FOOD CHEMISTRY

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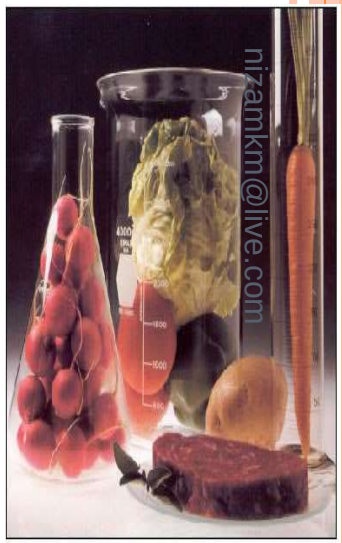
CHAPTER- 1

❖ FOOD CHEMISTRY

- Food Chemistry is the study of chemical processes and interactions of all biological and non- biological components of foods



- It covers the basic composition, structure and properties of foods and the chemistry changes occurring during processing and utilization

- It also covers the chemistry of water, carbohydrates, proteins, lipids, vitamins, minerals and enzymes

BASIC CONSTITUENTS OF FOOD

- **FOOD** is any substance usually composed of carbohydrates, fats, proteins, water etc that can be eaten or drunk by human for nutrition
- The constituents of foods are divided into **two**

MAJOR	MINOR
Carbohydrates	Vitamins
Fats	Minerals
Proteins	Enzymes
	Pigments
	Flavors
	& Acids

- There is also the ever present and important constituent is **Water**

- All these constituents are arranged in foods to give the foods their:-

- ✓ Structure
- ✓ Texture
- ✓ Flavor
- ✓ Colour
- ✓ & Nutritive value

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CLASSIFICATION OF FOODS

- Foods are classified, according to their functions in the body

Energy Yielding Foods

- ✓ This group includes foods rich in carbohydrates & fats
- ✓ 1 gm of **CHO** yields **4** calories
- ✓ 1gm of **fat** yields **9** calories

- **It is divided into two:-**
- ✓ Pure Carbohydrates like sugar, fats & oils
- ✓ Cereals, pulses, roots & tubers

- **Sugars** provide **energy** & **Fats and oils** also provide **concentrated** source of **energy**

- **Cereals** provide in addition to **energy** large amounts of **proteins, minerals and vitamins** in the diet

- **Pulses** also give **proteins and vitamins** besides giving energy to the body

- **Roots & tubers** mainly provide **energy** but they also contribute to some extent **vitamins & minerals**

Body Building Foods

- Foods rich in **proteins** are called Body Building Foods
- **They are classified into two groups**

- ✓ **Milk, Meat, Egg & Fish**: – They are rich in proteins of high biological value. These proteins have **all** the **essential amino** acids in correct proportions for the synthesis of body tissues

- ✓ **Pulses, Oil-seeds & Nuts**: - They are rich in protein but may **not contain** all the essential amino acids required by the human body

❖ Protection & Regulation

- ❖ Foods rich in **proteins, vitamins & minerals** have **regulatory** functions in the body
- ✓ E.g. maintaining heart beat, body temperature, clotting of blood & excretion of wastes

- ❖ **Protective** foods are classified into **two** groups:-
- ➢ Foods **rich** in vitamins, minerals & proteins of **high** biological value

- ✓ E.g. Milk, egg, fish & liver
- ➢ Foods rich in **certain** vitamins & minerals only
- ✓ E.g. Green leafy vegetables & some fruits

❖ WATER

- Water is an essential constituent of any foods
- It may occur as…….
  - an **intracellular or extracellular** component in **vegetable & animal** products
  - as a **dispersing** medium or **solvent** in many foods & as the **dispersed** phase in some **emulsified** products such as **butter, margarine**
  - & as a **minor** constituent in some foods

- The presence of water in food is described as the **moisture content** or **water activity (aw)** of the food

- **Moisture** refers to the **amount** of **water** present in food while **water activity (aw)** refers to the **form** in which **water exist** in the food

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❖ WATER CONTENT OF SOME SELECTED FOODS

PRODUCTS	WATER %		PRODUCTS	WATER %
Tomato	95 %		Cheese	37%
Lettuce	95 %		Bread	35%
Cabbage	92 %		Jam	28%
Orange	**87 %**		Honey	20%
Apple	**87 %**		Butter & margarine	16%
Milk	**87%**		Wheat flour	12%
Potato	78 %		Rice	12%
Banana	75%		Coffee beans roasted	5%
Chicken	70%		Milk powder	4%
Meat	65%		Shortening	0%

FORMS OF WATER IN FOODS

- Water exists in 3 forms in foods:-
  - ✓ Free water
  - ✓ Absorbed water
  - ✓ Bound water



- Chemically, each form of water is the same **(H_2O),** but differences exist in the **physical & chemical** conditions in which water can exist
- The **form** in which water occurs in foods determines the **physical** properties of the food
  - ✓ For e.g. Fluid milk & apples contain approximately the **same amount** of **water** but have different **physical** structures

❖ FREE WATER

- ✓ Most water in foods is called free water
- ✓ Free water is **lightly entrapped** & therefore easily pressed from food
- ✓ It acts as a dispersing agent & solvent & can be removed by drying foods

❖ ADSORBED WATER

- ✓ This water associates **in layer** through intermolecular **hydrogen bonds** around hydrophilic food molecules
- ✓ i.e. the water is held tightly in **cell walls** or protoplasm & is held tightly to **proteins**

❖ BOUND WATER

- ✓ Bound water is the water that **remains unfrozen** at temperature below **$0^{o}C$** usually **$-20^{o}C$**
- ✓ Also it is the amount of water in a food that is **unavailable** as a solvent
- ✓ The amount of unfreezable water, based on **protein** content, vary from one food to another

- ➢ For E.g., About **8-10 %** of the total water in **animal** tissue is **unavailable** for ice formation. Egg white, egg yolk, meat & fish all contain approximately **0.4gm** of unfreezable water/g of dry protein. Most fruits & vegetables contain less than **6%** unfreezable water

DETERMINATION OF MOISTURE CONTENT

- The ease at which **H_2O** is removed from a food by evaporation depends on its **interaction** with other component present
- **Free** water is most **easily** removed from foods by **evaporation**, where as more **severe** conditions are needed to remove **bound** water

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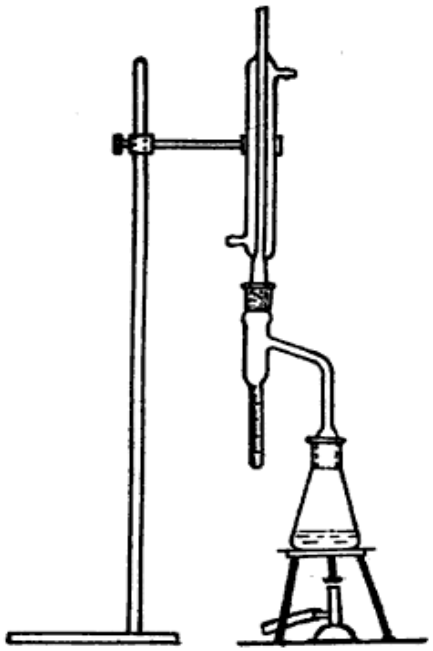
Some methods include:-

- ✓ Oven drying methods
- ✓ Vaccum oven
- ✓ Distillation methods



: Apparatus for determination of moisture by immiscible solvent distillation method.

OVEN DRYING METHODS

- The **Sample** is weighed. The sample is usually weighed into a **flat** bottom **shallow** dish made up of **aluminium** or similar material which **will not** react with the **food** nor **pick up** water readily
- **Weighed** samples are placed in an **oven** for a specified **time & temperature**. The oven **temperature** is usually set at **100°C** or **105°C** & the **time varies** depending on the **sample**
- They are dried until they reach **constant** mass. The **difference** in **weight** is the **water** which has evaporated

$$\% \text{ Moisture} = \frac{\text{Wt of wet sample} - \text{Wt of dry sample}}{\text{Wt of wet sample}} \times 100$$

❖ Vaccum oven methods

- **Weighed** samples are placed under **reduced pressure** (typically 25 – 100mm Hg) in a vaccum oven for a specified **time & temperature** & their dried mass is determined
- The **boiling point** of water is **reduced** when it is placed under vaccum
- The **thermal** energy used to evaporate the **water** is applied **directly** to the sample through the **metallic** shelf
- There is an **air inlet & outlet** to carry the moisture **lost** from the sample out of the vaccum oven, which prevents the **accumulation** of moisture within the oven

- **Advantage of vaccum oven** over conventional oven drying techniques:-

- If the sample is heated at the **same** temperature, **drying** can be carried out much **quicker**

- **Lower** temperature can be used to remove the moisture (e.g., 70º C instead of 100º C) & so problems associated with **degradation** of **heat labile** substances can be **reduced**

❖ DISTILLATION METHODS

- Distillation methods are based on **direct measurement** of the **amount of water** removed from a food simply by evaporation
- Distillation methods are illustrated by the **Dean & stark method**
- A known **weight** of food is placed in a flask with an **organic** solvent such as **xylene or toluene**

- **Toluene** with a **B.P** of **110.6º C**
- **Xylene** with a **B.P** of **137º – 140º C**

❖ THE **ORGANIC SOLVENT** MUST BE:….

- ✓ **Insoluble** with water
- ✓ Have a **higher boiling point** than water
- ✓ Be **less dense** than water
- ✓ & be **safe** to use

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- The flask containing the sample & the organic solvent is attached to a **condenser** & a **graduated** glass tube
- Then the mixture is **heated**
- The **water** in the sample **evaporates** & moves **up** into the **condenser** where it is **cooled** & **converted back** into **liquid water** which is collected into the **graduated tube**
- When **no more** water is collected in the graduated tube, **distillation** is **stopped** & the **volume** of water is **read** from the tube

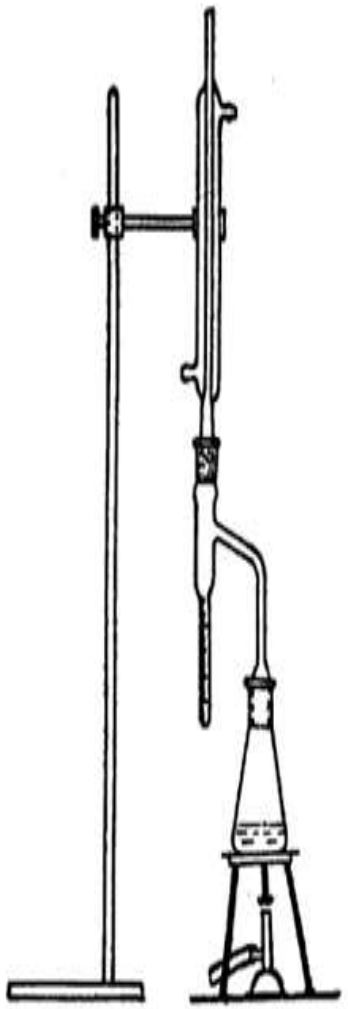
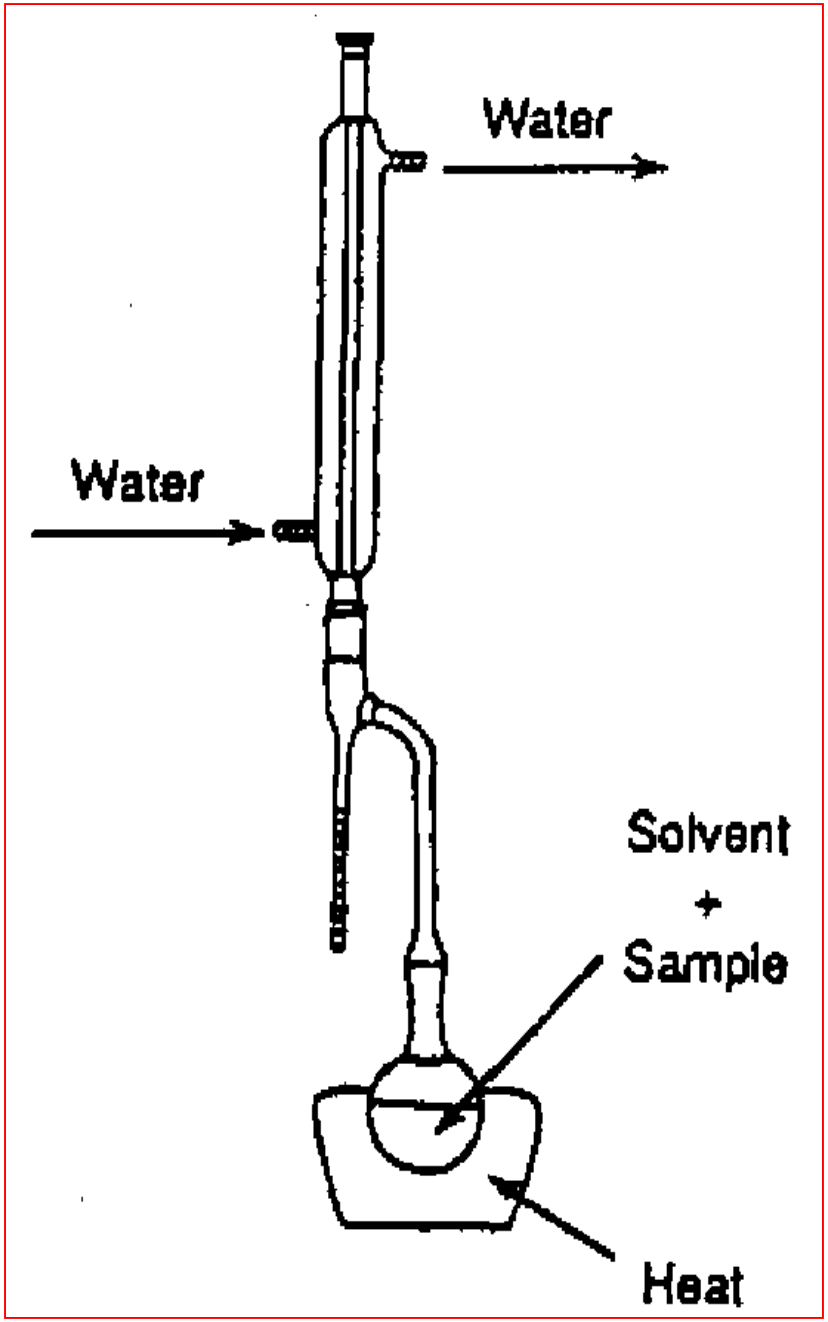
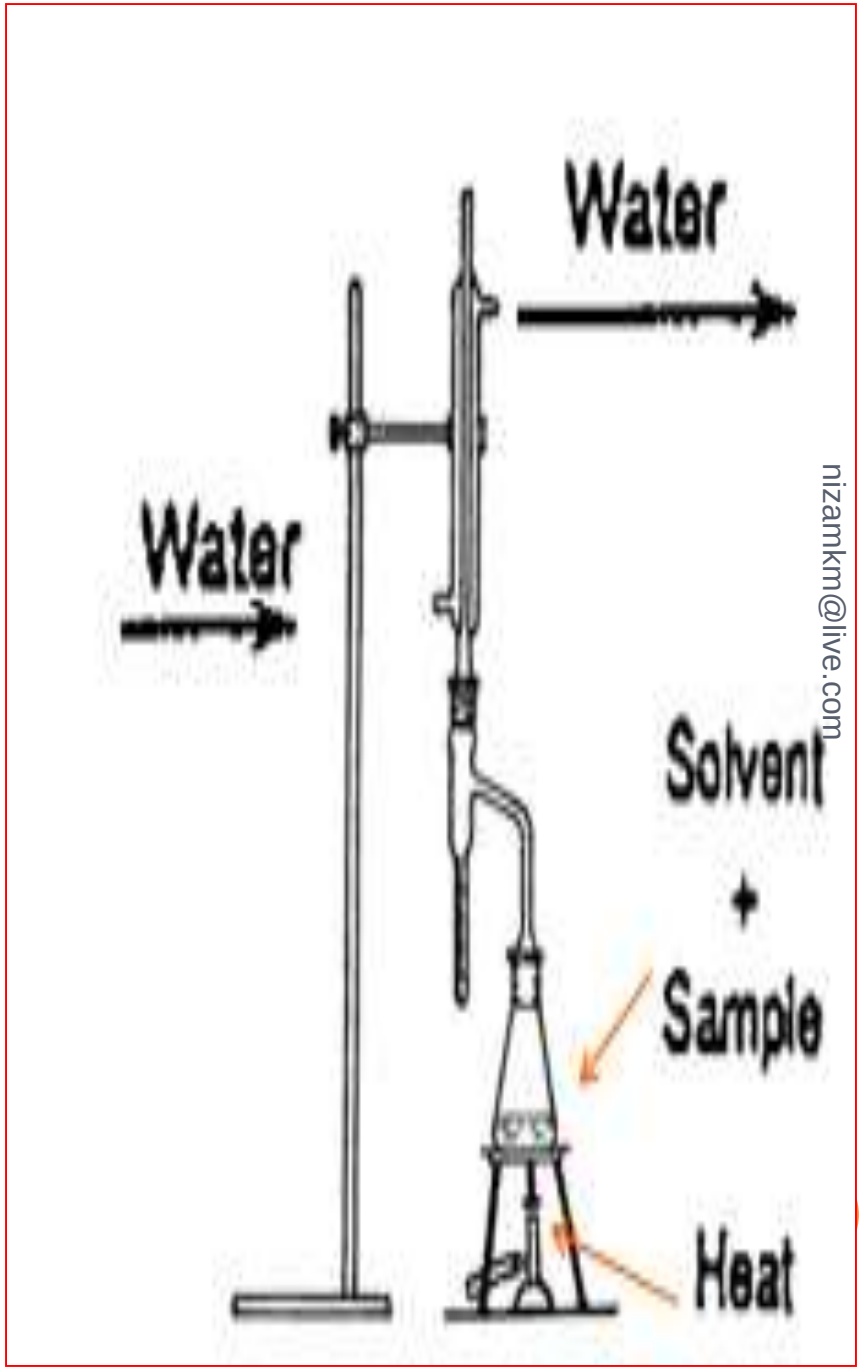


Fig. 1.1 : Apparatus for determination of moisture by immiscible solvent distillation method.





WATER ACTIVITY

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❖ WATER ACTIVITY

- Water Activity is the measure of the availability of **water** molecule to enter into **microbial, enzymatic or chemical reactions**
- It can be represented by the symbol **a_w**
- The availability determines the **shelf life** of food
- Regarding the forms of water, **bound** water is inversely related to water activity
- As the % of **bound** water in a food **increases** the **a_w decreases**

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- **a_w** is calculated as ratio of the **water vapour pressure** of the **substance divided** by the **vapour pressure** of **pure water** at **same** temperature
- Vapour pressure can be measured by using a **manometer**

$$a_w = \frac{p}{p_o}$$

where

a_w = water activity

p = vapor pressure of water in a food

p_o = vapor pressure of water at the same temperature

- In simpler terms **a_w** is a measure of relative humidity **(RH)**

- By multiplying **a_w** by **100**, the relative humidity (RH) of the atmosphere in equilibrium with the food (RH % or ERH) is obtained

- The **ERH** of a product is defined as the relative humidity of the air surrounding the food at which the product neither gains nor loses its natural moisture & is in equilibrium with the environment

$$\text{RH (\%)} = 100 \text{ X } a_w$$

$$a_w = \frac{\text{ERH}}{100}$$

❖ WATER ACTIVITY OF SOME FOODS

FOOD	a_w
Pure water	1
Fresh meat	0.985
Milk	0.97
Bread	0.96
Potato chips	0.80
Flour	0.72
Raisins	0.60
Macaroni	0.45

❖Some foods are stable at **low** moisture content where as others are stable at relatively **high** moisture content

✓E.g.: **Peanut oil** deteriorates at moisture content **above 0.6%** where as **potato starch** is stable at **20%** moisture

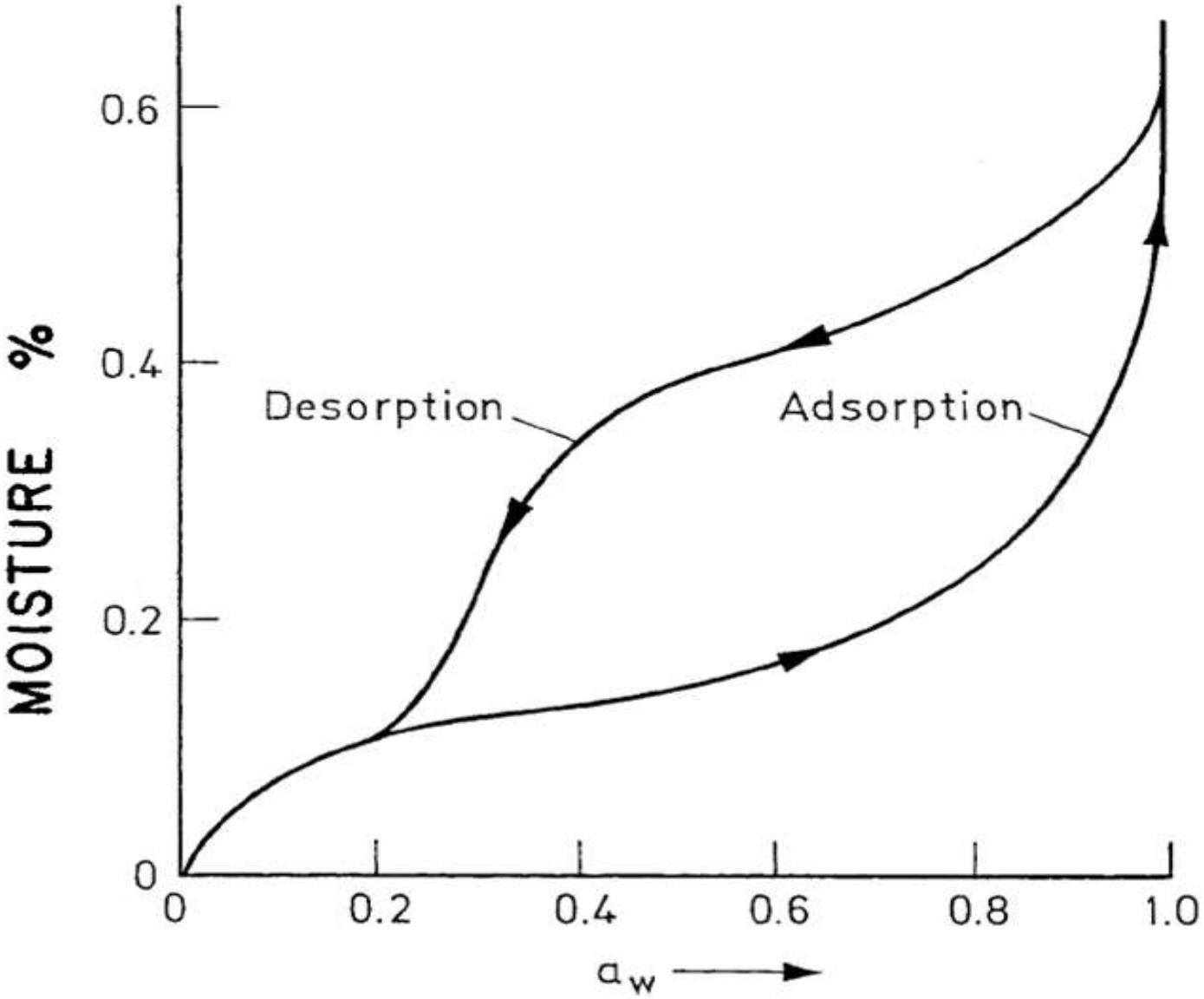
- **Water activity** is related to moisture content in a **non-linear** relationship known as **moisture sorption isotherm curve**

- The relationship between **water content & a_w** is indicated by the **sorption isotherm** of a food

- The plotting of the **uptake** termed **adsorption** or the **loss** of water termed **desorption** provides a record of **a_w** of a particular **food** at a particular **temperature** over **varying** levels of **humidity** in the environment

- The plot of **adsorption** is **not identical** with the plot of **desorption**

❖ Adsorption & Desorption Isotherms



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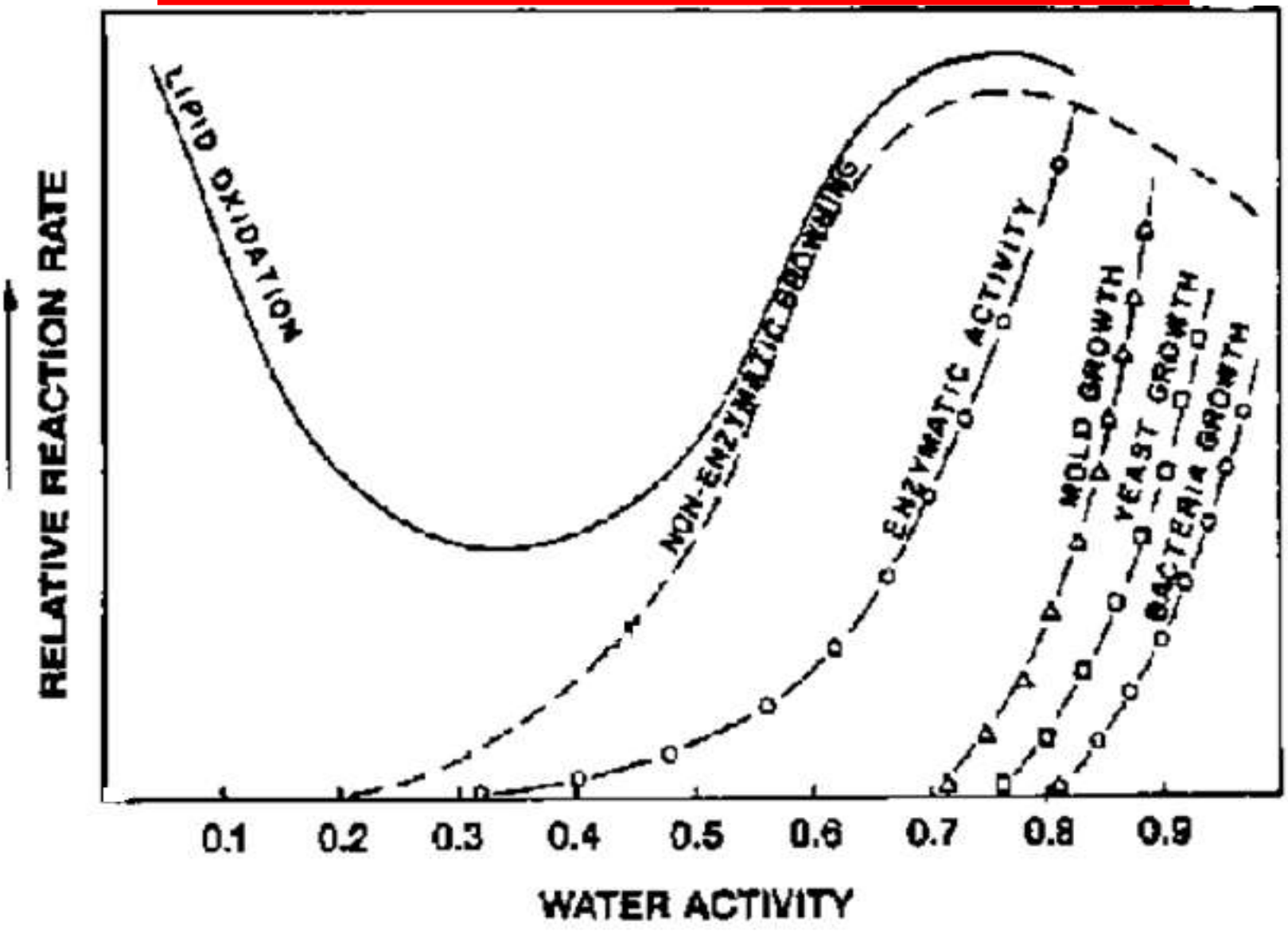
- Water activity has an important role in **food preservation**
- Each microorganism has a **critical a_w** below which the growth **cannot** occur
- For e.g.: **Pathogenic** microorganisms cannot grow at **a_w** below **0.86**, **Yeast & molds** are tolerant & usually no growth occurs at or below **0.62**
- So **a_w** is important in foods and it is a major factor in food spoilage & safety
- **Decreased a_w** retards the growth of microorganisms, slows enzyme catalyzed reactions & retards non enzymatic browning
- **Lipid oxidation** rates are **high** in **a_w** values from a minimum at **0.3 – 0.4** to a maximum at **a_w 0.8**

Relationship of Food Deterioration Rate as a Function of Water Activity



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- With **a_w** at **0.3**, the product is most stable with respect to lipid oxidation, non enzymatic browning, enzymatic activity & the various microbial parameters

- As **a_w** **increases** towards the **right** the probability of the food product **deterioration increases**

- For decreasing **a_w** & thus improving the **shelf life** of food is by the use **additives** with high water binding capacity **(humectants)**

- In addition to common salt, glycerol, & sucrose have the potential as humectants

CARBOHYDRATES

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CARBOHYDRATES

- Carbohydrates are organic compounds made up of **carbon, hydrogen, & oxygen**

- Carbohydrates are polyhydroxy aldehydes or polyhydroxy ketones and their derivatives

- Commonly, the **hydrogen & oxygen** in the carbohydrates are present in **2:1 ratio** as in **water**, from which the name carbohydrate (carbon Hydrate) was derived

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- CHO are some times referred as **saccharides meaning sugar**
- Simple CHO are called **sugars**
- One of the simplest carbohydrates is **glucose** ($C_6H_{12}O_6$) or monosaccharide & they link together to form more complex carbohydrates (oligo or polysaccharides)
- The names of most CHO are characterized by ending **"OSE"**

- ✓ E.g., Glucose
- ✓ Lactose - Milk Sugar
- ✓ Maltose- Malt sugar
- ✓ Fructose- Fruit Sugar

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- CHO occur in many plant & animal tissues as well as microorganisms

- In **animal** organism the main sugar is **glucose** & storage CHO is **glycogen**, in **milk** the main sugar is the disaccharide **lactose**

- In **plant** organism a wide variety of monosaccharides and oligosaccharides occur & the storage carbohydrate is **starch.** The structural polysaccharide of plant is cellulose

- The **gums** are a group of polysaccharides obtained from **plants, seaweeds**, and **microorganisms**

CLASSIFICATION OF CARBOHYDRATES

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CLASSIFICATION OF CARBOHYDRATES

DIGESTABLE & INDIGESTIBLE CHO

- **Dietary** carbohydrates may be categorized as digestible & Indigestible based on their **ability to digest** by **enzymes** present in **saliva, stomach or intestine**

- ✓ **DIGESTIBLE**:- Dietary CHO may be categorized as digestible by enzymes present in the saliva, stomach or intestine or absorbable without digestion
  - ➢ **E.g.,** Lactose, Sucrose, Human milk, Vegetable starch, Oligosaccharides

- ✓ **INDIGESTIBLE**:- **E.g.,** Dietary fibers found in cereals, Vegetables & fruits & fructo oligosaccharides such as inulin, present in certain vegetables & processed foods

❖ Depending upon whether or not they undergo **HYDROLYSIS**

Monosaccharides	Disaccharides	Trisaccharides	Polysaccharides
❖Made up of **2- 6 carbon** units ✓Glucose ✓Fructose ✓Galactose	❖Made up of **2 mono**saccharides ✓Sucrose (Glucose+Fructose) ✓Maltose (Glucose+Glucose) ✓Lactose (Glucose+Galactos)	❖Made up of **3 mono**saccharides ✓ Raffinose	❖Contain 10 or more monosaccharide units ✓ Dextrin ✓ Starch ✓ Cellulose ✓ Hemicellulose ✓Pectin ✓Gums

MONOSACCHARIDES

- It consists of a single polyhydroxy aldehyde or ketone group and is commonly known as **simple** sugars
- These **can't be hydrolyzed** into **simpler** forms
- Serve as the **building blocks** of **complex sugars** and **polysaccharides**
  - ✓ E.g. Glucose, Fructose, Galactose
- The general formula is **$(CH_2O)_n$** where **n** is **3 to 7**
- Monosaccharides with **5 & 6** carbon atoms are more common

- All the carbon atoms contain one hydroxyl **(–OH)** group and except one **carbonyl oxygen** (as in **–CHO**, or **C=O**)

- Based on **functional** group monosaccharides are classified in **2 types-**

- **ALDOSES**

- **KETOSES**

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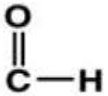
ALDOSES

- If the **carbonyl oxygen** group is present at the **terminal position, the monosaccharide** is an **aldehyde** derivative and the sugar is called **aldose** sugar
- ✓ Eg. **Glucose**

- The aldoses contain an **aldehyde (**  **)** group

- The aldoses may be represented by the general formula……..

❖ KETOSES

- If it is present in any other position, the monosaccharide is a **ketone** derivative that is known as **ketoses**
  - ✓ E.g., Fructose

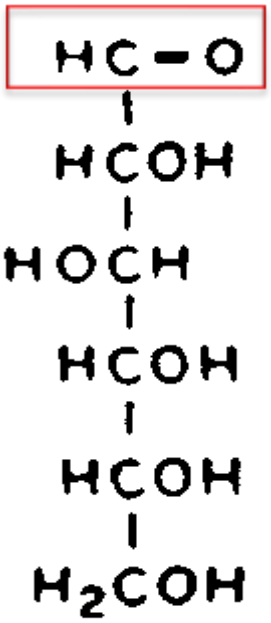
- Ketoses which contain a **ketone** ()group

- The ketoses may be represented by the general formula……

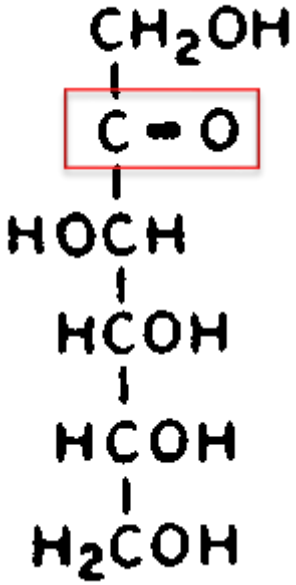
❖ Numbering of carbon atoms in Monosaccharides

- The carbon atoms are numbered as ……

C - 1 is an **aldehyde** functional group & **C- 2** is a **ketone** functional group



GLUCOSE



FRUCTOSE

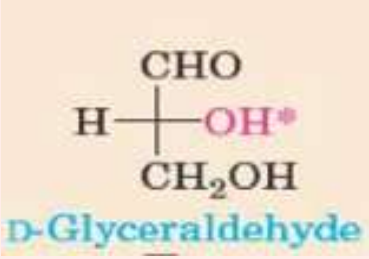
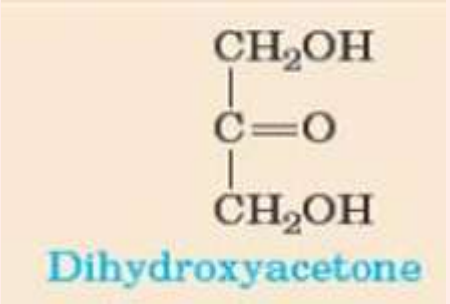
- Monosaccharides can further be divided on the basis of the number of **carbon atoms** they possess

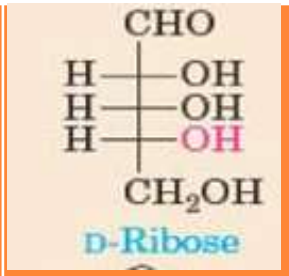
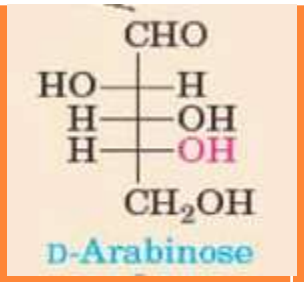
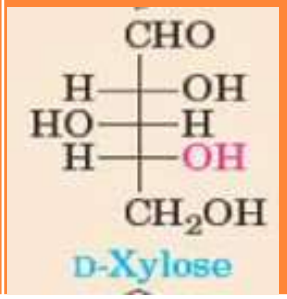
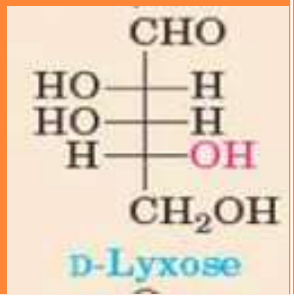
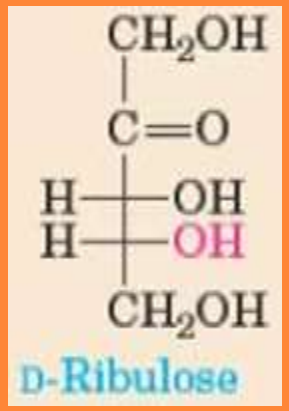
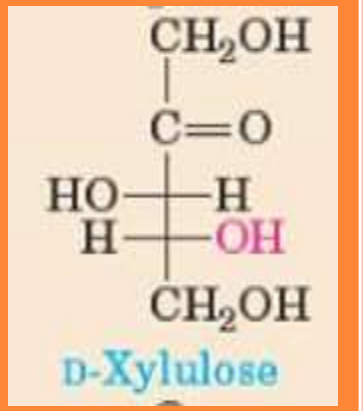
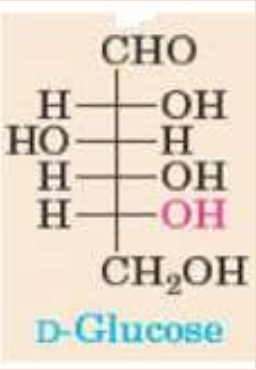
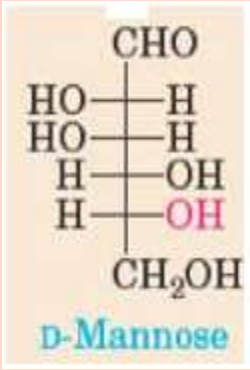
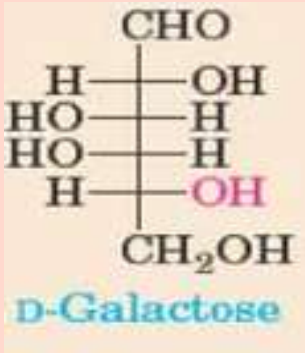
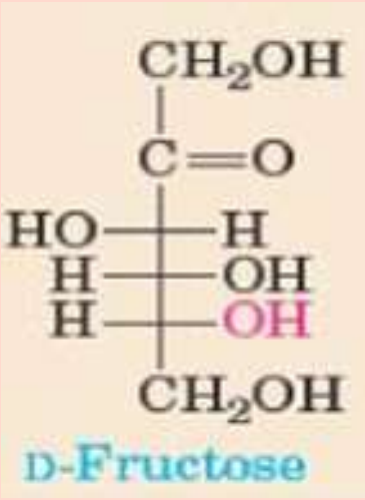
- The number of carbon atoms in an **aldose or ketose** may be specified by
  - ✓ Triose
  - ✓ Tetrose
  - ✓ Pentose
  - ✓ Hexoses

- For ex. **Glucose** with **six** carbon atom is an **aldohexose**

  Fructose with **six** carbon atom is a **ketohexose**

❖ DIFFERENT TYPES OF MONOSACCHARIDES

Monosaccharide		Specific Example	
No. Carbon atoms	**Called as**	**Aldoses**	**Ketoses**
3	Triose		
4	Tetrose		

5	**Pentoses**	 D-Ribose  D-Arabinose  D-Xylose  D-Lyxose	 D-Ribulose  D-Xylulose
6	Hexoses	 D-Glucose  D-Mannose  D-Galactose	 D-Fructose

ISOMERISM OF MONOSACCHARIDES

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❖ ISOMERISM OF MONOSACCHARIDES

- **Existence** of different compounds having **same molecular** formula but **different structural** forms are **isomers**

- Monosaccharides exhibit a variety of isomerism such as

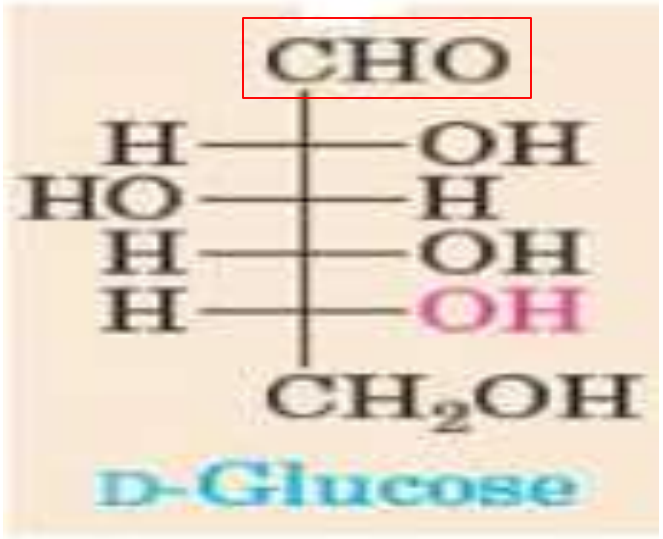
✓ Aldose- Ketose isomerism

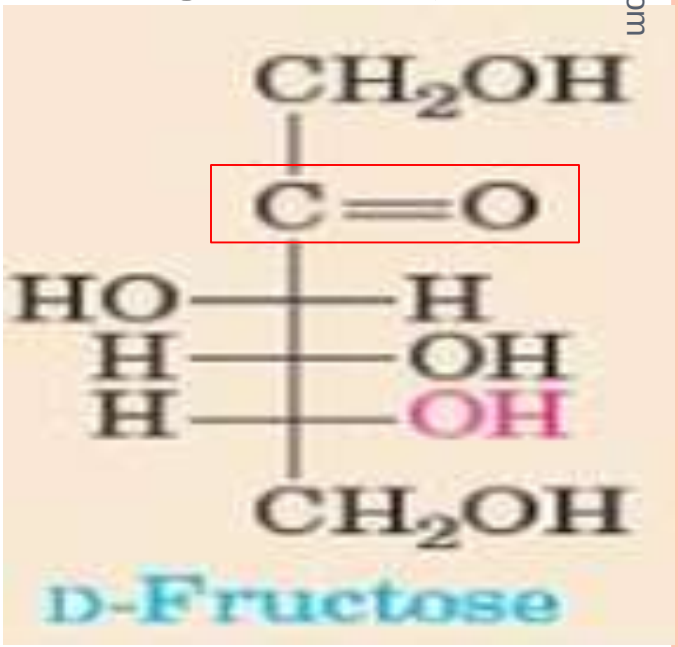
✓ Sterio isomerism

✓ Optical isomerism

ALDOSE- KETOSE ISOMERISM

- In a **monosaccharide** either an **aldehyde or a ketone** group is present. The former is called **aldose** while the latter is known as **Ketose**
- Glucose & fructose both have a formula **$C_6H_{12}O_6$** but **glucose** is an **aldohexose** (aldehyde bearing hexose) & **fructose** is a **Ketohexose** (Ketone bearing hexose), so they are **isomers** to one another

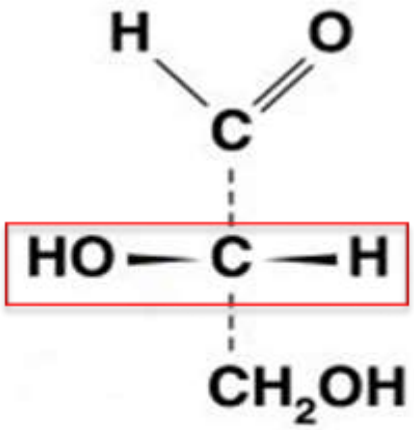




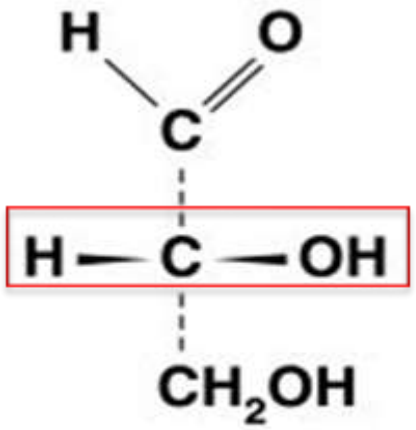
❖ OPTICAL ISOMERISM

- A **compound** is said to have **optical activity** when it **rotates** the **plane polarized light** passing through it
- Two compounds having similar formula may have different optical activity
- When a optically active substance **rotates** the plane of polarized light in a **clockwise** direction, it is called as **dextrorotatory** or '**d- isomer**' & when it rotates the plane polarized light in the **anticlockwise** direction, it is **laevorotatory** or '**l- isomer**' of the substance
- The **d & l** isomers are also expressed as **(+) & (-)** respectively

- The two forms of glyceraldehydes **(d & l forms)** rotate the plane of polarized light in the opposite direction by the same amount
- As it turns out **D- Glyceraldehyde** rotates the plane of polarized light to the **right** & is therefore dextrorotatory labelled as **(+)** & rotates the plane of polarized light to the **left** & is therefore **laevorotatory** labelled as **(-)**



l-glyceraldehyde (-)



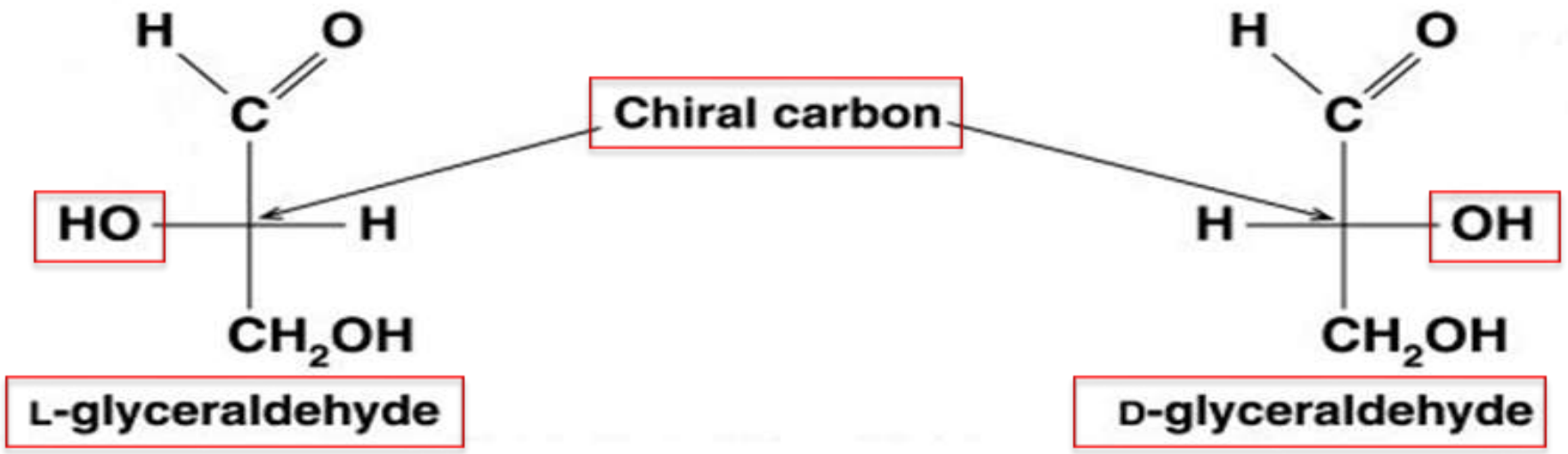
d-glyceraldehyde (+)

❖ STERIO IOSMERISM

- It occurs when the **same compound** due to **different spatial** arrangement of the groups attached to its **asymmetric carbon** atom exists in more than one form

- When any carbon atom of a compound is attached with **four** different groups or atoms, it is called an **asymmetric carbon atom**

- **In the case of Glyceraldehyde t**he carbon atom **C-2** is unique since it has four different groups (OH, CHO, H, CH_2OH) attached & is therefore an **asymmetric carbon.** The **C-2 atom** is called **Chiral carbon atom**
- According to this observation monosaccharide have two different forms namely **D- sugars & L- sugars**, depending on their relation to the direction of the **–OH** group on the **number 2 carbon atom**

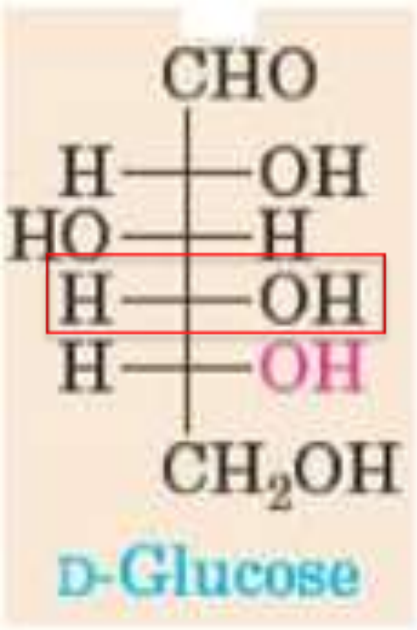


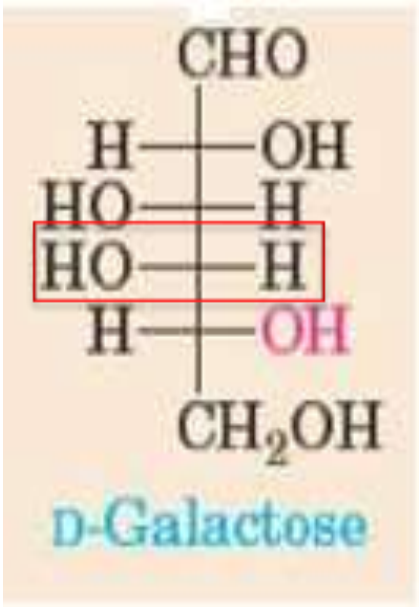
- The **D- form** will have the **–OH** group next to the bottom carbon atom (primary Alcohol group) on the **right** side, while the **L- form** will have it on the **left** side

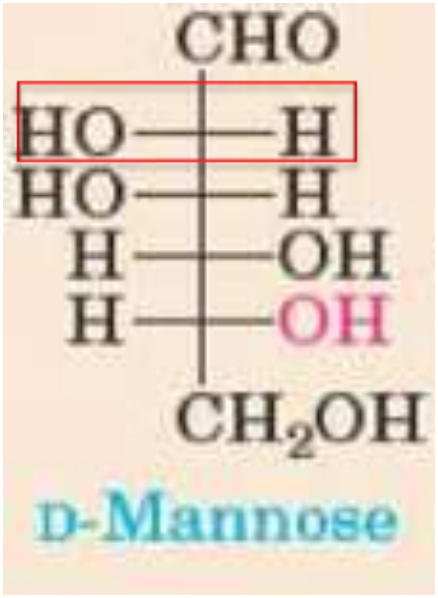
- i.e., the **D- form** will have the **–OH group** on the **right side** of the **penultimate C- atom (C- atom away from functional group & near to terminal C- atom)** , while the **L- form** will have it on the **left side** of the penultimate **C- atom**

- Another type of **sterioisomerism** known as **epimerism**
- **Two sugars** which differ from one another only in the configuration around a **single C- atom** is said to be **epimers**
- A pair of **diasteriomers (**optical isomers that are **not mirror images** are called **diasteriomers**) that differ only in the configuration around a single carbon atom are said to be **epimers**
- These are **structural isomers** i.e. They have **same molecular formula** of **$C_6H_{12}O_6$** but different **structural formula** & consequently they differ in their **physical & chemical** properties

- Actually these isomers are formed as a result of interchange of the **– OH & - H** on carbon atom **2, 3 & 4** of glucose
- **Glucose & Galactose** differ in the configuration of a **single carbon** atom i.e, carbon atom **4**, while **glucose & mannose** differ in a C- atom **2**, Compound that differ in this manner are called as **epimers**

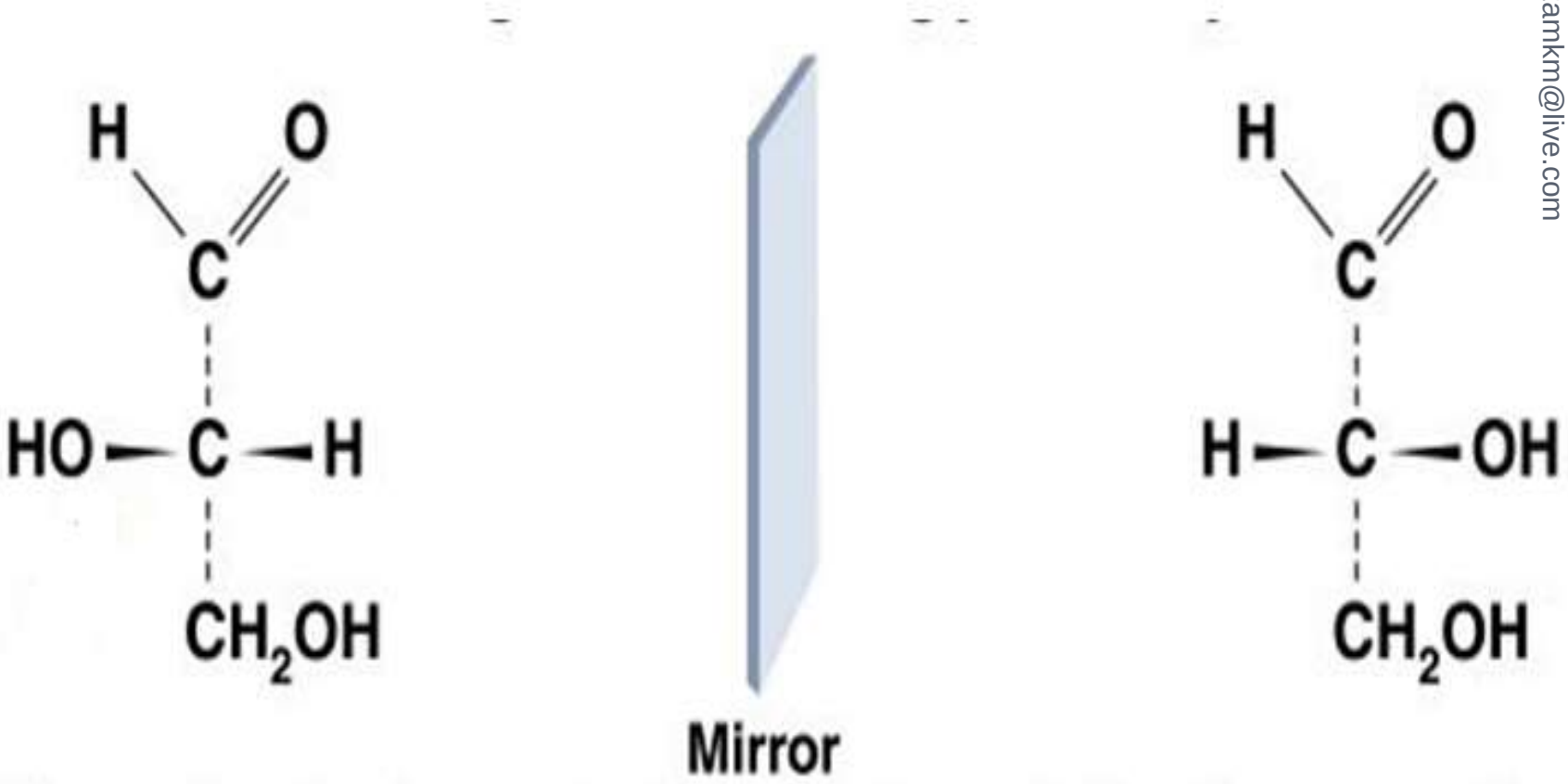


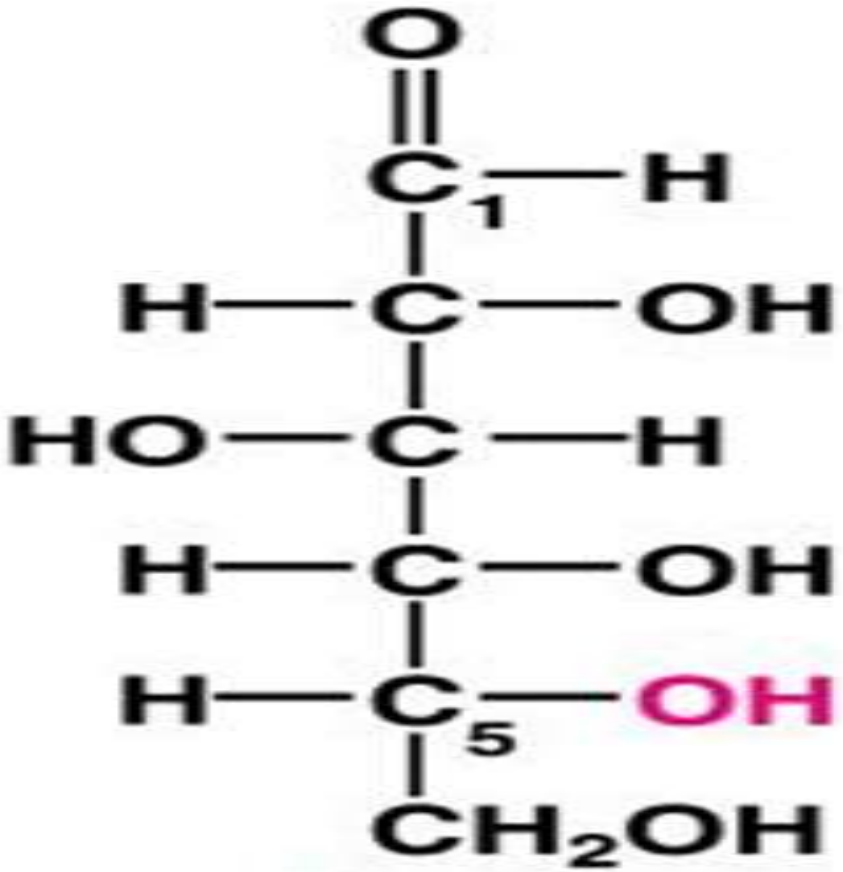




Enantiomers:

- The Non super impossible **mirror images of stereo isomers** are known as **enantiomers**





Glucose

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STRUCTURE OF CARBOHYDRATES

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STRUCTURE OF CARBOHYDRATES

- Carbohydrates are represented by **three** types

- ✓ Fischer Projection
- ✓ Haworth Cyclic Structure
- ✓ Conformational formula

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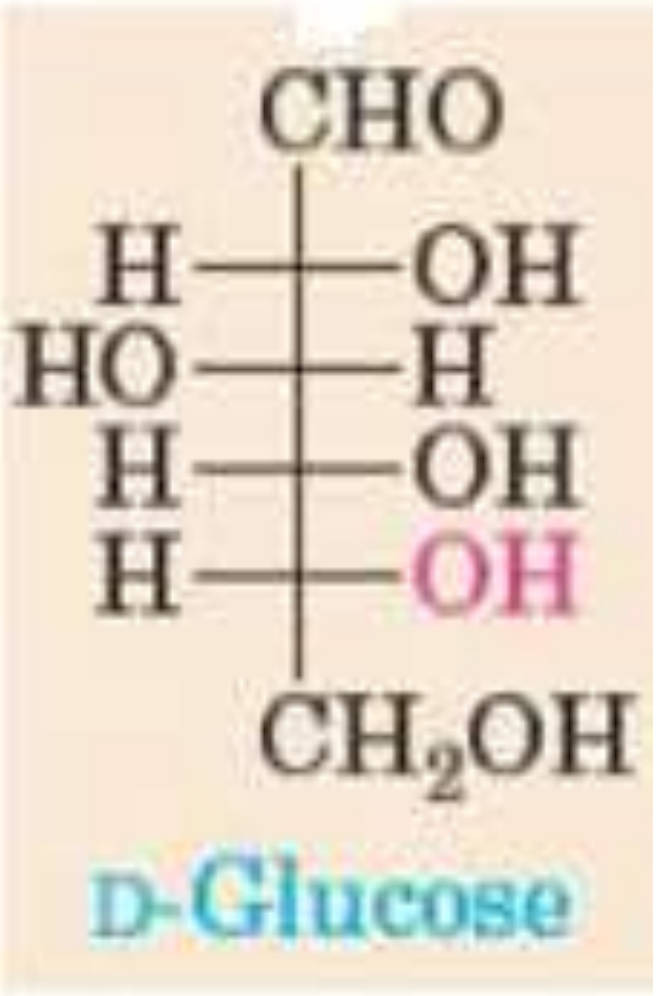
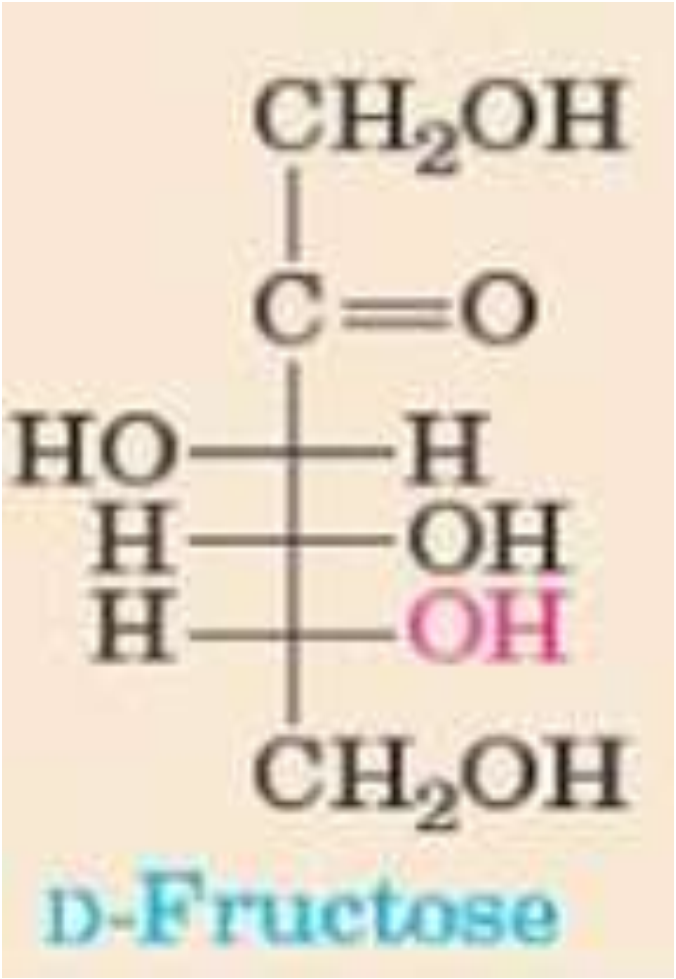
❖ FISCHER PROJECTION





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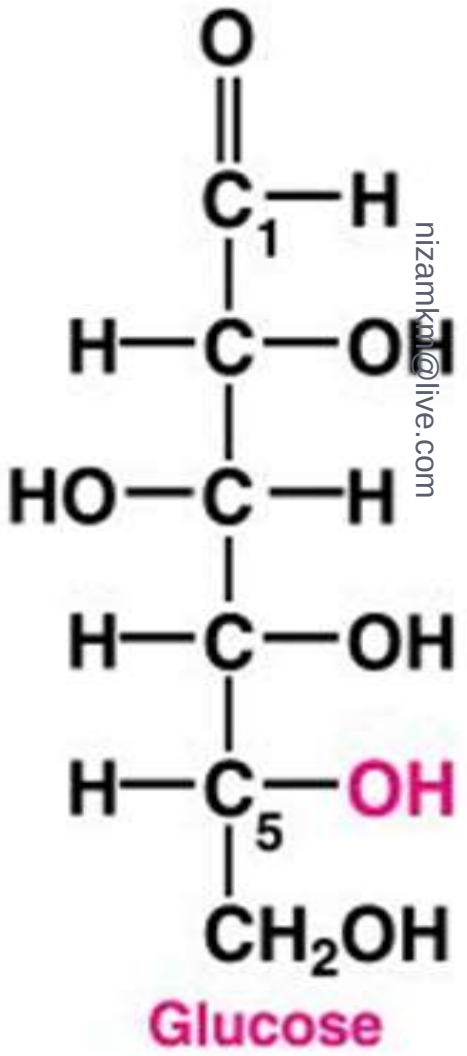
❖CYCLIC HEMIACETAL FORMS OF D-GLUCOSE

- Aldohexose, Ketohexose & aldo pentose **in solution** undergo **cyclisation** when **treated** with equivalent amounts of **alcohol** & form a **Hemiacetal or hemiketal** in the **aldose & Ketose** respectively

- The glucose structure contains an **aldehyde** group & **five hydroxyl** group in the **same** molecule

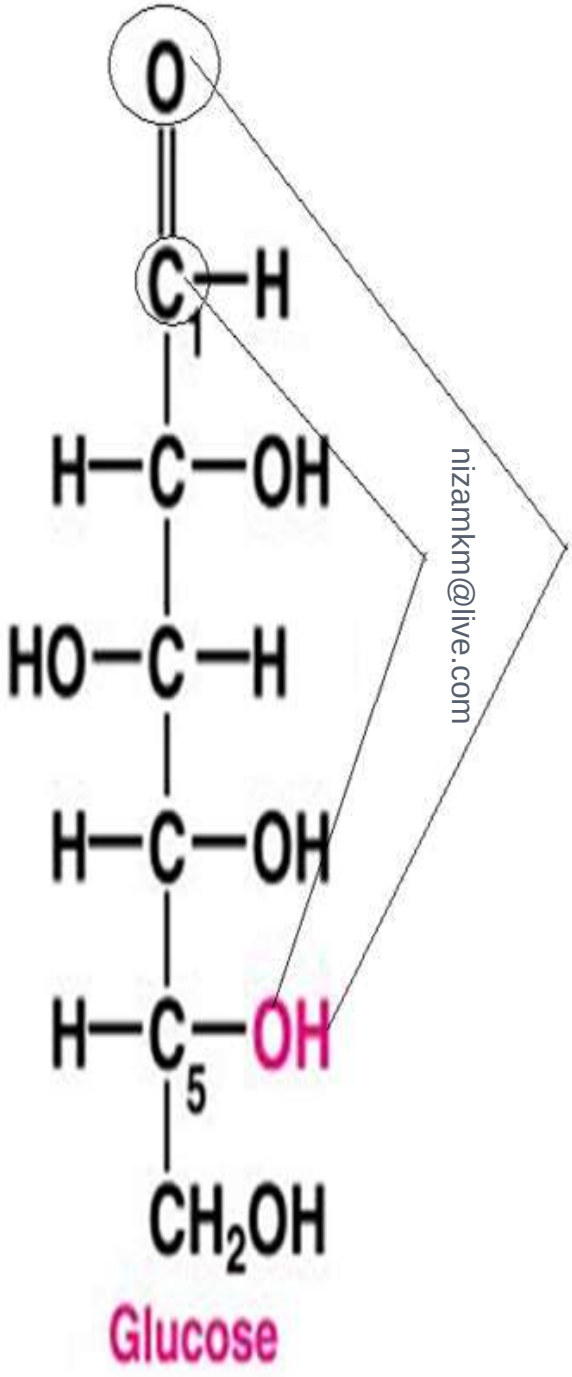


- Consequently their can be **intramolecular** interaction between the **carbonyl** group & **one** of the **hydroxyl** group

- The hydroxyl group on **C5** is able to react with the **carbonyl** group on **C1** to produce a closed **pyranose** ring

- The reaction results in a **ring** i.e., the product is **cyclic hemiacetal**

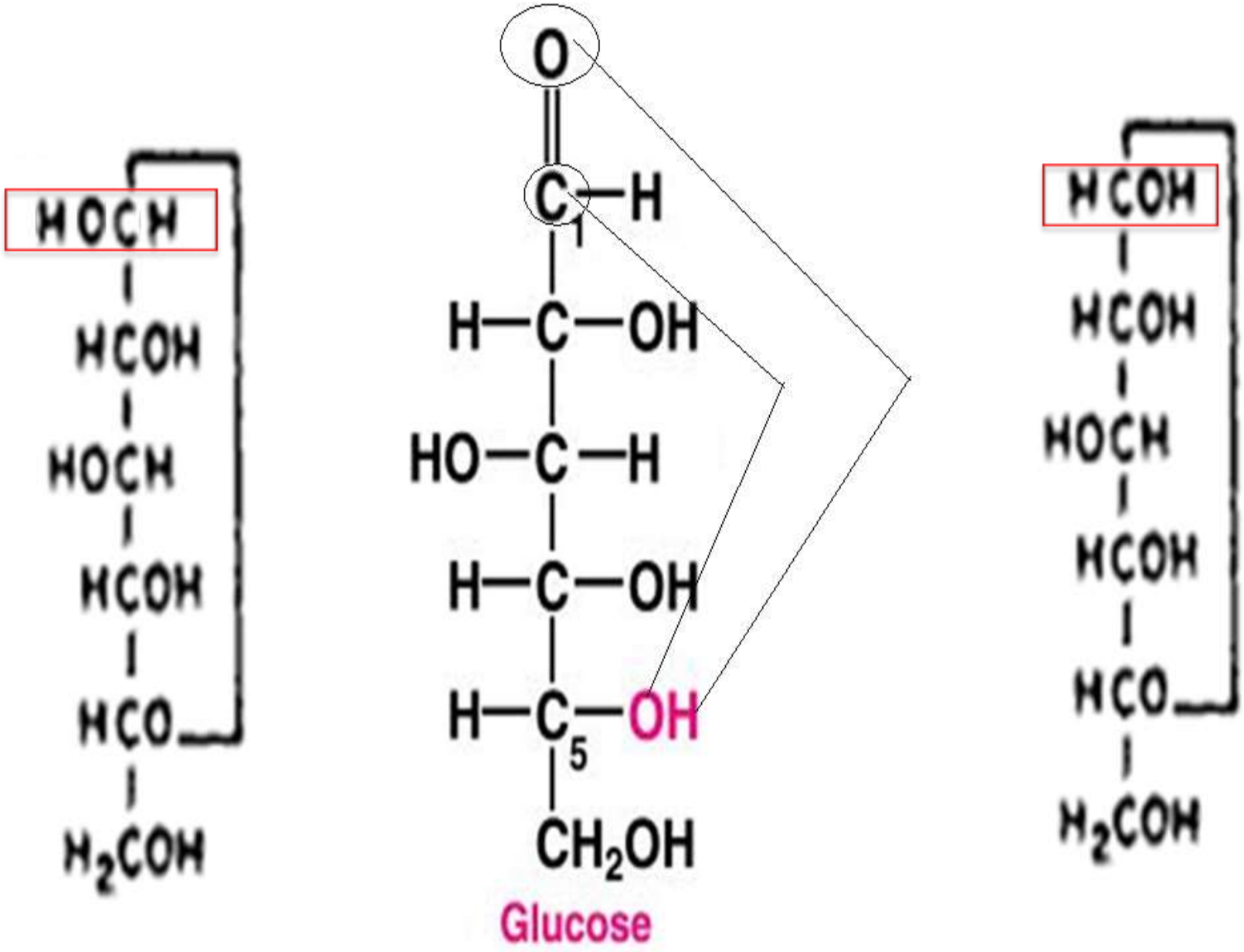
- i.e., linking the carbonyl carbon atom with the other carbon atom by a **C-O-C** linkage



- As a result of **cyclisation**, carbon **one** becomes **asymmetric** resulting in the formation of **two isomers**

- The isomers having the **hydroxyl** group to the **right** of the **C-1** is designated as **α- D glucose** and the one having the hydroxyl group on the **left** of **C-1** is designated as **β-D glucose**

- The **α & β** sugars are known as **anomers** i.e., anomers **differ** only in the configuration around **C-1** & this carbon is referred to as **anomeric carbon**



Glucose

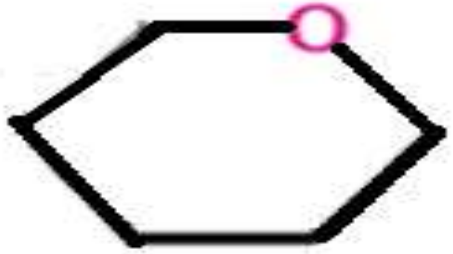
❖ HAWORTH CYCLIC STRUCTURE

- The **Fischer** projection don't accurately describe the true **shape** of the **cyclic hemiacetal** forms of glucose

- So **W. N. Haworth** (English Chemist) suggested a new formulation, in which **rings** are written as **flat or planar** hexagons, is more **correct**

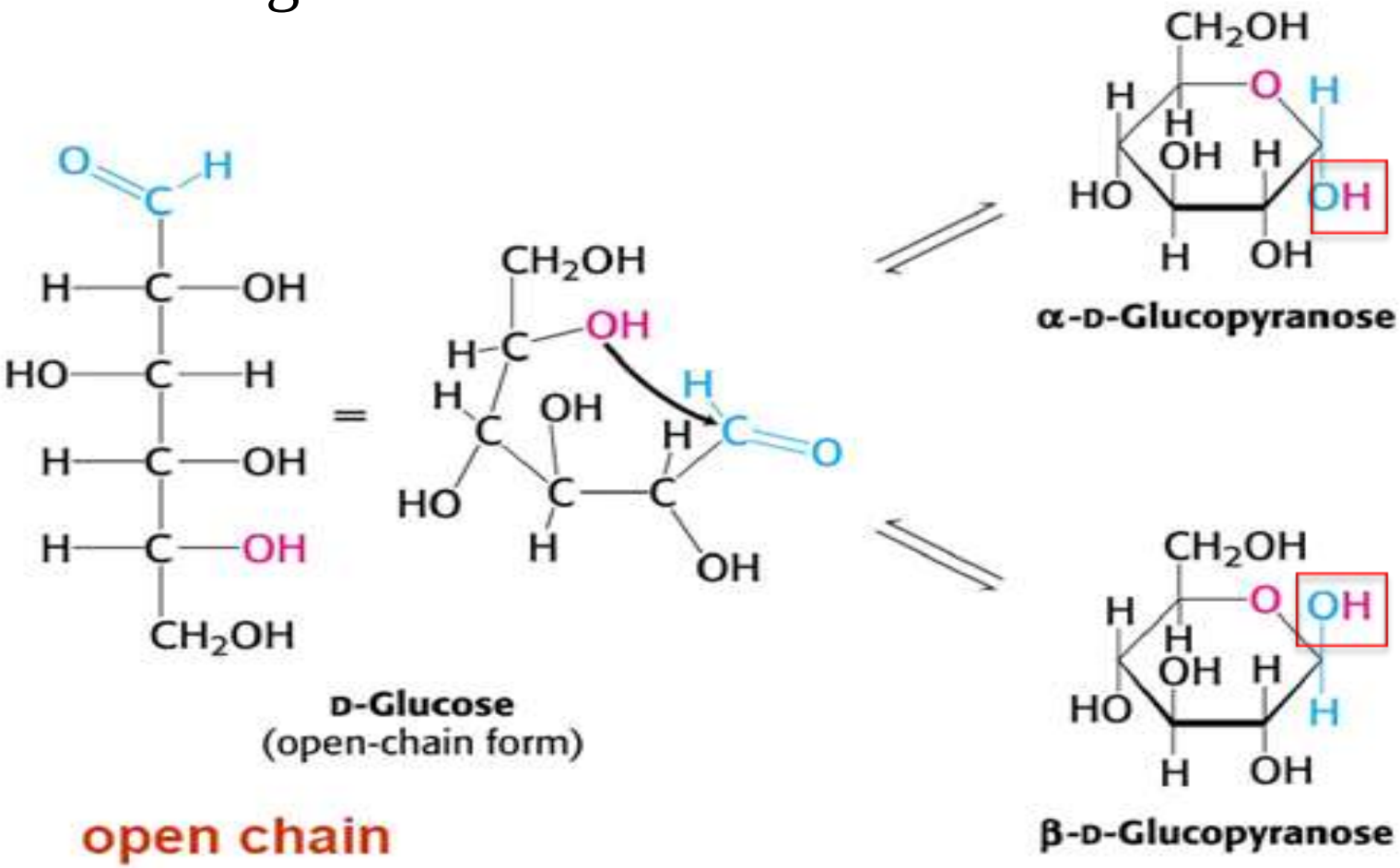
- The **six** membered ring shown for **α & β- D** glucose is known as **pyran** ring because **pyran** is the name of a **heterocyclic** compound whose ring consists of **five carbon** atoms & **one oxygen** atom

- Any **CHO** containing a **six** membered ring is called **pyranose** & its glycosides are called **pyranosides**

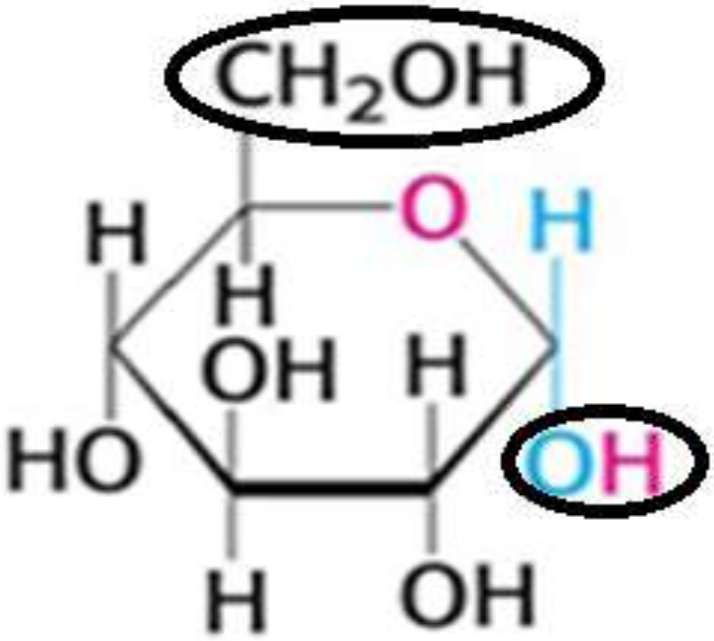


Pyran

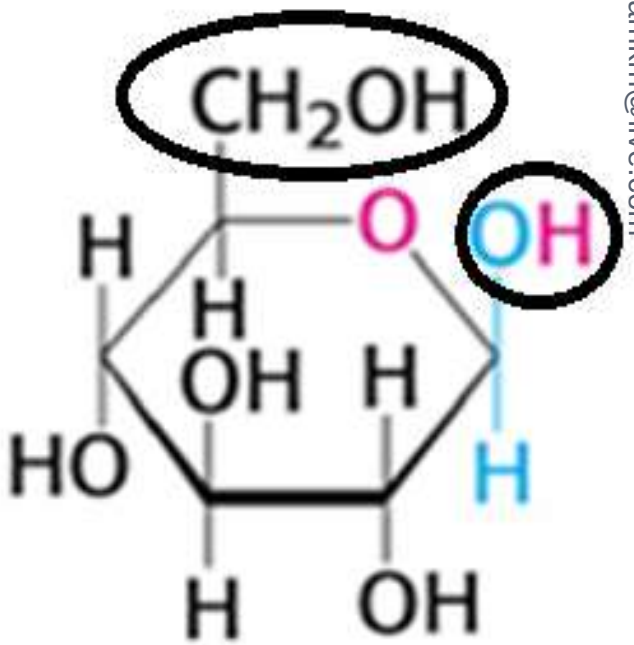
- The **Haworth** formula for **α– D glucose** shows the **C1 - OH** group below the **plane of the pyranose ring**, for **β- D glucose C1** alcohol pointing **above** the **plane** of pyranose ring



- i.e., the **α- form** has the **– OH** group on the **opposite** side from the **– CH_2OH** & **β- form** has the **–OH** group on the **same** side as the **CH_2OH** group

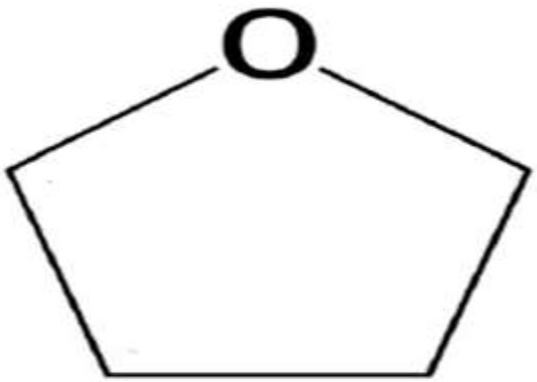


α-D-Glucopyranose



β-D-Glucopyranose

- A carbohydrate containing a **five** membered ring is called **furanose** because **furan** is the name of a heterocyclic compound whose ring consists of **four carbon** & **one oxygen** atom
- The **glycosides** of furanose are called **furanosides**



Furan

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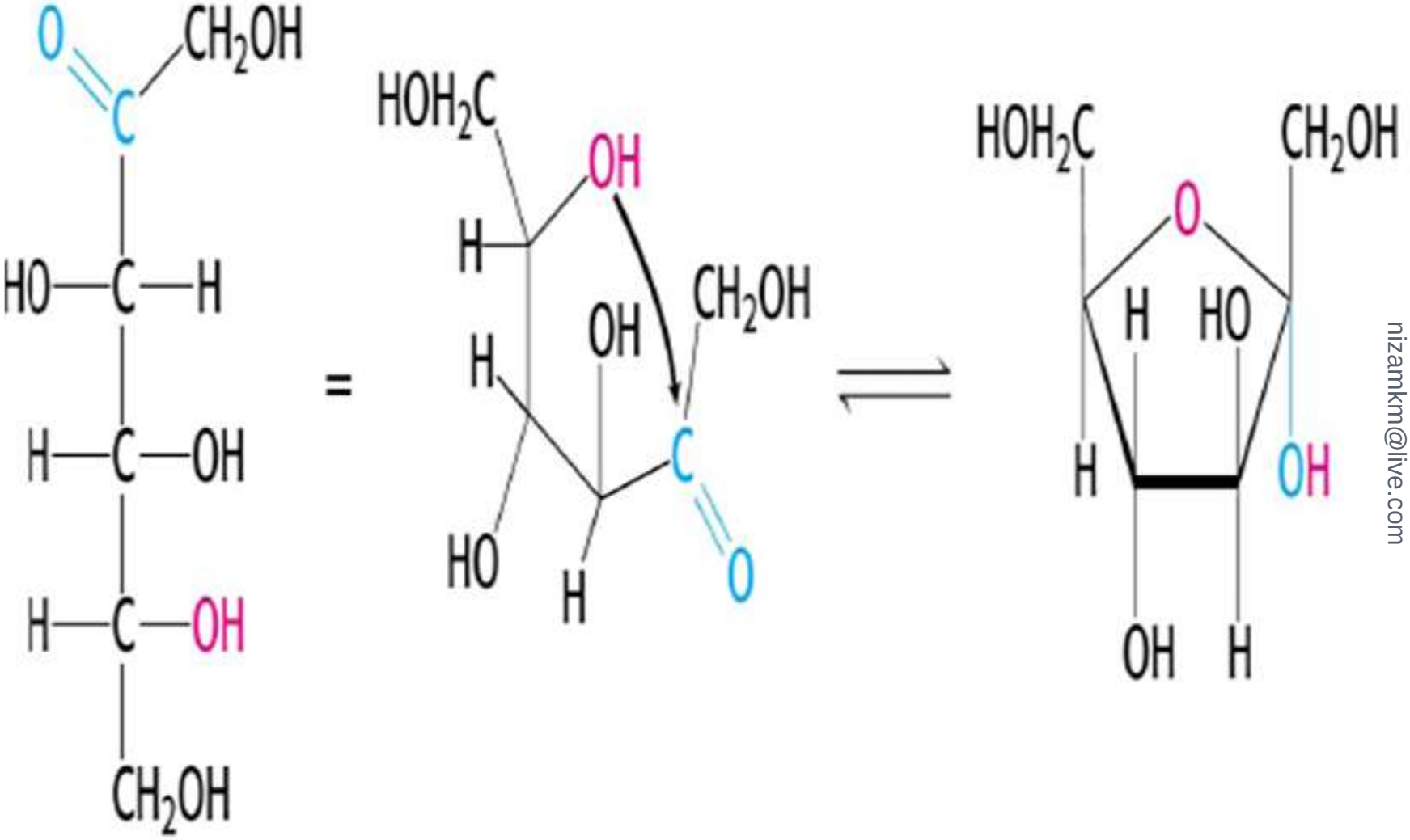
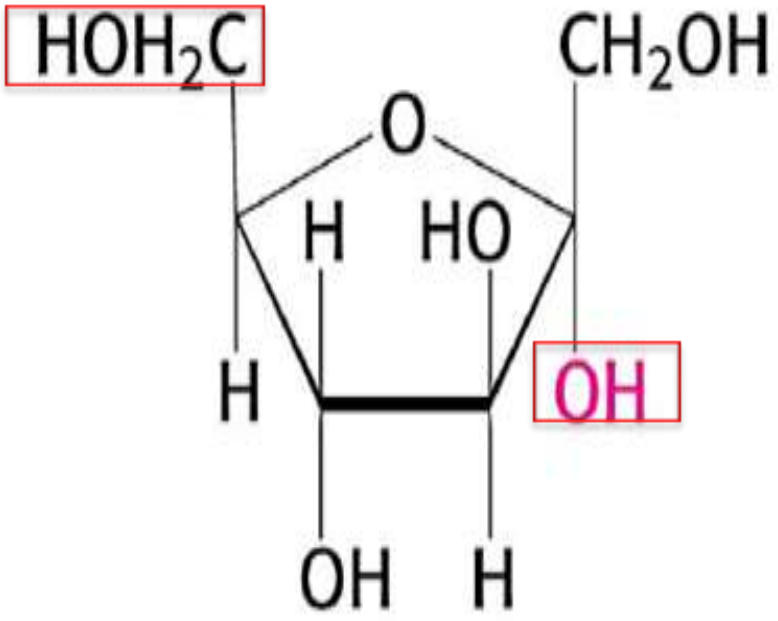
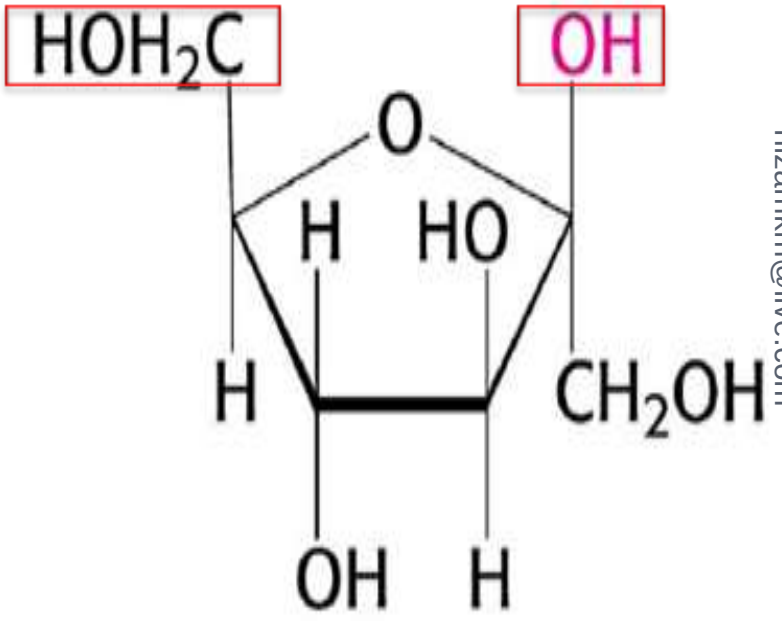


D-Fructose
(open-chain form)

α-D-Fructofuranose
(a cyclic form of fructose)



α-D-Fructofuranose



β-D-Fructofuranose

❖ CONFORMATIONAL FORMULA

- The sugar ring in the **Haworth** structure is **not planar** & therefore it **does not** represent the correct conformation of monosaccharide. So conformational formula's are used

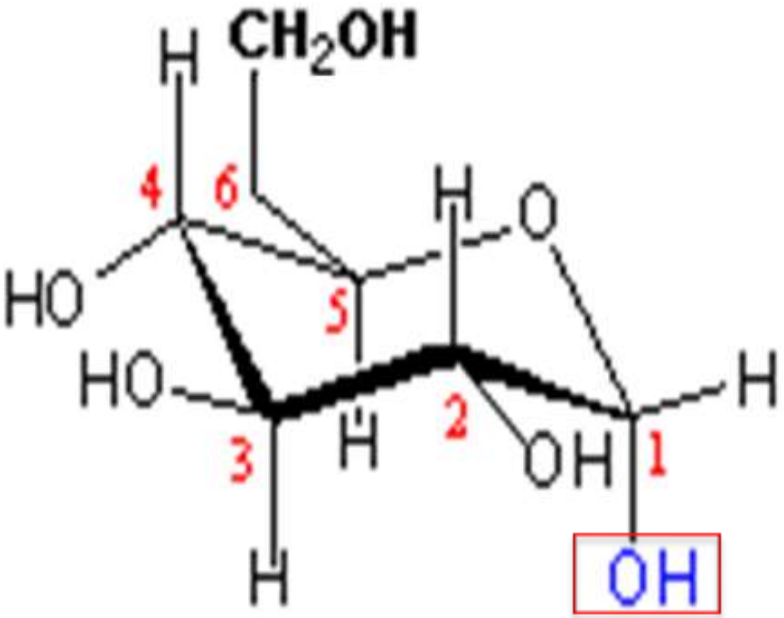
❖ There are **two types**

✓ Boat Conformer

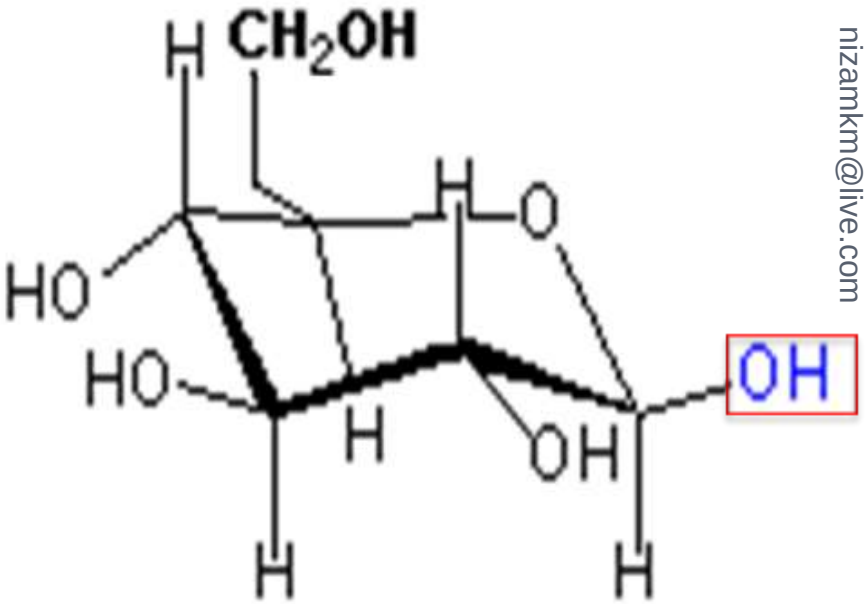
✓ Chair Conformer

- The **chair** conformer is more stable than **boat** form

- The **stable chair** conformational formula of **α-D glucose & β- D glucose are……**



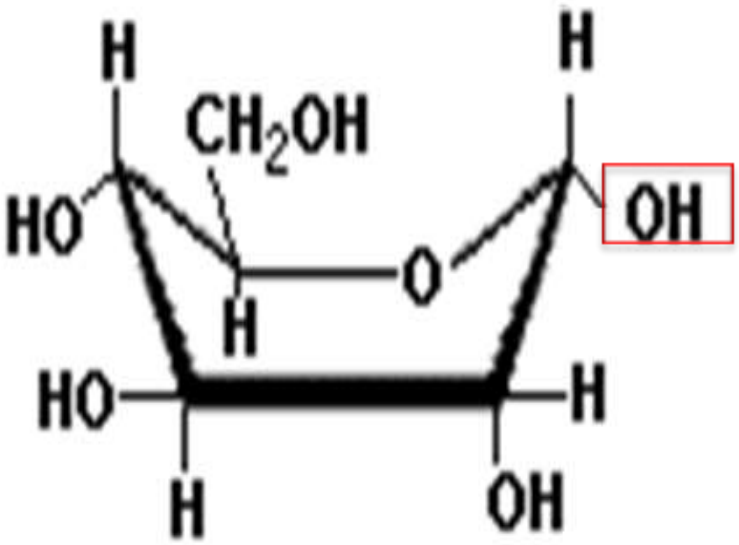
α-D-glucopyranose



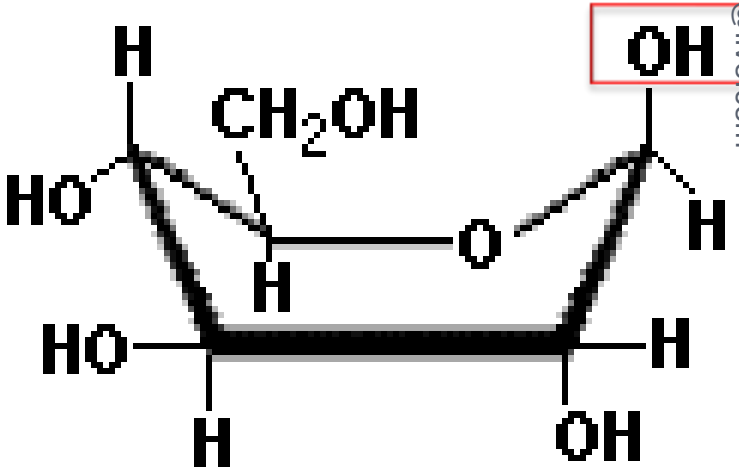
β-D-glucopyranose

❖BOAT CONFORMER

α-D glucose (boat form)



β-D-Glucose(boat form)



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❖ PROPERTIES OF MONOSACCHARIDES:

- The taste is sweet
- They are solid at room temperature
- They are soluble in water because of the **hydroxyl group**; the very **concentrated** solutions are thick
  - ✓ E.g.: Honey

- They are **reducing sugars** containing potential reducing group such as **free aldehydes or ketone** have the ability to **reduce** Fehling's solution & Tollen's reagent are referred to as **reducing sugars**
  - ✓ E.g.; glucose & fructose

- **Aldoses** have an aldehyde **(CHO)** group can be easily oxidised to **COOH** (Carboxylic group)**.** For this reason they are called **reducing sugars**

- Ketose have a hydroxyl **(–OH)** group on the carbon next to the **carbonyl group** which can be **oxidised** & they are called **reducing sugars**

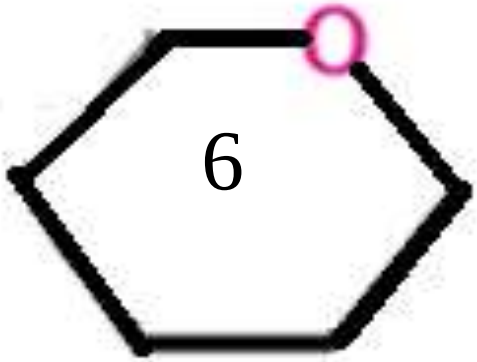
MUTAROTATION

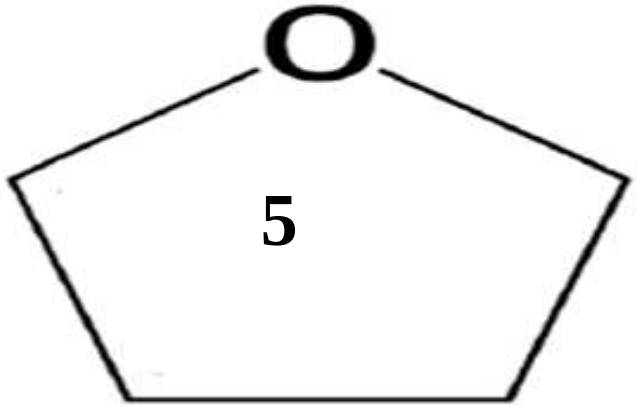
- **D- glucose** can be obtained in two forms - **α** form & **β** form
- **α** form has a **melting** point **146° C** & a **specific rotation** of **+113º**
- **β** form has a **melting** point of **150° C** & a **specific rotation** of **+19º**
- If either form of these crystalline form is dissolved in **water** & allowed to **stand,** the **specific rotation** of the solution so prepared changes gradually until a final value of **+53°** is obtained
- Its **spontaneous** change of this kind in the **specific rotation** of a solution of an optically active compound is called **mutarotation**

- Ability to exists either a **linear or ring** structure

- In monosaccharide **5 carbon** atom mainly exist in **cyclic** form

- **6** membered ring is called **pyranose** ring & **five** membered rings are called **furanose** ring





- **Optical Rotation (Refer)**

- These sugars are readily **fermented** by microorganisms

- They **prevent** the growth of microorganisms in high concentration so they may be used as **preservatives**

❖ CARAMELIZATION

- It is **non- enzymatic** browning
- Caramelization occurs during dry heating and roasting of foods with a high concentration of carbohydrates **(sugars)**
- When **sugars** are subjected **to heat** in the **absence** of water or are heated in concentrated solutions a series of reactions occur that finally leads to **caramel** formation
- **Typical caramel** flavor is the result of a number of sugar **fragmentation** reactions (**flavour** production) **& dehydration** products, including **diacetyl, acetic acid & formic acid**
- Caramelization results from the action of the **heat** on sugars at about **175° C**

- At **high** temperature sugars **dehydrate, break down & polymerize** (polymerization reactions, **colour** production) into **viscous caramels**, the chemical changes associated with melting sugars result in a **deep brown amber color & new flavors**

- ✓ E.g., is the **Browning of bread-** when toasted in which, **caramelization** takes place under the oven heat & the **sugar** adds golden brown, flavorful & slightly crisp surface that tastes great & helps retain moisture in the product

- Once the **melting point** has been obtained the **sugars** will **caramelize**

- Each sugar has its own caramelization **temperature**

- ✓ **Galactose**
- ✓ **Sucrose**
- ✓ **& glucose**

  Caramelize at about **160° C**

- ✓ But **fructose** caramelizes at **110° C**

- ✓ & **maltose** caramelizes at about **180° C**

- **Caramel** has a pungent taste, is often bitter, is much **less sweet** than the original sugar from which it is produced & soluble in water

PROCESS OF CARAMELIZATION

Melting of the sugar at high temperatures

Foaming (boiling),sugar decomposes into glucose & fructose

Condensation, individual sugars lose water and react with each other, for example **difructose-anhydride**

Isomerization of aldoses to ketoses and further dehydration reactions

Last reactions include both **fragmentation** reactions (flavour production) and **polymerization** reactions (colour production).

Diacetyl is an important **flavour** compound, produced during the first stages of Caramelization. Diacetyl is mainly responsible for a buttery or butterscotch flavour

- Commercial caramels are produced directly by heating sugar, or by heating sugar in the presence of co-factors, such as **ammonia or sulphite**
- This results in caramels with different colours or charged caramels
- These aspects are very important for the use of different caramels in foods
- Caramels used to colour **soft drinks** should be **negatively** charged to prevent reaction with **phosphates** which causes precipitation and loss of colour
- On the other hand, caramels used for **bakery** goods should be **positively** charged

- The highest rate of the colour development is caused by **fructose** as Caramelization of fructose starts at **lower** temperature

- Baked goods made from honey or fructose syrup thus are generally a bit darker than those made with sugar

- Caramels are complex mixture of various high molecular weight components. They can be classified into three groups:

✓ Caramelans ($C_{24}H_{36}O_{18}$)

✓ Caramelens ($C_{36}H_{50}O_{25}$)

✓ Caramelins ($C_{125}H_{188}O_{80}$)

❖ ESTERIFICATION

- As monosaccharides posses hydroxyl groups (-OH), they form esters with acids

- E.g., esterification of glucose to Glucose - 6-phosphate

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❖ OXIDATION REACTION

- Mild oxidizing agents such as sodium hypoiodite (NaOI) & bromine water oxidize **aldose to aldonic acids** when **–CHO** (aldehyde group) of the aldose is converted to **– COOH** (Carboxylic group)

✓ Ex. Glucose is oxidized to gluconic acid

- On the other hand, strong oxidizing agents such as **nitric acid** oxidizes **aldose to glucaric** (aldaric) acid

- Here both **–CHO & CH_2OH** are oxidized to – COOH

✓ Ex: **Glucose** is oxidized to **glucaric acid**

- As ketoses **don’t** undergo oxidation, this reaction used to distinguish an **aldose from a ketose**

- Dilute hydrochloric acid (HCl) oxidizes only the **terminal –CH2OH** group with the formation of **uronic acid**
- Glucose is then oxidized to **glucuronic** acid

DERIVED MONOSACCHARIDES

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❖ DERIVED MONOSACCHARIDES

- This group includes compound which are structurally similar to the monosaccharides but deviating from them in some regard

- There are **two** important derivatives

✓ **DEOXY SUGARS**

✓ **AMINO SUGARS**

DEOXY SUGARS

- Sugars in which one of the hydroxyl group is **replaced** by a hydrogen atom are known as **deoxy sugars**

- The common example is deoxy ribose found in nucleosides, nucleotides & nucleic acids (DNA)

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❖ AMINO SUGARS

- Sugars in which **hydroxyl** group has been **replaced** by an **amino** group are known as **amino sugars**

- ✓ For example D- Glucosamine, D- galactosamine, D-mannosamine, all of these are found in a wide variety of biological materials

- **Glucosamine** is the product of hydrolysis of **chitin**, the major polysaccharide of shells of insects & crustaceans

OLIGOSACCHARIDES

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❖ OLIGOSACCHARIDES

- The oligosaccharides are carbohydrates contain **2 to 6** monosaccharide units joined by a linkage known as **glycosidic linkage**
- They are classified as **di, tri, tetrasaccharides** etc depending on the number of subunits
- They can be hydrolyzed by **acids or enzymes** into their subunits

❖ DISACCHARIDES

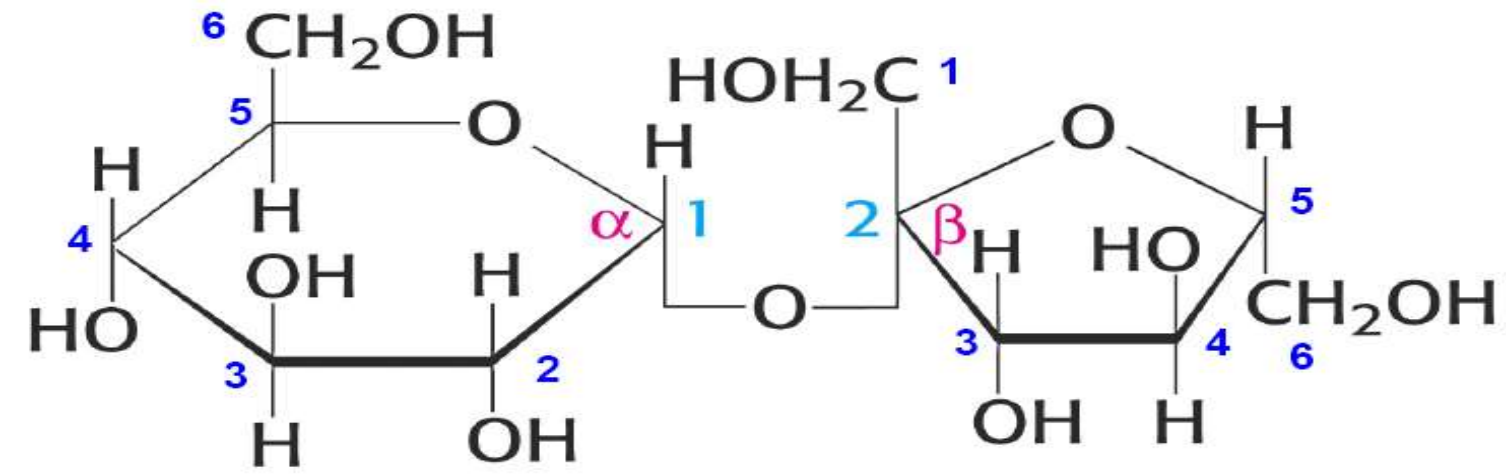
- These are formed when **2** monosaccharide molecules joined together with the **elimination** of one molecule of **water**
- i.e., these consists of two monosaccharide units/ molecules joined by **glycosidic** linkage
- They have the general formula **$C_{12}H_{22}O_{11}$**, upon hydrolysis which yield **two** monosaccharide molecules
- Ex. of **disaccharides** are :-

✓ Sucrose, Lactose, Maltose

SUCROSE

- It is the ordinary **household** sugar
- The most common sources are sugar **cane** & sugar **beets**
- In sucrose **both** the **carbonyl groups** are involved in the formation of glycosidic bond
- So sucrose contains **no active** group i.e., both the **reducing groups** are involved in linkage, so it is a **non- reducing** sugar

- It is formed by the elimination of a molecule of **water** from **α- D-** Glucose & **β- D-** fructose



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

- The figures in **brackets** indicate the position of the **glycosidic linkage** between the **two** monosaccharide units

❖ MALTOSE

- It is α–D glucosyl- 1, 4 – D glucose
- Maltose is a **malt** sugar, found in germinating cereals, produced during digestion of **starch** into **glucose**
- It's a **reducing** sugar because only **one** reducing group forms the linkage
- On hydrolysis yields **two** molecules of **glucose**

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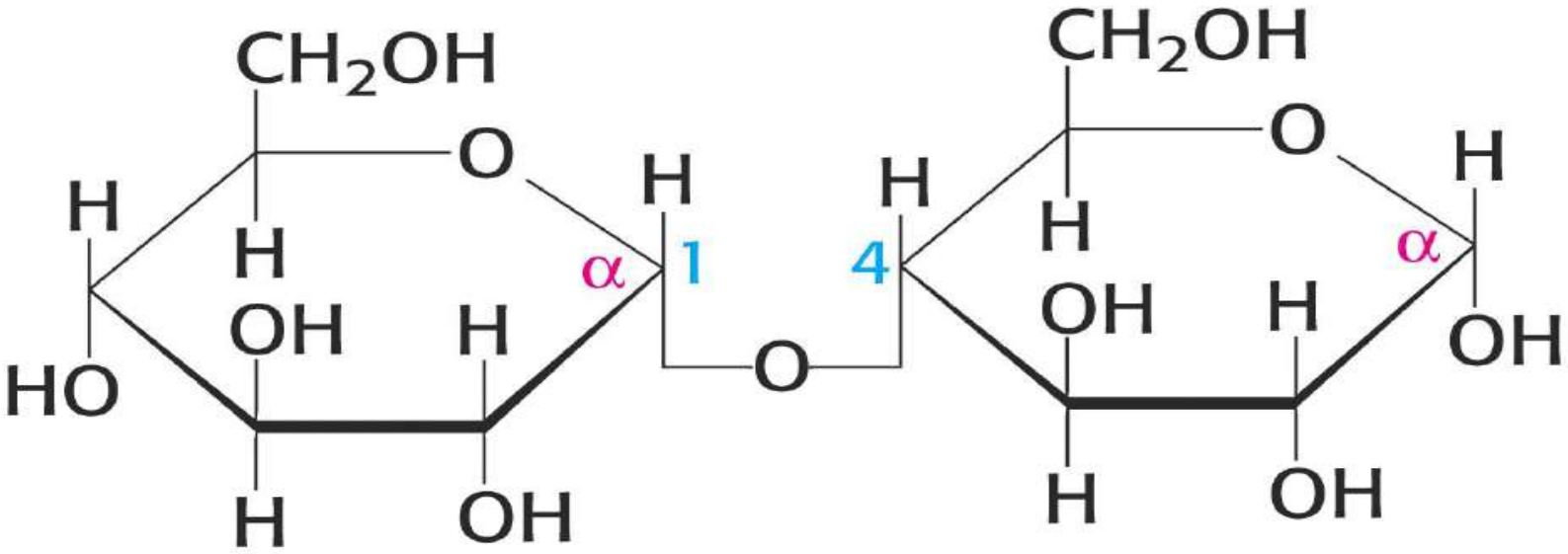
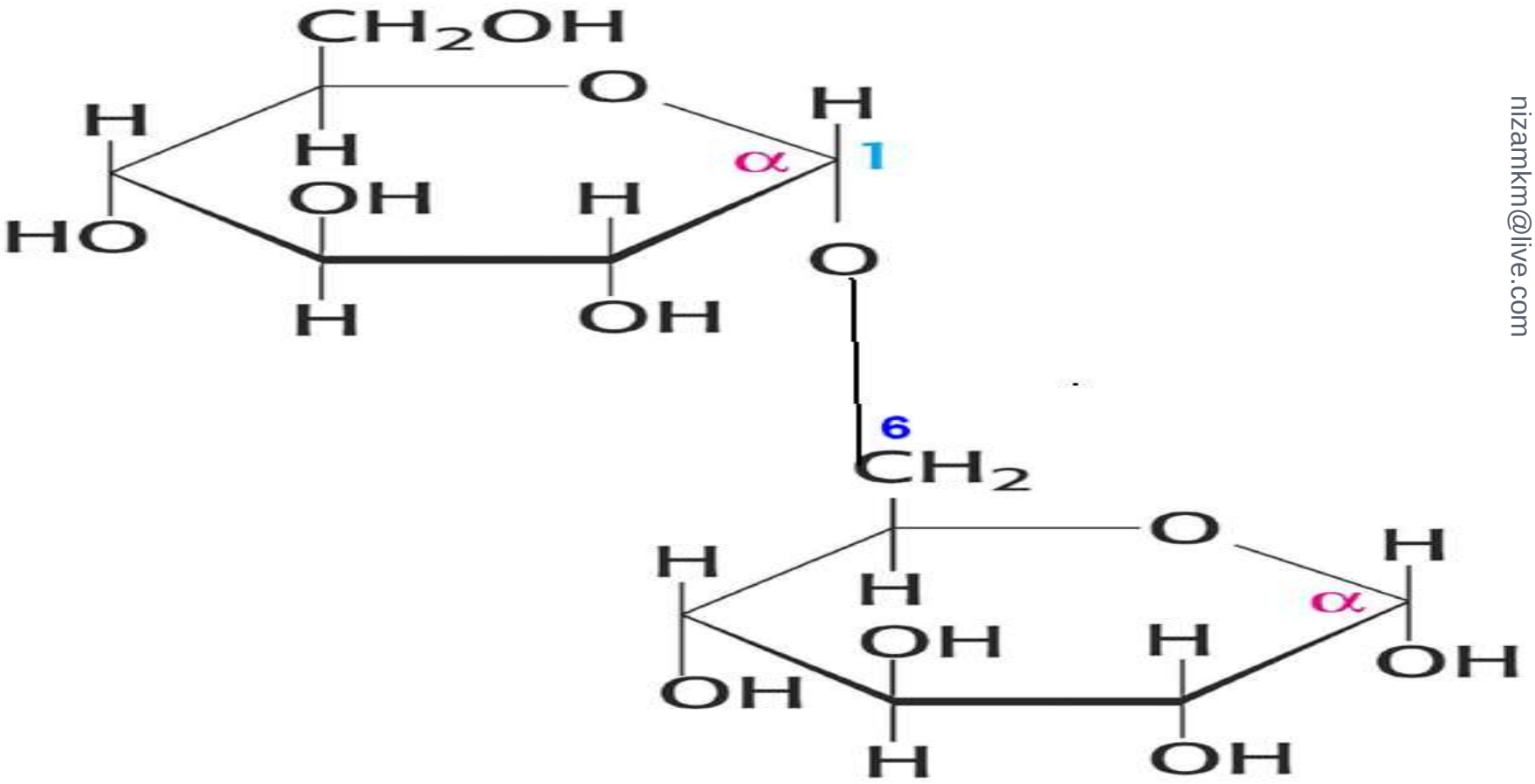
- Maltose consists of **2** molecules of **glucose** with a **glycosidic linkage** formed between the anomeric hydroxyl of **one** glucose unit & the hydroxyl on the **fourth** carbon atom



Maltose
(α-D-Glucopyranosyl-(1 → 4)-α-D-glucopyranose

❖ ISOMATOSE

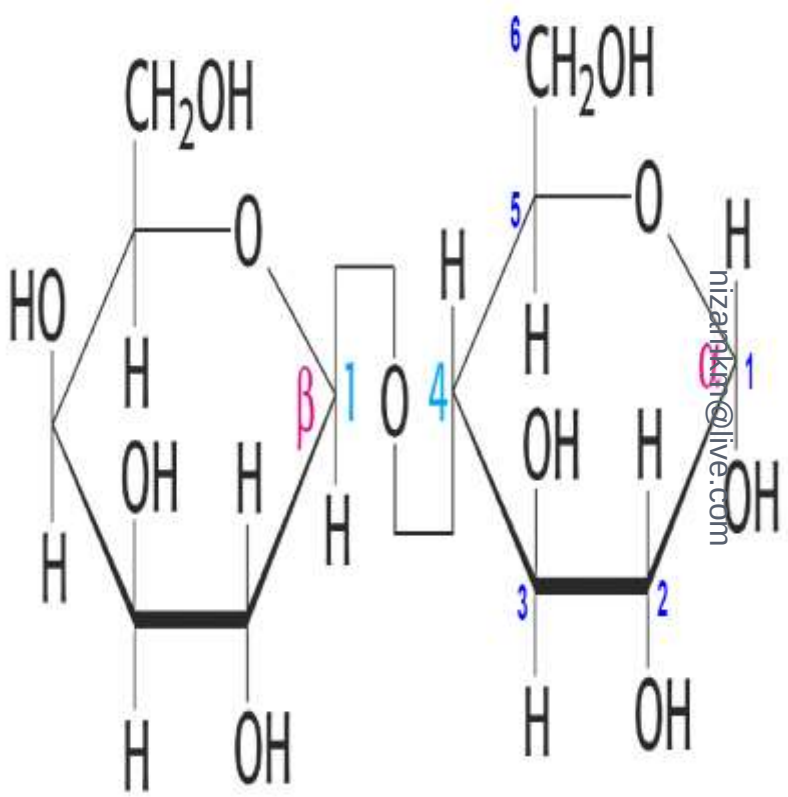
- Its structure is similar to **maltose**, except it has an **α-1,6** glycosidic linkage



α D glucopyranosyl (1,6)- α D glucopyranose

❖ LACTOSE

- It is **milk** sugar found in milk of mammals
- Less sweet than sucrose
- It's a **reducing** sugar because the reducing groups of **glucose** doesn't take part in linkage
- On hydrolysis yields one molecule each of **glucose & galactose**



Lactose
(β-D-Galactopyranosyl-(1→4)-α-D-glucopyranose

❖ LACTOSE INTOLERANCE

- Lactose as such **cannot be** absorbed in blood stream unless it is first hydrolyzed into monosaccharide units
- **Lactase** is an enzyme that specifically breaks the **β 1,4 glycosidic** linkage of lactose yielding equimolar mixture of **glucose & galactose**
- Some individuals **don't have** the capacity to produce **enough lactase** in their body so lactose **is not** hydrolyzed and absorbed. This condition is known as **lactose intolerance**
- In **lactose intolerant** individuals, lactose ingested in large amounts in the form of milk causes **watery diarrhoea, nausea, abdominal pains etc.**

❖ TREHALOSE

- It is found in mushroom, yeast, & fungi
- It's a **non reducing** sugar because both **reducing** groups of glucose are involved in linkage
- On hydrolysis yields **two** molecules of **glucose**
- It is α D-glucopyranosyl **(1-1)** α D glucopyranose

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❖ CELLOBIOSE

- It **doesn’t** occur in nature
- It is formed as an **intermediate** product during the **acidic** hydrolysis of **cellulose**
- In structure it is similar to that of **maltose** except that it has the **β** configuration at its glycosidic component
- On hydrolysis it yields **glucose**

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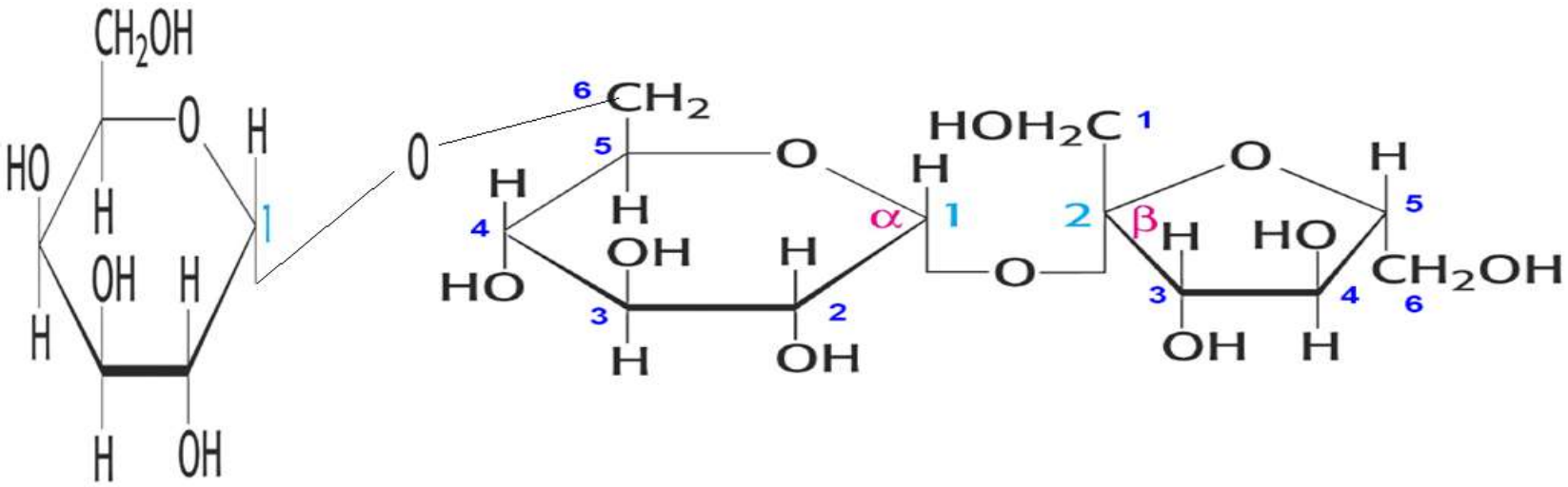
TRISACCHARIDES

- Some trisaccharides are freely available in nature
- Trisaccharides are oligosaccharides composed of **3** monosaccharides with **two glycosidic** bonds connecting them
- They are not common in **food** but are formed during breakdown of **starch** into simpler **sugars**

- One important member of this group is **raffinose,** which is made up of the derivative of **galactose, glucose & fructose**
- It is **not hydrolyzed** by enzymes of digestive tract of human beings, it passes to the **colon** where it is fermented by **bacterial enzymes** producing gas
- Raffinose occur in small amounts in many foods and in fair amount in **beetroot & cotton seed** meal



❖ TETRASACCHARIDE

- **Stachyose** is a tetrasaccharide
- It is made up of **2** molecules of **galactose, 1** molecule of **glucose**, **1** molecule of **fructose**
- i.e., α- D galactopyranose **(1,6),** α D-galactopyranose **(1,6),** α- D glucopyranose **(1,2)** β D- fructofuranose

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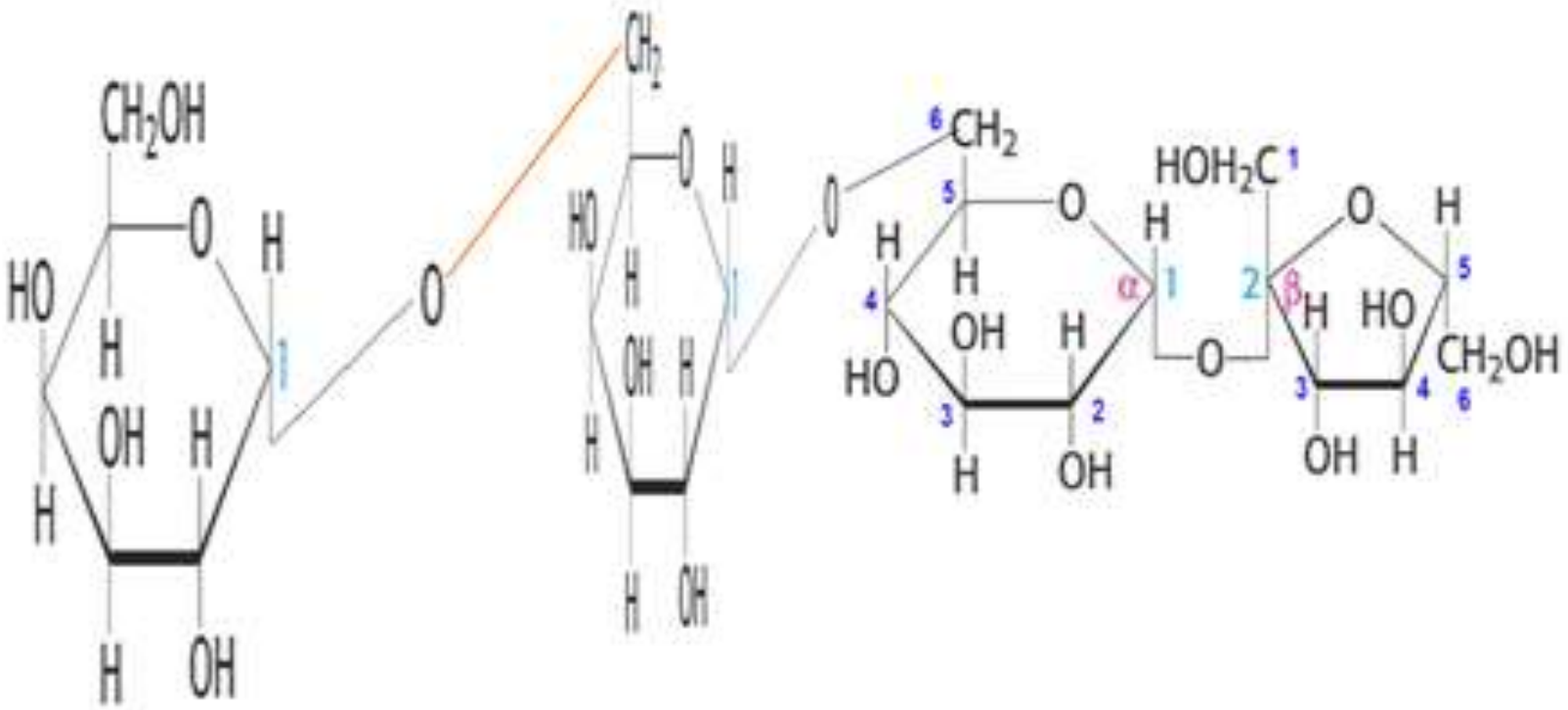
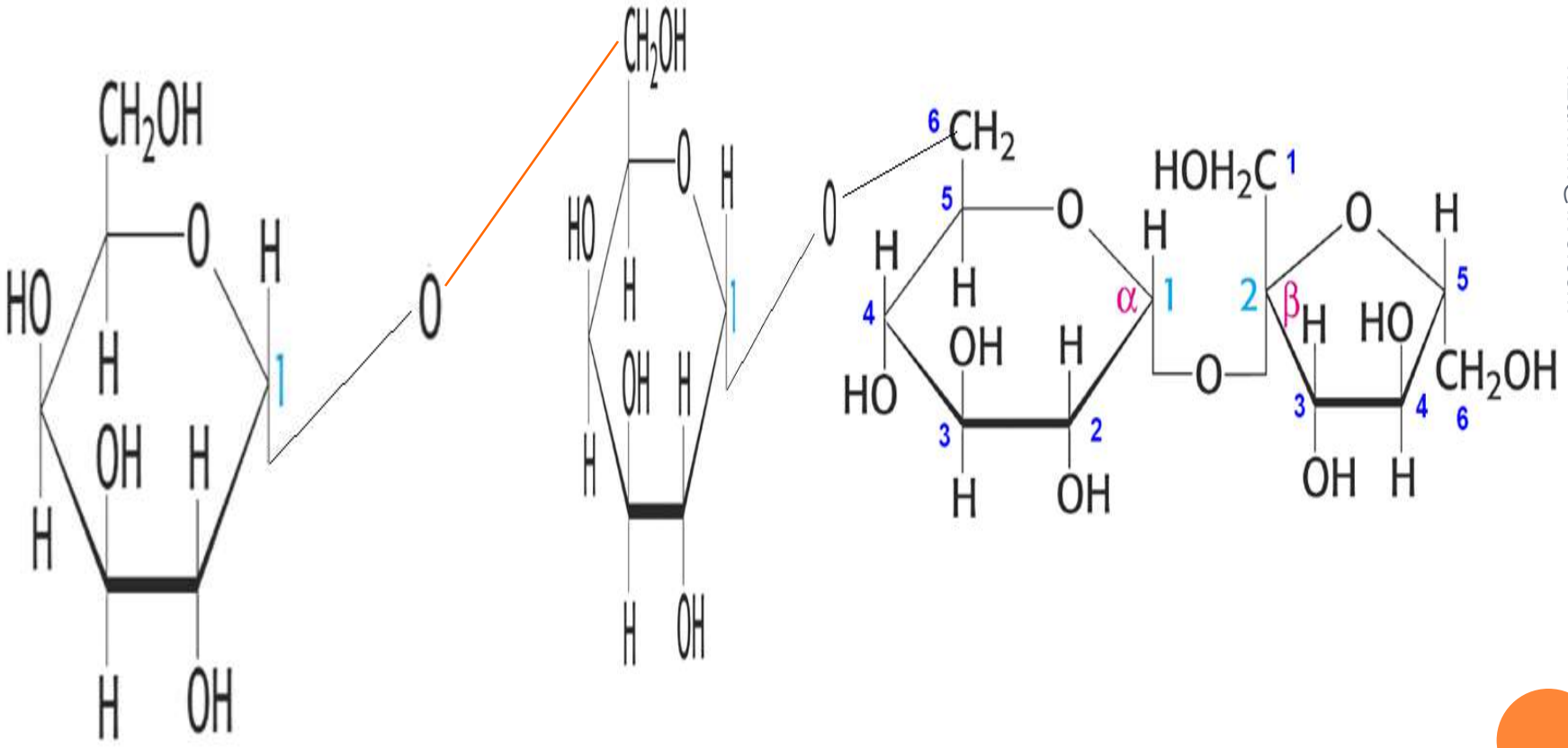


- **i.e., <u>Raffinose & stachyose</u>** are formed by the addition of **one & two** galactose residue respectively to a **sucrose** molecules



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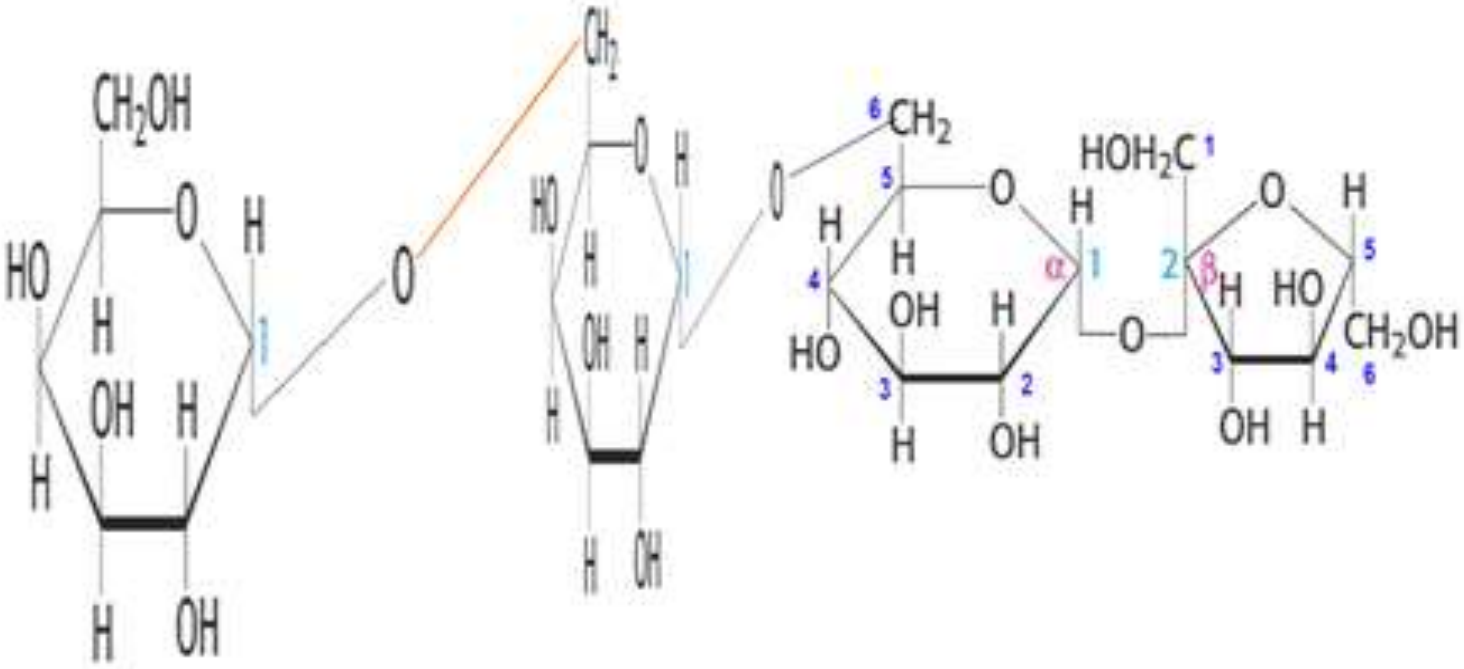

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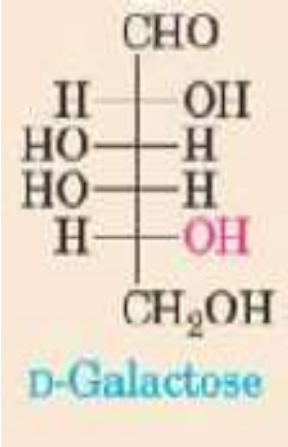
- Galactose: - It is found in combination with glucose in the disaccharide lactose in milk. This sugar is converted to Glucose in human body



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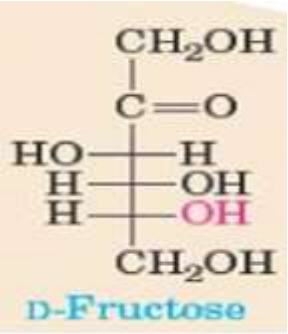
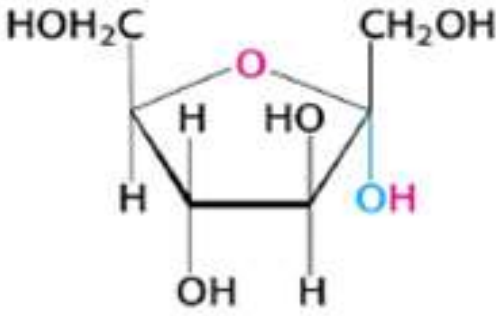
- Ketoses – If the carbonyl group is present at any other position the monosaccharide is a ketone derivative and the sugar is called ketose sugar
- E.g., Fructose: - It is the sweetest of all sugars & is also known as fruit sugar because it is found in fruits & honey. In human body it is converted to glucose & oxidized as a source of energy



D-Fructose



α-D-Fructofuranose

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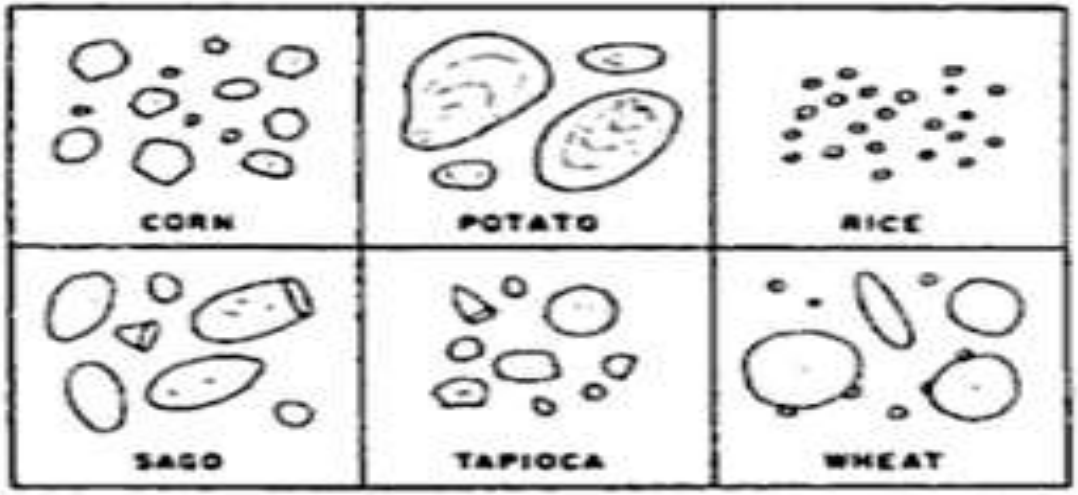
- **POLYSACCHARIDES**
- Polysaccharides are produced when many monosaccharide units are joined together by glycosidic linkage. Polysaccharides yield more than 6 molecules of monosaccharides on hydrolysis .Some polysaccharides are linear & others are highly branched
- Chemically polysaccharides are of two types:-
- **Homo polysaccharides / Homoglycans**
- Which possess only one type of monosaccharides
- E.g., Starch, cellulose, glycogen
- Here glucose is the monosaccharide units
- **Hetero polysaccharides / Heteroglycans**
- Which are formed by more than one type of monosaccharides
- E.g. Hyaluronic acid
- Here monosaccharide units include glucuronic acid, N- acetyl glucosamine
-

- **HOMOPOLYSACCHARIDE**
- **STARCH :**
- Starch contains only glucose residues & is found as a storage carbohydrate in plants. Potato, wheat, rice, corn, tapioca etc are some of the common food sources of starch in our diet. It occurs as small granules with the size range & appearance characteristics to each plant species



Appearance of Starch Granules as Seen in the Microscope

- Starch is mainly used in foods to modify texture & consistency, to bind H_2O, to thicken the foods & to form soft spoonable gels. Natural starch is insoluble in water & gives blue color when treated with iodine solution
- Starch consists of two forms: - The straight chain polysaccharide called amylose, branched chain polysaccharide called amylopectin. Most natural starches are mixture of these two. Normally 65-85% of starch is amylopectin and 15-35% is amylose

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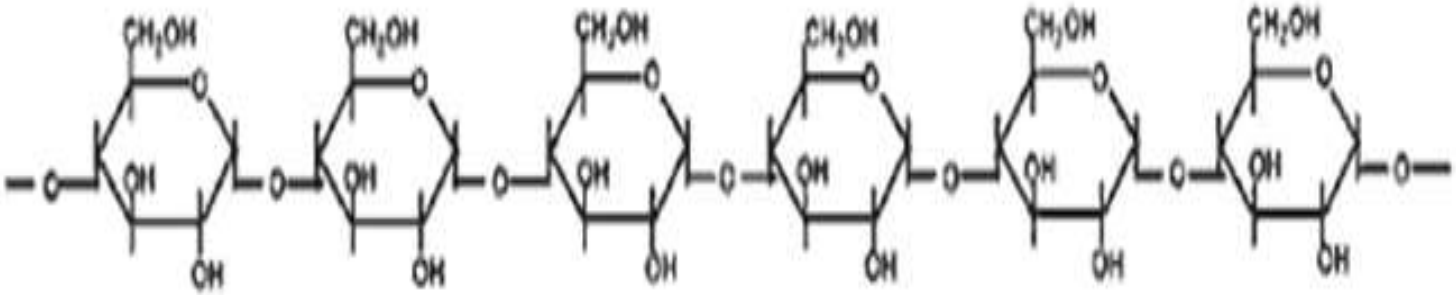
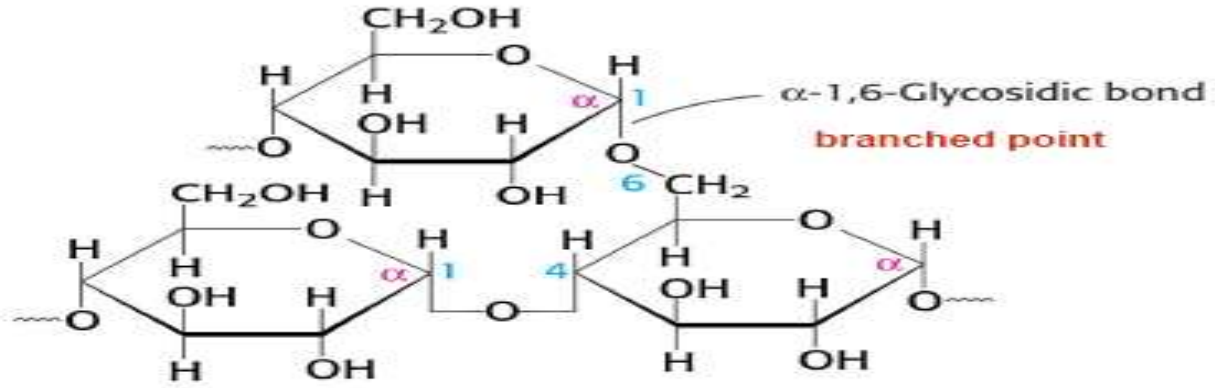
- **AMYLOSE:**
- It is a straight chain polysaccharide formed by 250-300 glucose residues, linked by α (1→4) glycosidic linkage. Amylose is soluble in water and gives deep blue colour with iodine. Amylose increases gel strength
-



AMYLOSE

- **AMYLOPECTIN:**
- It is a highly branched polymer of glucose. In **this** molecule branching occurs at intervals of 24-30 glucose residues. Glucose units of the main chain are joined by α (1→4) glycosidic linkage (similar to amylose) and the glucose units at the branch are joined by α (1→6) glycosidic linkage to the main chain. It has about 3000-6000 glucose units. It is insoluble in water. Amylopectin with iodine gives red to violet colour. Amylopectin decreases gel strength and viscosity



- **Starch hydrolyzing enzymes:**
-
- Hydrolysis of starch by enzymes give shorter chain of glucose units called dextrins, maltose and finally D-glucose
- Starch → Dextrins → Maltose → D-glucose
- Dextrins are polysaccharides formed by partial hydrolysis of starch
- There are different enzymes widely distributed in nature react with starch mainly:-
- α **-amylase**:-
- α -amylase cleaves both amylose and amylopectin molecules internally, producing oligosaccharides. The large oligosaccharides, may be singly,

- doubly, triply branched through 1→6 linkages. Since amylase acts only on the 1→4 linkages of starch
- **β-amylase:**
- They release the disaccharide maltose sequentially from the non-reducing end of amylose & amylopectin, but it cannot cleave 1→6 linkages at branch points. So we use debranching enzymes like isoamylase and pullulanase. These enzymes catalyse the hydrolysis of 1→6 linkages in amylopectin producing numerous linear but low molecular weight molecules
-

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- **PROPERTIES OF STARCH:**
-
- **Starch gelatinization:**
- Starch is insoluble in cold water but in warm water it swells until its gelatinization temperature begins to lose its structure and leaches out its constituents. This act of converting into a substance like jelly is called gelatinization. It is a phenomenon which takes place in the presence of heat and moisture. Cooking the starch to 100° C disrupts H- bonding & causes swelling of the granule & solubilization of the constituent starch polymers. The suspension increases in viscosity, becomes less opaque & eventually forms a paste. This process is referred to as gelatinization. During gelatinization, water is absorbed & as a result, the starch granule swells irreversibly to several times of its size

- Gelatinization occurs in 3 stages:
- The **first** stage is **imbibition (to absorb)** 25-30% water. The viscosity of starch water mixture does not change. This change is reversible because the starch may be dried again with no observable change in structure
- 2nd stage occurs at approximately 65° C, when the granules begin to swell rapidly & take up large amount of water. The granules change in appearance. This change is not reversible. Some amylose are leached out from the granules
- The 3rd stage is marked by more swelling, enlargement of starch granules & finally the granules ruptures; the viscosity of fluid increases & the starch granules stick together

- The swelling of starch, particularly amylose, which results in an increase in viscosity of a starch-water mixture & the formation of a gel is occur through the binding of water
-

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RETROGRADATION

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- RETROGRADATION
- In a very dilute solution of starch the individual amylose molecules are not sufficiently entangled to produce a gel,so that the growing micelles eventually cause precipitation. This is known as retrogradation
- Retogradation of cooked starch involves both amylose & amylopectin.
- Amylose undergoing retrogradation at much more rapid rate than amylopectin
- It is initiated after the removal of a gelatinized starch-water dispersion from the heat

- i.e. retrogradation is a reaction that takes place in gelatinized starch ,when the amylose & amylopectin chains realign themselves causing the liquid to gel

- When native starch is heated & dissolved in water the crystalline structure of amylose & amylopectin molecules are lost & they hydrate to form a viscous solution .If the viscous solution is cooled or left at lower temp. for long enough period ,the linear molecules of amylose & linear parts of amylopectin molecules are retrograded & rearranged themselves again to a more crystalline structure .This is due to intermolecular hydrogen bond formation b/w linear amylose molecules especially.

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- **Rate of retrogradation depends on:-**
  - ✓ Molecular ratio of amylose to amylopectin
  - ✓ Structure of amylose & amylopectin molecules
  - ✓ Temperature
  - ✓ Starch concentration
  - ✓ Presence of surfactants & salts
- **Quality defects occurs due to retrogradation are:-**
  - ✓ Bread staling
  - ✓ Loss of viscosity & precipitation in soups & sauces
  - ✓ Deceased storage stability

- TO AVOID RETROGRADATION USE :-

- Amylopectin starch

- Modified starch

which attract small side chains that will acts as a steric hindrance to re crystallisation

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STALING

- The change in texture & flavor of starch based products during storage is called staling
- The pdt becomes dry & hard often caused by starch retrogradation
- Mainly occurs in bread
- Stale bread is dry & leathery
- Staling is not simply a drying out process due to evaporation .Bread will stale even in moist environment

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- Staling begins as soon as baking is complete & the pdt.begins to cool, because the basic cause of bread staling is a change in the nature of starch
- i.e. in fresh bread the starch exist in alpha form .At temp.below 53 C the alpha form is unstable & some of its change to beta form
- Alpha starch has a greater water holding capacity than beta starch & hence the change from alpha to beta starch is accompanied by an exudation of water from starch .This water was taken up by gluten
- Above 55 C alpha starch is stable & doesn't change to beta starch & hence bread stored at this temp. will not stale . But this is not a practical solution to the problem

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- Staling of baked goods is noted by an increase in crumb firmness & loss in product freshness
- **To retard crumb firming use :-**

✓ Glyceryl monopalmitate (GMP)

✓ Sodium stearoyl-2- lactylate (SSL)

These are incorporated in the dough of **bread & other baked goods** to increase shelf life

✓ Staling can be delayed also by storing bread at **-20 C** .Bread that has staled with little loss of moisture can be refreshed **by heating**

Rate of staling depends on:-

✓ Product formulation

✓ Baking process

✓ Storage conditions

Starch dextrinization

- Dextinization of starch may occur in food items due to either enzymes ,heat or acid /alkali stress
- Dextrinization or pyroconversion is brought about by the action of heat on dry powdered starch
- Usually the heat treatment is carried out with added hydrochloric/ phosphoric acid at levels of 0.15 & 0.17 % respectively
- After the addition of the acid, the starch is dried & heated in a cooker at a temp. ranging from 100-200 C
- Two types of reactions occur:-
- Hyrolysis
- Transglucosidation

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- **Hydrolysis:-**
- At low degree of conversion, hydrolysis is the main reaction & the resulting product is known as **white dextrin**
- **Transglucosidation:-**
- It involves initial hydrolysis of alpha 1,4 glycosidic bonds & recombination with free hydroxyl groups at other locations
- In this manner new randomly branched structures or dextrins are formed ,this reaction happens in the more highly converted products known as **yellow dextrins**
- The dextrins have film forming properties & are used for coating & as binders

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- For eg. When flour is heated until brown ,the starch granules undergo a process known as dextrinization
- Dextrins are fragments of starch molecules composed of chains of glucose molecules .
- As the starch undergoes dextrinization ,it loses its thickening power
- Extensive dextrinization as occur when flour is browned with dry heat , may cut the thickening power as much as one half

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MODIFIED STARCH:-

- Food starches, which have one or more of their original characteristics altered by treatment in accordance with good manufacturing practice are referred to as modified starches
- It can be either physical or chemical
- It can be modified by acid treatment,enzyme treatment,cross bonding,substitution,oxidation & heat.
- By slight & relatively simple modifications Positive attributes of starches can be greatly improved & or negative characteristics diminished

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- Modification of native starch are designed to change :-
  - Gelatinization temperature & cooking characteristics
  - Retrogradation characteristics
  - Resistance to change in viscosity of pastes due to acid conditions ,mechanical shear ,high temp. etc.
- **Uses of modified starch**
  - To improve :-
    - ✓ Viscosity
    - ✓ Shelf stability
    - ✓ Texture
    - ✓ Appearance & emulsification

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- **SOME IMP. MODIFIED STARCHES ARE:-**

1. **Pre-gelatinized starch :-**

- ✓ It is the major physically modified starch
- ✓ It is an instant starch
- ✓ Starch → gelatinized → dried → pregelatinized starch
- ✓ It subsequently swells in liquid without the application of heat
- ✓ It is used in all cases where a cold water paste is needed such as in convenience foods & in instant pudding mixes

2. ACID MODIFIED STARCH:-

- It is prepared by treating the suspension of native starch with dil.acid at temp. below the gelatinization temp.(50 C)
- When the desired viscosity obtained after treatment the acid is neutralized & the starch is recovered by centrifugation / filtration & then washed & dried
- It appears less viscous in hot form, but forms a thick gel upon cooling
- It is used in the manufacture of gum candies

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3.OXIDIZED STARCH (BLEACHING)

- The bleach most commonly used is sodium hypochlorite
- It is prepared by treating the starch slurry with sodium hypochlorite at 21-38 C
- During the bleaching process the starch is oxidized
- Small amounts of carboxyl /carbonyl groups are introduced & some glycosidic bonds are cleaved
- The product obtained have hydroxyl group per 25-50 glucose residue

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- **THE ADV. OF THIS STARCH IS :-**

✓ It decreases pasting temp.

✓ Decreases thickening power

✓ Decreases the tendency to retrograde

- It is used as a lower viscosity filler for salad dressings & mayonnaise

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4. STARCH ESTERS

- Starch monophosphate ester is produced by dry heating of starch with alkaline orthophosphate /alkaline triphosphate at 120-175 C
- The thickening & paste clarity properties of the esterified starch are better than in corresponding native starch
- Esterified starch has an improved freeze thaw stability
- It is used as thickeners & stabilizers in bakery products ,soups powders ,sauces & pudding

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PRODUCT CONTAINING MODIFIED STARCH & THEIR ACTION

product	Modified starch	How does it work
Instant desserts	Enable the product to thicken without requiring heat	Starch is added in a pregelatinized form which swells in cold water ,thickening the product without use of heat
Jelly beans	Produces a very strong gel coating	Starch is treated with an acid to produce a very strong gel .this forms the shell of the jelly bean

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Battered Fish	**Improves the adhesion of the coating**	**Oxidation of starch can improve its binding properties ,which can be used to increase the stickiness of foods, such as batter applied fish**
Canned soups	Prevents product from separating on standing	Bonding starch with phosphate allows the starch to absorb more water & helps keeps the ingredients of the soup together

- **RETROGRADATION**

- In a very dilute solution of starch the individual amylose molecules are not sufficiently entangled to produce a gel, so that the growing micelles eventually cause precipitation. This is known as retrogradation. Retrogradation of cooked starch involves both amylose & amylopectin, amylose undergoing retrogradation at much more rapid rate than amylopectin. Retrogradation is a reaction that takes place in gelatinized starch, when the amylose & amylopectin chains realign themselves causing the liquid to gel. When native starch is heated & dissolved in water, the crystalline structure of amylose & amylopectin molecules are lost & they hydrate to form a viscous solution. If the viscous solution is cooled or left at lower temperature for long enough period, the linear molecules of amylose & linear parts of amylopectin molecules are retrograded & rearranged themselves again to a more crystalline structure. This is due to intermolecular hydrogen bond formation between linear amylose molecules especially

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- GLYCOGEN

- It is the storage polysaccharide found in the muscle & liver of animals & humans
- It is a branched polymer having about 8-10 glucose units in each branch
- Each glycogen molecules may contain 5000-10,000 glucose units
- It is non-reducing, readily soluble in water & gives red colour with iodine
- Like amylopectin, its straight chains are formed by alpha 1-4 glycosidic linkages & alpha 1-6 glycosidic linkages exist at branch points
- It is similar to amylopectin in chemical structure but is much more branched & of high molecular weight

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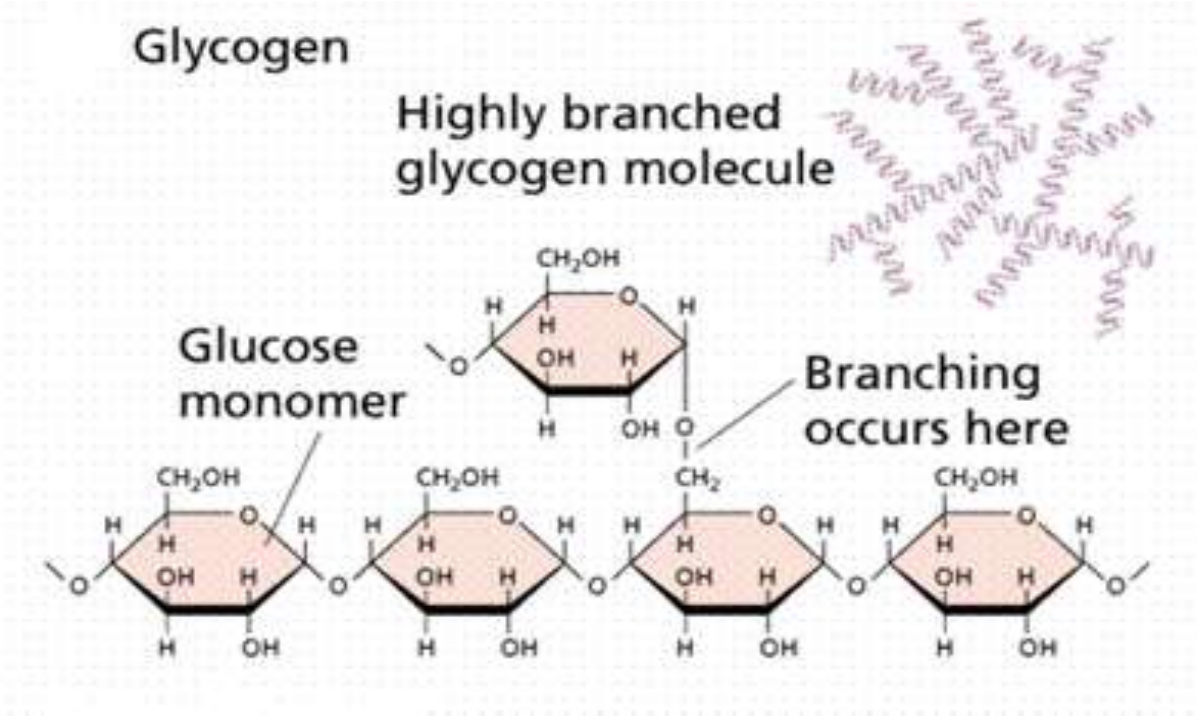

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- **DEXTRINS**
- These are the substances which are produced in the course of the hydrolytic breakdown of starch
- Dextrins are polymers of D-glucose held by alpha (1,4) glycosidic linkages
- Dextrins are formed due to partial hydrolysis of starch by enzymes such as salivary amylase, dil. mineral acids or heat
- Dextrins form sticky solutions in water, when hydrolyzed yield maltose & finally glucose

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- **CELLULOSE**
- It is the main constituent of plant cell walls
- It is a polymer of beta-glucose with beta 1-4 linkages b/w glucose units
- This doesn't occur in the animal body
- It is a homopolymer of glucose like starch, except the linkages joining the glucose units are beta 1-4 rather than alpha 1-4
- Strong hydrochloric acid hydrolyses cellulose to glucose
- Cellulose & its modified forms serve as dietary fiber because they don't contribute significant calories as they pass through the human digestive system

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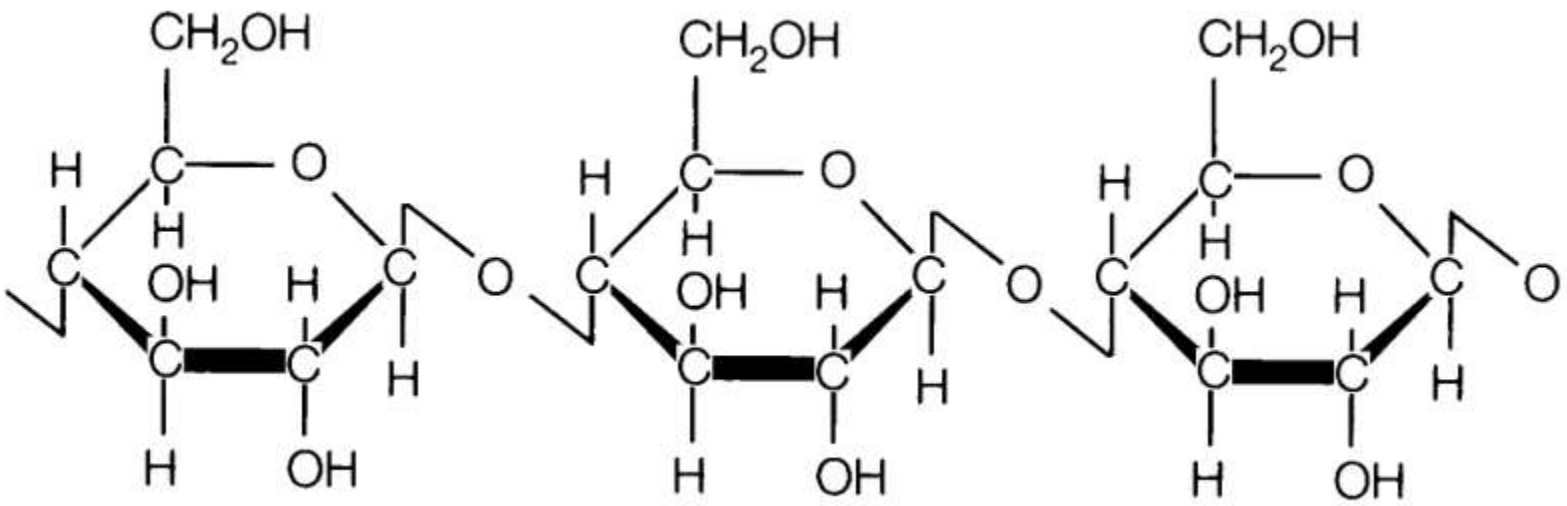

Beta (1-4) glycosidic linkage in cellulose

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- **PECTIN**
- It is found in fruits & vegs. & mainly prepared from waste citrus peel & apple skin
- It is generally soluble in water & insoluble in most organic solvents
- Pectins are mainly used as gelling agents ,but also acts as a thickener, water binder & stabilizer

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- HETEROPOLYSACCHARIDES

- **GUMS**

- This large group of polysaccharides & their derivatives is characterized by its ability to give **highly viscous solutions** at low concentrations
- Gums are widely used in the food industry as gelling, stabilizing, & suspending agents
- This group includes naturally occurring compounds as well as their derivatives such as exudate gums, seaweed gums, seed gums, microbial gums etc.

SOME IMPORTANT GUMS

SOURCES	GUMS
Algal polysaccharides	Agar Alginate Carrageenan
Seed Gums	Locust bean Gum Guar gum
Tree exudate gums	Gum arabic Gum ghatti Gum karaya Gum tragacanth
Microbial polysaccharides	Xanthan gum Gellan Gum

- **FIBRES & THEIR ROLE IN HUMAN DIET**
- Dietary fiber is a complex mixture of plant materials that are resistant to breakdown by the human digestive system
- i.e., Dietary fiber is the edible part of plants that are resistant to digestion & absorption in the human small intestine (can not be broken down by human digestive enzymes) although micro-organisms that live in the large intestine are able to digest fiber

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- **COMPONENTS OF DIETARY FIBER:-**
- On the basis of solubility components are classified into:-

INSOLUBLE DF	SOLUBLE DF
CELLULOSE	PECTIN
SOME HEMI CELLULOSE	GUMS
LIGNIN	MUCILAGES/BETA GLUCAN

- **Insoluble** fiber is most frequently found in whole-grain products such as whole-wheat bread, Wheat & corn bran, tomato peel etc
- Insoluble fiber possess **water attracting** properties that help to increase bulk, soften stool & shorten transit time through the intestinal tract
- Foods containing **soluble** fibers are fruits, vegetables, dry beans and peas, and some cereals such as oats
- Soluble fiber undergoes **metabolic processing** through **fermentation** yielding end products with broad, significant health effects

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- **HEALTH BENEFITS OF DIETARY FIBER**
-
- Both soluble and insoluble dietary fibre can promote a number of positive physiological effects, helping to prevent constipation, lower blood cholesterol levels and control blood glucose levels
- A low fibre intake is associated with constipation and some gut diseases such as bowel cancer
- Sources of insoluble fibre can act as bulking (laxative) agents and an increase in fibre intake should be accompanied by an increase in water intake thus help to prevent constipation
- Soluble forms of fibre eaten in large amounts can help reduce blood cholesterol levels
- They can also help people with diabetes to control their blood glucose levels
-

- **DIETARY FIBER & COLON CANCER:-**
- Fruits, veg. & grains, in addition to fibre, also contain a variety of anti carcinogenic compounds which may contribute to this protective effect
- Several **mechanism** have been formulated by which fiber may provide protection action against colon cancer .These include :-
- Fibre that increases stool bulk results in the dilution of carcinogens
- Fibre also decreases transit time thereby reducing the interaction of carcinogens with colonic mucosal cells
- Fiber binds potential carcinogens

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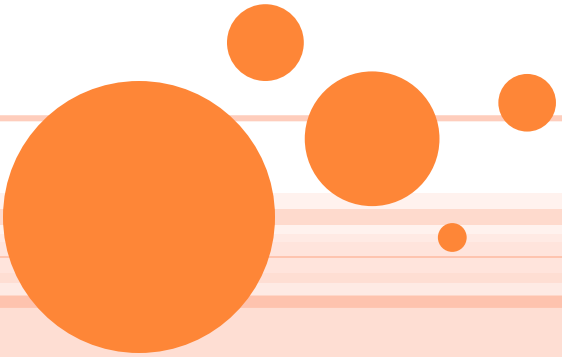

CELLULOSE

- It is the main constituent of plant cell walls
- It is a polymer of beta-glucose with beta 1-4 linkages b/w glucose units
- This doesn’t occur in the animal body
- It is a homopolymer of glucose like strach,except the linkages joining the glucose units are beta 1-4 rather than alpha1-4
- Strong hydrochloric acid hydrolyses cellulose to glucose (i.e. hydrolysis of cellulose leads to cellobiose & finally to glucose)

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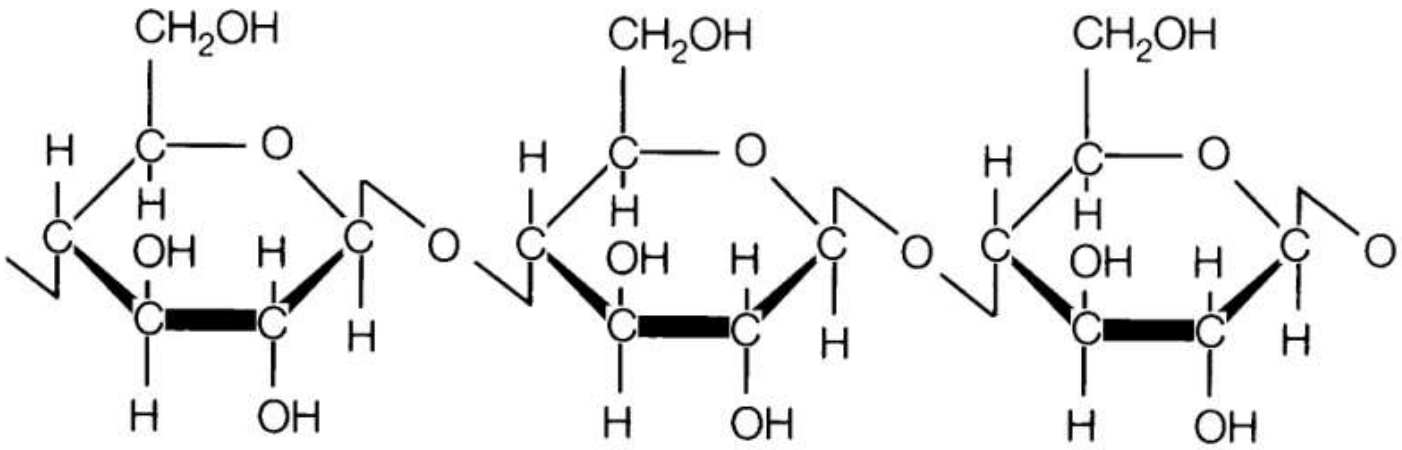
- Cellulose & its modified forms serve as dietary fiber because they don’t contribute significant calories as they pass through the human digestive system
- **STRUCTURE** OF **CELLULOSE**



Beta (1-4) glycosidic linkage in cellulose

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SOME IMPORTANT FORMS OF CELLULOSE

- **POWDERED CELLULOSE**
- High quality cellulose can be obtained from wood through pulping & subsequent purification
- The manufacture of powdered cellulose begins with wood pulp that undergoes a series of bleaching steps & drying ,following drying the pure white cellulose is cut into desired fiber length by mill/by cutters
- Wood pulp → bleaching steps (series) → drying → pure white cellulose → cut into desired fiber length

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ADV: OF POWDERED CELLULOSE(P.C)

- Reduced calorie baked goods made with P.C have an increased content of dietary fiber ,stay moist & fresh longer
- The P.C used in foods has negligible flavor, color & microbial contamination
- P.C is added to bread to provide non-calorie bulk

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CARBOXY METHYL CELLULOSE(CMC)

- CMC is a linear, long chain, water soluble, modified polysaccharide
- It is a derivative of cellulose made by its reaction with alkali & chloroacetic acid
- Purified CMC is white to cream colored; tasteless, odorless, & free-flowing powder
- CMC is soluble in cold water & mainly used for controlling viscosity without gelling

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- As its viscosity drops during heating, it may be used to improve the volume yield during baking by encouraging gas bubble formation
- Its control of viscosity allows use as thickener & emulsion stabilizer(eg. with milk casein)
- CMC is used in the manufacture of ice cream
- It contributes a good body & smooth texture, retards the enlargement of ice crystals during storage & improves the melting characteristics

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FOOD APPLICATION OF CMC

FOOD	FUNCTION	PROPERTIES UTILIZED
BAKED GOODS	Adhesion	Film formation, viscosity
BEVERAGES	Body, texturized stabilizer	Rheological dispersant
MILK & YOGHURT DRINKS	Stabilization	Interaction with milk protein, dispersant
Sauces, syrups& Toppings	Stabilization, thickening	Rheological

MICROCRYSTALLINE CELLULOSE

- It is made by hydrolysis of purified wood pulp,followed by separation of the constituent micro crystals of cellulose
- Two types of micro crystalline cellulose are produced

1. Powdered MCC
2. Colloidal MCC

- Powdered MCC & Colloidal MCC are stable to both heat & acids

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POWDERED MCC

It is a spray dried product

Used as a flavor carrier

Used as an anti caking agent (shredded cheese)

COLLOIDAL MCC

To make colloidal MCC considerable mechanical energy is applied after hydrolysis

It is a water dispersible

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Functions of Colloidal MCC

- To stabilize foams & emulsions especially during high temp. processing
- To improve adhesion
- To replace fat & oil
- To control ice crystal growth
- Stabilize pectin & starch gels

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GLYCOGEN

- It is the storage polysaccharide found in the muscle & liver of animals & humans
- It is a branched polymer having about 8-10 glucose units in each branch
- Each glycogen molecules may contain 5000-10,000 glucose units
- It is non-reducing,readily soluble in water & gives red colour with iodine
- Like amylopectin, its straight chains are formed by alpha 1-4 glycosidic linkages & alpha 1-6 glycosidic linkages exist at branch points
- It is similar to amylopectin in chemical structure but is much more branched & of high molecular weight

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(c) Glycogen

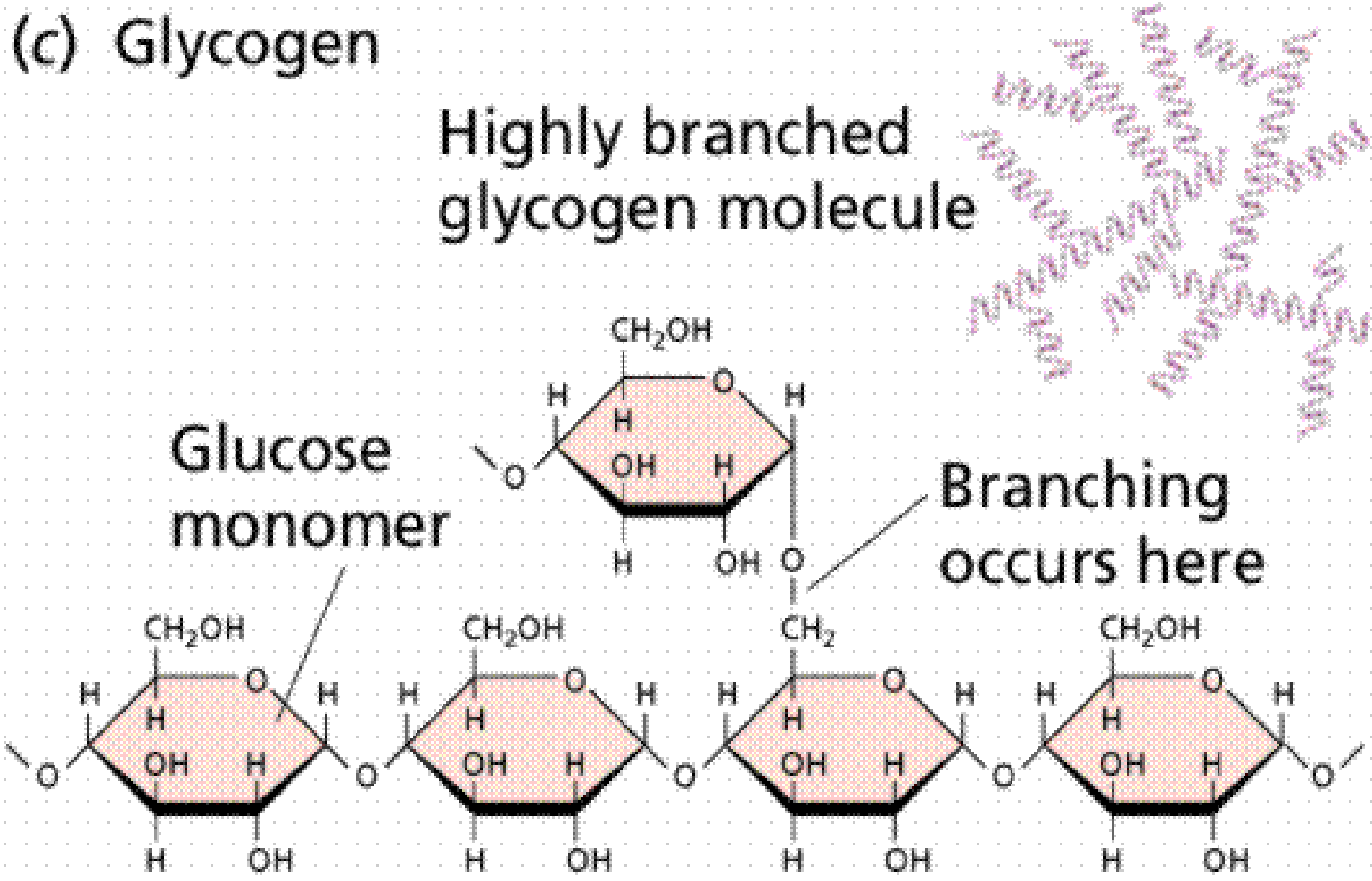

Figure 3.12 (3)

DEXTRINS

- These are the substances which are produced in the course of the hydrolytic breakdown of starch
- Dextrins are polymers of D-glucose held by alpha (1,4) glycosidic linkages
- Dextrins are formed due to partial hydrolysis of starch by enzymes such as salivary amylase ,dil. mineral acids or heat
- Dextrins form sticky solutions in water, when hydrolysed yield maltose & finally glucose

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INULIN

- It is a starch found in tubers & roots
- It can be hydrolyzed to give fructose
- Inulin is a plant polysaccharide made up of fructose , soluble in warm water & doesn't give any colour with iodine
- Inulins have sweet taste & are present in many vegs. & fruits including onion, garlic, bananas, asparagus etc
- Inulins are polymers consisting of fructose units that typically have a terminal glucose

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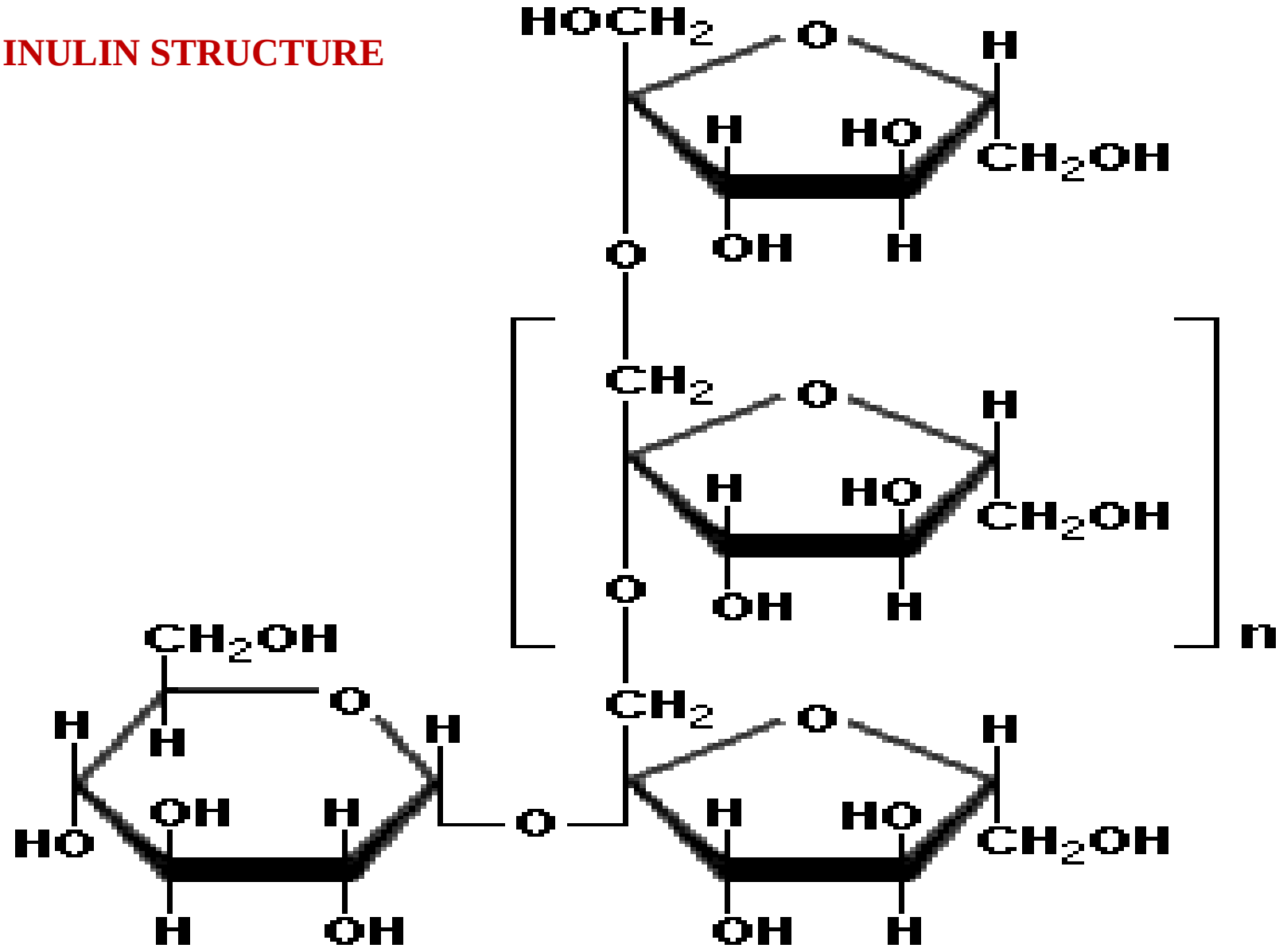
INULIN STRUCTURE



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PECTIN

- Pectic substances are polysaccharides of galacturonic acid or of its methyl ester
- It is an acidic structural polysaccharide ,found in fruits & vegs. & mainly prepared from waste citrus peel & apple skin
- It is generally soluble in water & insoluble in most organic solvents
- Pectins are mainly used as gelling agents ,but also acts as a thickener, water binder & stabilizer
- Two types of pectin :- Low & High methoxyl & these forms different kinds of gels
- Low methoxyl (LM) pectin has a degree of methylation of 25-50 % & forms calcium gel

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- In LM pectin gels, calcium ions acts as a bridge b/w neighboring pectin molecules
- Low methoxy pectins form thermoreversible gels in the presence of calcium ions & at low pH (3-4.5)
- The lower methoxy content ,the slower is the setting
- High methoxyl (HM) pectin has 50-80 % methylation & forms acid gels
- HM pectin gels require the presence of at least 55 % by wt. of sugar & a pH below 3.6
- HM pectin gels are formed by non-covalent forces ,hydrogen & hydrophobic ,that arise from stabilization of the junction b/w molecules by the sugar ,which acts as a dehydrating agent

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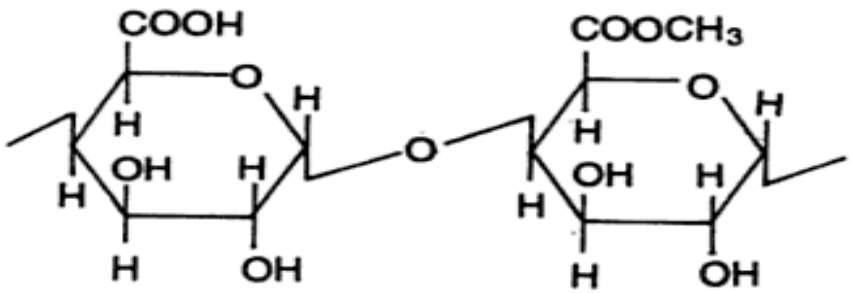
- High methoxy pectins rapidly form thermally irreversible gels in the presence of sufficient sugar (eg.65% by wt) such as sucrose & at low pH
- The chief products of the hydrolysis of pectic substances are galacturonic acid ,a derivative of galactose in which the 6-carbon is oxidized to a carboxyl group & methyl alcohol
- The 1-4 link is an alpha ether link b/w the 1st carbon on one galacturonic residue & the fourth carbon on another

alpha galacturonic acid + methyl alpha



Pectic Substance Chain.

FOOD APPLICATIONS OF PECTIN

PRODUCT GROUP	FUTN. OF PECTIN	PCETIN LEVEL
Jam ,jellies & preserves	Gelling agent, thickener	0.1 - 1.0
Bakery fillings & glazing	Gelling agent, thickener	0.5 - 1.5
Fruit preparations	Thickener, stabilizer	0.1 - 1.0
Fruit beverages & sauces	Thickener, stabilizer	0.01 - 0.5
Confectionery	Gelling agent, thickener	0.5 - 2.5
Dairy products	Stabilizer, gelling agent	0.1 - 1.0

HYALURONIC ACID

- It is a heteropolysaccharides of animal tissues
- It is a viscous polysaccharide made up of chains of N-acetyl glucosamine & glucuronic acid residues
- The acid is found in the connective tissue & acts as an intercellular cement
- Hyaluronic acid is more abundant in skin & soft tissues
- Hyaluronic acid seems to be linear molecule ,these units are joined beta 1-3 & beta 1-4

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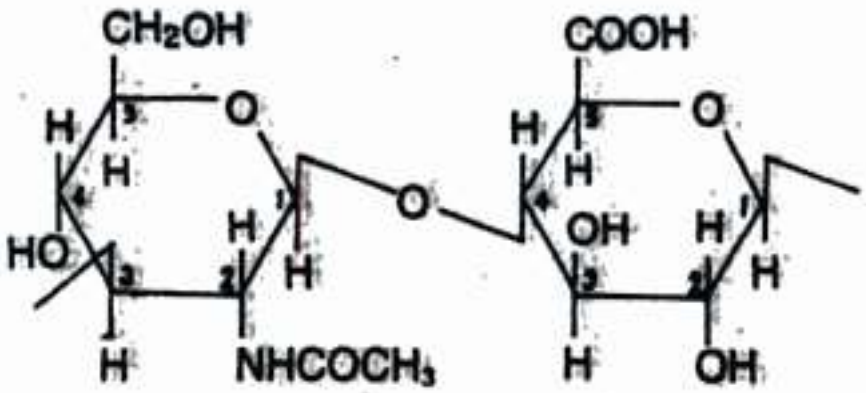

Portion of Hyaluronic Acid.

CHONDROITIN SULPHATE

- This polysaccharide occurs in cartilage
- Its structure is similar to that of hyaluronic acid

HEPARIN:-

- It’s a heteropolysaccharide
- It is a mucopolysaccharide
- Heparin is made up of chains of glucuronic acid & glucosamine containing sulfate ester groups

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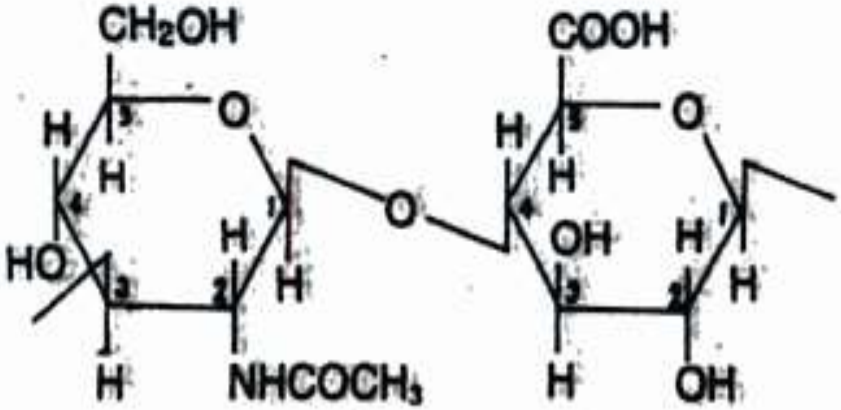

Portion of Hyaluronic Acid.

GUMS

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GUMS

- This large group of polysaccharides & their derivatives is characterized by its ability to give **highly viscous solutions** at low concentrations
- Gums are widely used in the food industry as gelling, stabilizing, & suspending agents
- This group include naturally occuring compounds as well as their derivatives such as exudate gums, seaweed gums, seed gums, microbial gums etc.

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SOME IMPORTANT GUMS

SOURCES	GUMS
Algal polysaccharides	Agar Alginate Carrageenan
Seed Gums	Locust bean Gum Guar gum
Tree exudate gums	Gum arabic Gum ghatti Gum karaya Gum tragacanth
Microbial polysaccharides	Xanthan gum Gellan Gum

ALGINATE

- It is an **algal polysaccharide**
- Alginates are produced by brown seaweeds
- It is a copolymer of 1-4 linked beta mannuronic acid & alpha glucuronic acid
- The commercially available alginates are white to cream coloured powders

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FOOD APPLICATIONS

- The alginate stabilizers possess good water holding properties, are readily dispersible in ice cream mixes & contribute good body properties & excellent texture production
- The presence of alginate minimizes surface hardening & improves the texture of the processed cheese
- The addition of 0.15 % alginate is sufficient to thicken cream & to act as a stabilizer upon whipping

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❖ LOCUST BEAN GUM

- It is a **seed gum**
- This is also called Carob bean gum
- It is extracted from the seed of the Carob tree
- Locust bean gum is slightly soluble in water at the room temperature & must be heated to 75 - 85 C for complete hydration & viscosity development

FOOD APPLICATIONS

- It has been used as a basic ice cream stabilizer
- It specifically retards ice crystal growth by forming structured gel at solid/ liquid interface
- Bread flour supplemented with locust bean gum produces a dough with constant properties & enhanced water binding characteristics
- Yields are improved & the baked products remain soft & palatable for long time

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❖ GUM KARAYA

- It is a **tree exudate** gum
- It is also known as *Indian tragacanth*
- Gum karaya is water – swellable rather than water – soluble
- At low concentrations it absorb water very rapidly to form viscous colloidal dispersions
- At higher concentrations (20-25 %) gum karaya exhibits strong adhesive properties

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FOOD APPLICATIONS

- The water absorbing & water holding capacity of karaya, together with an excellent acid compatibility made it suitable for its use in foods
- Karaya has effective foam stabilization properties which has been employed in stabilizing packaged whipped cream products & other aerated dairy products
- Karaya has been used to prevent syneresis & improve the stability characteristics of cheese spreads ……

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- It is used as a good emulsion stabilizer for French style salad dressings
- Karaya in combination with alginate or carrageenan is used to retard **staling** of bread & other baked goods
- In ground **meat** products, karaya provides good water holding & binding properties to yield products with smooth, desirable textures & appearance

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XANTHAN GUM

- Xanthan gum is a **microbial** polysaccharide
- It is completely soluble in hot or cold water

- **FOOD APPLICATIONS** :-
- Xanthan gum is mainly considered to be non-gelling & used for the control of viscosity
- It gives enhanced mouth feel with full bodied taste
- Xanthan gum solutions shows excellent stability at 80 C, this property has a practical utility for hot foods, such as gravies

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- The addition of xanthan gum is able to maintain freeze-thaw stability
- The freeze thaw stability of starch based salad dressings can also be maintained by the addition of 0.1 % xanthan gum
- It is utilized for the stabilization of low calorie & other aerated desserts, instant milk shakes, break fast drinks, soup & sauces

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DIETARY FIBER

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DIETARY FIBER

- Dietary fiber is a complex mixture of plant materials that are resistant to breakdown by the human digestive system
- i.e., Dietary fiber is the edible part of plants that are resistant to digestion & absorption in the human small intestine (can not be broken down by human digestive enzymes) although micro-organisms that live in the large intestine are able to digest fiber.

COMPONENTS OF DIETARY FIBER:-

- On the basis of solubility components are classified into:-

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INSOLUBLE DF	SOLUBLE DF
CELLULOSE	PECTIN
SOME HEMI CELLULOSE	GUMS
LIGNIN	MUCILAGES/BETA GLUCAN

- **Insoluble** fiber is most frequently found in whole-grain products such as whole-wheat bread, Wheat & corn bran, tomato peel etc
- Insoluble fiber possess **water attracting** properties that help to increase bulk, soften stool & shorten transit time through the intestinal tract

- Foods containing **soluble** fibers are fruits, vegetables, dry beans and peas, and some cereals such as oats.
- Soluble fiber undergoes **metabolic processing** through **fermentation** yielding end products with broad, significant health effects

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- Based on the location on the plant, DF components can be categorized as :-

Plant cell wall constituents	Non-plant cell wall Constituents
LIGNIN	GUMS
CELLULOSE	MUCILAGES
HEMICELLULOSE	
PECTIN	

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IMPORTANT COMPONENTS OF DIETARY FIBER

Component	Properties	Foods High in Content
Cellulose	Water insoluble but can be modified chemically to be more soluble. Poorly fermented by colonic bacteria	Bran, legumes, peas, outer covering of seeds, apples
Hemi cellulose:- Its structure consists of heterogeneous group of polysacc - haride substances containing no. of	It contain acids in their side chains are slightly charged & water soluble. Others	

sugars in its backbone & side chains. Sugars which form backbone include xylose, mannose, galactose. Sugars present in the side chain are arabinose, glucuronic acid & galactose. Hemic-elluloses are categorized on the basis of	are insoluble. Ferment ability by intestinal flora is influenced by the sugars & positions e.g. hexose & uronic acids are more accessible to bacterial enzymes	Bran & whole grains

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predominant sugar in their backbone, e.g. xylan, mannan, galactan		
Lignin:- Main non-carbohydrate component of fiber. It is a three-dimensional polymer composed of phenol units	It is highly insoluble in water & responsible for the structural adhesion of plant cell wall components . It has hydrophobic binding capacity. It is not fermented by colonic micro flora	Mature root vegetables such as carrots, wheat, & fruits with edible seeds such as strawberries

Pectin	**They are water soluble & gel forming. They have ion binding potential .They are completely metabolized by colonic bacteria**	**Apples, Guavas, Strawberries, citrus fruits**
Gums	They are water soluble .They are highly fermented by colonic bacteria	Oat meal, barley, & legumes

Beta glucan/ Mucilage:- **It is a polymer of glucose with mixed glucosidic bonds of both the beta(1-3) & beta (1-4) types**	**It is soluble & hydrate, well forming viscous solutions & are often referred to as food gums or mucilage**	**Grains, especially barley & oats**

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Health benefits of dietary fiber

- Both soluble and insoluble dietary fibre can promote a number of positive physiological effects, helping to prevent constipation, lower blood cholesterol levels and control blood glucose levels
- A low fibre intake is associated with constipation and some gut diseases such as bowel cancer
- Sources of insoluble fibre can act as bulking (laxative) agents and an increase in fibre intake should be accompanied by an increase in water intake thus help to prevent constipation,

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- Soluble forms of fibre eaten in large amounts can help reduce blood cholesterol levels
- They can also help people with diabetes to control their blood glucose levels.
- On the other hand, eating a diet low in fibre is associated with diverticulitis (where the bowel wall becomes inflammed and ultimately damaged) and bowel cancer
- Improvements in gastrointestinal health

DIETARY FIBER & COLON CANCER:-

- Fruits, veg. & grains, in addition to fibre, also contain a variety of anti carcinogenic compounds

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which may contribute to this protective effect

- Several **mechanism** have been formulated by which fiber may provide protection action against colon cancer .These include :-
- Fibre that increases stool bulk results in the dilution of carcinogens
- Fibre also decreases transit time thereby reducing the interaction of carcinogens with colonic mucosal cells
- Fiber binds potential carcinogens
- High bile acid concentrations are associated with increased risk of colon cancer .Fibers absorb bile acids, thereby reducing the risk

- Lignin may acts as a free radical scavenger, thus reducing the risk of cancer
- Further fiber has been shown to lower serum oestrogen concentrations & therefore may have a protective effect against hormone related cancers

FIBER & CARDIOVASCULAR DISEASES

- A protective effect of dietary fiber for CHD, particularly viscous fibers that occur naturally in foods, which reduce total cholesterol & LDL cholesterol concentrations
- Reduced rates of CHD were observed in individuals consuming high fiber diets
- The type of fiber is important, oat bran (viscous

fiber) significantly reduces total cholesterol ,but wheat bran (primarily non-viscous fiber) may not

- Pectin can also helps to lower the amount of cholesterol in the blood
- Viscous fibers are thought to lower serum cholesterol concentrations by interfering with absorption & recirculation of bile acids & cholesterol in the intestine & thus decreasing the concentration of circulating cholesterol
- The body eliminates cholesterol through the excretion of bile acids

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- Water soluble fiber binds bile acids, suggesting that a high fiber diet may result in an increased excretion of cholesterol
- Thus it is important to note that with respect to CVD, only soluble fibers which are also viscous have been shown to reduce serum cholesterol

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FUNCTIONAL PROPERTIES OF CARBOHYDRATES IN FOOD

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1. FUCTIONAL ROLE OF SUGARS IN FOODS

- The most obvious role of sugar in foods is to impart **sweetness**
- There are a number of other roles in food systems
- In **baked** products, sugar not only contribute to the **browning** of the product ,but it may serve to **tenderize** the product through its action on both the gelatinization of starch & denaturation of protein

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1. SWEETNESS:-

- ✓ It is the most recognized functional property of sweeteners
- ✓ The combination of sugar & fats in **confections** provide a **sweet taste & texture**
- ✓ In **beverages** sucrose provides **sweetness** without altering the flavors of the beverages

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2 . TEXTURE:-

- ✓ Sugars make an important contribution to the texture of foods, commonly referred to as **mouth feel**
- ✓ For e.g., **Glucose syrups** in **ice-cream** provide **body & texture**
- ✓ Adding sugar syrups helps to **prevent lactose crystallization,** which would cause a sandy or grainy texture associated with frozen **dairy products**

- **Honey** has a non-crystallization property & can therefore be used in **confectioneries** to maintain a soft & smooth consistency

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- In **bakery** applications, sugars are used to impart **flavour, aroma & colour**
- Addition of **sugar** will ensure that **gluten** maintains an optimal elasticity, allowing the dough **to expand & rise properly**
- Sugars allow the dough **to rise** at an optimal rate during **leavening**
- Under appropriate conditions, the yeast cells **break down** the sugar crystals, releasing **CO2** that causes the dough to rise

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- Sugars naturally interact with **proteins** from the beaten eggs to stabilize the **foam** structure .This makes the egg foam more **elastic,** allowing it to expand as it takes up gases from the **leavening** process
- Glucose, fructose, sucrose & maltose are used in **bread** making to increase dough **yield** & prevent excessive **stickiness**

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3. PRESERVATION

- Sugars play an important role in preservation
- The addition of glucose, or fructose to **jams & jellies** inhibits **microbial growth** & subsequent spoilage
- Both **honey & invert** sugar help to **retain** moisture due to their high **fructose** content
- Sugars are added to **canned vegetables** both to maintain **firmness** & minimize **oxidation**

4. FERMENTATION

- **Ethanol** is made by the fermentation of **sugars**
- **Zymase**, an enzyme from yeast , changes the simple sugars into **ethanol & CO2**
- Starches from potatoes, corn , wheat etc are used in the production of ethanol by fermentation
- Starches must be broken down into simple sugars
- Sugars such as sucrose, glucose, & fermentable corn syrups contribute to sweetness & softness in white breads
- Sugars that remain after fermentation affect flavor, contribute to the colour, & texture of crusts & influence the overall texture of the product

5. APPEARNCE

- The **browning** reactions are complex reactions which occur when foods are processed
- In some cases the brown flavor is highly desirable
- In coffee, the brown crust of bread, & all baked goods, potato chips, roasted nuts etc controlled **browning** is necessary
- Non-enzymatic browning reactions have been recognized to occur in foods during processing
- *ADD CARAMELIZATION*

6. FREEZING POINT

- Sugars are effective in **lowering** the freezing point of a **solution**, which is important in manufacturing frozen **desserts & ice cream** products
- Monosaccharides & corn syrups, containing a high proportion of **low molecular weight sugars** are more effective at **lowering** the freezing point
- This property ensures smaller **ice crystals** & greater **smoothness** of the product

7. ANTIOXIDANT ACTIVITY

- Many **carbohydrates** are excellent **scavengers** for metal ions
- **Glucose, fructose** etc have the ability **to block** the reactive sites of ions, such as **copper & iron**
- This characteristics of monosaccharides aids in **food preservation** by retarding catalytic **oxidation reactions**

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2. FUNCTIONAL PROPERTIES OF STARCHES

- Starches have an enormous number of **food uses**, including :-

- ✓ Adhesive
- ✓ Bindings
- ✓ Clouding
- ✓ Film forming
- ✓ Foam strengthening
- ✓ Antistaling
- ✓ Gelling, Moisture retaining
- ✓ Stabilizing, Texturizing
- ✓ Thickening etc

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FUNCTIONS OF STARCHES

FUNCTION OF STARCH	EXAMPLES
Thickener	Puddings, sauces, pie fillings
Binder	Formed meats
Encapsulation, emulsion stabilizer	Flavors
Water binder	Cakes
Free flowing / bulking agent	Baking powder
Releasing agent	Candy making
Fat replacer	Salad dressing, baked goods, dairy products

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- Starch is the main **thickener i**n gravies, sauces, & puddings i.e. starch absorbs water & becomes a gel when cooked
- As the starch swells up with water, the amylose leaches out & the **amylopectin** form the **gel**
- Some starches have higher **amylopectin** content, & make better **gels** than those containing lots of amylose
- As **a thickener,** the **amylose** has the main function
- Starches are good at absorbing water & bulking /swelling up, they are important in the **mouthfeel** of many food products, & are used as fat substitutes

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- The water binding ability of starches can provide **body & texture** to food stuffs
- Starches are added to processed **meat** (e.g, sausages) as a filler, binder, moisture retainer & fat substitute
- They are used in extruded cereals, ready to eat breakfast cereals & snacks to hold the **shape** of the material

ADD FUNCTIONAL PROPERTIES OF :-

Modified Starch & Cellulose, Pectin, Gums, Dietary fiber, Honey, Invert Sugar, Syrups, etc.

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Invert Sugar

- True invert sugar is a 50:50 mixture of glucose & fructose produced by cleavage of the glycosidic linkage of sucrose with dil. Acid or the enzyme invertase
- It is too sweeter than sucrose, because fructose is sweeter than either glucose or sucrose, invert sugar is sweeter than white sugar
- Sucrose can be split into its two component sugars (glucose and fructose). This process is called inversion, and the product is called invert sugar.
- Commercial invert sugar is a liquid product that contains equal amounts of glucose and fructose.

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- **Invert sugar** is sometimes referred to as **artificial honey** since its composition and properties are nearly same.
- The Invert sugar is greater in demand than pure glucose as food and drink sweeteners, because fructose is sweeter than glucose
- Invertase enzyme is used traditionally in the production of inverted sugars for industry, especially in the manufacture of candies and preserves
- Invert sugar has a lower **water activity** than that of sucrose, so it provides more powerful preserving qualities (a longer shelf life) to products that use it.

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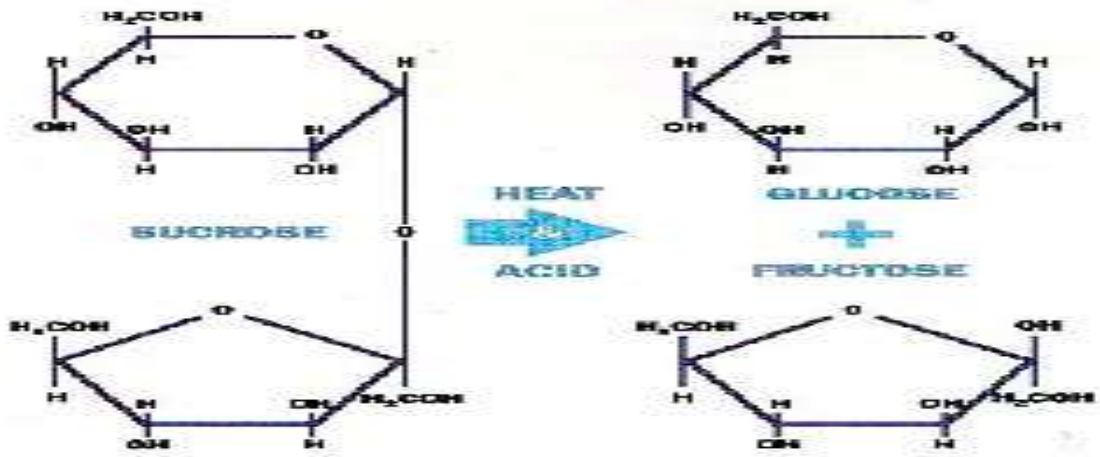
Chemical reaction of the Inversion

- Invert sugar is prepared by the hydrolysis of sucrose to glucose and fructose. This is achieved by subjecting a sucrose solution to acid and heat
- $C_{12}H_{22}O_{11}$ (sucrose) + H_2O (water) →

  $C_6H_{12}O_6$ (glucose) + $C_6H_{12}O_6$ (fructose)



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- Some of the **important applications** of Invert Sugar are :-

- ✓ Invert sugar is used mainly by food manufacturers to **retard the crystallization** of sugar and to **retain moisture** in the packaged food.
- ✓ It acts as a humectant & a water binder & promotes non-enzymatic browning
- ✓ Sweet-meat, bread, biscuits, chocolates, condensed milk, jams, jelly etc.
- ✓ Beverages including aerated beverages
- ✓ As a substitute for honey
- ✓ Infant foods

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SYRUPS

- Syrups are used in the canning of fruits
- These are added to improve the flavor, fill the space b/w the pieces, & aid in the transfer of heat during processing
- The syrup is made by hydrolyzing starch to produce a mixture of sugars
- Syrups fall into **two classes**, those derived from **sucrose** from sugar refining or by complete or partial inversion & those derived from starchy materials, in particular **corn starch**, by hydrolysis

SUGAR SYRUP:

- Cane sugar is used for preparing syrups
- The purity of sugar should be at least **99.5 %** as sucrose & shouldn't contain any residual sulphur dioxide which cause sulphur staining in the can

Preparation of syrups:-

- Syrups are prepared by mixing sugar with water
- Light syrup can be prepared without heating whereas heating has to be applied to prepare heavy syrup
- To remove insoluble foreign matter, syrups should be passed through a fine screen or filtered through muslin cloth

SUCROSE / INVERT SYRUPS:-

- These are mixtures of sucrose & invert sugar with varying proportion of other matter derived from the cane sugar liquor during refining
- The latter give rise to golden or darker colors & distinctive flavors
- Generally the flavor increases with the color
- Common types of syrup are, golden syrup, they are recommended for biscuit manufacture on account of their pleasant flavors & stability of the flavor during baking
- By combining sucrose & invert sugar it is possible to obtain more concentrated syrups which are stable in crystallization than with sucrose alone

INVERT SYRUP:-

- It is relatively simple to make invert syrup
- A solution of sucrose is acidified & heated
- Normally dil. Hydrochloric acid is used, after 1hr at 75 C inversion is 95 % complete
- Sodium bicarbonate is added to neutralize the acid. This is **invert syrup.** Thus invert syrup contains some salt

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- The sucrose is hydrolyzed into glucose & fructose
- The hydrolysis can also be achieved with the enzyme **invertase**
- The syrup is a clear liquid & has no particular flavor other than sweetness

HIGH FRUCTOSE CORN SYRUP (HFCS)

- It is manufactured from corn starch
- The corn starch is hydrolyzed by acid or enzyme & then the resulting glucose is inverted into fructose
- The % of inversion can be changed by altering the processing conditions

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HONEY

- Honey is produced by honeybees
- They suck up nectar from flowers or other sweet saps found in living plants, store the nectar in their honey sac, & enrich it with some of their own substances to induce changes
- When the bees return to the hive, they deposit the nectar in honey combs for storage & ripening
- Honey production starts immediately after the flower pollen, nectar is collected & deposited in the Bee's pouch (honey sac)
- The mixture of raw materials is then given to worker bees in the hive to deposit it in the six-sided individual cells of the honeycomb

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- The changing of **nectar into honey** proceeds in the cell in the following stages :-
- ✓ Water evaporates from the nectar, which then thickens
- ✓ The content of invert sugar increases through sucrose hydrolysis by acids & enzymes derived from bees, while an additional isomerization of glucose to fructose occurs in the honey sac
- ✓ Absorption of proteins from plant & bees, & acids from the bee's body; assimilation of minerals, vitamins & aroma substances & absorption of enzymes from the bee's salivary glands & honey sacs ……..

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- When the water content of the honey drops to 16 – 19 % , the cells are closed with a wax lid & ripening continues, as reflected by a continued hydrolysis of sucrose by the enzyme invertase & by the synthesis of new sugar
- The flavor & color of honey are influenced by the kinds of flowers from which the nectar originates

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COMPOSITION OF HONEY

- Honey is essentially a concentrated aqueous solution of invert sugar ,but it also contains a very complex mixture of other carbohydrates, several enzymes, amino acids & organic acids, minerals, aroma substances ,pigments etc

WATER

- The water content of honey should be less than 20 %
- Honey with higher water content is readily susceptible to fermentation by osmophilic yeasts
- Yeast fermentation is negligible when the water content is less than 17.1 %

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CARBOHYDRATES:

- Fructose & glucose are the predominant sugars in honey
- The content of sucrose varies appreciably with the honey ripening stage

ENZYMES:

- The most prominent enzymes in honey are alpha glucosidase (invertase), alpha & beta amylases, glucose oxidase, catalase & acid phosphatase

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AMINO ACIDS:

- Honey contains free amino acids at a level of 100mg/100g solids
- Proline, which originate from bees, is the prevalent amino acid fraction

ACIDS:

- The principal organic acid in honey is gluconic acid, which result from glucose oxidase activity
- Other acids present in honey only in small amounts are acetic, butyric, lactic, citric, succinic, formic, malic & oxalic acids

AROMA SUBSTANCE:

- These are esters of aliphatic & aromatic acids, aldehydes, ketones, & alcohols

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PIGMENTS:

- The amber colour appears to originate from phenoloic compounds & from products of the nonenzymic browning reaction between amino acids & fructose

STORAGE

- Honey color generally darkens on storage
- The aroma intensity decreases depending on pH, storage time, & temperature
- Honey should be protected from air moisture & kept at temperatures lower than 10 C when stored
- The desired temperature range for use is 18 - 24 C

USES:

- Honey is used primarily to impart flavors
- It is a very special syrup used in **baking** particularly for its flavor
- It is used in the manufacturing of **alcoholic beverages** by mixing with alcohol or by fermentation into honey flavored wine in addition to providing its unique flavor & humectancy
- Honey can enhance spicy or fruity flavors in fruit jelly candies, mint creams
- It is more costly than HFCS, sucrose, or invert sugar

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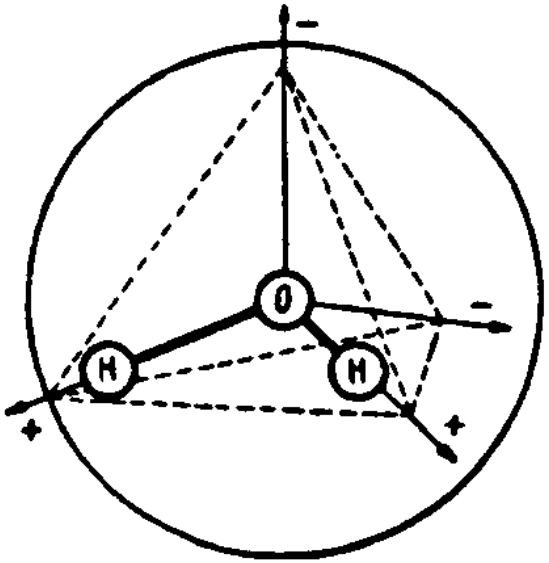
❖STRUCTURE OF WATER MOLECULES

- The chemical structure of water is H_2O

- Water molecules are dipoles in which the hydrogen atoms are slightly **+ive** represented by the symbol **δ+** and the oxygen atom slightly **–ive** represented by the symbol **δ-**

- Within a water molecule the H- atoms are bonded to Oxygen by a covalent pair of electrons, but the angle between these atoms is 105º



Structure of the Water Molecule

- Water molecules possess the ability to form bonds known as hydrogen bonds, either with other water molecules or with molecules of other substances

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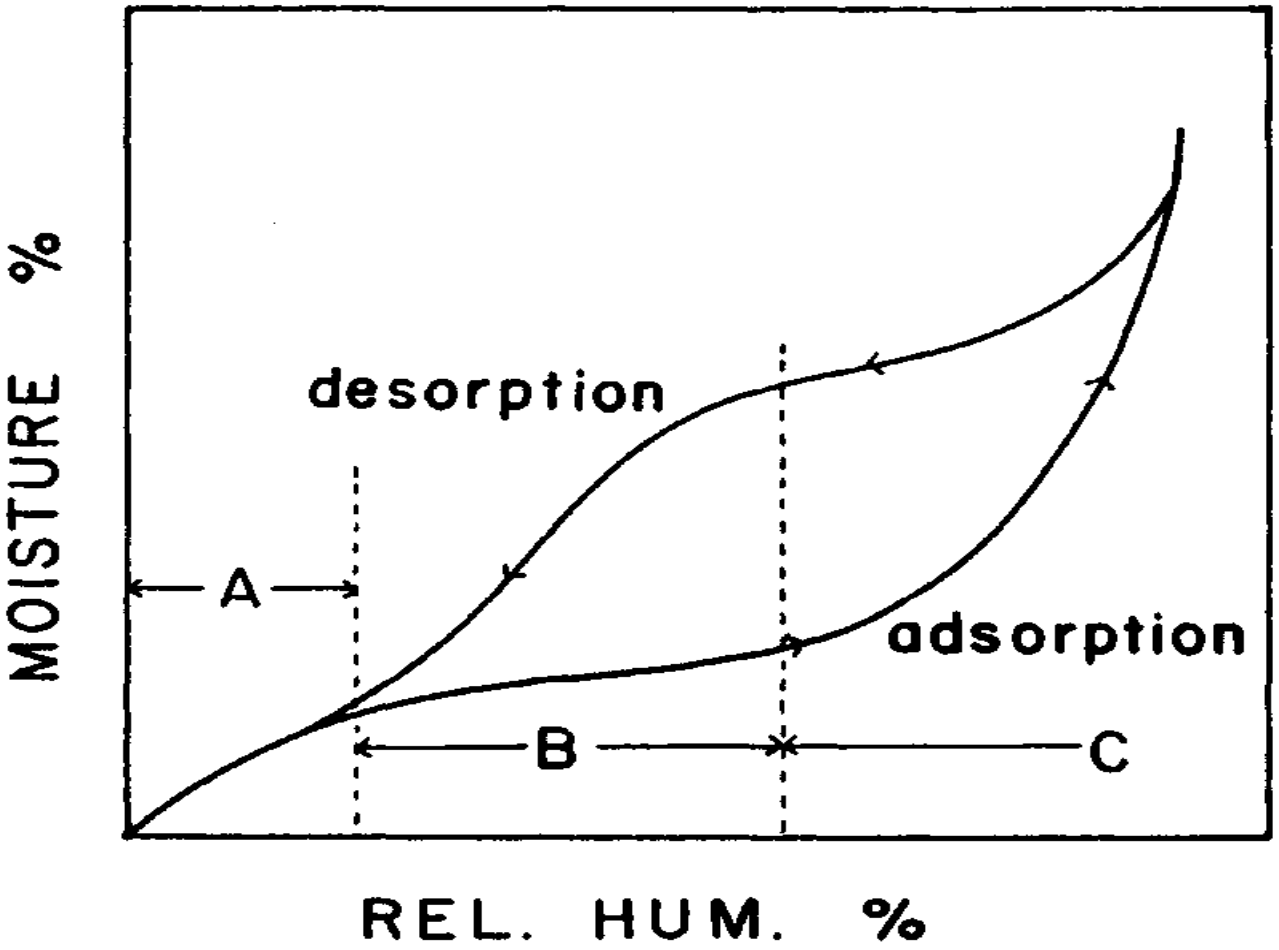
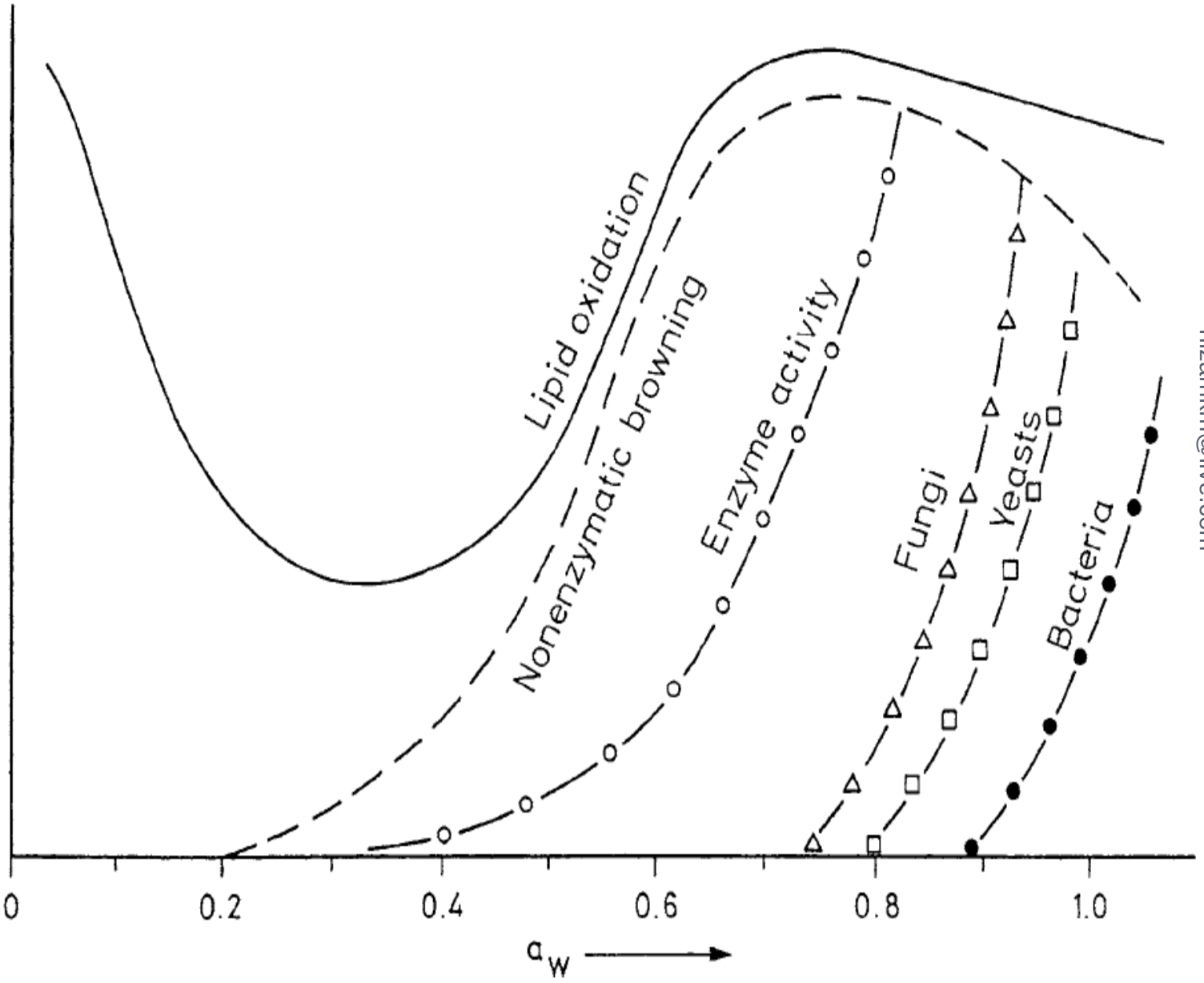


Figure 1–7 Adsorption and Desorption Isotherms



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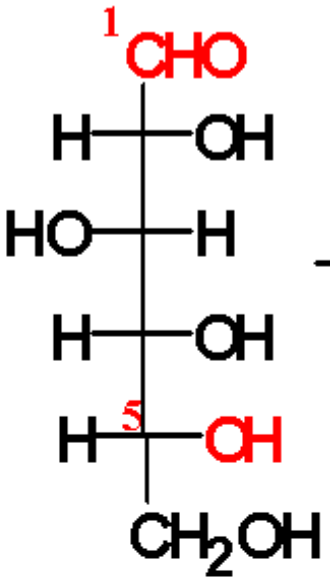
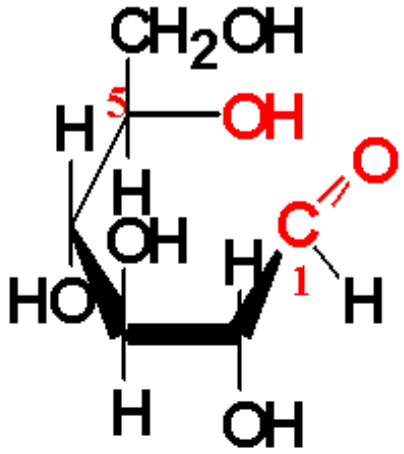
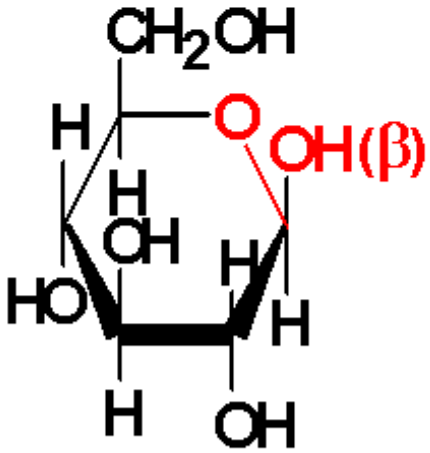


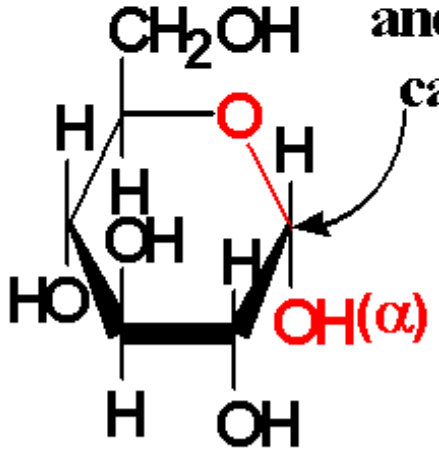
D-Glucose



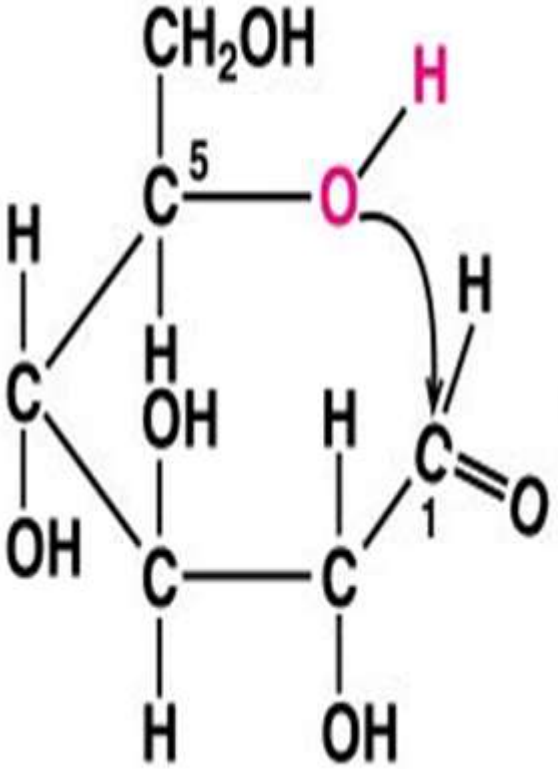


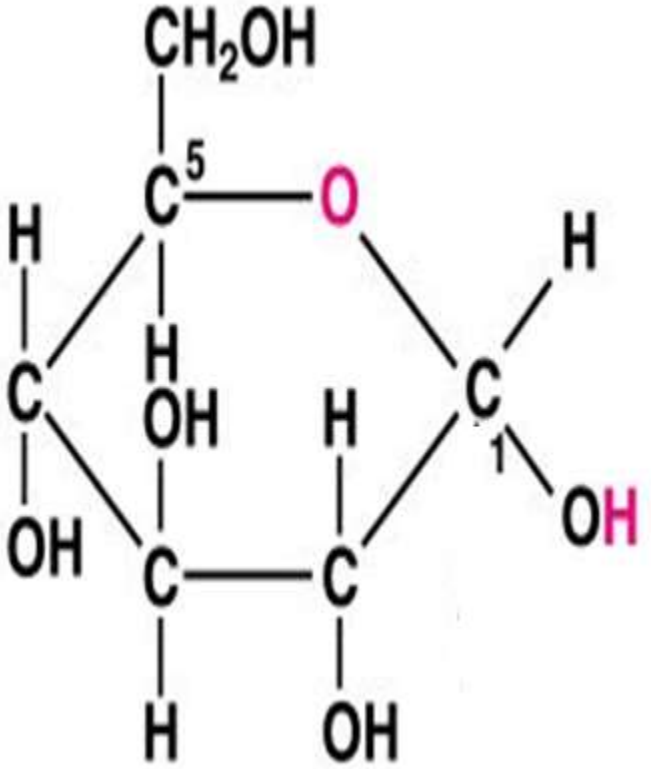
β-D-Glucopyranose
(β-D-Glucose)

+



α-D-Glucopyranose
(α-D-Glucose)





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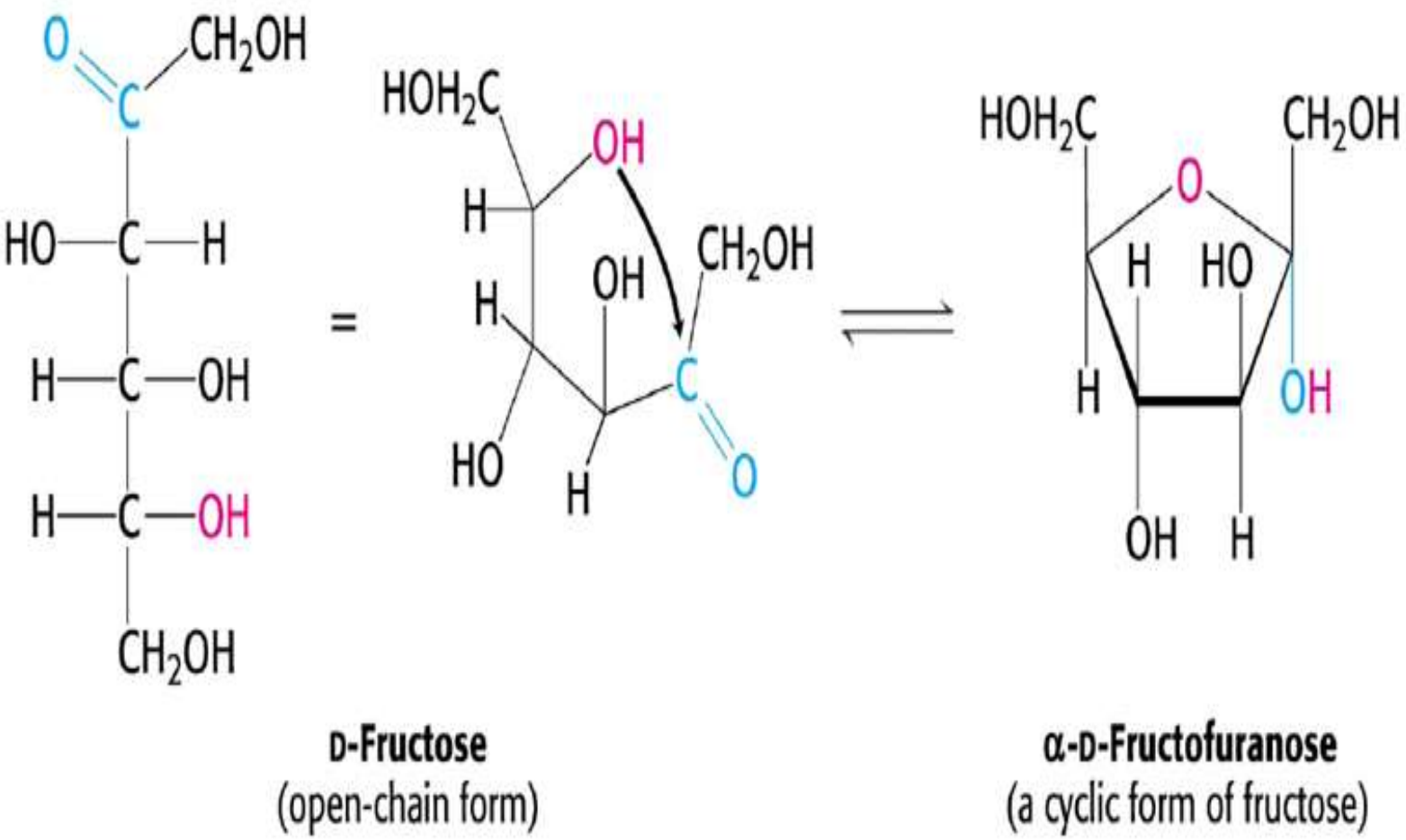

D-Fructose
(open-chain form)

α-D-Fructofuranose
(a cyclic form of fructose)

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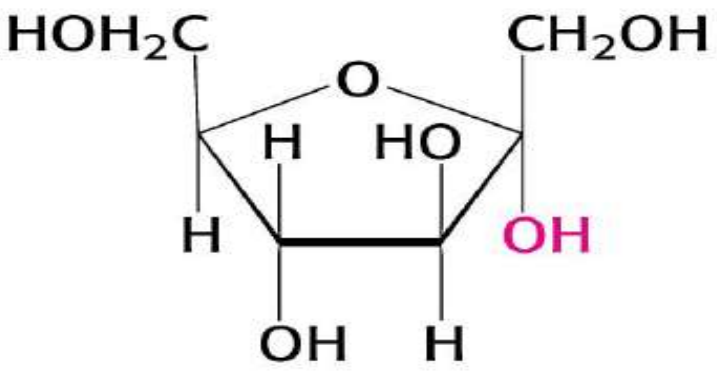
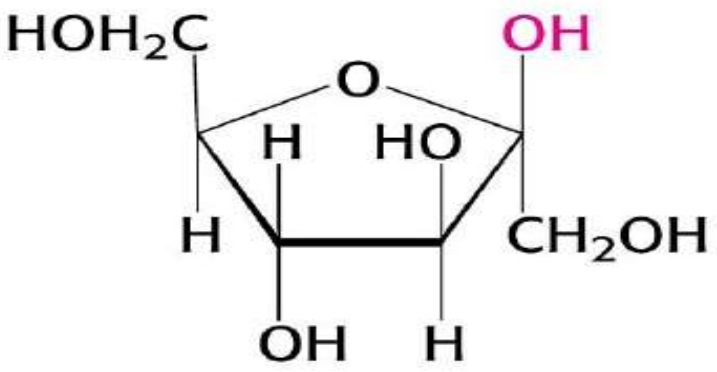
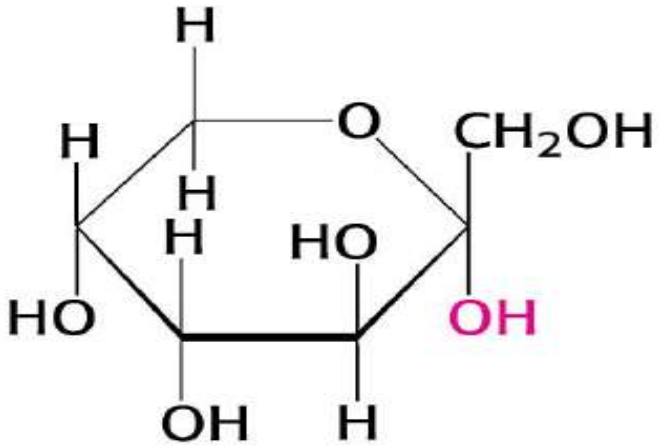


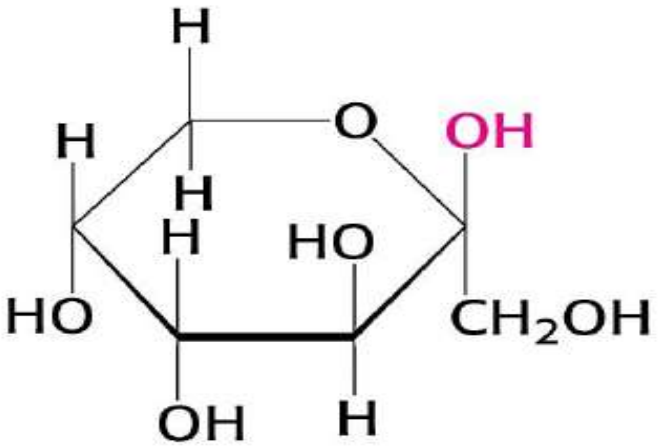
α-D-Fructofuranose



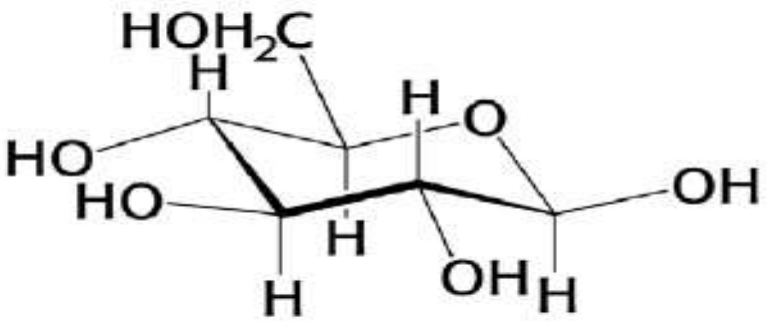
β-D-Fructofuranose



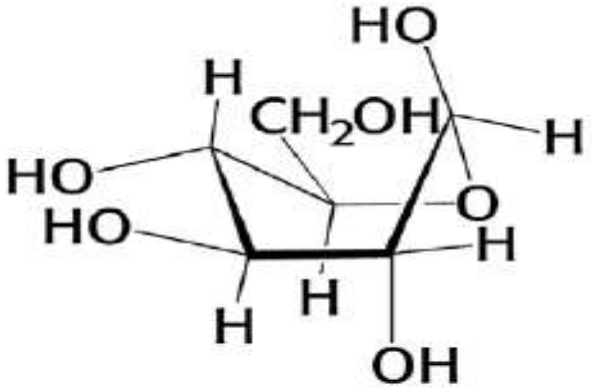
α-D-Fructopyranose



β-D-Fructopyranose



Chair form



Boat form

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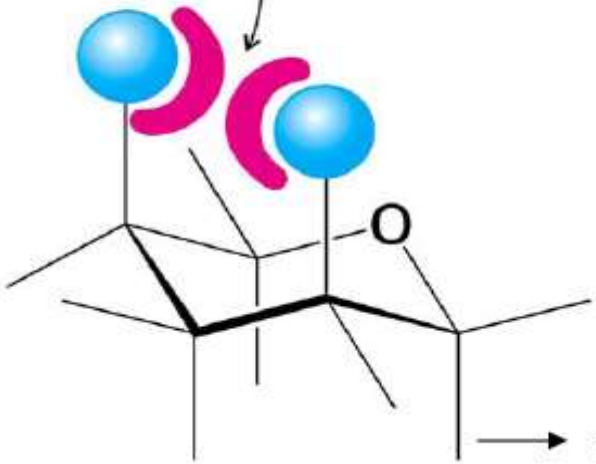
Steric hindrance

In the chair form



equatorial position

axial position