
# Molecular Biology

Lec : one

Done by : Jas Melhem

# Carbohydrates of biological importance 1

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(molecular biology)

# What does biochemistry deal with?

* • Metabolism: كيمياء الأيض
  - Anabolism
  - Catabolism

بناء
هدم

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

→ the human body breaks them down into smaller particles so it can deal with them properly.

→ cannot be oxidized

→ the human body deals with non-oxidizable foods as they are (هم و عم)

→ they are absorbed and used without any modifications, unlike oxidizable food with require breakdown and modification

# 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.

C H O

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

two to one

2:1

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

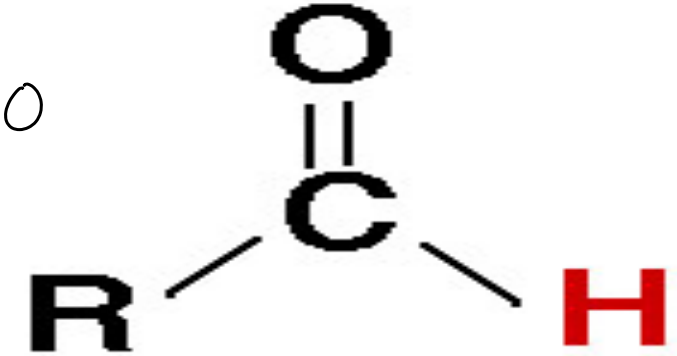
the smallest/simplest sugar found is $C_3H_6O_3$

# Definition of carbohydrates (CH2O)

- Simple sugars or its derivatives (مشتقاتها), containing elements like (C, H, O), it is produced by photosynthesis (عملية البناء الضوئي), animals depend on carbohydrates as a source of Energy.
- Simple sugars are considered as **polyhdroxyketones** or **polyhydroxyaldehydes**

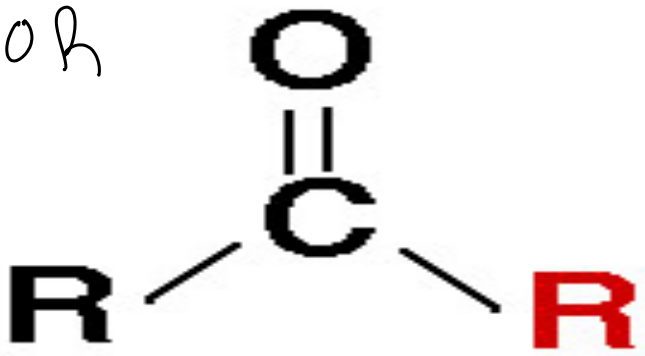
- carbohydrates are found in plants as in starch (نشا) and cellulose (fibers that serve as structural components of plant cell walls)
- carbohydrates are found in animals as glycogen (stored in the liver & muscles)


RCHO




Makes Aldose (aldo sugar)

RCOR




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.***

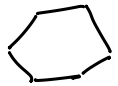
R is a carbon chain

## Classification of Carbohydrates (according to hydrolysis):

Hydration: addition of $H_2O$ without molecule breakdown

↳ addition of water to break molecules

- **Monosaccharides**: contain one sugar unit



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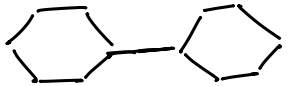
  - E.g. glucose.
- **Disaccharides**: contain two sugar units



2

  - 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:**

تصنيف

(first classification)

**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.

Heptoses Also exist! (contains seven carbon atoms)

# Classification of monosaccharides:

## Classification of monosaccharides:

## II. According to function group: (المجموعة الوظيفية) (second classification)

ketone / aldehyde

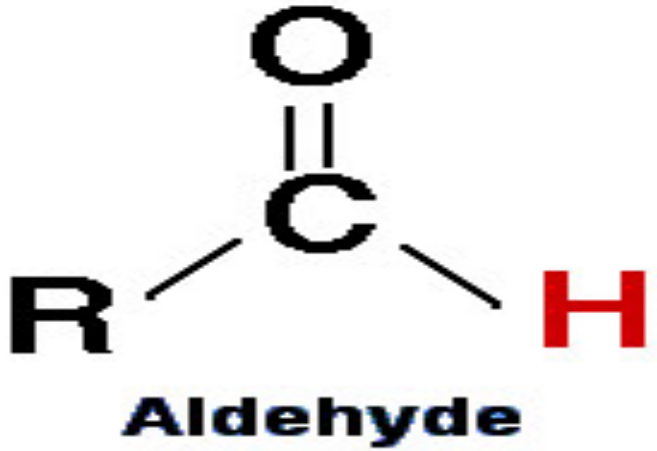
(also called active group)

- **Aldose** (contains aldehyde)
- **Ketose** (contains ketone)

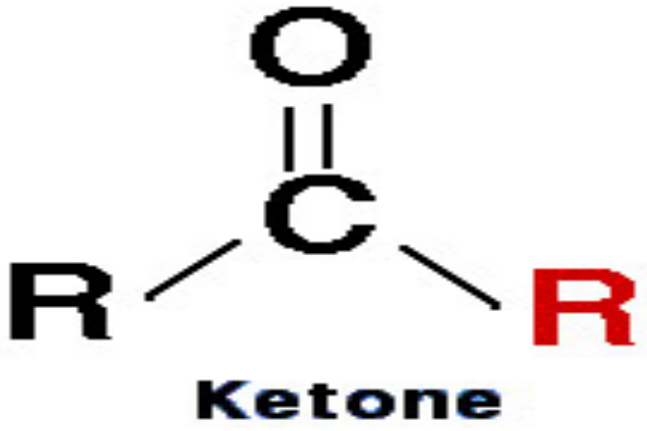
? what are anomeric carbons and how to Identify them?

- the anomeric carbon is found in sugars (Aldoses & Ketoses)
- they are found in the function group (Ketone or Aldehyde) (it is the carbon that is double-bonded with oxygen)
- in Aldoses, the anomeric carbon is the first carbon you will see, it will be double-bonded with oxygen
- in Ketoses, it will be the second carbon you will see, Also double-bonded with oxygen

(the anomeric carbon will be shown in further slides)


Aldose (aldo sugar)




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.***

the third classification

according to the number of carbons ⊕ the function group

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

Another way of naming sugars!

# Aldoses and Ketoses

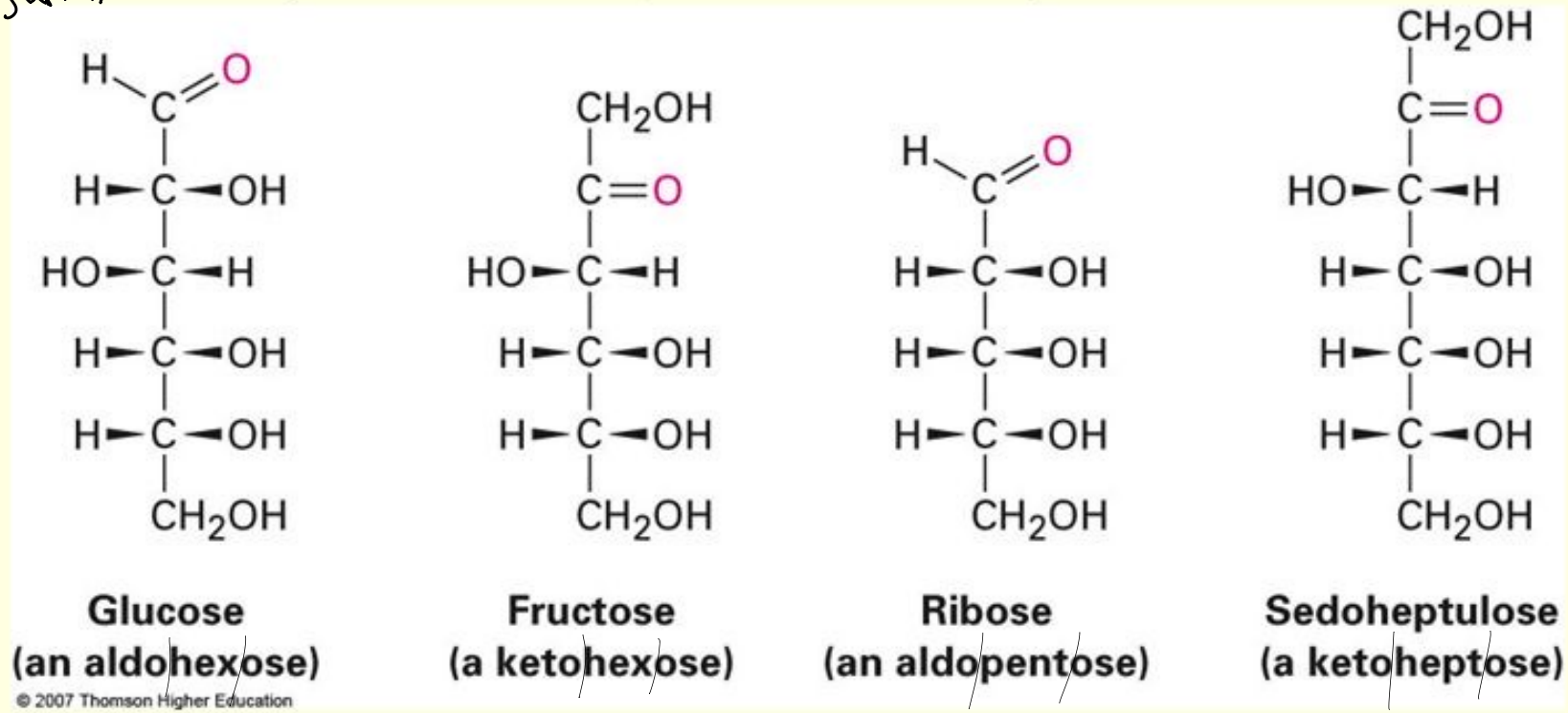
في بداية الكلمة

في نهاية الكلمة (دليل على انه سكر)

بالوسط بين prefix و suffix

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

ex:



**Glucose (an aldohexose)** | **Fructose (a ketohexose)** | **Ribose (an aldopentose)** | **Sedoheptulose (a ketoheptose)**

## what is an assymetrical carbon? (also named chiral carbon)

- an assymetrical carbon is a carbon that bonds with 4 different sides. if two sides (or more) are identical.... the carbon is not assymetrical (not chiral)

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## what is a penultimate carbon?

it is the carbon that determines whether a sugar is (L) or (D). (D and L sugars are isomers)

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## what is an (L) sugar? what is a (D) sugar?

* we should use capital (L) and capital (D) when we classify sugars based on the position of the hydroxyl group on the penultimate carbon (capital ليش)

→ D and L designations (تسميات) of sugars are based on the position of the hydroxyl (OH) on the chiral carbon farthest from the carbonyl group . All D-sugars have the –OH on the right side and L-sugars have the –OH on the left side .

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3 carbon sugars

- glyceraldehyde
  - * has an assymetrical carbon!
    - L-glyceraldehyde
      - * the farthest chiral carbon from the carbonyl group has hydroxyl (OH) on the left side
    - D-glyceraldehyde
      - * the farthest chiral carbon from the carbonyl group has hydroxyl on the right side
- dehydroxyaceton (DHA)
  - * does not have an assymetrical carbon!

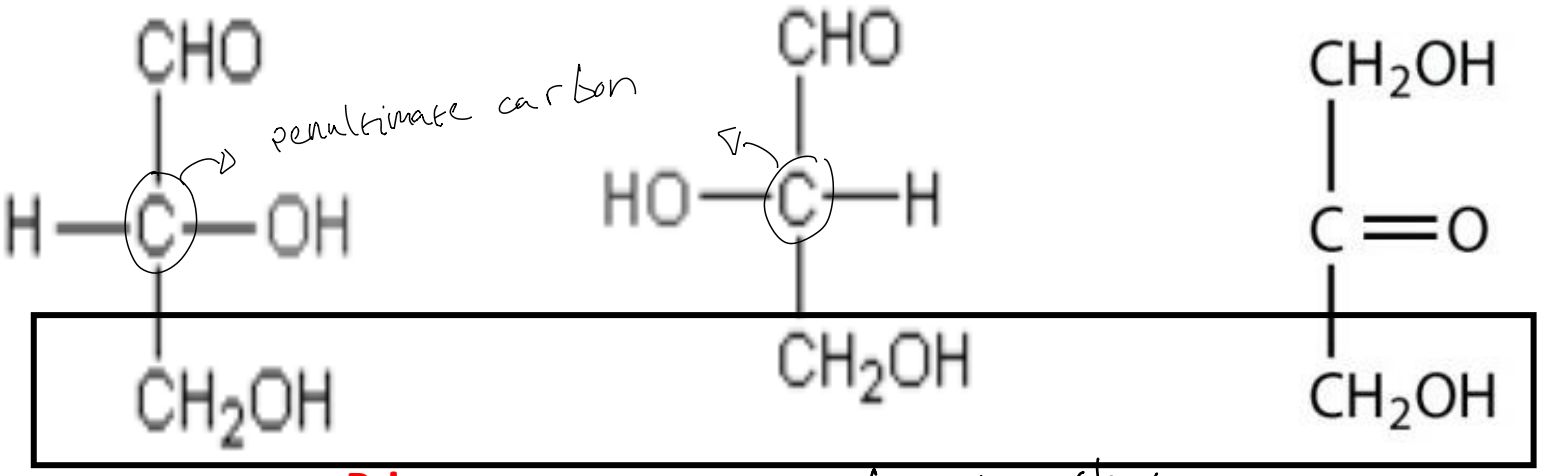
(the carbon that determines if a sugar is L or D is called a penultimate carbon)

↳ the simplest monosaccharides because (it contains the least amounts of carbons (3 C))

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

(يعني إلهم دخل في التفاعل)

or chiral (no assymetrical carbon)




**Primary group**

isomers

* the carbon atom that determines if a sugar is L/D is called a penultimate carbon

**D- Glyceraldehyde**

Dihydroxyaldose

**L- Glyceraldehyde**

**Dihydroxyacetone**

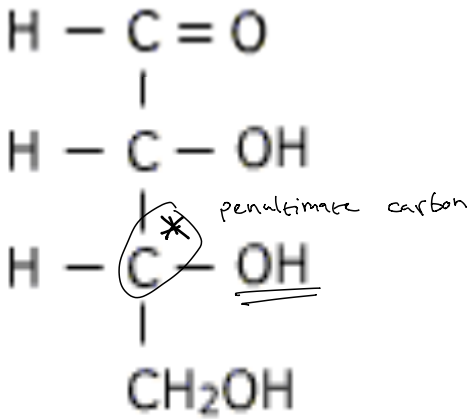
Dihydroxyketose

**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

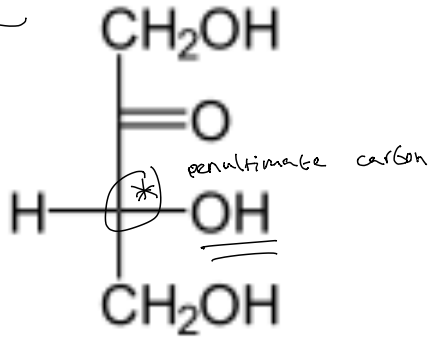
* Erythrulose/DHA (and) reacts with the amino acids in the proteins of the first layers of skin (the stratum corneum and epidermis)

* Erythrose was first isolated in 1849 from rhubarb




another way of drawing a carbon skeleton.

every cross-section (كل تقاطع) resembles a carbon. (C) عبارة عن




D-Erythrulose

**D-Erythrose**

the farthest chiral carbon from the carbonyl has hydroxyl on the right side.

**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

it is important to know that fruits contain lots of aldo sugars

# Case

- Sarah, 28-year-old female, complains of intermittent abdominal discomfort and sweet-smelling urine (متقطع) (رائحة سكرية في البول)
- Clinical Examination: Healthy with mild epigastric tenderness. (upper abdomen) (no major sign in clinical examination)
- Urinalysis shows elevated sugars, blood: normal glucose (تحليل السكر عالية بالبول)

(*) In normal circumstances, sugar should not be found in urine. (*) In case of a diabetic (a person with diabetes), sugar in urine is high, but if a diabetic has low sugar in urine (which is not normal for a diabetic) he has high blood sugars. urine sugars with good health (no diabetes) and normal blood sugars.

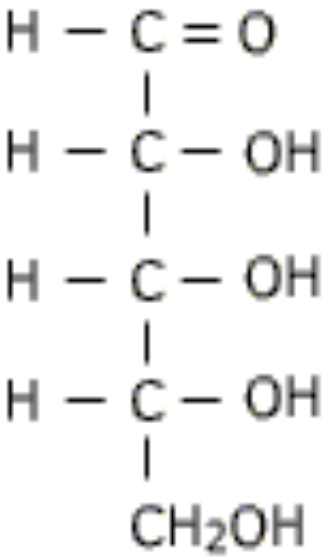
↳ the patient in this case has elevated

two possible diagnosis :-

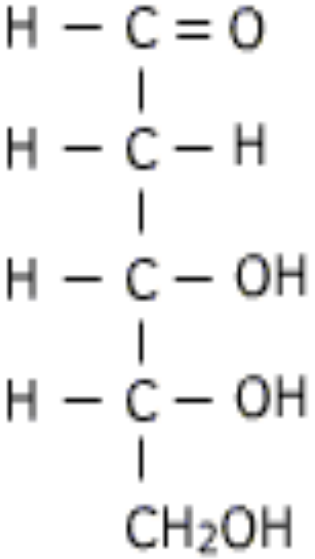
→ Alimentary pento suria (ingestion of large amounts of fruits)
(relates to diet) (transient) (urinary)

→ inborn deficiency of enzymes (وراثي) L- xylulose reductase

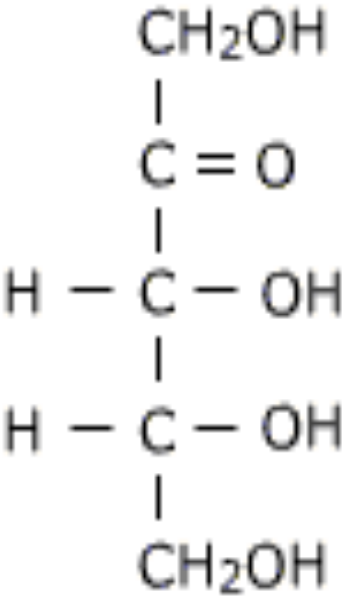
- **Examples of pentoses are:**
- aldopentoses: ribose and deoxyribose, ketopentose: ribulose



D-ribose



D - deoxyribose



D - 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. (like FAD, FMN)

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

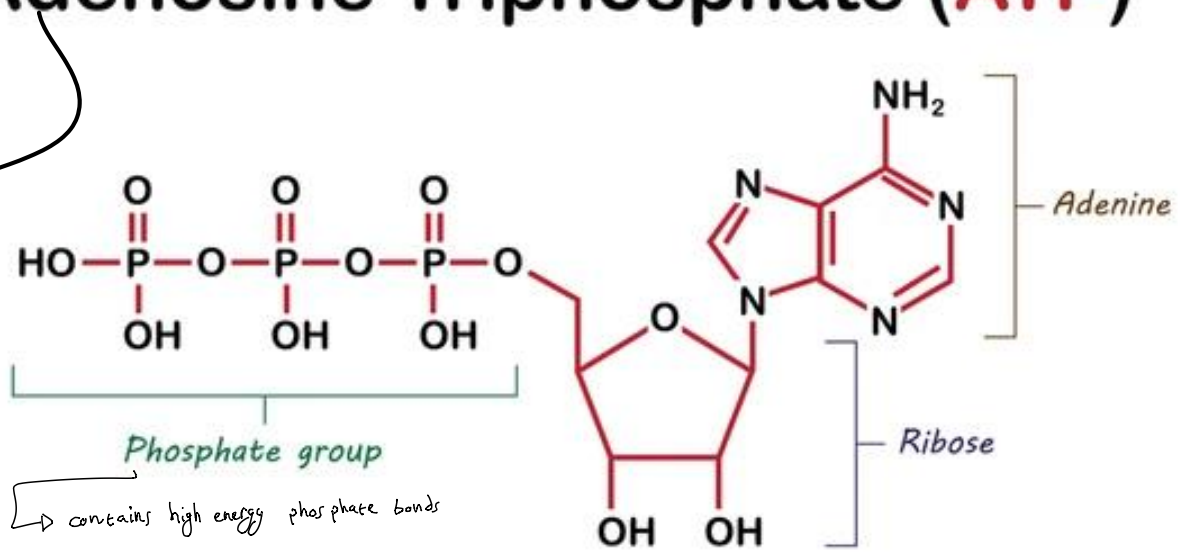
- They are components of some vitamins (ribitol in vitamin **B2)**

a pentose sugar found in B2 vitamin

# ATP

Biology

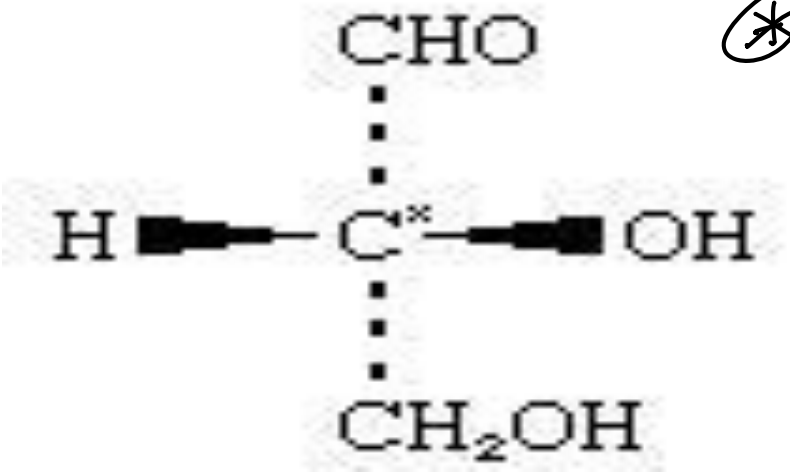
## Adenosine Triphosphate (ATP)




* 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

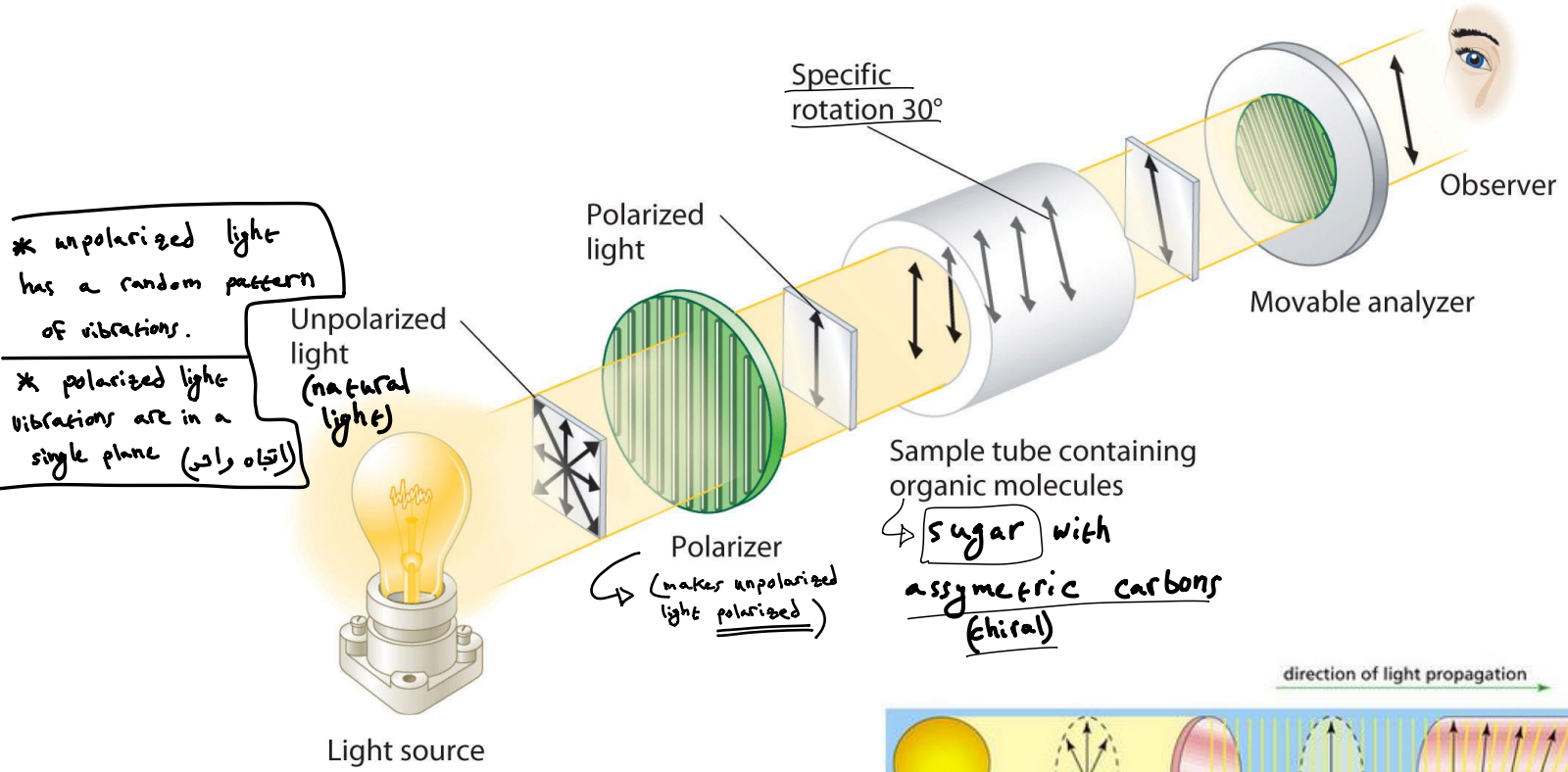



(*) this is an assymetric carbon (chiral carbon).

optical activity ✓

optical isomerism ✓

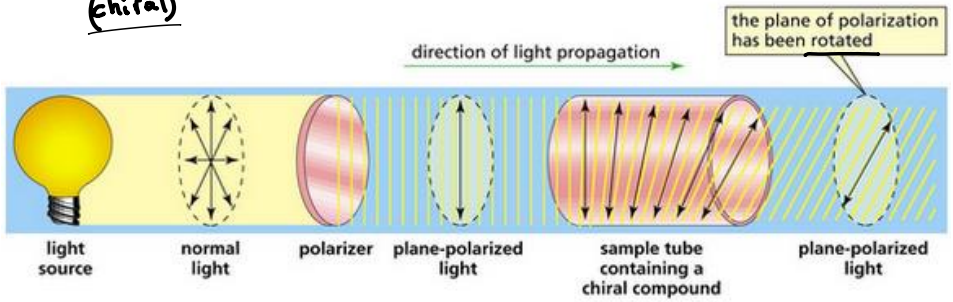
- A **polarimeter** is a scientific instrument used to measure the angle of rotation caused by passing polarized light through an optically active substance.




* unpolarized light has a random pattern of vibrations.

* polarized light vibrations are in a single plane (اتجاه واحد)

sugar with assymetric carbons (chiral)




[* we can name assymetric carbons → optically active carbons]

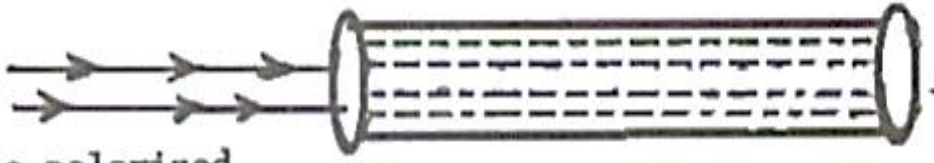
# Optical activity

- 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 **(+)**.
  ⇦ small letter
- If it rotates plane polarized light to the left it is called **levorotatory** or **l** or **(-)**.
  ⇦ small letter
- Glucose contains 4 asymmetric carbon atoms. It is dextrorotatory so it is named **dextrose** (another name for glucose)
- Fructose contains 3 asymmetric carbon atoms. It is levorotatory so it is called **levulose** (another name for fructose)

* if we classify sugars based on the position of (OH) we use capital letters (D/L configuration).
* if we classify sugars based on the direction in which the polarized light plane was rotated we use small letters.

(normal / natural) Ordinary light
(i.e. light vibrates in all directions)

Plane polarized light
(i.e. light vibrates in one direction)



Plane polarized light

Solution of optically active substance
(contains assymetric carbons)

Right
Dextrorotatory
(d or +)

Left
Levorotatory
(l or -)

- The optical rotation is proportional to the concentration of the optically active substances in solution (علاقة طردية)

(والعكس صحيح) ⊛ more concentration of optically active substance leads to more rotation of the P.P.P

- Polarimetry may therefore be applied for concentration measurements

(concentration of optically active substance)

- 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.

للمعرفة فقط

* example of molecular formulas:

$C_6H_{12}O_6$, $C_8H_{18}$, $C_{10}H_{22}$, $P_4O_{10}$

same molecular formula?

No — Yes

Non-isomers — Isomers (if two substances have the same molecular formula they are isomers) (but they have different compounds)

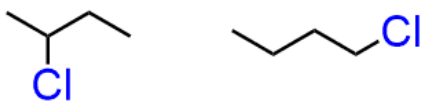
not the same molecular formula?? → non-isomers

# Isomers

Same molecular formula- different compounds

## Constitutional

same formula, different connectivity



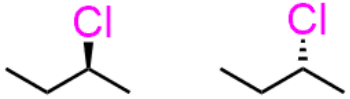

## Stereo

same formula, same connectivity, different arrangement

### Enantiomers

mirror images

(عكس بعضي)




### Diastereomers

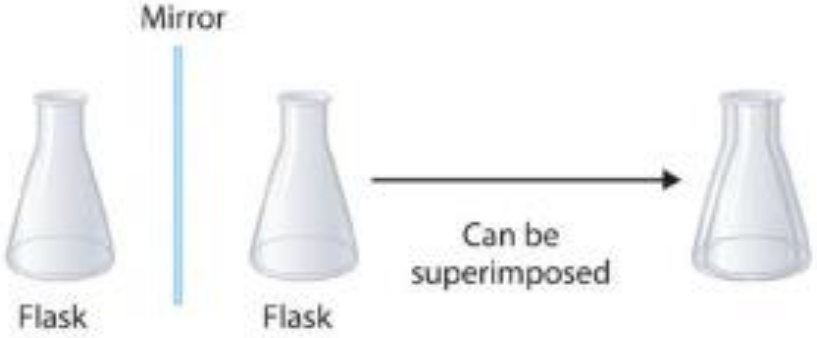
not mirror images


(عكس بعضي لا)

ex: Fructose & glucose are constitutional isomers because they have different connectivity.

How so?? → because the function group in glucose (aldehyde) is in the first carbon while the function group in fructose (ketone) is in the second carbon.

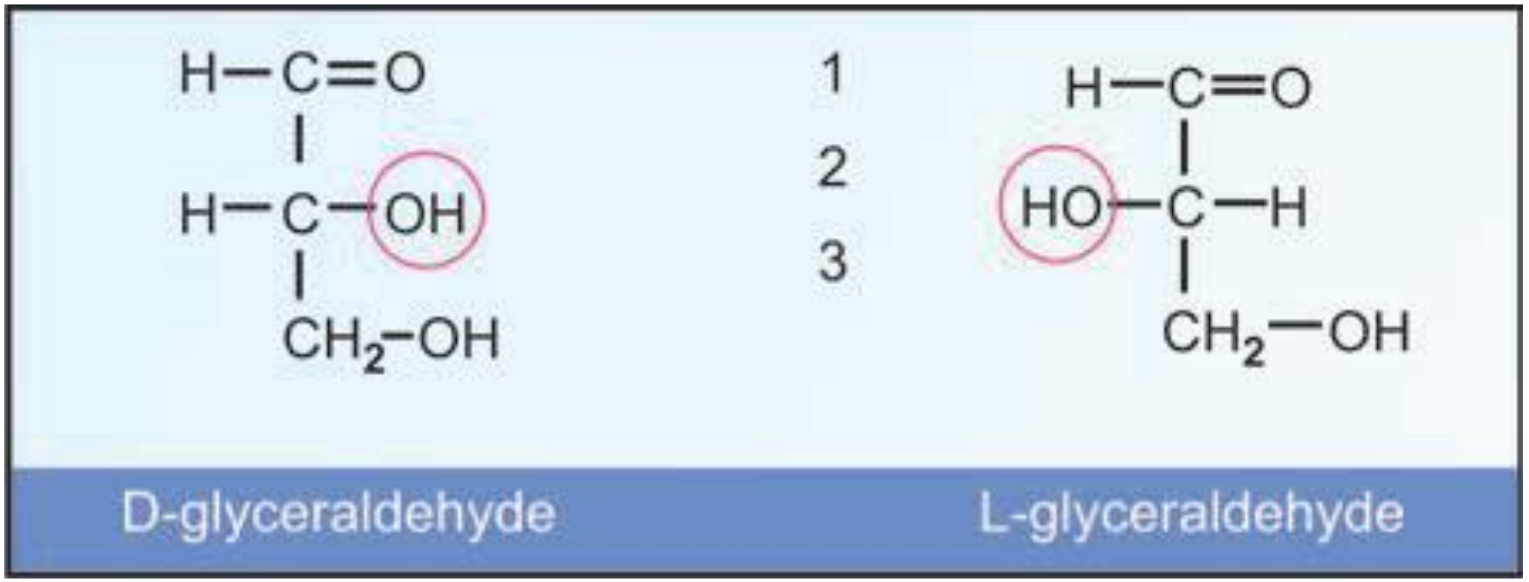

**(a) Chiral objects**




**(b) Achiral objects**

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

# What is this?



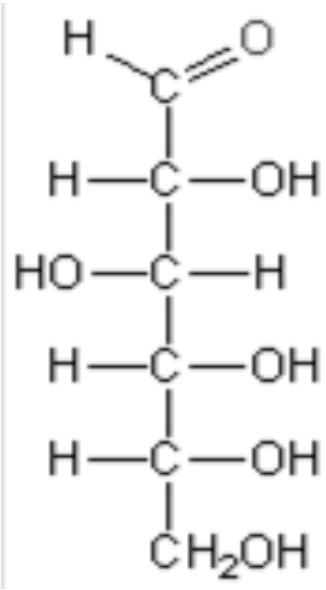

mirror steereo isomers

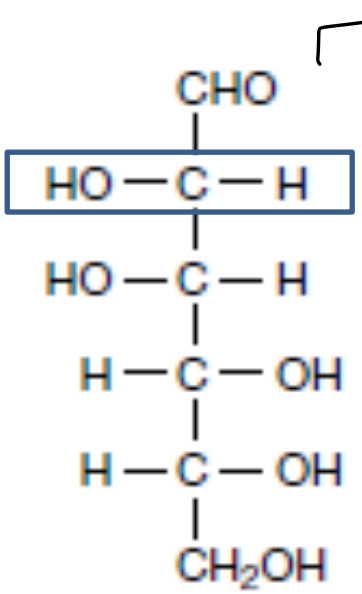
(enantiomers)

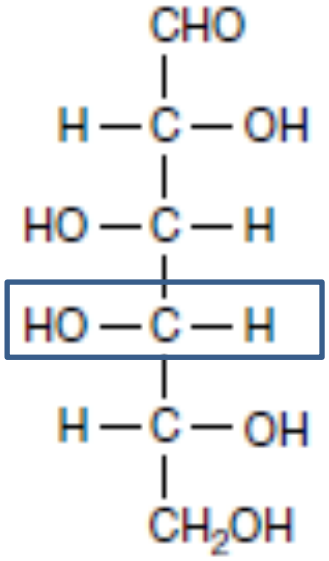
* All are isomers because they share the same molecular formula ($C_6H_{12}O_6$)

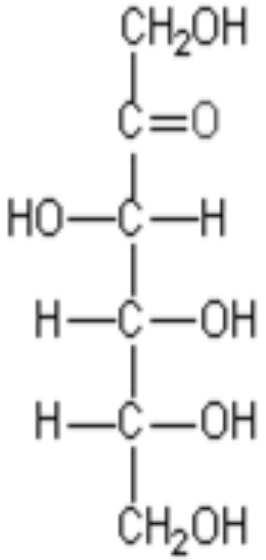
## Examples of hexoses are:

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




**D-Glucose** | **D-Mannose** | **D-Galactose** | **D-Fructose**

(D-glucose & D-Fructose are constitutional isomers)

Galactose and mannose are not epimers but diastereo-isomers.

look at $C_2$, $C_4$ and compare....

↳ (because they differ in the configuration around more than one carbon) (C2 & C4)

same connectivity but not mirrority so they are considered 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 $C_4$
  - They 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.

- **Importance of hexoses:**

**D-glucose "grape sugar":**

* it's very important for the brain and for the RBCs

- 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.

oral glucose tolerance test

dl : deci liter

**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 |

(impaired glucose tolerance) = pre diabetes

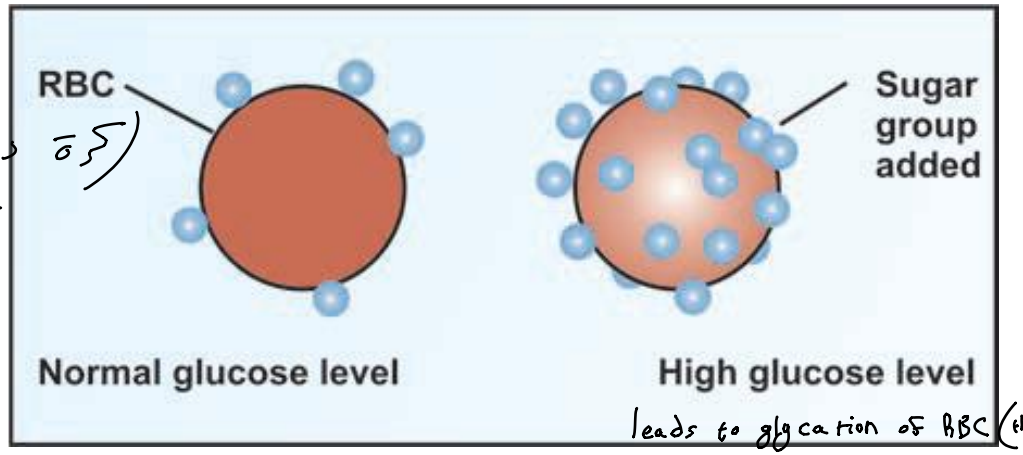
**Box 24.3.** Diagnostic Criteria for Diabetes Mellitus

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. ← 2+1 يعني
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.

قياس عشوائي من دون وقت معين

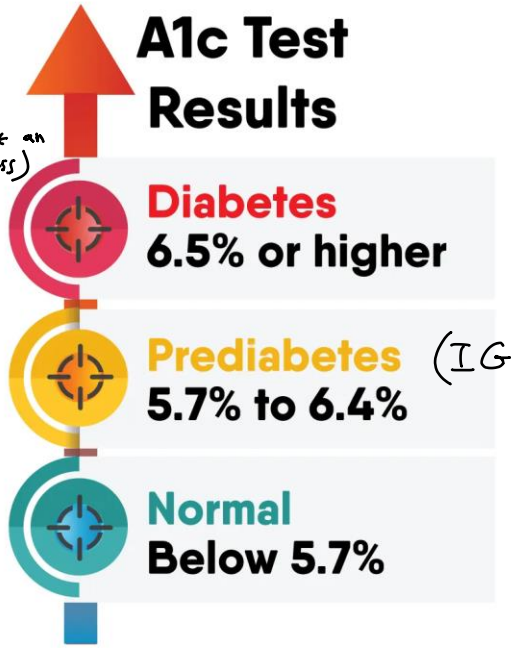
more than 200mg/dl and test is done in more than one occasion

(أكثر من مرة)




(كرة دم حمراء)

leads to glycation of RBC (this process is not an enzimatic process) (happens without enzimes)




* the A1c test gives us an impression on glucose control for the past 3 months (إنطباع)

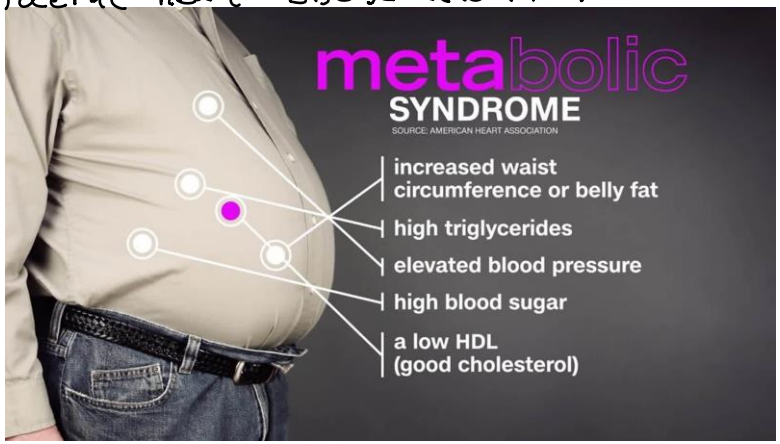
* 3 months is the life span of RBCs

* this test is a monitoring mechanism for diabetes

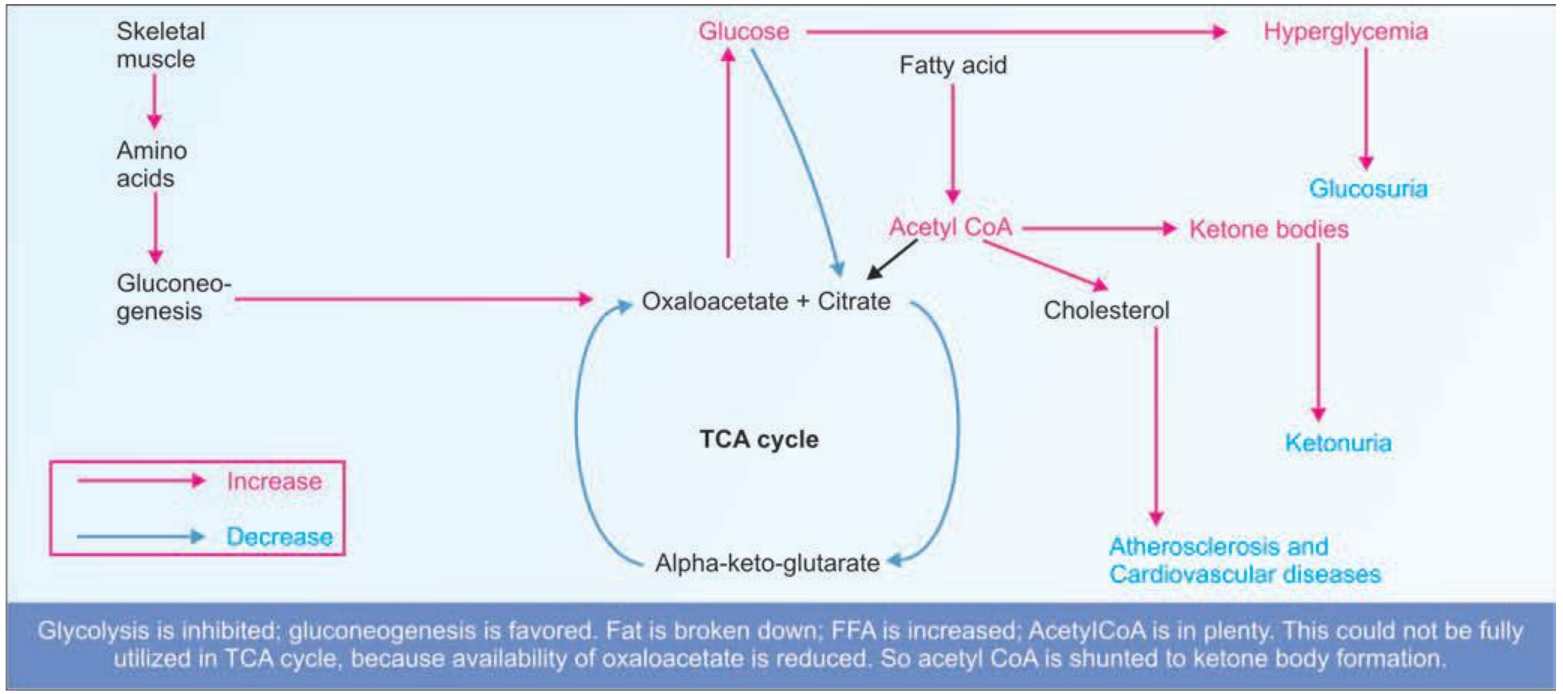
a number of conditions that occur together before ischaemic heart disease and in pre diabetes.

## 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.