Carbohydrates of biological importance 1

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Majority of sides: Dr. Walaa Bayoumie El Gazzar

What does biochemistry deal with?

- Metabolism:
  - Anabolism
  - Catabolism

- Foods:
  - Oxidizable: carbohydrates, lipids, proteins
  - Non-oxidizable: minerals, vitamins, water

Syllabus

- 6.1 Define carbohydrates and list their classification.

- 6.2 Recognize the structure and functions of monosaccharides.

- Carbohydrates are organic compounds composed of carbon, hydrogen, and oxygen.

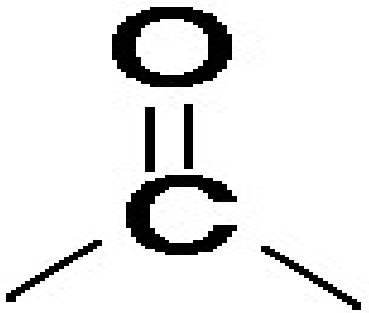
- Carbo=carbon, hydrates=hydrogen and oxygen in their proportion in water H2O

- They generally have the common formula **(CH2O)n** where the least number of n=3

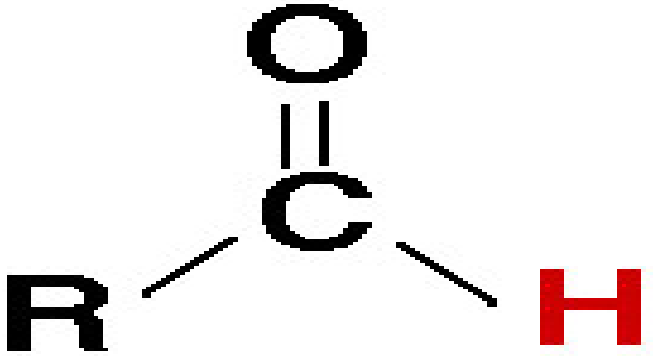
Definition of carbohydrates

- Simple sugars or its derivatives

- Simple sugars are considered as **polyhdroxyketones** or **polyhydroxyaldehydes**

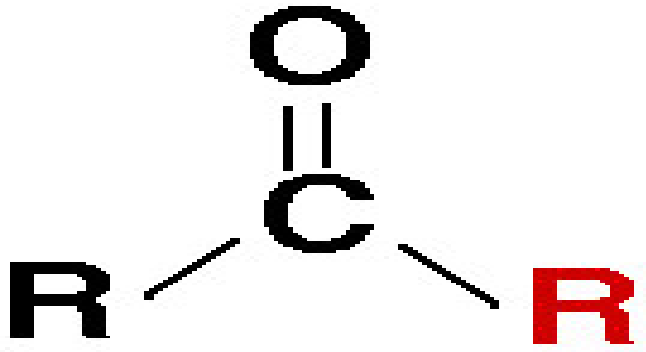


Carbonyl group



Aldehyde

Makes Aldose (aldo sugar)



Ketone

Makes Ketose (keto sugar)

- **Ketones and aldehydes are simple compounds that contain a carbonyl group (a carbon-oxygen double bond).**

- ***where R can be a carbon-containing substituent.***

Classification of Carbohydrates (according to hydrolysis):

- **Monosaccharides**: contain one sugar unit
  - E.g. glucose.
- **Disaccharides:** contain two sugar units
  - Maltose.
- **Oligosaccharides**: contain 3-10 sugar units
  - E.g. Raffinose
- **Polysaccharides**: contain more than 10 sugar units
  - Starch or glycogen.

I. Monosaccharides

- **Definition:** They are simple sugars that cannot be hydrolyzed into smaller one.
- **Classification of monosaccharides:**

I. According to the number of carbon atoms: e.g.

1) Trioses: contain three carbon atoms.

2) Tetroses: contain four carbon atoms.

3) Pentoses:contain five carbon atoms.

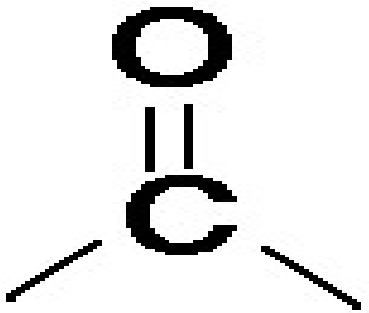
4) Hexoses: contain six carbon atoms.

Classification of monosaccharides:

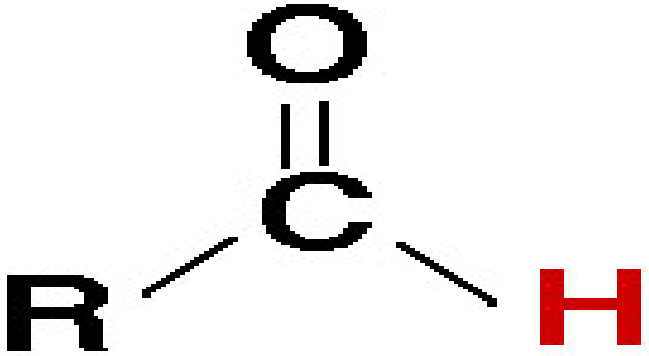
Classification of monosaccharides:

II. According to function group:

- **Aldose**
- **Ketose**

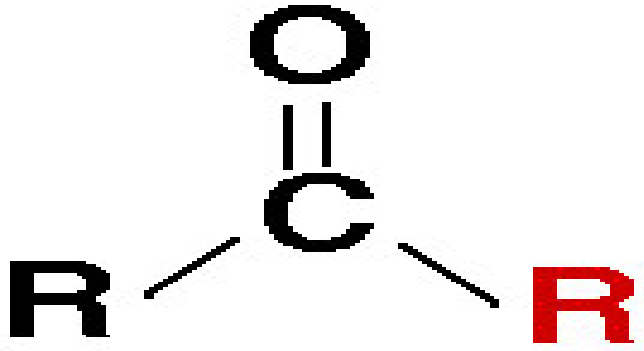


Carbonyl group



Aldehyde

Aldose (aldo sugar)



Ketone

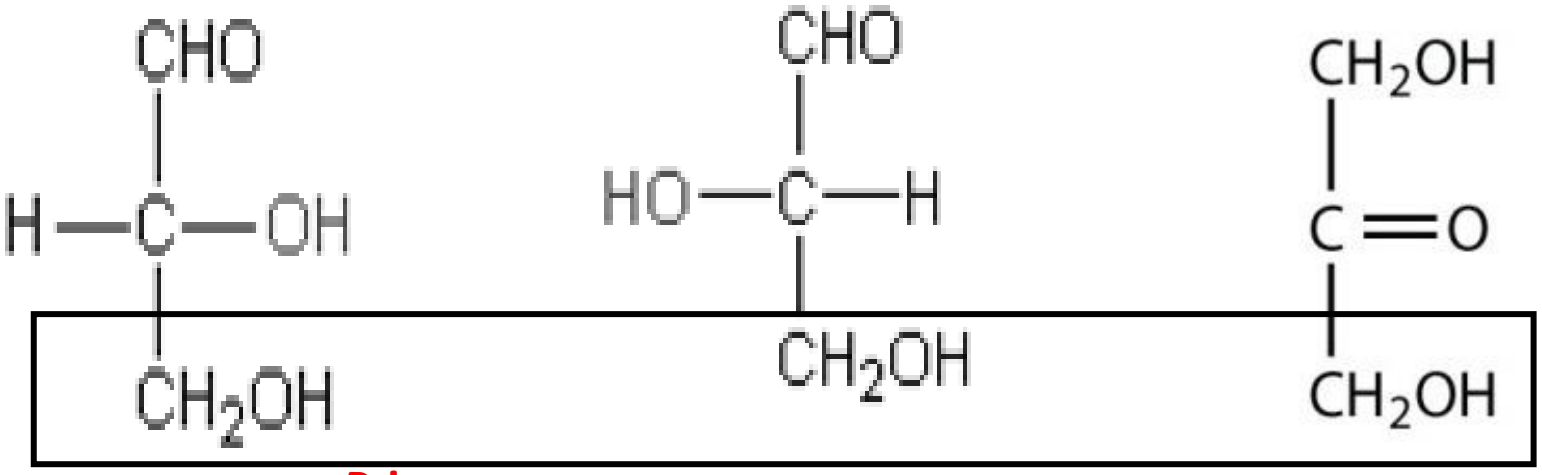
Ketose (keto sugar)

- **Ketones and aldehydes are simple compounds that contain a carbonyl group (a carbon-oxygen double bond).**

- ***where R can be a carbon-containing substituent.***

Number of carbons	Aldo-sugars (e.g.)	Keto-sugars (e.g.)
3C (triose)	Glyceraldehyde	Dihydroxy acetone
4C (tetrose)	Erythrose	Erythrulose
5C (pentose)	Ribose Aldopentose	Ribulose
6C (hexose)	Glucose	Fructose

- Glyceraldehyde and dihydroxyacetone.(They are intermediates in the break down of glucose).



Primary group

D- Glyceraldehyde

Dihydroxyaldose

L- Glyceraldehyde

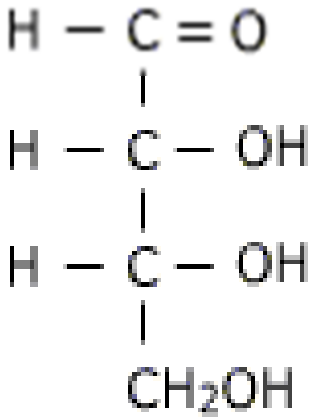
Dihydroxyacetone

Dihydroxyketose

D & L denote the absolute configuration. i.e. D means that OH group on the subterminal carbon atom is at the right but L means OH group on the subterminal carbon atom is at the left.

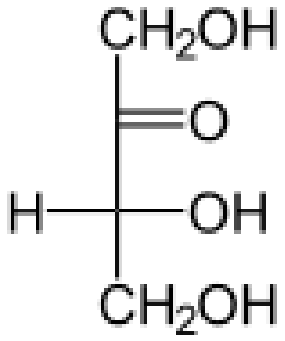
- **Examples of Tetroses are:**
- Aldotetrose: Erythrose
- Ketotetrose: Erythulose

Erythrose was first isolated in 1849 from rhubarb



D-Erythrose

Erythrulose/DHA reacts with the amino acids in the proteins of the first layers of skin (the stratum corneum and epidermis)



D-Erythrulose

D-Erythrulose

- **Most physiologically important isomers that can be utilized in the body are the D form**

- Some sugars occur naturally in their L-forms:

- L-arabinose and L-fucose ($C_6H_{12}O_5$) which are components of glycoprotein

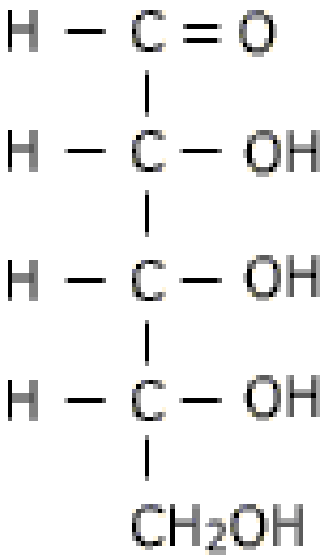
- L-xylulose (pentose) is an intermediate in metabolism and can be utilized by isomerization into D-form

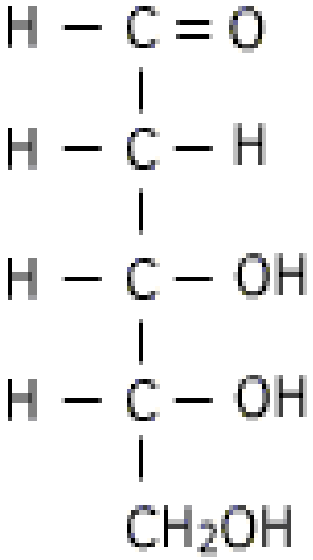
- L- arabinose is an aldopentose present in some fruits such as cherries, grapes, plums, and prunes

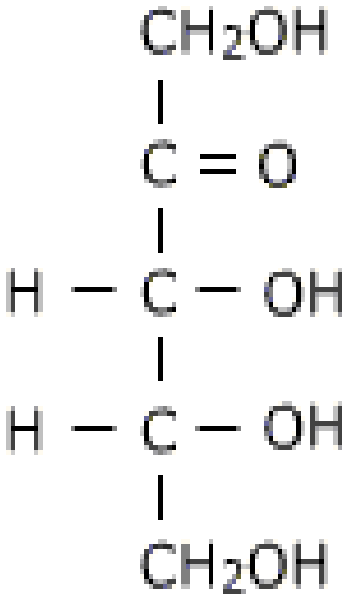
Case

- Sarah, 28-year-old female, complains of intermittent abdominal discomfort and sweet-smelling urine
- Clinical Examination: Healthy with mild epigastric tenderness.
- Urinalysis shows elevated sugars, blood: normal glucose

- **Examples of pentoses are:**
- aldopentoses: ribose and deoxyribose, ketopentose: ribulose







Functions of pentoses:

- Ribose and deoxyribose enter in the structure of nucleic acids RNA and DNA.

- Ribose enters in the structure of ATP, GTP and other high energy phosphate compounds.

- Ribose enters in the structure of coenzymes NAD,NADP and flavoproteins.

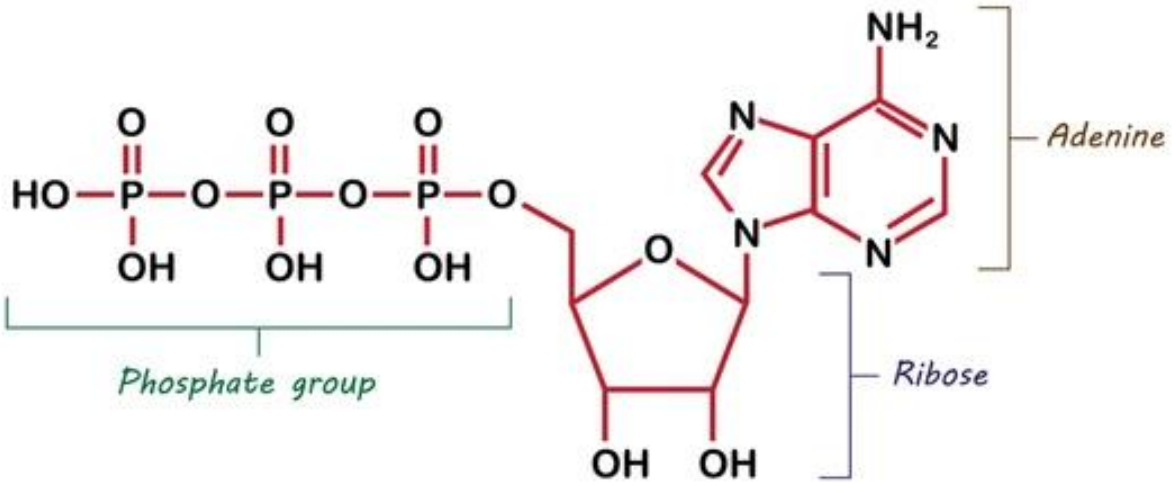
- Ribose phosphate and ribulose phosphate are intermediates in pentose phosphate pathway (a minor pathway for glucose oxidation).

- They are components of some vitamins (ribitol in vitamin **B2)**

ATP

Biology

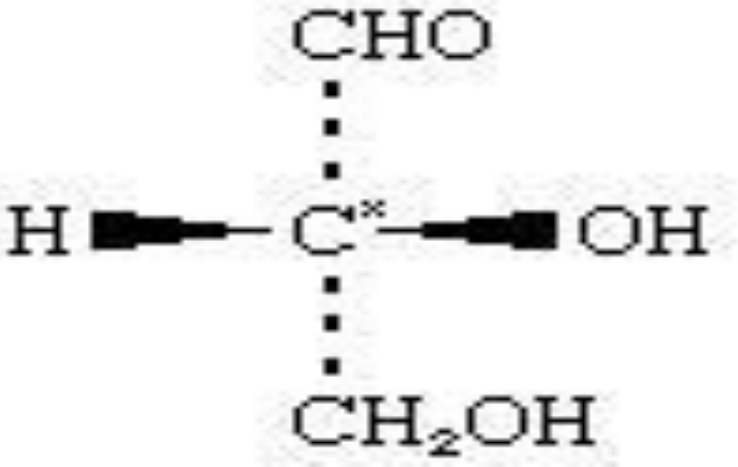
Adenosine Triphosphate (ATP)



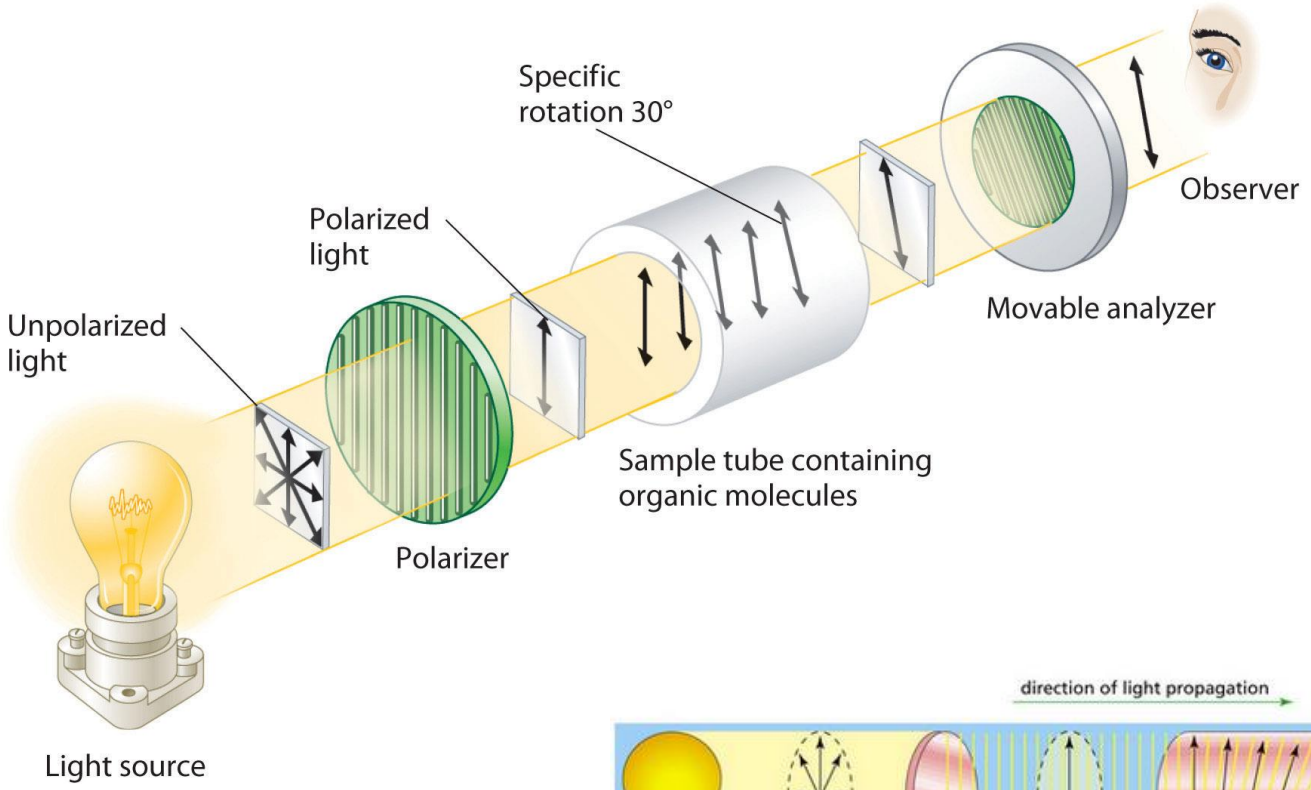
- Energy-carrier in all of living things
- Consist of nitrogenous base (adenine), sugar (ribose) and phosphate group

Asymmetric carbon atom:

- It is the carbon atom to which four different groups or atoms are attached. Any substance containing asymmetric carbon atom has optical activity & optical isomerism

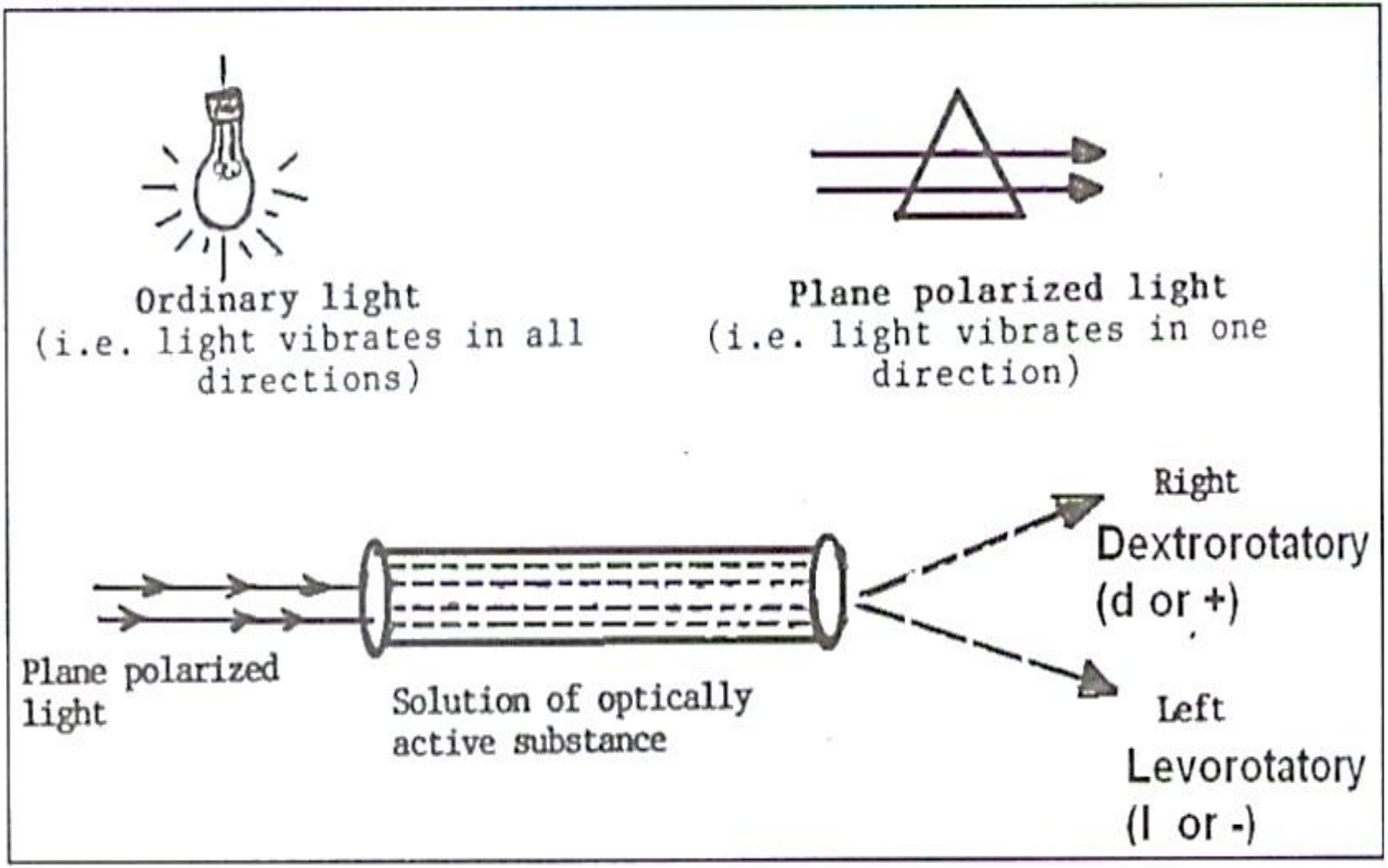


- A **polarimeter** is a scientific instrument used to measure the angle of rotation caused by passing polarized light through an optically active substance.



Optical activity

- It is the ability of substance to rotate plane polarized light (P.P.L) either to the right or to the left.
- If the substance rotates plane polarized light (light vibrate in one direction) to the right it is called: **dextrorotatory** or d or **(+)**.
- If it rotates plane polarized light to the left it is called **levorotatory** or **l** or **(-)**.
- Glucose contains 4 asymmetric carbon atoms. It is dextrorotatory so it is named **dextrose**
- Fructose contains 3 asymmetric carbon atoms. It is levorotatory so it is called **levulose**


Ordinary light
(i.e. light vibrates in all directions)
Plane polarized light
(i.e. light vibrates in one direction)
Right
Dextrorotatory
(d or +)
Plane polarized light
Solution of optically active substance
Left
Levorotatory
(l or -)

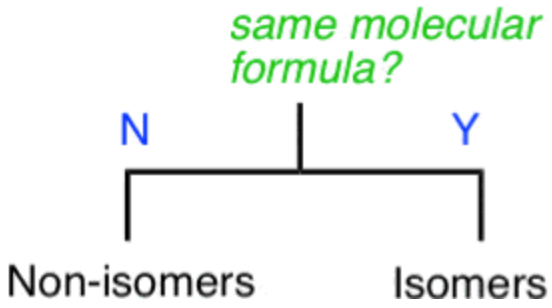
- The optical rotation is proportional to the concentration of the optically active substances in solution

- Polarimetry may therefore be applied for concentration measurements

- Concentration and purity measurements are especially important to determine product or ingredient quality in the food & beverage and pharmaceutical industries

Isomers

- It is the ability of substance to present in more than one form (isomer).
- A substance containing one asymmetric carbon atom has 2 isomers.
- A substance containing 2 or more asymmetric carbon atoms can exist in a number of isomers = 2^n where n is the number of asymmetric carbon atoms. e.g. glucose has 4 asymmetric carbon atoms so the number of its isomers equal 2^4= 16 isomers.

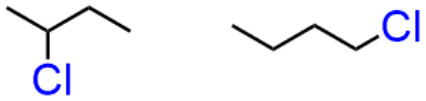


Isomers

Same molecular formula- different compounds

Constitutional

same formula, different connectivity

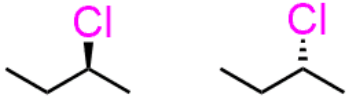


Stereo

same formula, same connectivity, different arrangement

Enantiomers

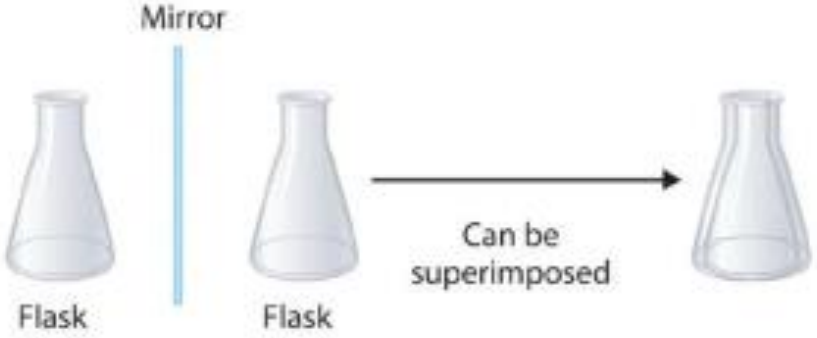
mirror images



Diastereomers

not mirror images

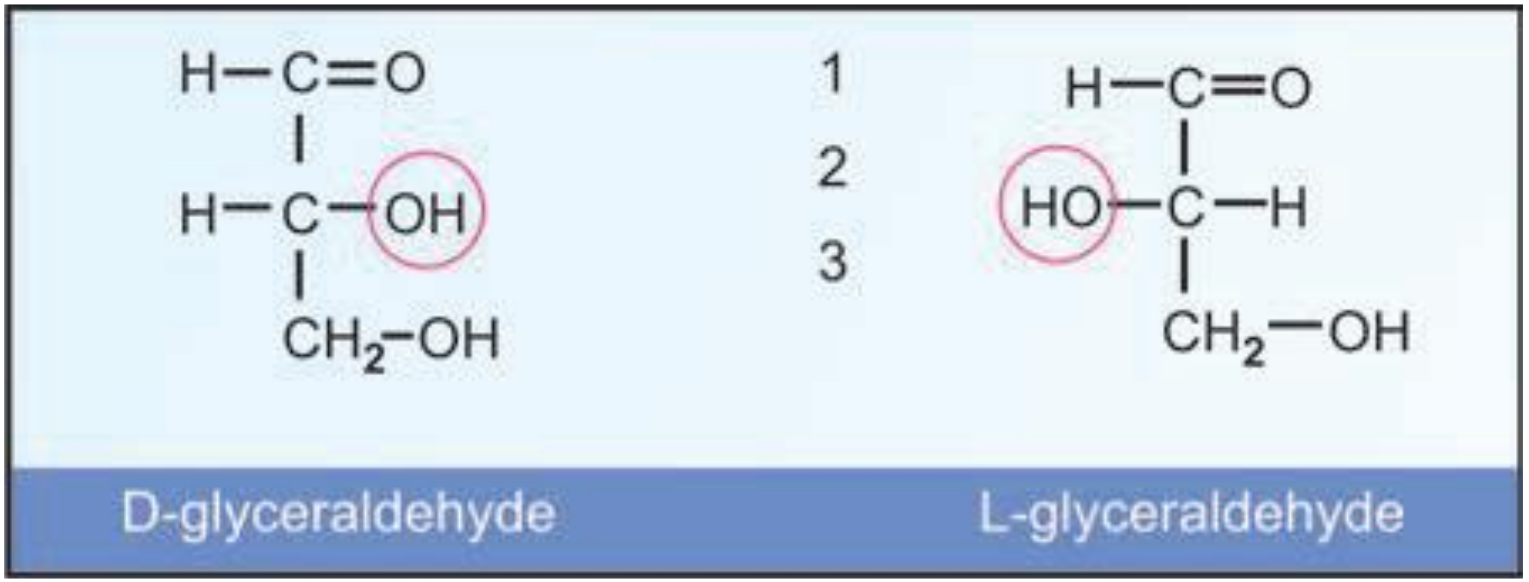
(a) Chiral objects



(b) Achiral objects

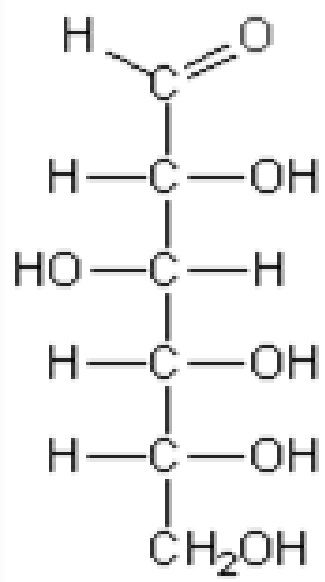
Compounds having same structural formula, but differing in spatial configuration are known as stereoisomers

What is this?

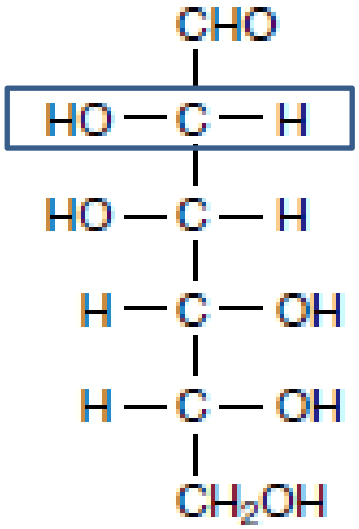


Examples of hexoses are:

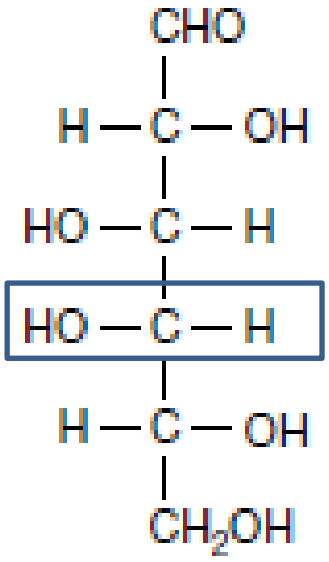
- aldohexoses: glucose, mannose and galactose,
- ketohexoses: fructose



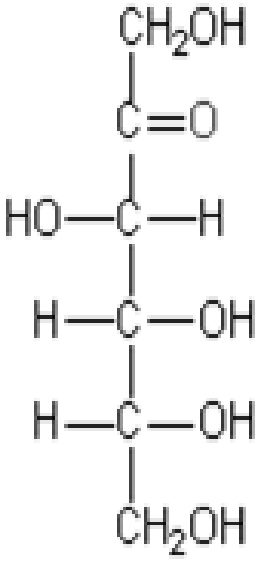
D-Glucose



D-Mannose



D-Galactose



D-Fructose

Galactose and mannose are
not epimers but diastereo-isomers.

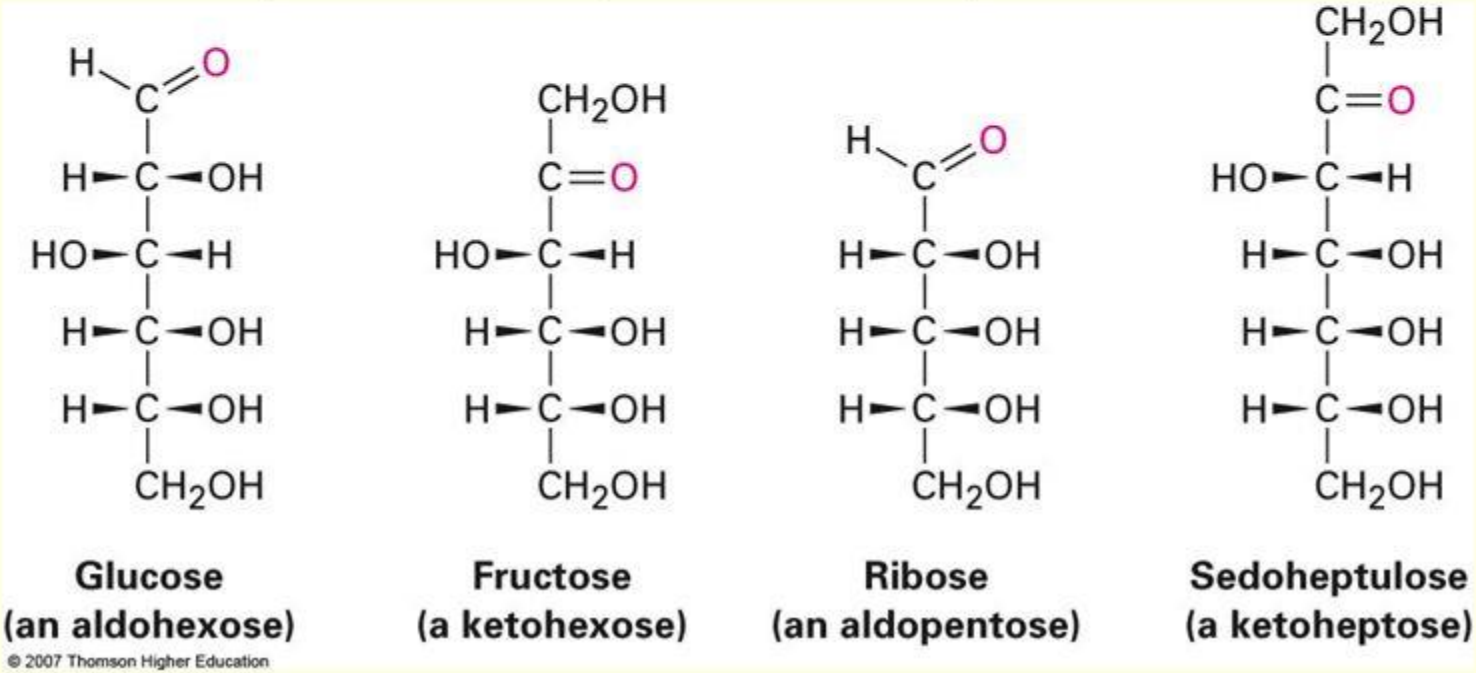
Epimeric carbon &epimers:

- **Epimers:** These are sugars which differ only in the configuration around a single carbon atom. e.g. Glucose & mannose with respect to C_2. Also, glucose & galactose with respect to C_4
    - The contain more than one asymmetric carbon atom, all of which identical but only one is different

- **Epimeric carbon:** e.g. carbon number 2 in glucose & mannose & carbon number 4 in glucose and galactose.

Aldoses and Ketoses

- *aldo-* and *keto-* prefixes identify the nature of the carbonyl group
- *-ose* suffix designates a carbohydrate
- Number of C's in the monosaccharide indicated by root (-tri-, tetra-, penta-, hexa-)



- **Importance of hexoses:**

D-glucose "grape sugar":

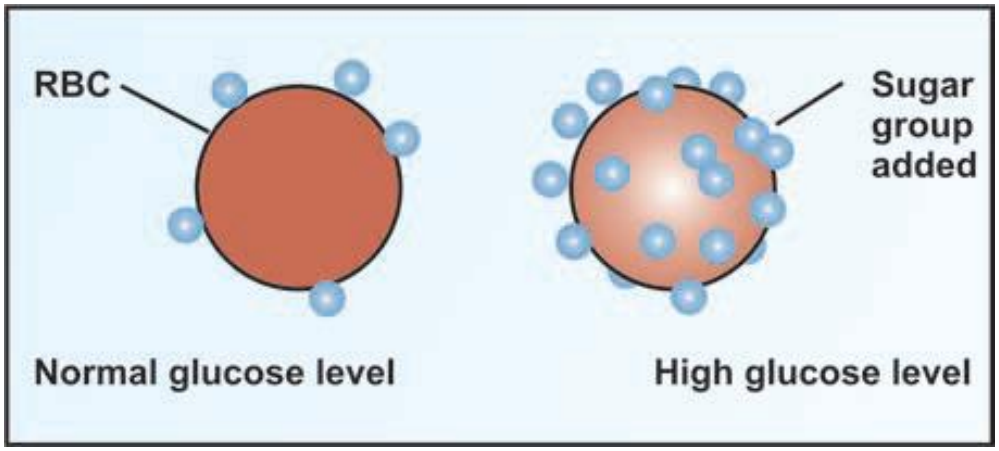
- It is called dextrose (dextro-rotatory).
- It is the most important sugar of carbohydrates.
- It is one of major sources of energy in the body.
- It is the principle sugar used by the tissues.
- It is widely present in fruits & vegetables associated with fructose.
- It enters in the formation of disaccharides & polysaccharides.
- In the liver & other tissues, it is converted to all carbohydrates in the body e.g. glycogen, galactose, ribose &fructose.

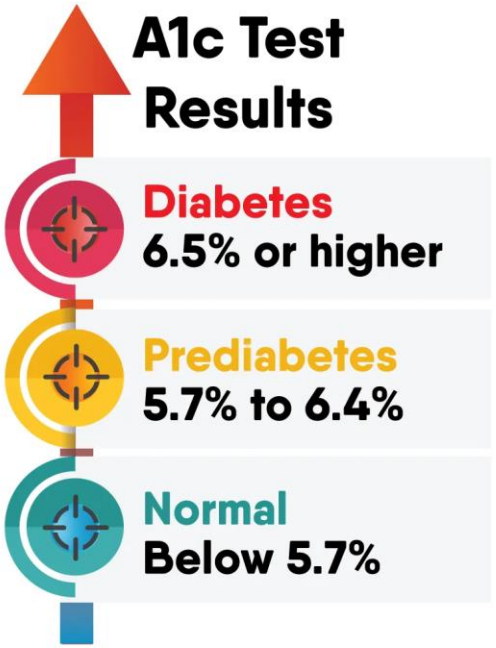
Table 24.1. The plasma glucose levels in OGTT in normal persons and in diabetic patients

	Normal persons	Criteria for diagnosing diabetes	Criteria for diagnosing IGT
Fasting	**< 110 mg/dl** <(6.1mmol/L)	**> 126 mg/dl** >(7.0 mmol/L)	**110 to** 126 mg/dl
1 hr (peak) after glucose	**< 160 mg/dl** < (9 mmol/L)	Not prescribed	Not prescribed
2 hr after glucose	**< 140 mg/dl** < (7.8 mmol/L)	**> 200 mg/dl** >(11.1 mmol/L)	**140 to** 199 mg/dl

Box 24.3. Diagnostic Criteria for Diabetes Mellitus

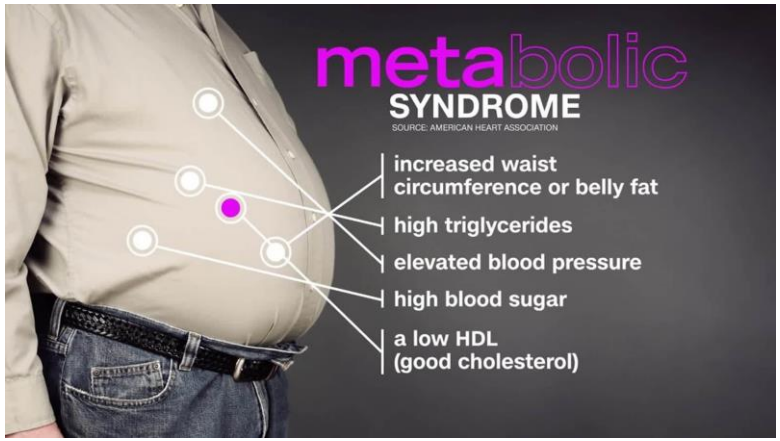
1. **If the fasting plasma glucose is more than 126 mg/dl, on more than one occasion.**
2. Or, if 2 hr post-glucose load value of OGTT is more than 200 mg/dl (even at one occasion).
3. Or, if both fasting and 2 hr values are above these levels, on the same occasion.
4. If the random plasma glucose level is more than 200 mg/dl, on more than one occasion. Diagnosis should not be based on a single random test alone; it should be repeated.


RBC
Sugar group added
Normal glucose level
High glucose level

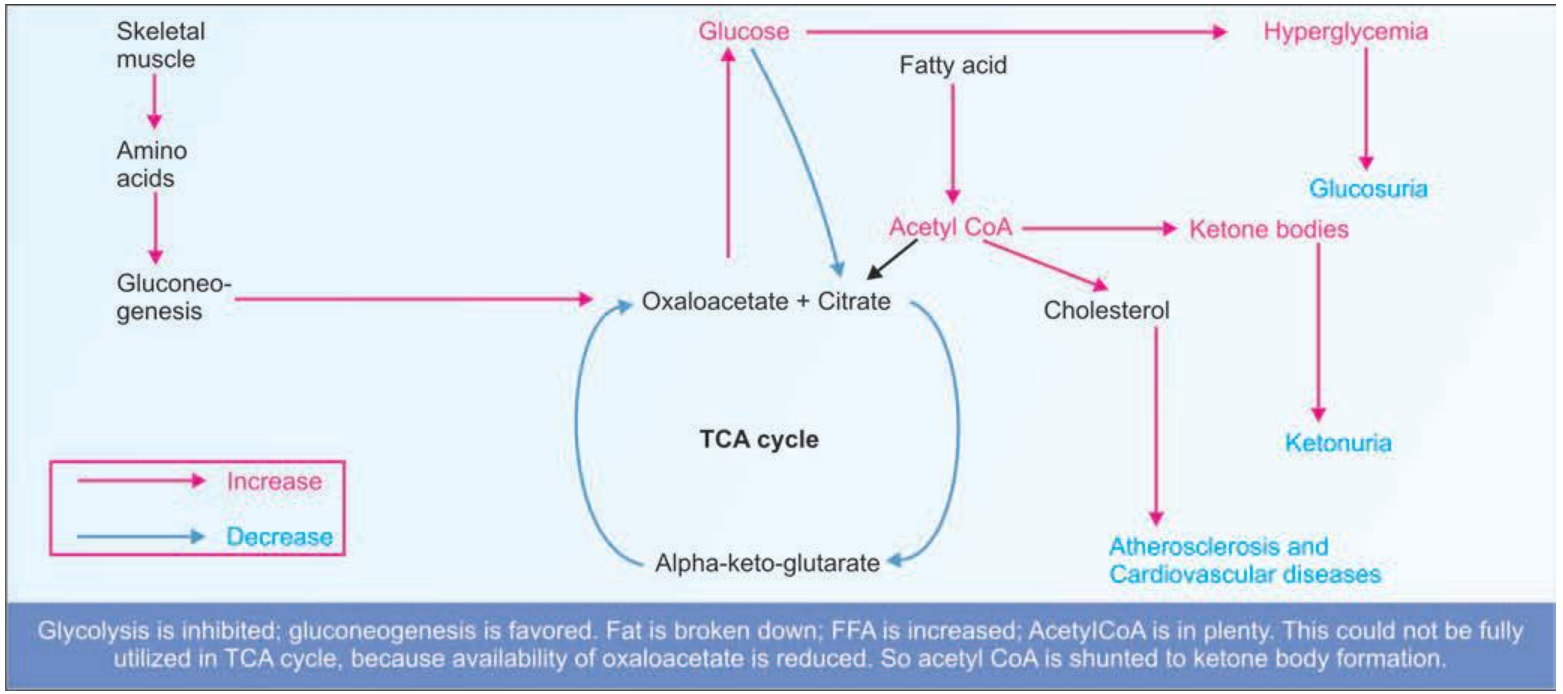

A1c Test Results
Diabetes
6.5% or higher
Prediabetes
5.7% to 6.4%
Normal
Below 5.7%

Box 24.6. Criteria for Diagnosis of Metabolic Syndrome

i. Elevated waist circumference: (For men >90 cm and for women, >80 cm).
ii. Elevated triglycerides: >150 mg/dL
iii. Reduced HDL ("good") cholesterol: For men, <40 mg/dL; for women, < 50 mg/dL
iv. Elevated blood pressure: >130/85 mm Hg
v. Elevated fasting glucose: >100 mg/dL
vi. Insulin resistance (hyperinsulinemia)
vii. Additional parameters include: coagulation abnormalities, hyperuricemia, microalbuminuria non-alcoholic steato-hepatitis (NASH) and increased CRP.
viii. Diagnosis is made, if any 3 out of the 5 criteria given above.



Diabetes biochemistry (FYI)



D-fructose "fruit sugar":

- It is called Levulose (levo-rotatory).
- It is the main sugar of semen (Source of energy for the sperms).
- It is sweeter than glucose.
- It is present in honey & fruits.
- It enters in the formation of sucrose.
- In the liver, it is converted into glucose.

D-galactose"milk sugar":

- It is synthesized in mammary gland to make the lactose of milk.
- In the liver, it can be converted into glucose.
- It enters in the structure of **glycolipids** which are found in many tissues especially in C.N.S.

D- mannose:

- It is a constituent of many glycoproteins.

Analyzing Carbohydrate Consumption in Jordan: Health and Economic Impact

- Q1: Identify prevalent carbohydrate sources in the Jordanian diet and their nutritional significance
  A. Identify commonly farmed “nutritional” fruits and vegetables in Jordan and state why they are healthy

  B. Identify commonly used “non-healthy” carbs in Jordan and state why they are unhealthy

  C. Identify the most affordable “healthy” carbs in Jordan

- Q2: How do economic considerations influence carbohydrate consumption patterns in Jordan?

- Q3: Propose medical, economic and farming strategies to promote healthier carbohydrate choices in Jordan, considering affordability.