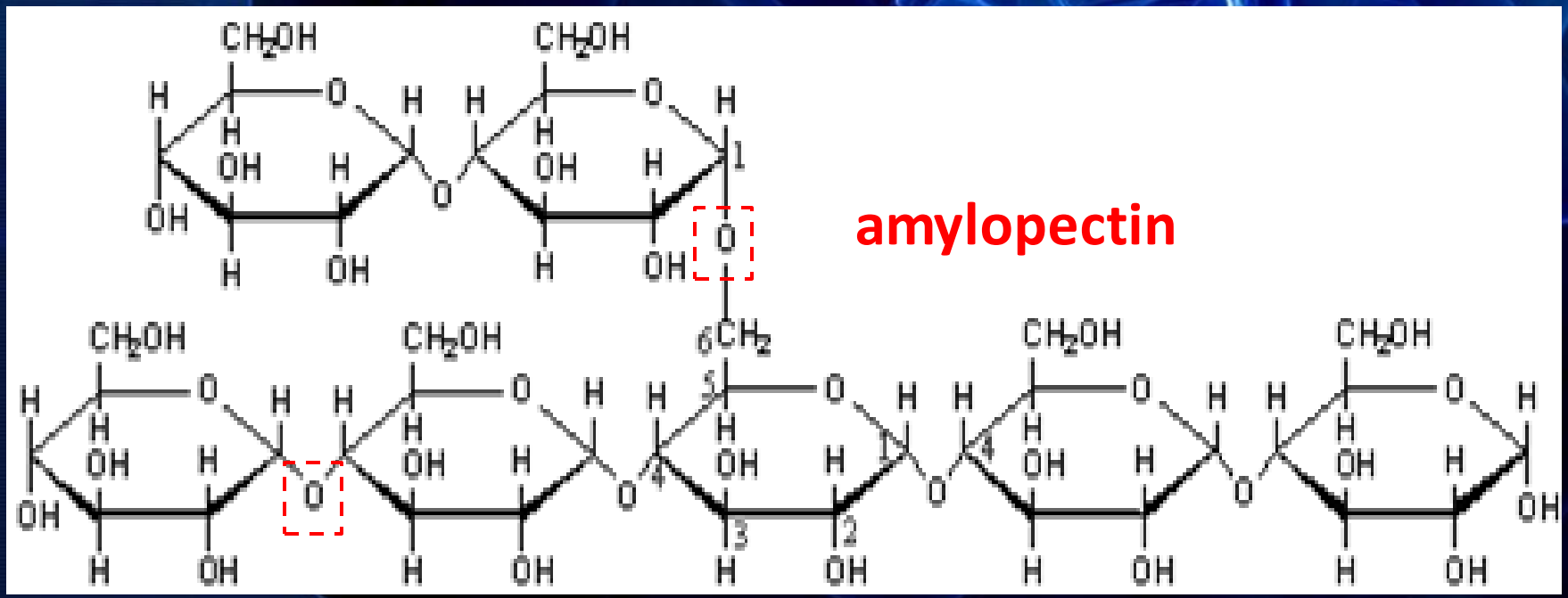
on heating, this suspension → colloidal solution

- It consists of **amylose** & **amylopectin**

Differences	Amylose	Amylopectin
Percentage	15-20 %	80-85 %
Chain	Long, non-branched	Highly branched
Site of bond	α-1,4	α-1,4 &1,6
Iodine test	Blue color	Purple to red



amylose



amylopectin

Hydrolysis of starch

1. Acid hydrolysis: (Dilute mineral acids)

2. Enzymes hydrolysis: α-amylase (salivary & pancreatic).

Differences	Salivary amylase	Pancreatic amylase
Source	Saliva	Pancreatic juice
Optimum pH	6.8 (slight acidic)	7.5 (alkaline)
Activator ions	Cl^-	HCO_3^-
Site of action	Mouth & short time in stomach	Intestine
Digestion Products	Incomplete (Dextrin mainly)	Complete digestion (Maltose)

Products of Starch Hydrolysis

Iodine test

Starch (blue colour)

Amylodextrin (puple colour)

Erythrodextrin (red colour)

Achrodextrin (no colour)

Maltose & Isomaltose

[(α-1,4)] [(α-1,6) branching point]

Glucose (complete hydrolysis of starch)

2- Dextrin:

- It is produced by **partial hydrolysis** of starch.
- It gives **different colors with iodine** as:
- **Amylodextrin → Purple color.**
- **Erythrodextrin → Red color.**
- **Achrodextrin → Colorless color.**

4. Dextrans (Glucosans)

- Storage polysaccharide of **yeast & bacteria.**
- Glucose units only linked Mainly by **α 1,6** linkage.
- **Occasional** branches (**α-1,2, α-1,3 or α-1,4**) depending on the species.
- Dextran solutions are given **intravenously** after blood loss due to **high viscosity, low osmotic pressure** and they remain in blood for few hours.
- **Disadvantage:** Interfere with blood grouping cross-matching. So cross-matching must be done before dextran administration in case of hemorrhage, as blood transfusion may be required

4- Glycogen (animal starch): (Glucosans)

- It is a non-reducing sugar.
- It gives **Pink color** with iodine.
- It is similar in its structure to amylopectin
- Highly branched formed of **α1,4 link** & **α1,6** at the branching point
- It is stored in **liver & muscle**.

5- Inulin: (Fructosan)

- It is found in **many plants** e.g. artichokes dahlia, onion & garlic.
- On hydrolysis: it gives **D-fructose** units (**β-1,2**).
- It is used as a test for **measuring of glomerular filtration rate (GFR).**

N.B.

Inulin has all the properties of an ideal marker for GFR:
It is freely filtered by the glomerulus,
It is not secreted or reabsorbed in the tubules,
It is not synthetized or metabolized by the kidney.

6- Cellulose: (Glucosans)

- **Insoluble in water**
- **Unbranched polysaccharides; it is long straight chains of β-glucose units linked by β-1, 4 glucosidic bond**

- **The most abundant structural unit in plants.**
- **Complete hydrolysis:**

[acid or enzyme (cellulase)] → **β-D-glucose units.**

- **Partial hydrolysis:** → **cellobiose (disaccharide)**
- **Many mammals (e.g. human) cannot digest cellulose due to absence of enzymes that attack the β link (absence of cellulase enzyme).**

The importance of Cellulose

1. **It acts as a laxative (prevents constipation):**

   It increases the bulk of stool & has the ability to absorb water. It stimulate intestinal peristalses.

2. **Being a constituent of dietary fibers:**

   ↓ absorb toxic compounds

   ↓ the incidence of cancer colon

3. **A source of Energy in herbivores** [their gut contain bacterial enzyme for the β link (cellulase)]

Difference	Starch	Cellulose	Glycogen
Units	α-glucose	β-glucose	α- glucose
Chains	Straight, branched.	Straight only	Straight, branched
Glycosidic Link	α -1,4 & (α-1,6 branch p)	B- 1,4	α -1,4 & (α-1,6 branch p)
Digest. in human	Saliv., pancr. amylases.	Not digested (no cellulase)	Saliv., pancr. amylases.
I_2 React.	**Blue color**	No color	**Pink color**
Functions	1. Storage CHO in plants 2. Major source of CHO for animals	1. Supportive in plants. 2. Laxative 3. ↓ absorb. of toxic subs. 4. Energy (herbivores)	1.Storage CHO in animals 2. Source of Energy for ms (ms contract.)


Thank you