AL-Maaqal University
College of Medical and Health Techniques
Division of Laboratory Techniques

Bio Chemistry

2021-2022

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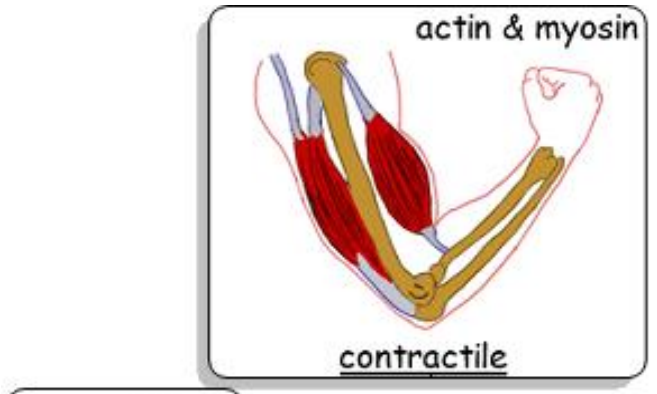
Lecture (1)

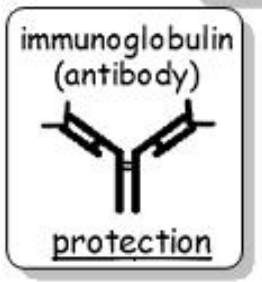
Amino acids and protein chemistry

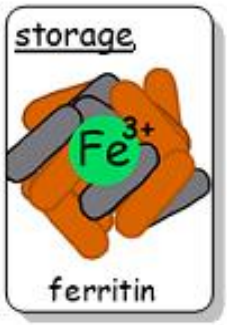
➢ Def :- Proteins are macromolecules composed of amino acids linked together through peptide bonds.

Biological importance of proteins

1- Catalysis : (Enzymes) are proteins
2- Structure (muscle protein).
3- Movement (myosin & actin).
4- Defense (Immunoglobulins "antibodies").
5- Regulation (Enzymes & Hormones).
6- Transport (globin).
7- Storage. (Mb & Ferritin).



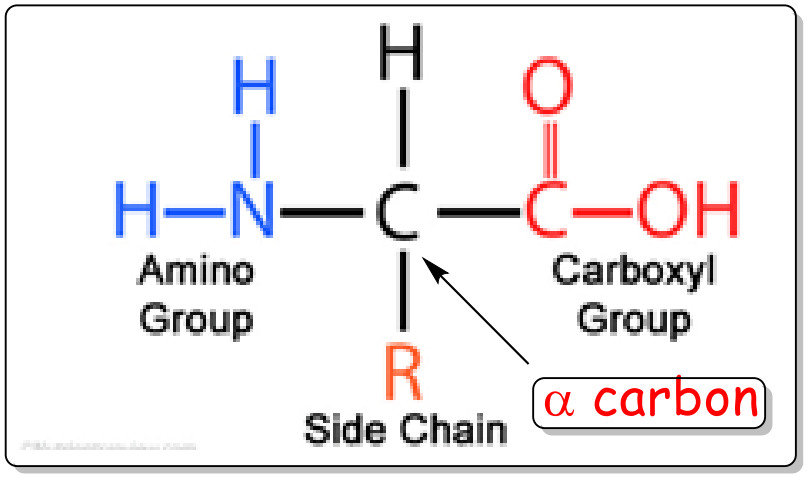




General structure of amino acids

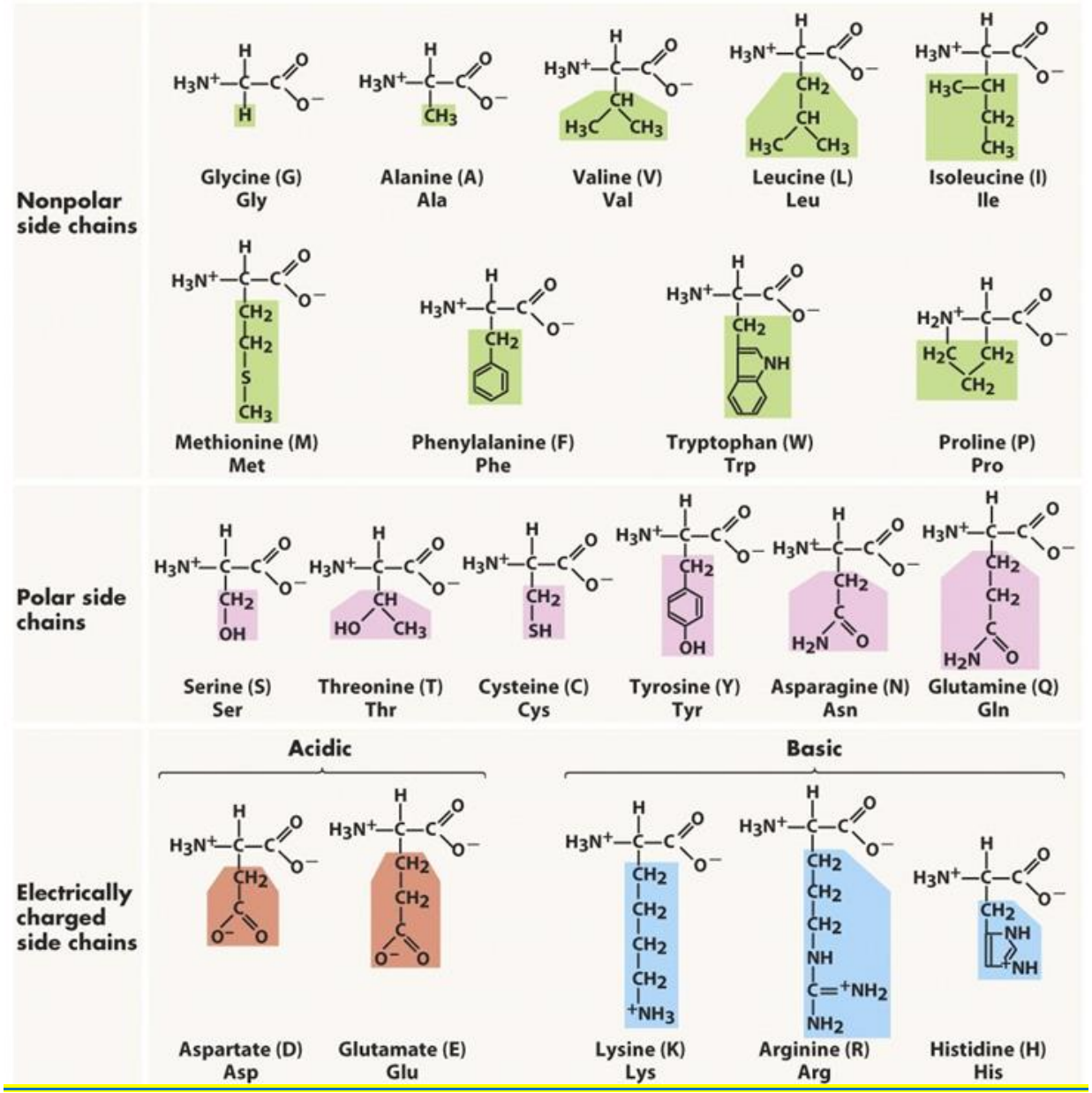
- The world "**acid**" means that there is **a carboxyl group** (-COOH) on the molecule.
- The world "**amino**" means that there is **an amino group** ($-NH_2$) on the molecule.

SO →**Amino acid describes a compound that contains both amino groups (NH_2) and carboxyl group (COOH)** " except proline and hydroxyl proline "



- Amino acids have this general form
- There are **20 amino acids** which make up the proteins, distinguished by the R-group.
- R-groups determine the properties of amino acids
- The simplest of the amino acids, **glycine**, has just H as an R-group.

General structure of amino acids



Classification of amino acids

I- According to the **Chemical structure**.

II- According to the **Polarity of the side chain**.

III- According to the **Biological value** .

IV-According to the **Nutritional value**.

I- Chemical classification

[A] **Amino acids may be** :- → Acidic → **Two** amino acids "**Aspartic acid** & **Glutamic acid** "

→ Basic → **Three** amino acids "**Lysine** & **Histidine** & **Arginine**"

→ Neutral → **15** amino acids

"**Neutral**" :- Means that the amino acid contains an **equal** number of carboxyl and amino groups

"**Acidic**" :- Means that the no of carboxyl groups is **more** than the no of amino groups

"**Basic** " :- Means that the no of amino groups is **more** than the no of carboxyl groups

[B] Amino acids may be :-

- Containing (OH) group :- **Serine** & **Threonine** & **Tyrosine**

- Containing aliphatic side chain :- **Valine** & **leucine** & **Isoleucine** & **glycine** & **Alanine**

- Containing sulfur atom :- **Methionine** & **Cysteine** "Cystine"

- Containing "basic" group :- **Lysine** & **Histidine** & **Arginine**

- Containing "acidic" group :- **Aspartic acid** & **Glutamic acid**

- Containing "amide" group :- **Asparagine** & **Glutamine**

- Containing aromatic ring :- **phenylalanine** & **Tryptophan** & **Tyrosine**

- Containing imino group:- One example → **proline**

[II] According to polarity

Amino acids may be :- **Polar** or **Non-polar** amino acids

Polar amino acids :-

- Contain polar hydrophilic side chain "R" such as :-

(1) **OH-group** → as in serine, threonine and tyrosine

(2) **SH-group** → as in cysteine

(3) **Amide-group** → as in glutamine & asparagine

(4) **COOH-group** → as in glutamic & aspartic

(5) **NH_2-group** (or) nitrogen act as a base → lysine & arginine & Histidine

[III] Nutritional Classification:

Amino acids may be :-

"Essential "

- Can't be synthesized in the body
- Must be supplied in diet.

" Non-essential "

- Can be synthesized in the body

Essential	Nonessential
Arginine[a]	Alanine
Histidine	Asparagine
Isoleucine	Aspartate
Leucine	Cysteine
Lysine	Glutamate
Methionine	Glutamine
Phenylalanine	Glycine
Threonine	Proline
Tryptophan	Serine
Valine	Tyrosine

[IV] Metabolic classification:

-Depending on the metabolic products of amino acids, They can be classified into :

(a) ketogenic amino acids :- -Which give ketone bodies on metabolism (**lysine** & **leucine**)

(b) Mixed ketogenic & glucogenic :- - Which give both ketone bodies and glucose on metabolism

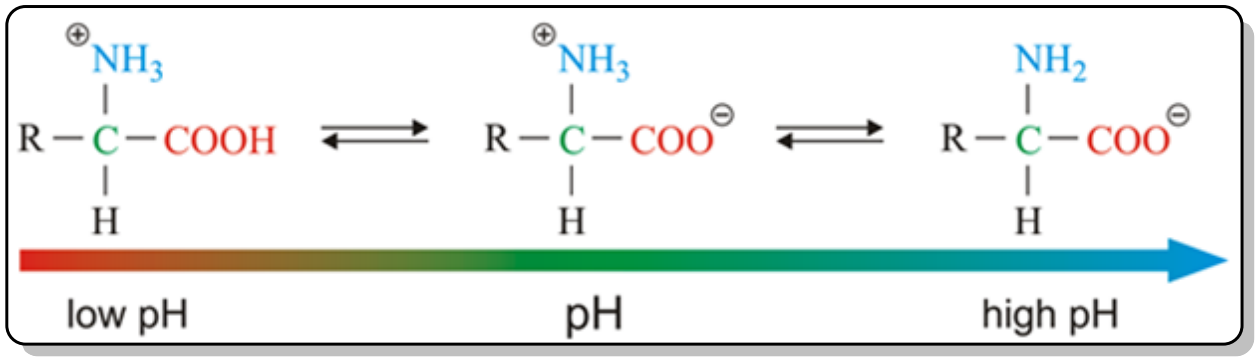
-**Isoleucine** *& **phenyl alanine** & **tyrosine** & **tryptophane**

(c) Glucogenic amino acids :- -Which give glucose on metabolism

- They include the **rest** of amino acids (14 a.a.)

Zwitter ion

Def :- Molecules that contain an equal number of ionizable groups of opposite charge and that therefore bear **no net charge**



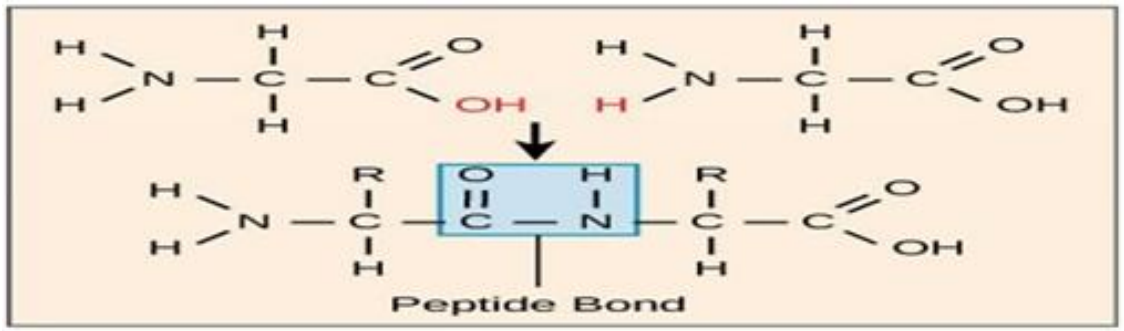
Amino acids are Amphoteric "They are capable of behaving as an acid and as a base"

i.e → Amino acids can **accept proton** by its amino group →Act as a base

→ Amino acids can **give proton** by its carboxyl group → Act as an acid

Isoelectric point (PI) :- Is the PH at which the amino acids carry no net charge

Formation of peptide bond



Structures of proteins

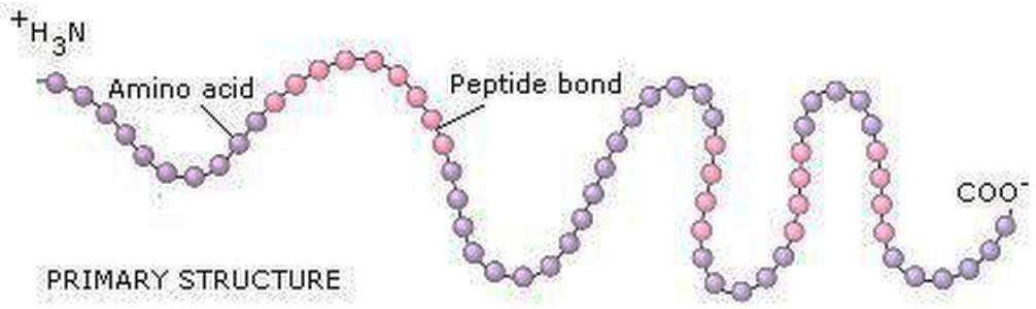
- Proteins are formed of a large number of amino acid linked together by peptide bonds to give a polypeptide chain.
- There are **four** orders of protein structures

Description of protein structure

- Primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure

Primary structure of Proteins

- Referred to the number, type and sequence of amino acids in the chain.
- The main bond in this structure is peptide bond.

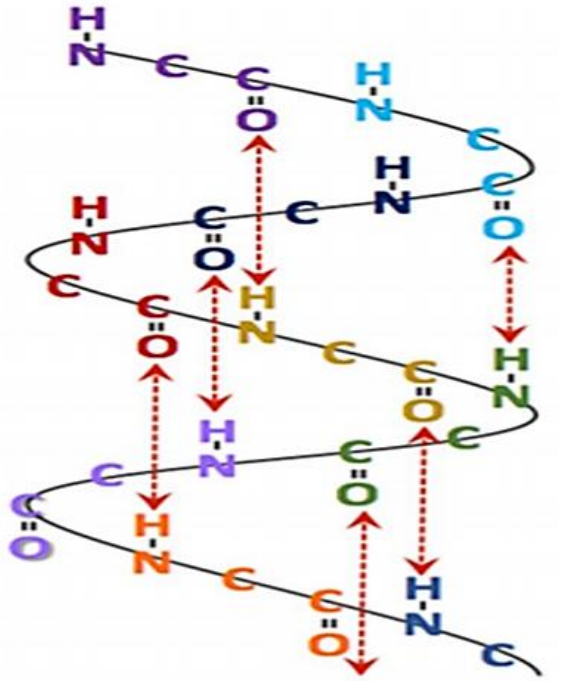


Secondary structure of Proteins

The chain will be folded to give a specific shape which may be:-

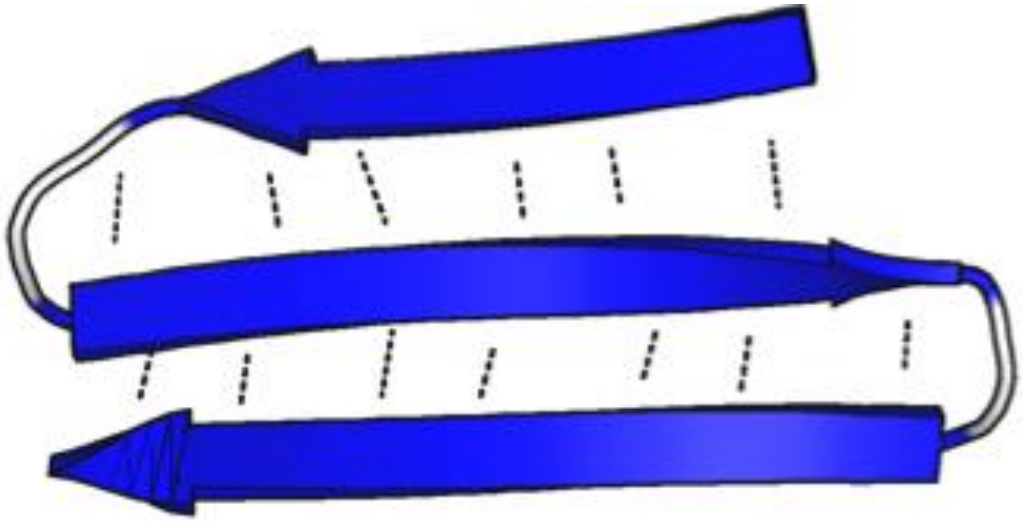
α- Helix

- The polypeptide chain is twisted to helix.
- The formation of the α-helix is stabilized by Hydrogen bonds between Carbonyl Oxygen of peptide bond and hydrogen of NH of the next 4th peptide bonds in the chain.



β- pleated Sheets

- Formed when hydrogen bonds are formed between two or more adjacent polypeptide chains.



Tertiary structure of Proteins

- Secondary structures are arranged to form final functional 3D structure called domain.

-It occur due to interaction between side chains (R) of the amino acids

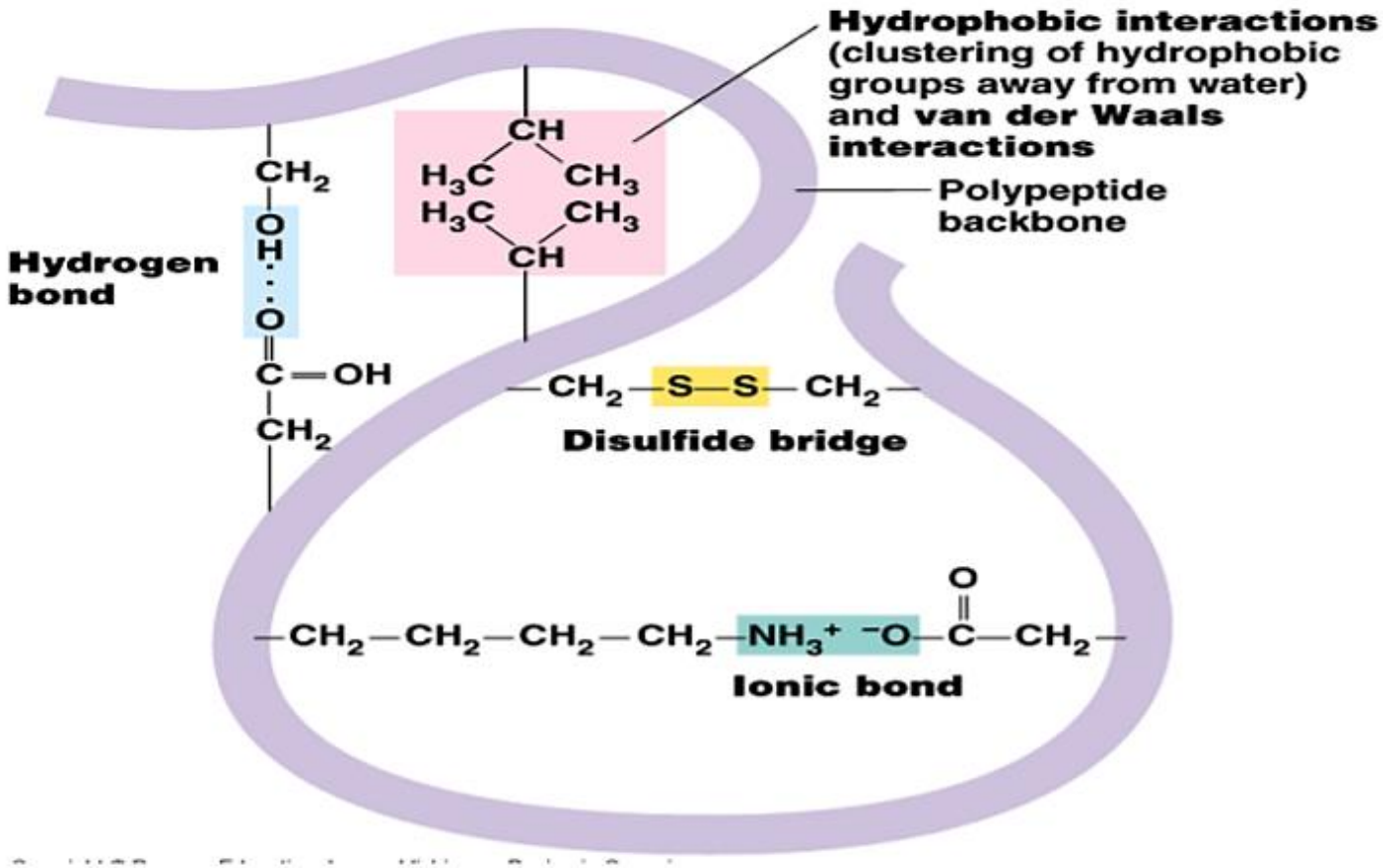
Forces Controlling Tertiary Protein Structure

a. Hydrogen bond: between polar side chains of amino acids

b. Hydrophobic forces: between the non-polar (R) groups of the amino acids

c. Electrostatic forces (ionic bonds, salt bridges): between oppositely charged (R) of amino acids

D. Disulfide bonds: - between sulfur amino acids (cysteine)



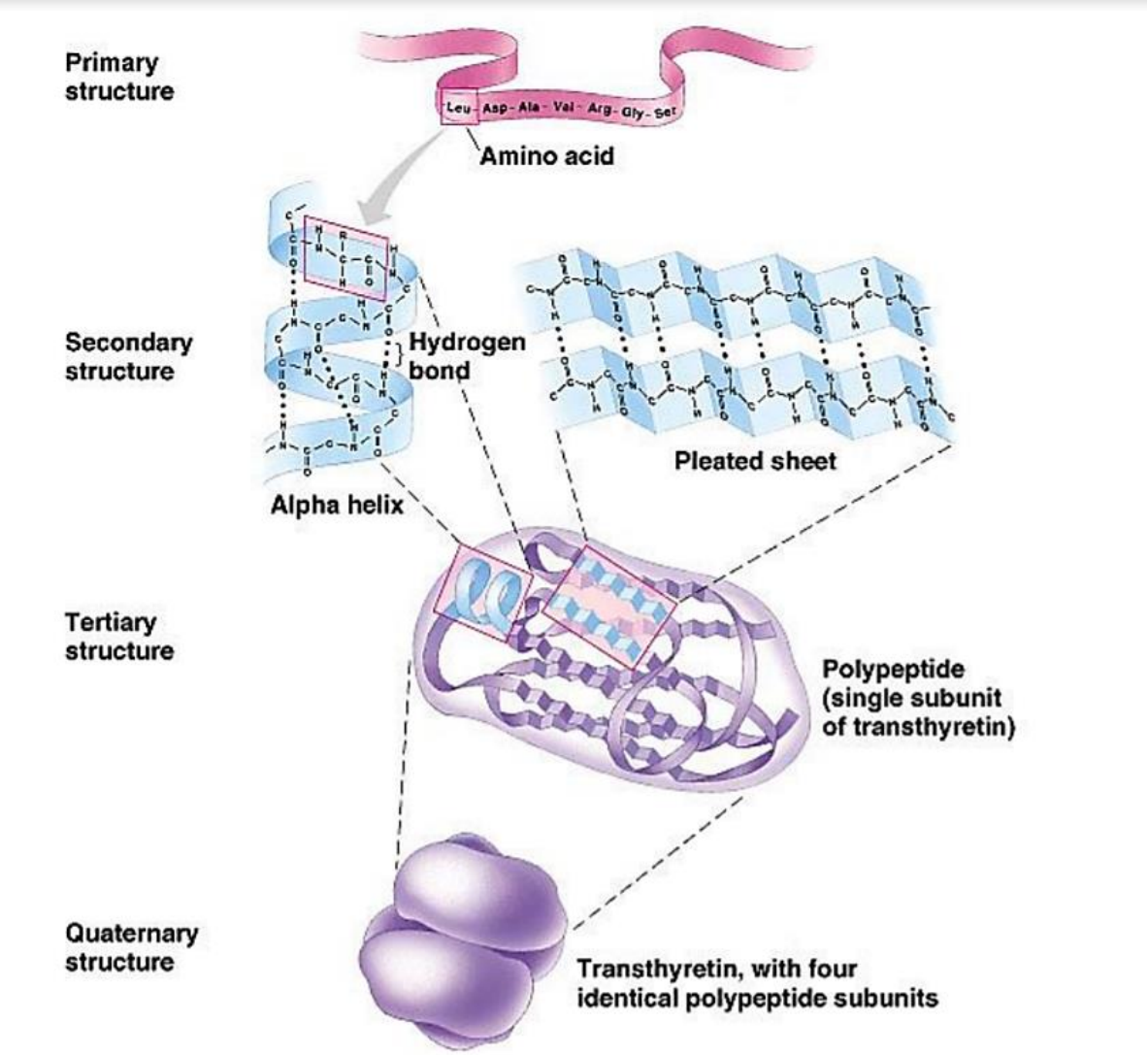
Quaternary structure of Proteins

- The arrangement of more than one polypeptide chains

Examples of oligomeric proteins :

1- Creatine kinase (**CK**)
enzyme is dimer

2- Haemoglobin and lactate dehydrogenase (**LDH**)
enzymes are tetramers.



Quiz

1. In a highly basic solution, pH = 13, the dominant form of glycine is:

a) NH_2-CH_2-COOH.
b) NH_2-CH_2-COO^-.
c) NH_2-CH_3^+-COO^-.
d) NH_3^+-CH_2-COOH.
e) NH_3^+-CH_2-COO^-.

2. For amino acids with neutral R groups, at any pH below the pI of the amino acid, the population of amino acids in solution will have:

a) a net negative charge.
b) a net positive charge.
c) no charged groups.
d) no net charge.
e) positive and negative charges in equal concentration.

3.The element found in all amino acids that is not found in carbohydrates is

(a) Sulphur
(b) Carbon
(c) Oxygen
(d) Hydrogen
(e) Nitrogen

4. The tertiary structure of protein is stabilized by

a) disulfide bridges.
b) hydrogen bonds,
c) ionic bonds.
d) hydrophobic interactions,
e) All of them.

5. One of the following proteins is a quaternary structure:

a) Hemoglobin
b) Collagen
c) a-keratin
d) None of them

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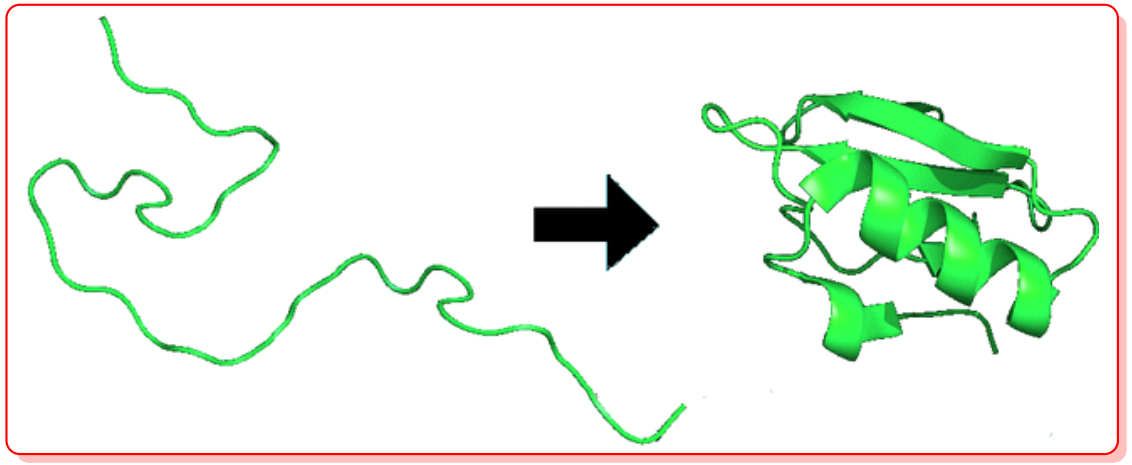
Lecture (2)

Protein Folding

Def :- Physical process by which a polypeptide chain form a stable 3D structure.

- It is essential for proper function of proteins.



- Protein mis-folding leads to loss of function and causes a wide range of diseases such as :- .

Alzheimer's disease and Parkinson's disease.

Note :-

-The functions of proteins depend on the ability to recognize and bind with a variety of molecules.

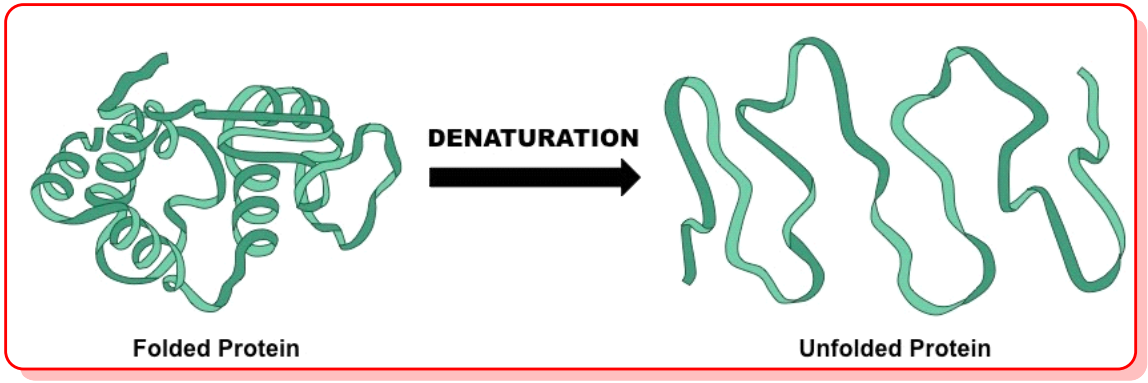
-This ability depends on 3D-structure of proteins.

Protein denaturation

Def :- Disruption of the secondary, tertiary, due to cleavage of non-covalent bonds.

N.B.:

-The primary structure of protein molecule, i.e., peptide bond is not affected.



Agents that cause denaturation:

a) Physical agents:

1. Heat
2. UV light
3. Ultrasound
4. High pressure
5. Violent shaking

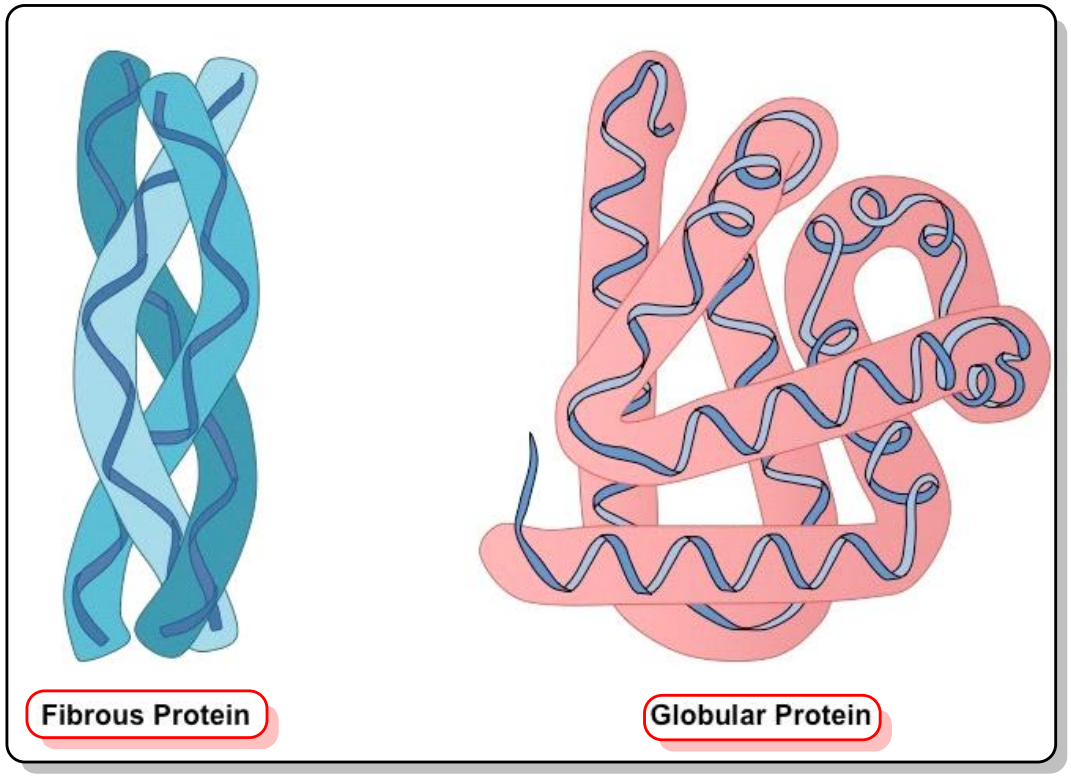
b) Chemical agents:

1. Strong acids.
2. Strong alkalis.
3. Organic solvents.
4. Heavy metal salts.

Classification of proteins

1- According to shape:

	Fibrous	Globular
Shape	Long, narrow fiber	Rounded (spherical)
Water solubility	Insoluble	Soluble
Stability	More stable	Less stable
Examples	Actin, Myosin, collagen	Albumin, hemoglobin, insulin



2- According to biological functions:

From the functional point of view, they may be divided into several groups.

- Enzymes (biochemical catalysts).

  In living organisms, almost all reactions are catalyzed by specific proteins called enzymes. They have a high catalytic power, increasing the rate of the reaction.

- Transport proteins

  Many small molecules, organic and inorganic, are transported in the bloodstream and extracellular fluids, across the cell membranes, and inside the cells from one compartment to another, by specific proteins such as :-

  Hemoglobin: - which carries oxygen from the alveolar blood vessels to tissue capillaries;
  Transferrin: - which carries iron in the blood

- Storage proteins

  Ferritin: - that stores iron intracellularly in a non-toxic form;
  Milk caseins: - that act as a reserve of amino acids for the milk;

➢ Mechanical support

Proteins have a role in the stabilization of many structures such as :-

1- Keratin	present in hair, nail
2- Elastin	present in joints and ligaments
3- Collagen	present in skin, bone and connective tissues

➢ Hormones

- Many hormones are proteins.
- They are regulatory molecules involved in the control of many cellular functions, from metabolism to reproduction.
- Examples are insulin, glucagon, and thyroid-stimulating hormone (TSH).

3- according to their chemical structure:

Proteins can be classified as:

(a) Simple proteins.

- On hydrolysis they yield only the amino acids
- Examples are: albumins, globulins, glutelins, albuminoids, histones and protamines.

(b) Conjugated proteins.

- These are simple proteins combined with some non-protein material in the body.
- Examples are: nucleoproteins, glycoproteins, phosphoproteins, haemoglobins

(c) Derived proteins.

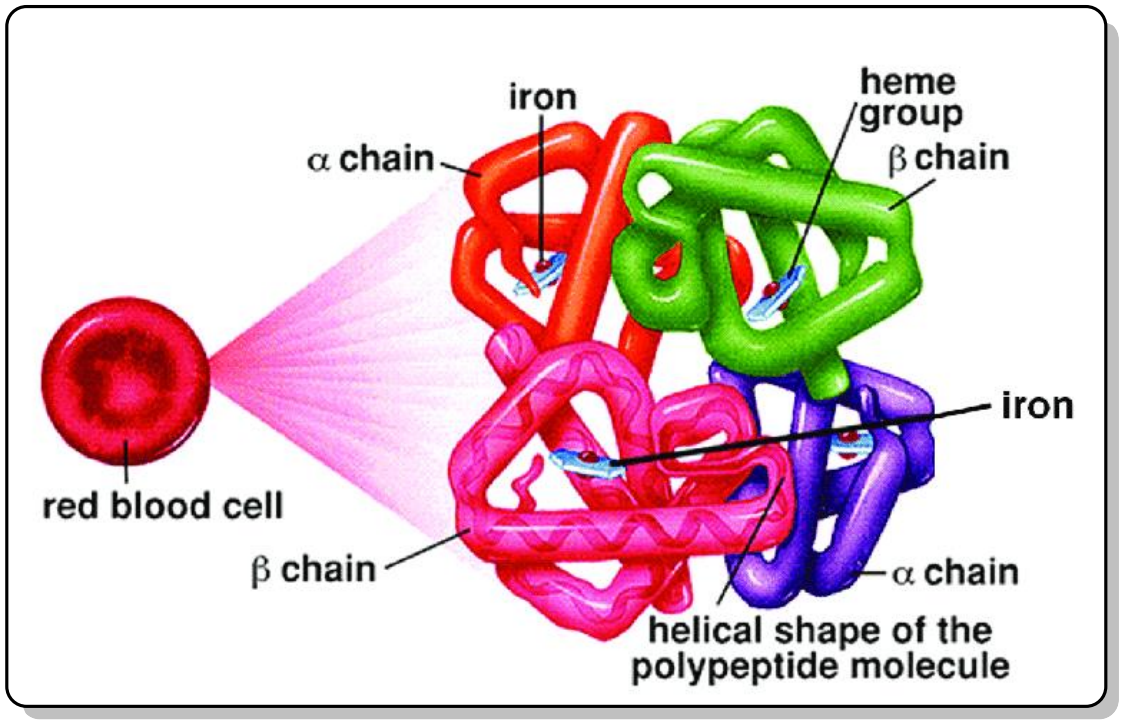
- These are proteins derived from simple or conjugated proteins
- Examples are: denatured proteins and peptides.

Hemoglobin

Def :- is the oxygen-transport metalloprotein in the red blood cells of almost all vertebrates

- **Hemoglobin** or **haemoglobin** abbreviated **Hb** or **Hgb**,
- Hemoglobin forms an unstable reversible bond with oxygen.
  - The oxygenated state: bright red.
  - The reduced state: purplish blue.

- **In Hemoglobin (Hemoglobin = Heme + Globin)**
  - **Heme** is a **Prosthetic group** & **Globin** is a **Protein part**



- **Normal concentration of Hemoglobin in the Human Blood:**

  Adult Males :-13.5 – 17.5 gm/dL

  Adult Females :-12.5 – 16.5 gm/dL

- **Hemoglobin** has important role in respiration
  - ❖ Hb Majorly Transports Oxygen (97% -100%)

$$\text{deoxy-hemoglobin} + O_2 \longleftrightarrow \text{oxy-hemoglobin}$$

  - ❖ Hb Minorly Transports – Carbon dioxide (15% -25%)
  - ❖ Transports-Protons(H^+)

HbA1c

What is HbA1c?

- The term *HbA1c* refers to glycated haemoglobin.
- It develops when hemoglobin becoming 'glycated'.
- By measuring glycated haemoglobin (HbA1c), clinicians are able to get an overall picture of what our average blood sugar levels have been over a period of weeks/months.
- For people with diabetes :-

  The higher the HbA1c, the greater the risk of developing diabetes-related complications.

How does HBA1c return an accurate average measurement of average blood glucose?

- When the body processes sugar, glucose in the bloodstream naturally attaches to haemoglobin.
- The amount of glucose that combines with this protein is directly proportional to the total amount of sugar that is in your system at that time.

HbA1c in diagnosis

HbA1c can indicate people with prediabetes or diabetes as follows:

HbA1c	mmol/mol	%
Normal	Below 42 mmol/mol	Below 6.0%
Prediabetes	42 to 47 mmol/mol	6.0% to 6.4%
Diabetes	48 mmol/mol or over	6.5% or over

How does HbA1c differ from a blood glucose level?

- HbA1c provides a longer-term trend, similar to an average, of how high your blood sugar levels have been over a period of time.
- An HbA1c reading can be taken from blood from a finger but is often taken from a blood sample that is taken from your arm.

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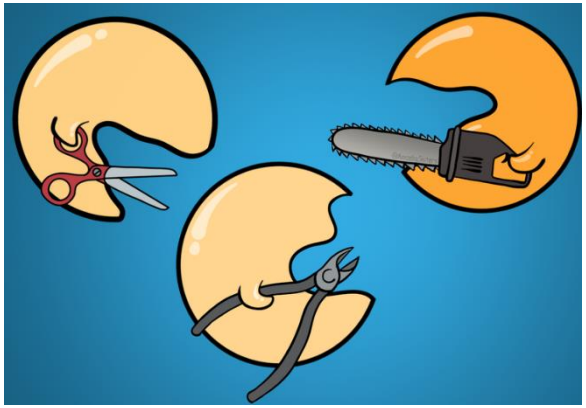
Lecture (3)

Enzymes

What are enzymes?

They are proteins that help speed up chemical reactions in our bodies.

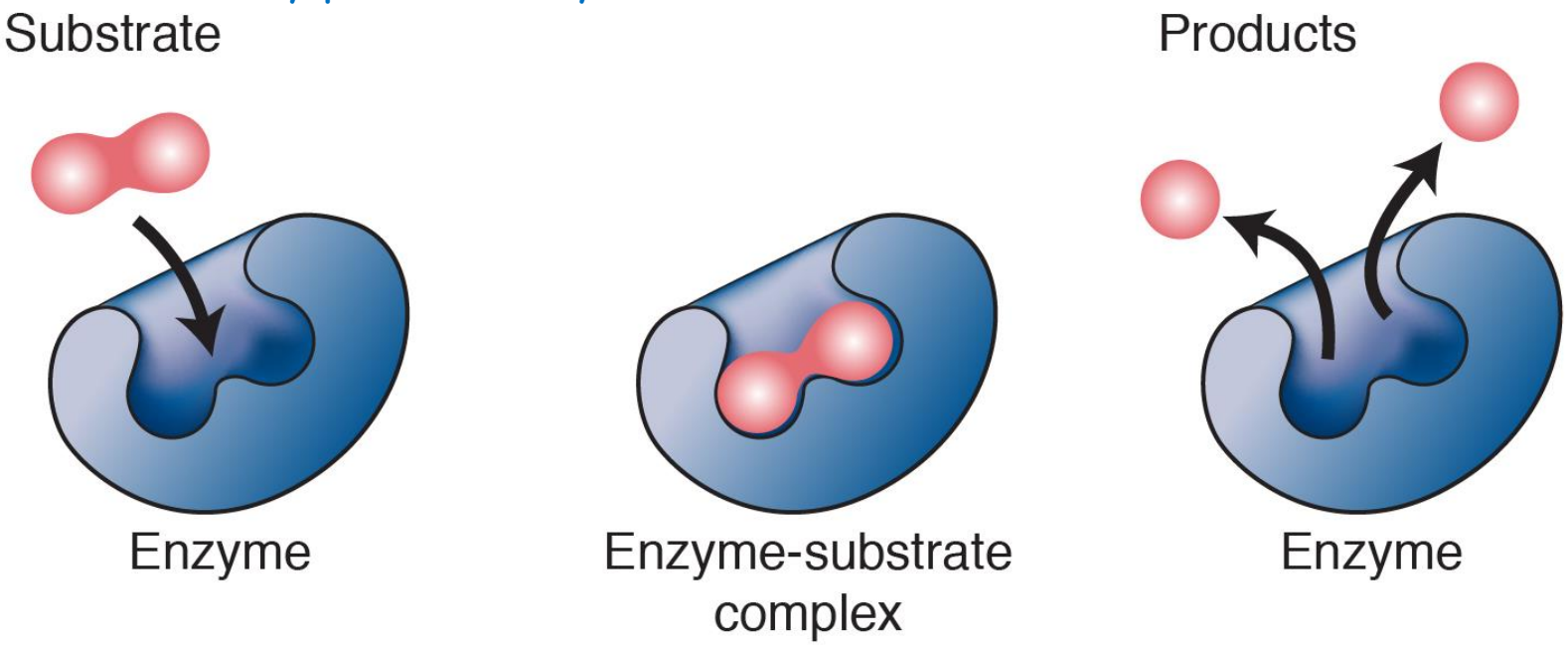


- They build some substances and break others down.
- All living things have enzymes.
- In some cases, enzymes can make a chemical reaction millions of times faster than it would have been without it.
- Most enzymes are built of proteins folded into complicated shapes; they are present throughout the body.
- There are thousands of individual enzymes in the body. Each type of enzyme only has one job, for example,
  - The enzyme **sucrase** breaks down a sugar called **sucrose**.
  - The enzyme **lactase** breaks down a sugar called **lactose**.

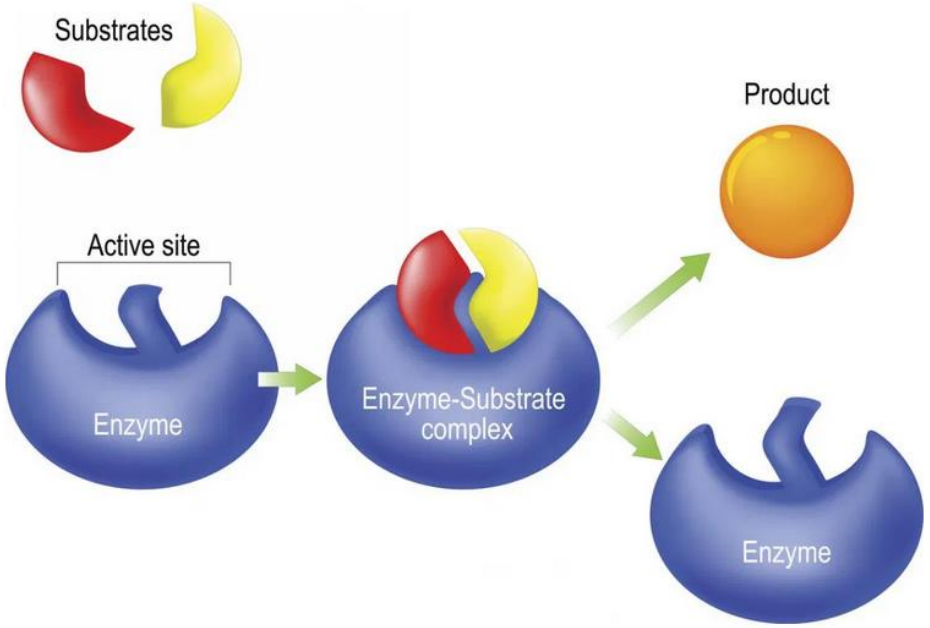
What is the substrate?

- The substance that the enzyme bind is called substrate
- A **substrate** binds to a specific region of the enzyme surface called the **active site** and is converted into **products**.

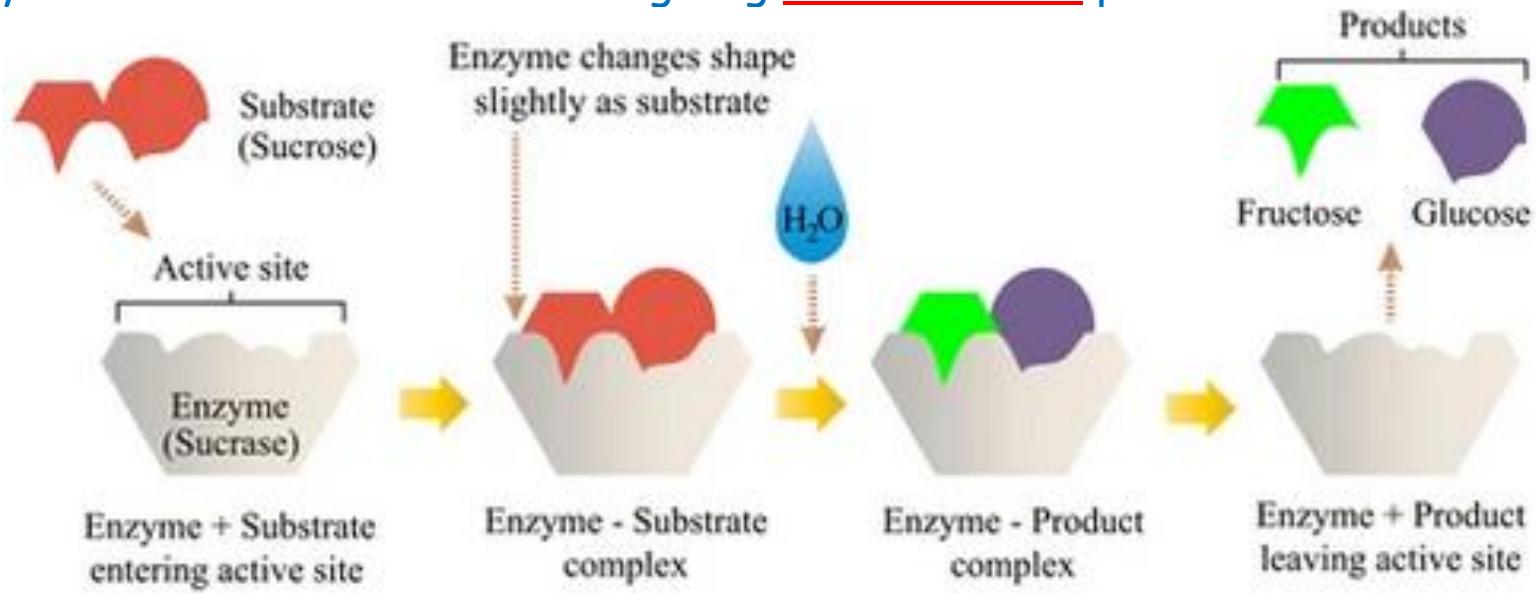
- Once the products leave the active site, the enzyme is ready to attach to a new substrate and repeat the process.
- Our bodies naturally produce enzymes.



- An enzyme can bind to <u>two or more</u> substrates giving the product.

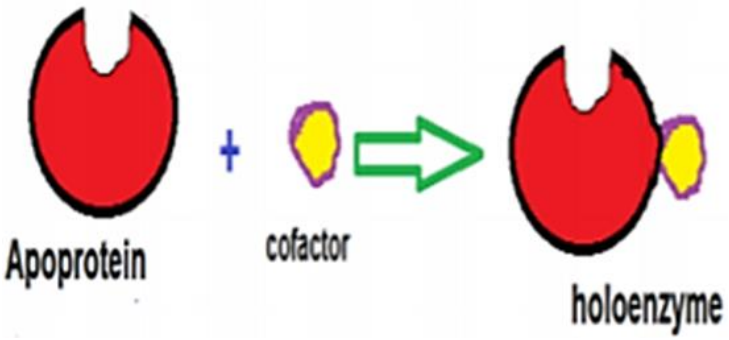


- An enzyme can bind to one substrate giving <u>more than one</u> product.



Chemical nature of enzymes

- Most enzymes are protein in nature but enzymes may be :
  - 1- Simple Protein enzymes: They are formed of protein only.
  - 2- Complex (conjugated) Protein enzymes: formed of two parts:
    - 1) Protein part: called apoenzyme
    - 2) Non- protein: called cofactor



- **Holoenzyme** – an enzyme in its complete form including polypeptide(s) and cofactor
- **Apoenzyme** – enzyme in its polypeptide form without any necessary prosthetic groups or cofactor

- The cofactor may be coenzyme or prosthetic group.

	Coenzyme	Prosthetic group
Chemical nature	Organic	Inorganic
Binding to enzyme.	Loosely bound	Firmly bound
Examples	NAD and FAD	Metal ions such as: Ca, Fe, Mg, Zn

Enzyme nomenclature (Naming):

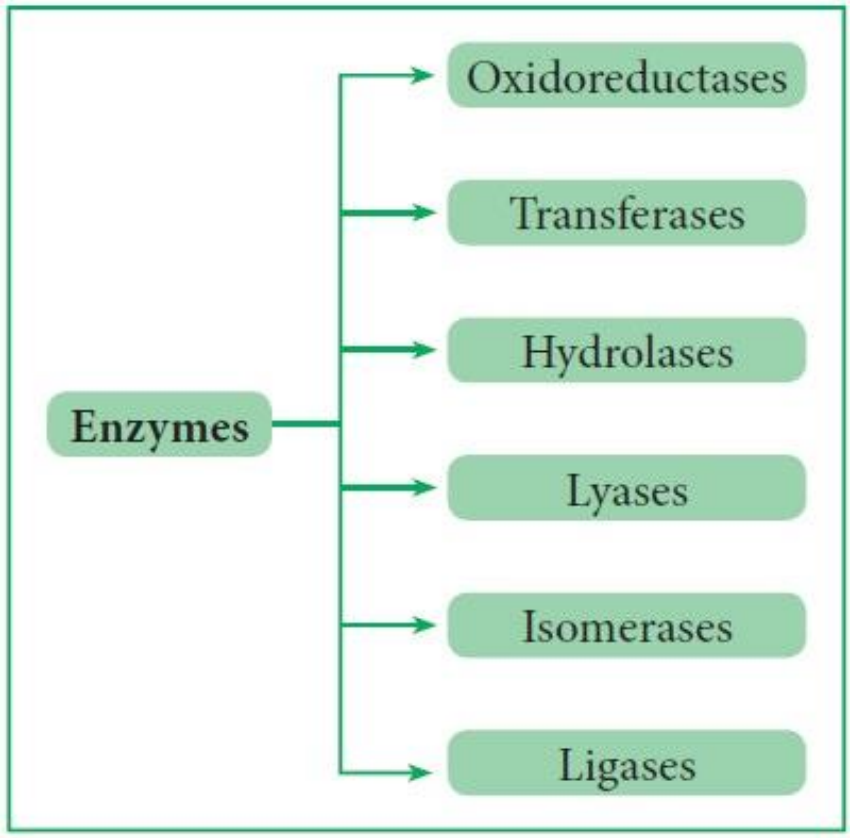
- Since enzymes react with only one type of substance or group of substances, called the substrate, enzymes often have been named by adding the suffix "-ase" to this substrate's name

  Ex :- Urease :- which catalyzes the breakdown of urea.

- Not all enzymes have been named in this manner, a classification system has been developed based on the type of reaction the enzyme catalyzes.

- Enzymes can be indexed with letters and numbers according to International Union of Biochemistry and Molecular Biology "**IUBMB**":

- There are six principal categories and their reactions: →



1. **Oxidoreductase:** Remove or add e^- or H
2. **Transferase:** Transfer chemical group from one substrate to another
3. **Hydrolase:** Breaks chemical bonds by adding the e^- of H_2O
4. **Lyase:** Form double bond by elimination of chemical group
5. **Isomerase:** Rearrange atoms of molecules to form structural isomer
6. **Ligase:** Join two molecules coupled with hydrolysis of ATP

Enzymes have 4 letter code

E.g. Hexokinase (E.C. 2.7.1.1.)

- Serial No. of enzyme
- **Class:** Transferase
- **Sub class:** Transfer of P
- **Sub sub class:** an alcohol as an acceptor

The four numbers representing four elements. :-

(i) the 1st number shows to which of the six main divisions (classes) the enzyme belongs,
(ii) the 2nd number indicates the subclass,
(iii) the 3rd number gives the sub-subclass,
(iv) the 4th number is the serial number of the enzyme in its sub-subclass.

Example: EC 1.1.1.1 alcohol dehydrogenase

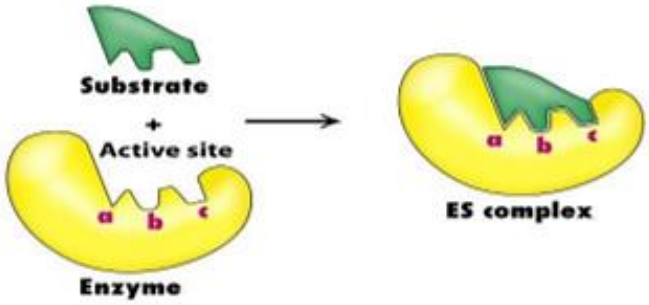
EC 3.3.1.21 β-glucosidase

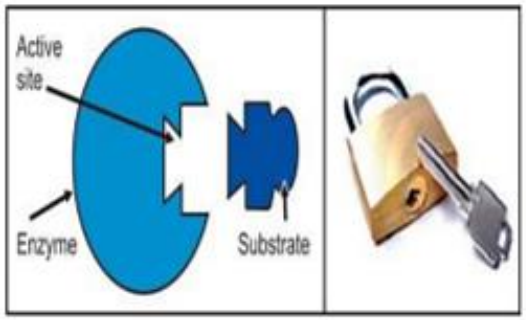
Mechanism of enzyme action

- The substrate (S) binds to the enzyme (E) to form **enzyme substrate complex** (ES)
- The complex (ES) cleaved to the products (P) and the original enzyme (E)
- Theories of enzyme substrate binding (Two theories):

1- Lock and key theory (Proposed by Fischer in 1894):

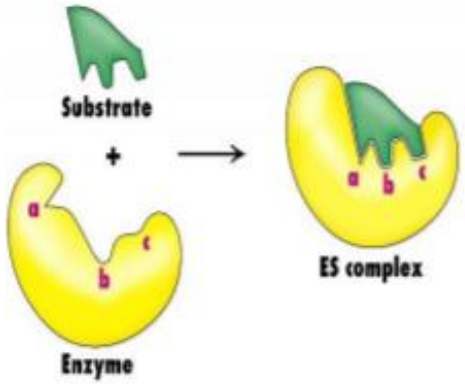
-The catalytic site of the enzyme has a shape that is complementary (fit) to the shape of the substrate. It is a rigid model (template theory).





2- Induced fit theory (Proposed by Koshland in 1958):

- The catalytic site of the enzyme is not complementary to the substrate.
- In this case, binding of the substrate to the enzyme induces changes in the shape of the catalytic site making it more fit for substrate.
- It a flexible model.



Factors affecting the rate of enzyme action

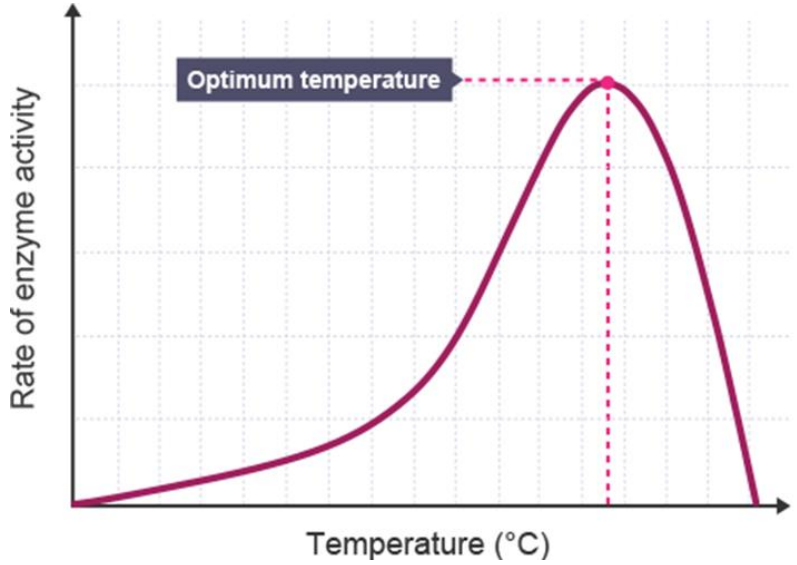
1- Effect of Temperature

- At low temperatures, the number of collisions between the enzyme and substrate is reduced because their molecular movement decreases. The reaction is slow.
- Higher temperatures disrupt the shape of the active site, which will reduce its activity, or prevent it from working. The enzyme will have been denatured.

- The human body is maintained at 37°C as this is the temperature at which the enzymes in our body work best. This not true of the enzymes in all organisms.

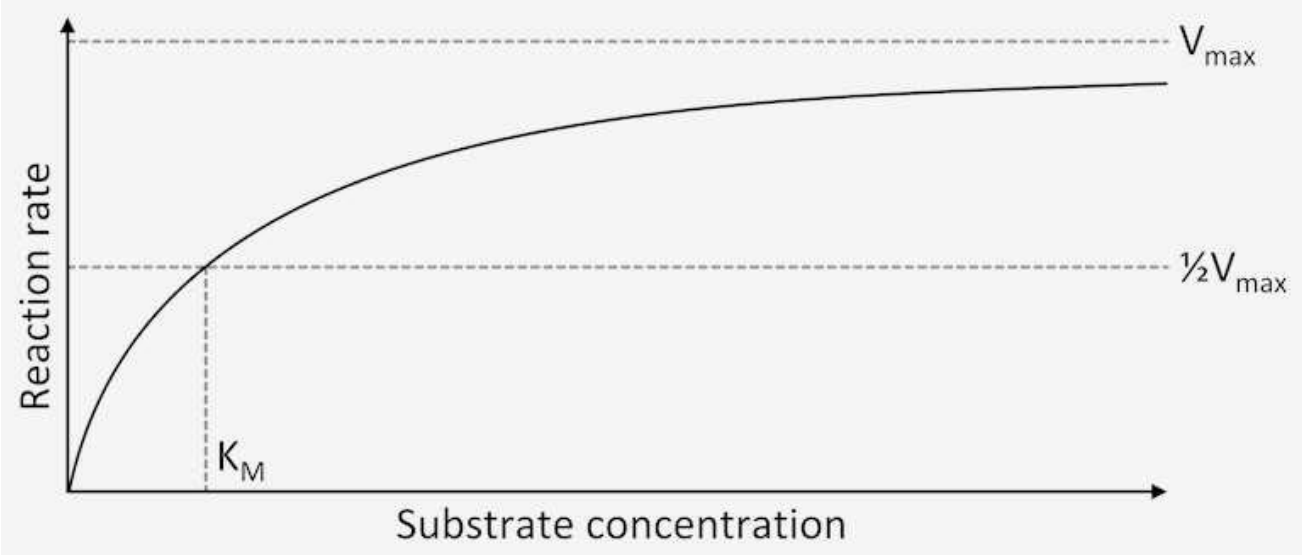
How temperature affects enzyme action?

- Enzymes work best at a particular temperature.
- High temperatures will break the forces stabilizing tertiary structure.
- The enzyme, including its active site, will change shape and the substrate no longer fit.
- The rate of reaction will be affected, or the reaction will stop.



2- Effect of substrate concentration

- Enzymes will work best if there is plenty of substrate available
- The rate of reaction increases as the substrate concentration increases up to certain point at which the reaction rate is maximal (Vmax.)
- **At Vmax**, the enzyme is completely saturated with the substrate, Then any increase in substrate concentration don't affect the reaction rate.



- **Km** :- the substrate concentration at which the reaction rate is **50% of the Vmax**.
  - Km is a measure of the affinity an enzyme has for its substrate.
  - As the lower the value of Km, the more efficient the enzyme is at carrying out its function at a lower substrate concentration.

3- Effect of pH

- Each enzyme has an optimum pH at which its activity is max.

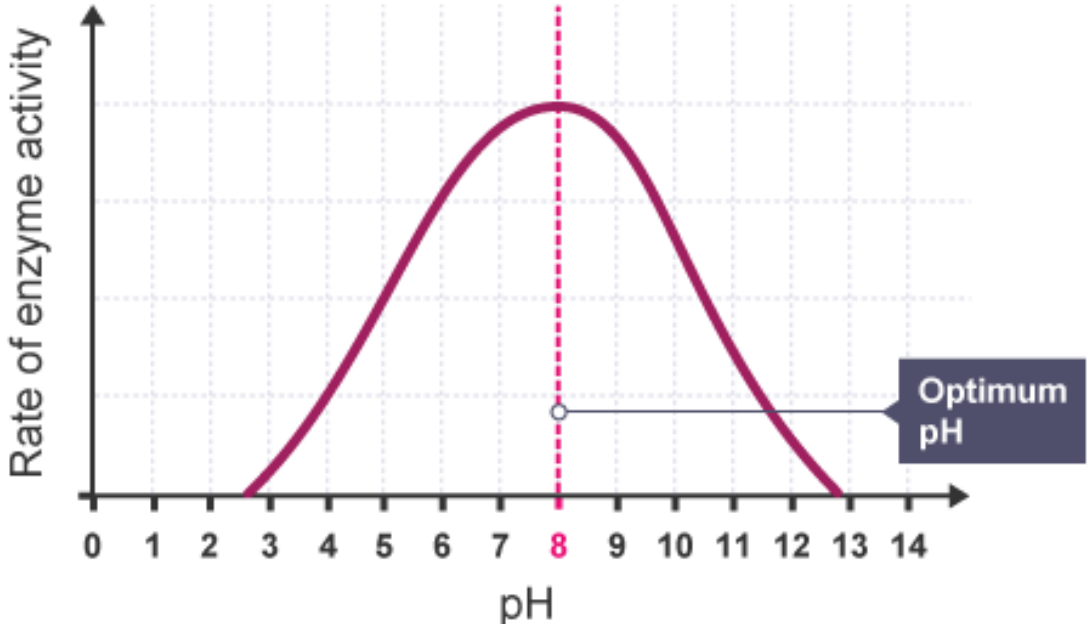
E.g. Optimum pH of pancreatic lipase = 7.5-8

Optimum pH of salivary amylase = 6.8

Changing the pH of its surroundings will also change the shape of the active site of an enzyme.

Notes :-

Changing the pH will affect the charges on the amino acid molecules, so the shape of the enzyme will change. (Denaturation of enzyme occurs).



4- Effect of enzyme concentration

- As the concentration of the enzyme is increased, the enzyme activity also increases.
- This increase in enzyme activity does not occur forever.
- So when the amount of available enzyme exceeds the amount of substrate then no more substrate can be broken down.

5- Effect of coenzyme concentration

- In the conjugated enzymes that need coenzymes, the increase in the coenzyme concentration will increase the reaction rate

6- Effect of time

- In an enzymatic reaction, the rate of reaction is decreased by time.

  This is due to:

  1- The decrease in substrate concentration.

  2- The accumulation of the products.

  3- The change in pH than optimum pH.

7- Effect of enzyme inhibitor

- Presence of enzyme inhibitor decreases or stops the enzyme activity

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Lecture (4)

Enzymes Inhibitors

The inhibitor: is the substance that decreases or stop the enzyme activity.

Types of inhibition:

- Competitive inhibition
- Non- competitive inhibition

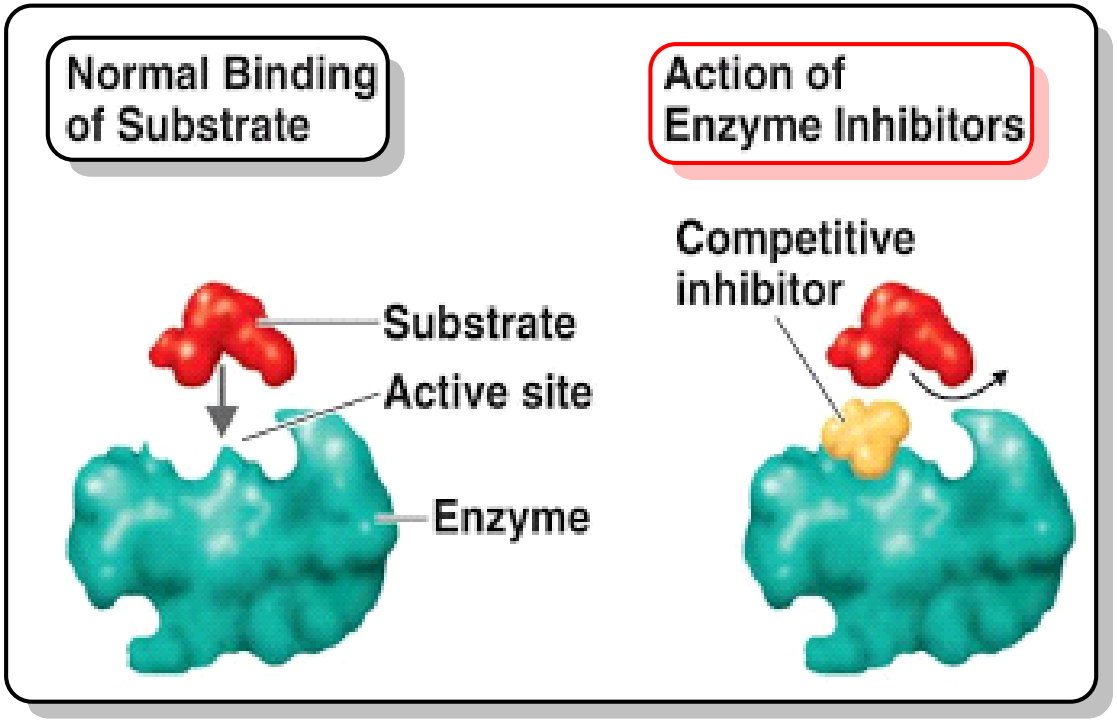
Competitive inhibition

1 - There is structural similarity between the inhibitor and the substrate

2- The inhibitor and the substrate compete with each other for the same active site of enzyme.

3- The inhibition is reversible (**the reaction returns again by removal of inhibitor**)

4 - It can be relieved by increasing substrate concentration



Examples :-

Enzymatic process	Substrate	Inhibitor
Folic acid synthesis in bacteria	Para aminobenzoic acid (PABA)	Sulfanilamide
Prothrombin synthesis	Vitamin K	Dicumarol
Xanthine oxidase	Xanthine	Allopurinol

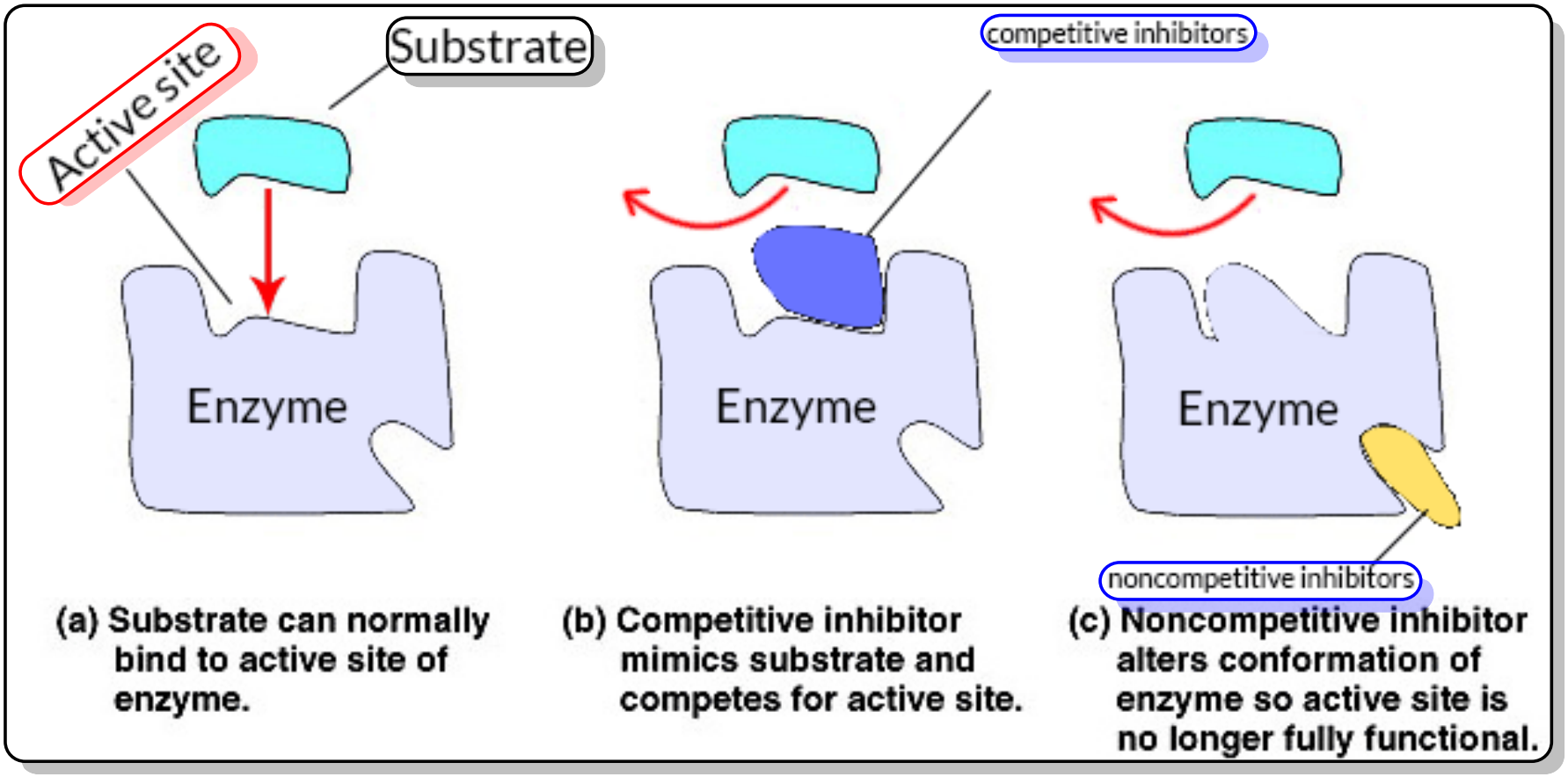
Non-competitive inhibition

1- There is no structural similarity between the inhibitor and the substrate.

2 -The inhibitor does not bind to the catalytic site, but bind to another site.

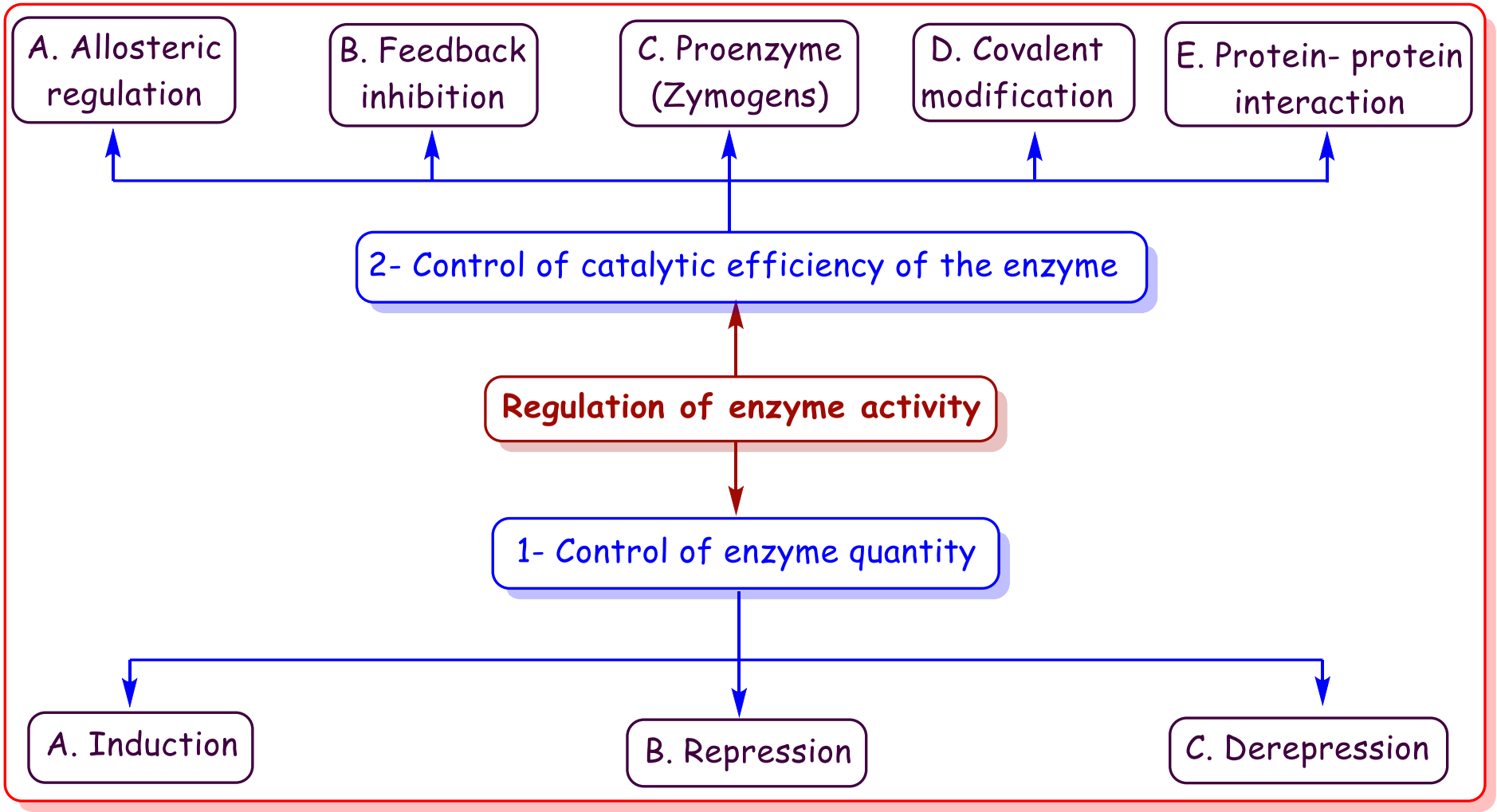
3- The inhibition is irreversible

4 - It can't be relieved by increasing substrate concentration



Regulation of enzyme activity

- Because enzymes regulate the metabolism of a cell, they tend to be carefully controlled



Control of enzyme quantity

A-Induction:

- Increase in the rate of enzyme synthesis by substances called inducers
- Inducers increase the rate of enzyme synthesis at the level of gene expression
- **E.g.:**

Induction of lactase enzyme in bacteria grown on CHO media

B-Repression: (Feedback regulation)

- Decrease the rate of enzyme synthesis by substances called repressors
- Repressors decrease the rate of enzyme synthesis at the level of gene expression
- **E.g.:**

Cholesterol decreases the rate of synthesis of HMG-CoA reductase which is a key enzyme in cholesterol biosynthesis

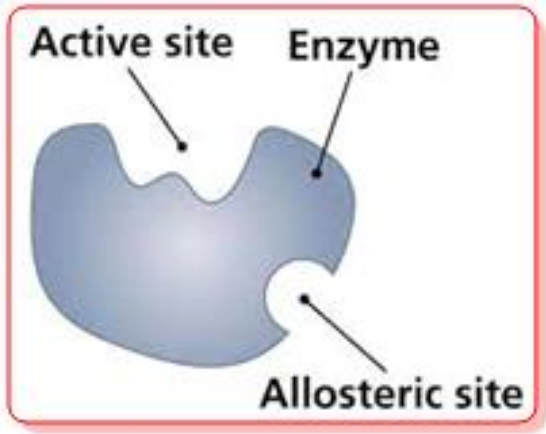
C-De-repression:

- Enzyme synthesis retains its normal rate after removal of repressor

Control of catalytic efficiency of the enzyme

A- Allosteric regulation: Is just any form of regulation where a regulator molecule (an activator or inhibitor) binds to an enzyme someplace other than the active site.

- The place where the regulator binds is called the **allosteric site**.



Types of effectors

i- If the binding increases the activity of enzyme, the effector is called positive effector or allosteric activator.

E.g. ADP is positive for phosphofructokinase enzyme

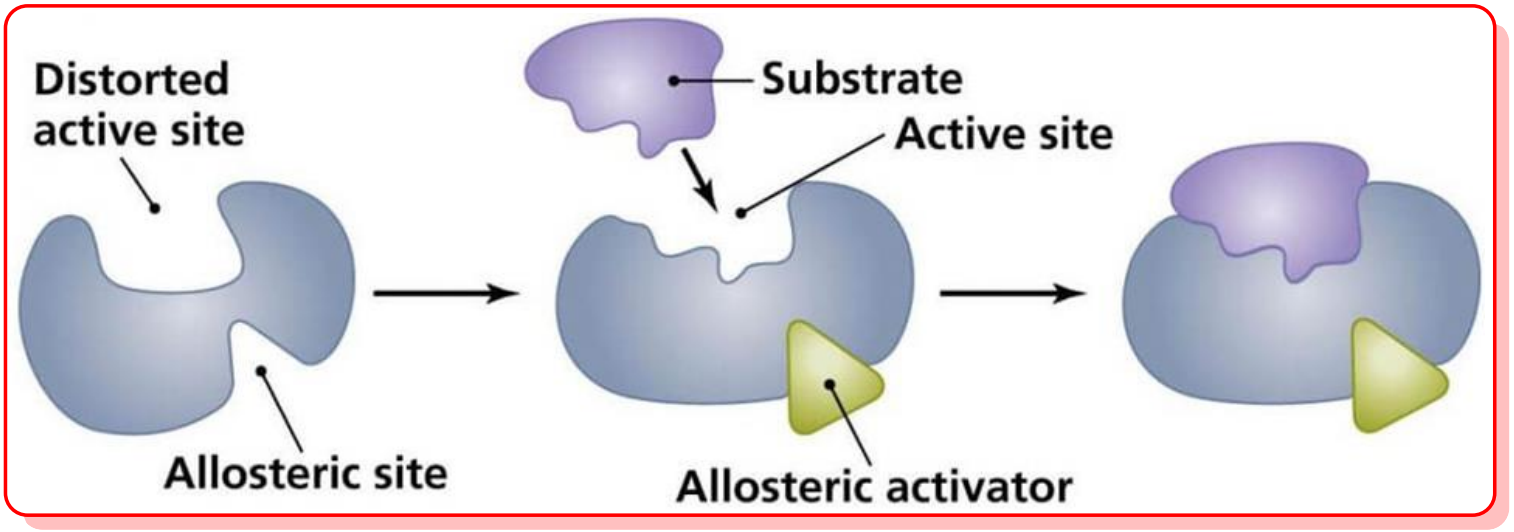
ii- If the binding decreases the enzyme activity, the effector is called negative effector or allosteric inhibitor.

E.g. ATP and citrate are allosteric inhibitors for phosphofructokinase enzyme.

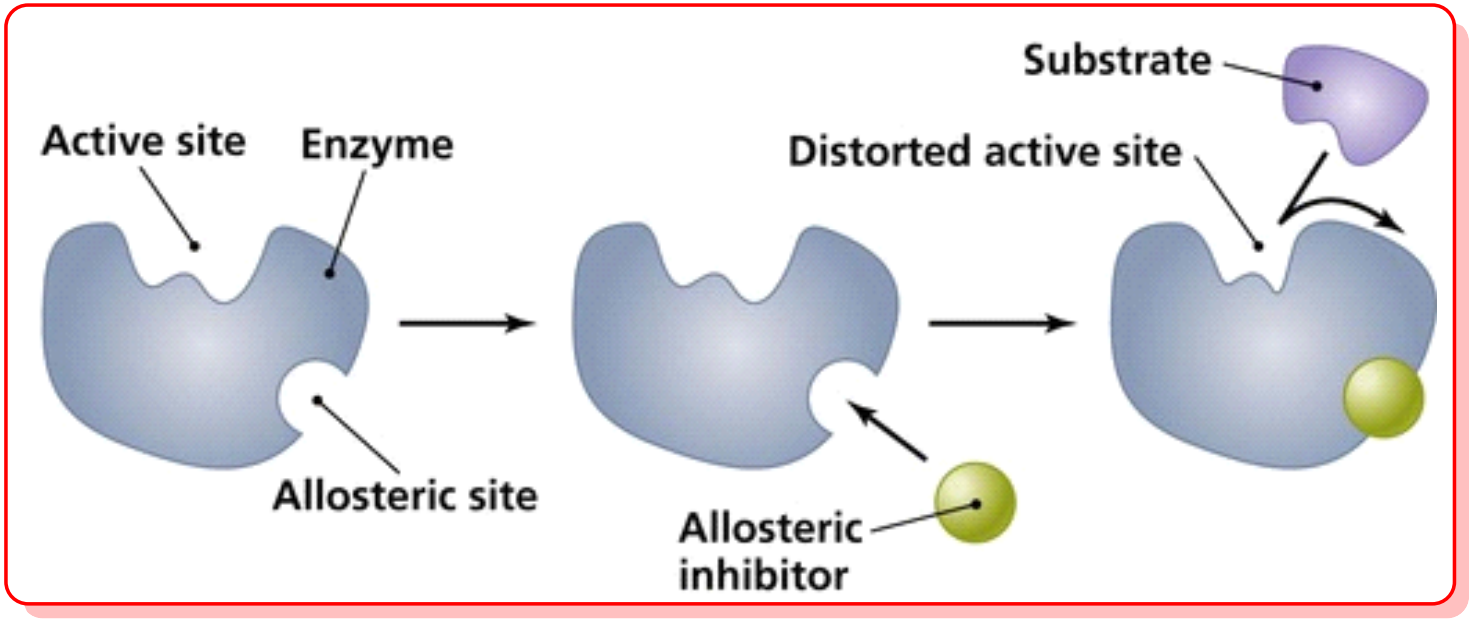
Mechanism of allosteric regulation:

- Binding of the allosteric effector to the regulatory site causes changes in the shape of catalytic site to be more fit to substrate (allosteric activator) or unfit for substrate (allosteric inhibition)

Allosteric activator

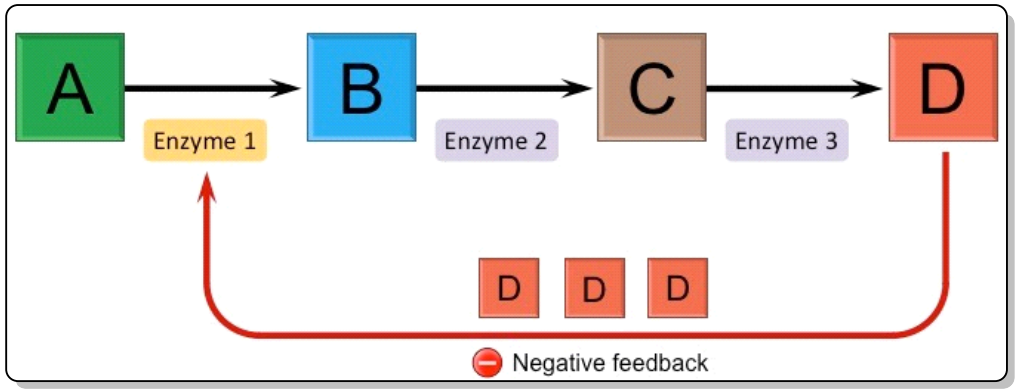


Allosteric inhibitor



B-Feedback inhibition:

- The end product of a reaction **inhibits** the activity of an enzyme early in the pathway.



C-Proenzymes (Zymogens):

- Some enzymes are secreted in inactive form called proenzymes or zymogens.
- Zymogens are inactive because it contains an additional protein that blocks the active site of the enzyme.
- Activation of zymogens occurs by removal of the peptide chain that masks the active site. **Examples:** Pepsinogen, trypsinogen & clotting factors

Biological importance of zymogens:

1- Protect the tissues of origin from auto digestion

2- Rapid mobilization of enzyme activity at the time of needs in response to physiological demands.

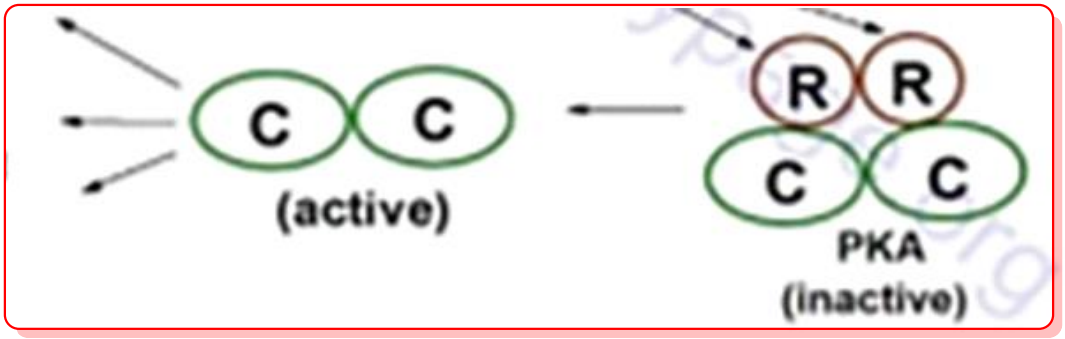
D-Covalent modifications:

- Modification of enzyme activity through formation of covalent bonds
  by: Methylation, Hydroxylation, Adenylation, Phosphorylation
- Phosphorylation is the most method used to control enzyme activity.
  - It occurs by addition of phosphate gp to the enzyme at the –OH of serine, threonine or tyrosine. This occurs by **protein kinase enzyme**
- Dephosphorylation occur by removal of phosphate group by **phosphatase enzyme**
- The phosphorylated form may be the active form in some enzymes.
- The dephosphorylated form may be the active form in other enzymes.

D- Protein- protein interaction:

- It occurs in enzymes formed of many protein subunits "chains".
- The enzyme may be present in inactive form through interaction between its subunits
- Activation of enzyme occurs by separation of the catalytic from the regulatory subunits.

Example: Protein kinase A (PKA) [Formed of 4 subunits 2C + 2 R]



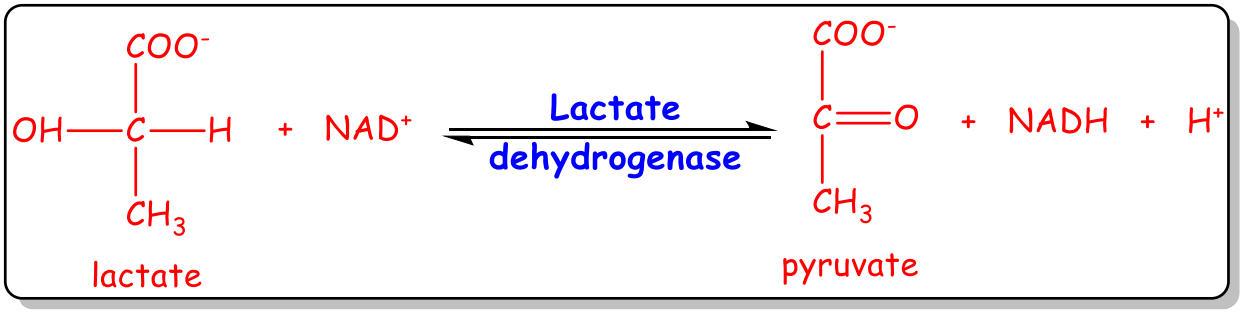
Isoenzymes

They are many forms of the enzyme that have the same catalytic activity,

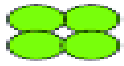
Examples: 1- Lactate dehydrogenase (LDH). 2- Creatine kinase (CK).

3- Acid phosphatase. 4- Alkaline phosphatase.

Example 1: Lactate dehydrogenase (LDH):



- LDH enzyme is formed of 4 protein subunits. of 2 types, H (heart) and M (muscle).
- Lactate dehydrogenase has 5 isoenzymes:

Isoenzyme	Formed of	Increases in	Shape
LDH1	HHHH	Myocardial infarction	
LDH2	HHHM	Myocardial infarction	
LDH3	HHMM	Leukemia	
LDH4	HMMM	Viral hepatitis	
LDH5	MMMM	Viral hepatitis	

LDH isozymes are clinically important to differentiate between heart, liver and blood diseases.

Example 2: Creatine kinase (CK):

- CK enzyme is a dimmer formed of 2 protein subunits.
- The subunits of CK are of 2 types, B (brain) and M (muscle).
- Creatine kinase has 3 isoenzymes.

Isoenzyme	Increases in	Shape
CK BB	Brain tumors	
CK MB	Heart diseases	
CK MM	Skeletal muscle diseases	

- CK isoenzymes are clinically important to differentiate between brain, heart and skeletal muscle diseases.

Source of isoenzymes:

1- Isoenzymes: produced by more than one gene; each gene produces one subunit .

2- Isoenzymes may be produced by the same gene but the subunits undergo different post-translation modifications in different organs.

Plasma enzymes

- Blood plasma contains many enzymes.
- They are classified into functional and non-functional plasma enzymes.

	Functional plasma enzymes	Non-functional plasma enzymes
Concentration in plasma	Present in plasma in higher concentration in comparison to tissues	Present in plasma in very low concentration in comparison to tissues
Functions	Have known functions	No known functions
The substrate	Their substrate are always present in the blood	Their substrate are absent from the blood
Site of synthesis	liver	Different organs e.g . liver , heart , brain and skeletal muscles
Effect of diseases	Decrease in liver disease	Different enzymes increase in different organ diseases
Examples	Clotting factors , lipoprotein lipase and pseudo-choline esterase	ALT , AST,CK,LDH, alkaline phosphatase , acid phosphatase and amylase

Sources of non-functional plasma enzymes:

1- Obstruction of normal pathway.

2- Increased permeability of cell membrane: as in tissue hypoxia.

3- Cell damage with the release of its contents of enzymes into the blood.

Medical importance of non-functional plasma enzymes:

1-**Diagnosis of diseases:**

2-**Prognosis & follow up of the disease:** by measuring the plasma enzymes before and after treatment.

Enzyme	Disease
Amylase, lipase	Pancreatitis
Creatine kinase	Heart, brain, skeletal muscle diseases
Lactate dehydrogenase	Heart, liver, blood diseases
Serum glutamic pyruvic transaminase (SGPT) = Alanine transaminase (ALT)	Liver diseases
Serum glutamic oxalacetic transaminase (SGOT) = Aspartate transaminase (AST)	Liver and heart diseases

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Lecture (5)

Carbohydrates are biomolecules consisting of carbon (C), hydrogen (H) and oxygen (O) atoms, usually with the general formula $C_n(H_2O)_n = C_nH_{2n}O_n$

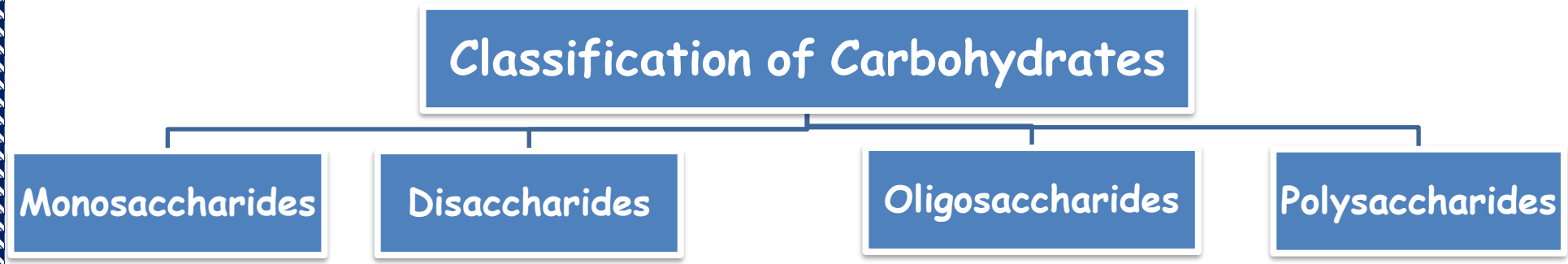
- There are some carbohydrates, which do not have this general formula
- There are substances which are not carbohydrates but have the formula $C_nH_{2n}O_n$

Importance of carbohydrates:

1) The chief source of energy.
2) Important structural components in animal and plant cells.
3) Important part of nucleic acids and free nucleotides and coenzymes.
4) Major antigens are carbohydrates in nature, e.g., blood group substances.
5) Biological role as part of hormones and their receptors and enzymes.

Note

- Carbohydrates are called **Saccharides** - Small carbohydrates called **Sugars**



Monosaccharides (simple sugars):

- ❖ They contain one sugar unit (Simplest form of sugars)
- ❖ Cannot be hydrolyzed and represent the **end products** of carbohydrate digestion.

Disaccharides:

- ❖ They contain 2 monosaccharide units per molecule

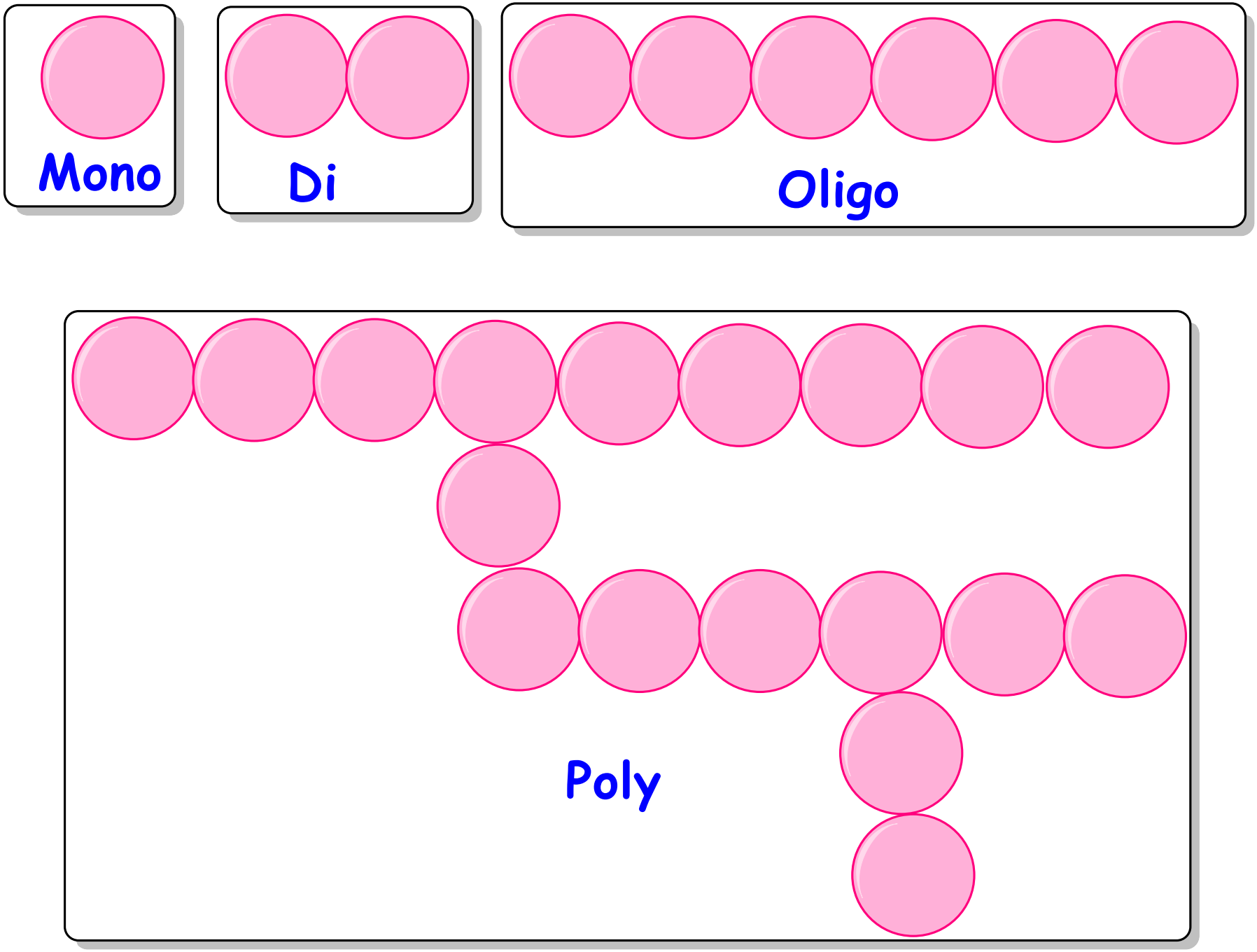
Oligosaccharides:

- ❖ They contain 3 - 10 monosaccharide units per molecule

Polysaccharides:

- ❖ They contain more than 10 monosaccharide units per molecule

Di, Oligo and Polysaccharides give monosaccharides on hydrolysis.


Mono
Di
Oligo
Poly

Monosaccharides

- Simplest carbohydrates, composed of single sugar unit according to the formula $C_nH_{2n}O_n$
- Monosaccharides can be classified according to :-

(1) The number of carbon atoms present in the monosaccharide

The name of any monosaccharides composed of two parts [**prefix** + **suffix**]

Prefix = No. of C. atoms **Suffix** = ose

# of Atoms	Prefix
1	mono
2	di
✓ 3	tri
✓ 4	tetra
✓ 5	penta
✓ 6	hexa-

A monosaccharide containing three carbon atoms is called a **triose**

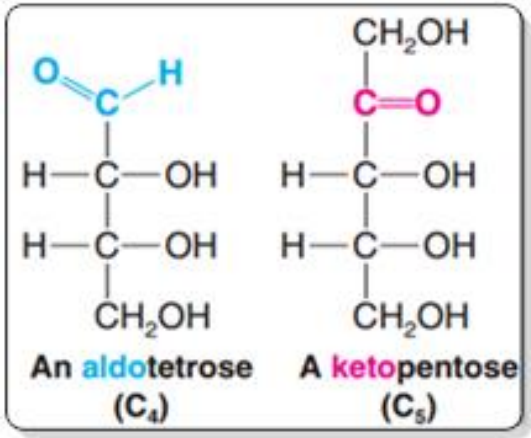
A monosaccharide containing four carbon atoms is called a **tetrose**

(pentose? hexose?)

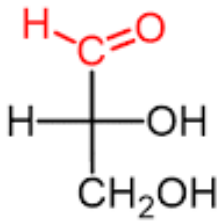
(2) Whether they contain an aldehyde or keto group :-

(i) **Aldoses** :- contain **C=O** in C_1 [aldehyde group]

(ii) **Ketoses** :- contain **C=O** in C_2 [ketone group]

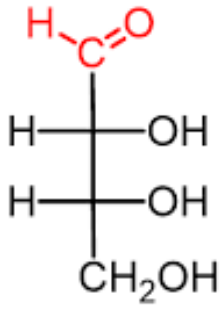


an aldose + a triose



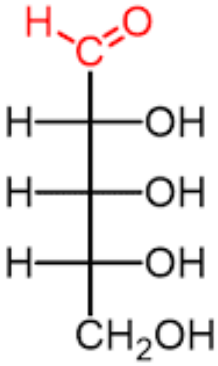
an aldotriose

an aldose + a tetrose



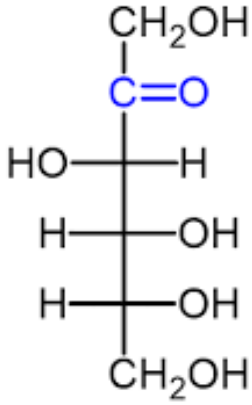
an aldotetrose

an aldose + a pentose



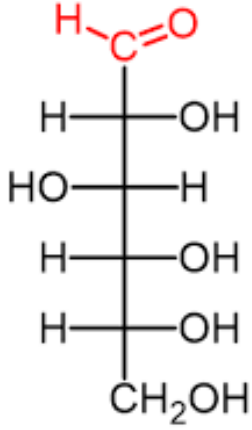
an aldopentose

a ketose + a hexose



a ketohexose

an aldose + a hexose



an aldohexose

Stereochemistry of carbohydrates

Stereoisomers: - They are compounds having the same structural formula but differ in :

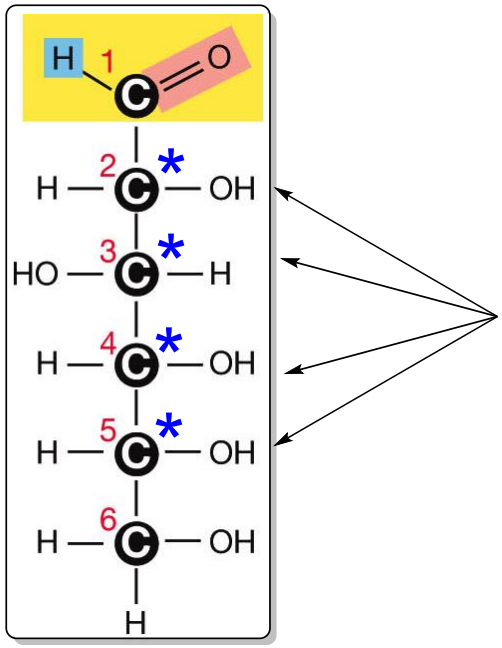
i) Arrangement of atoms in the molecule in space

ii) Properties.

Chiral carbon

- is any carbon atom attached to **4 different groups**.
- Also called **Asymmetric carbon**.

Example :- Glucose

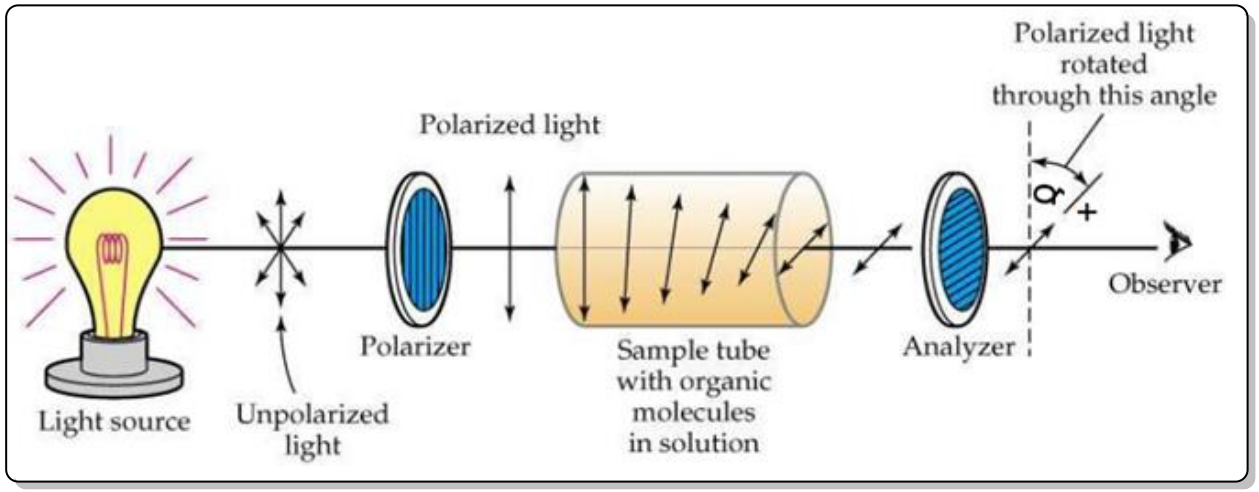


4 chiral carbons

Optical activity is the ability of a chiral molecule to rotate the plane of plane-polarized light (**The rotation may be clockwise or Anti-clockwise**).

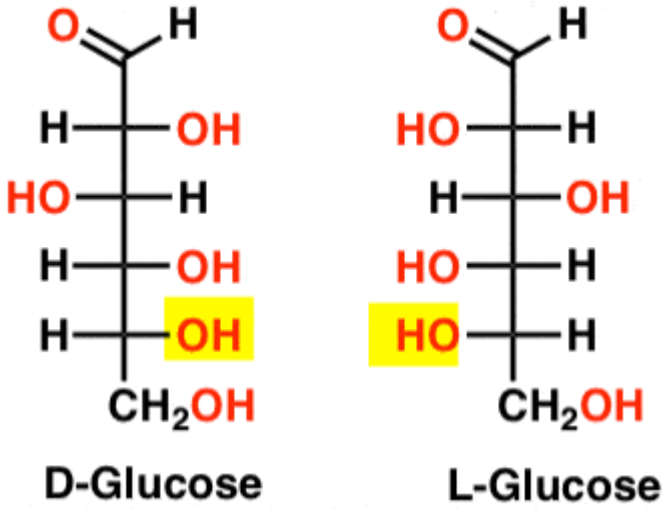
D- and L- sugars

- If the rotation was **clockwise**, the sugar called **dextrorotatory**,
- If the rotation was **Anti-clockwise**, the sugar called **levorotatory**

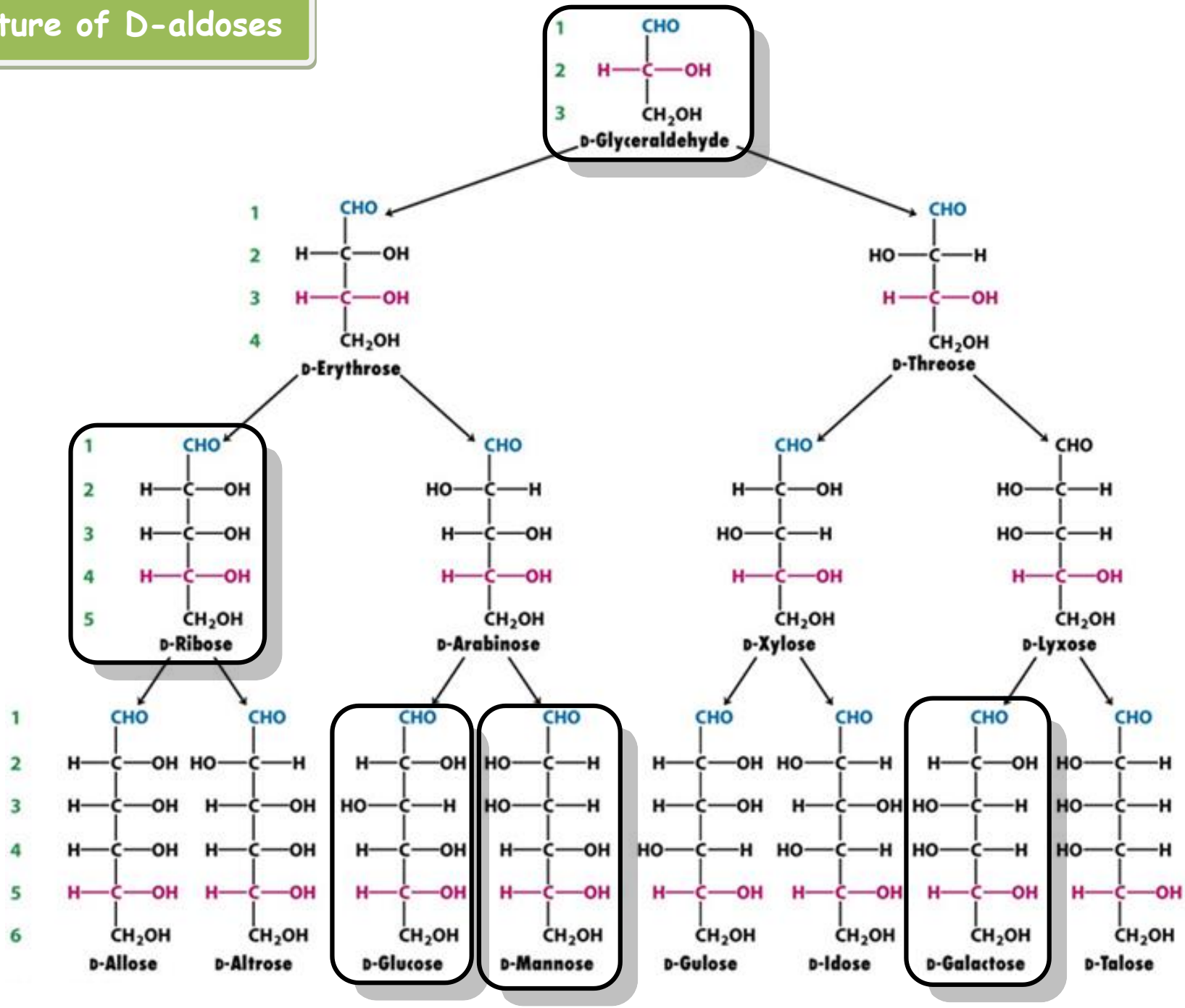


D-sugar :- The OH of **pre-last** carbon is on the **right**

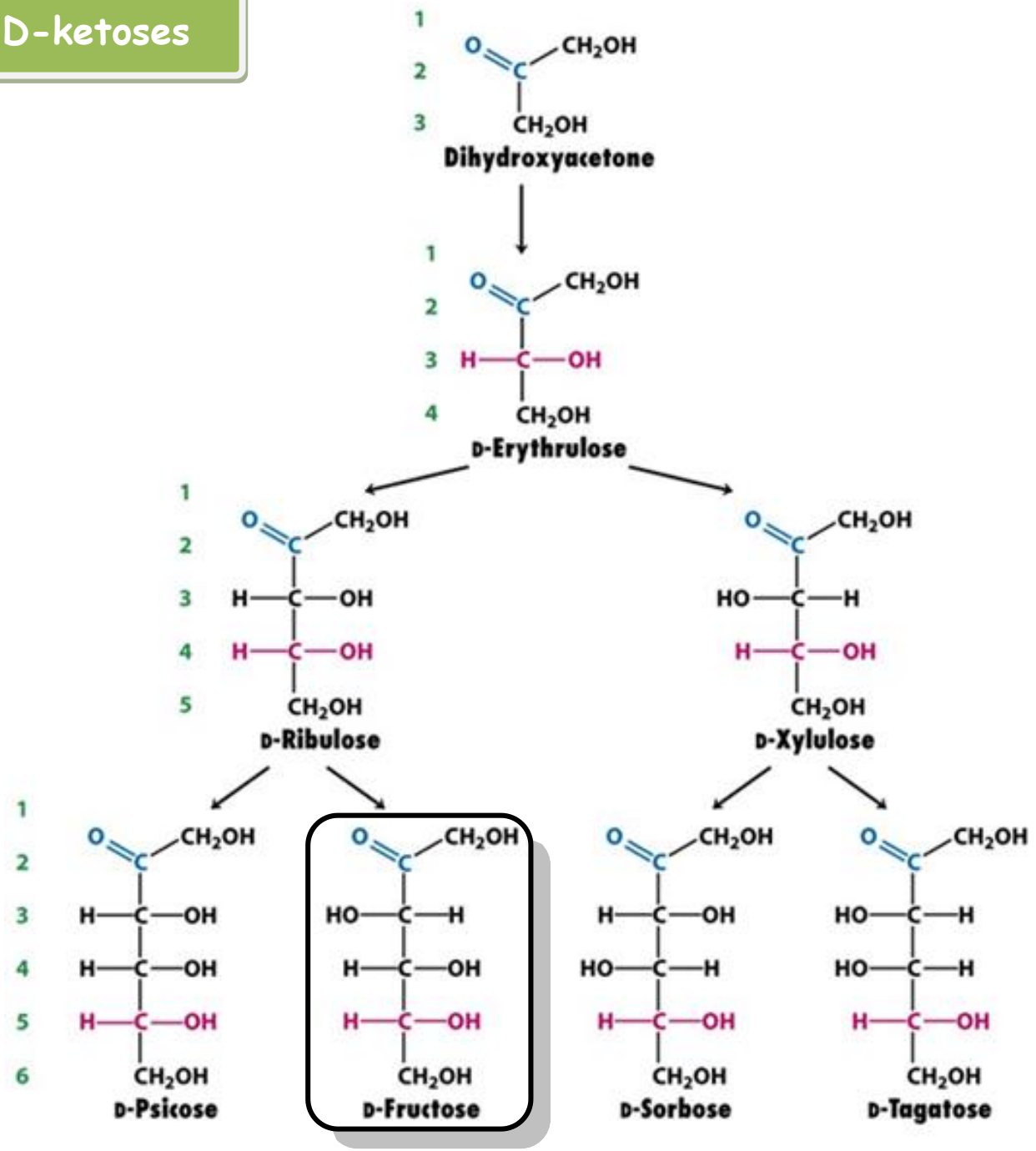
L-sugar :- The OH of **pre-last** carbon is on the **left**



Structure of D-aldoses

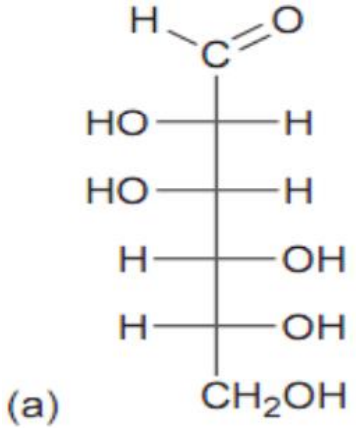


Structure of D-ketoses

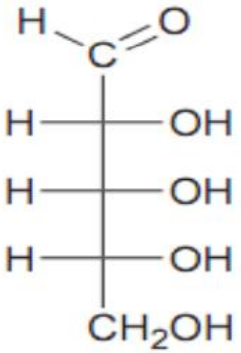


Problems

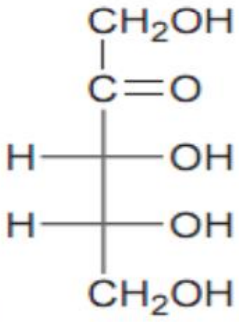
Q1: Classify the following monosaccharides:



(a)



(b)



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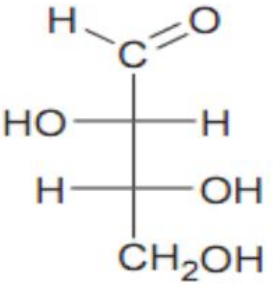
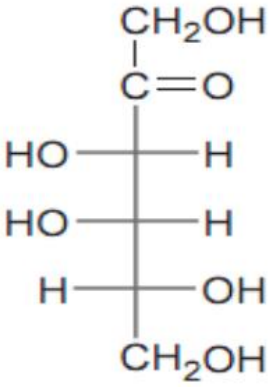


(d)

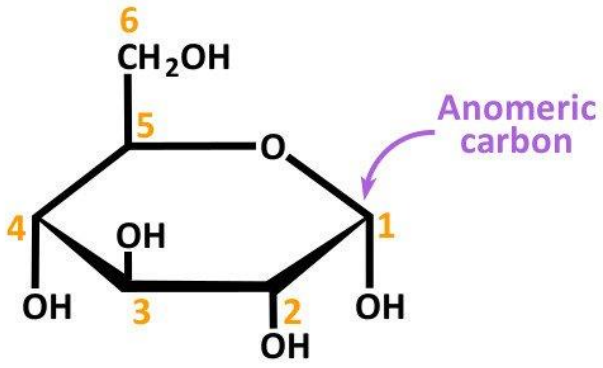


(e)

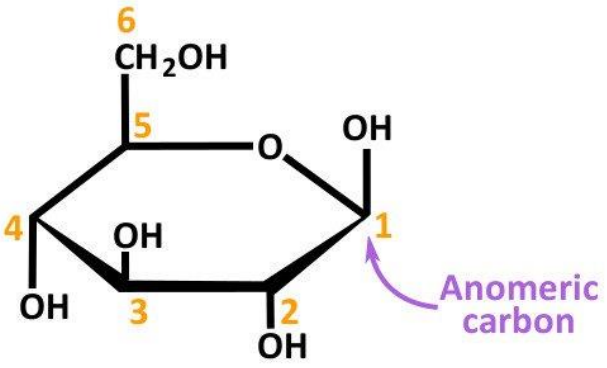
Some definitions

- **Aldose**: A carbohydrate containing an aldehyde functional group.
- **Ketose**: A carbohydrate containing a ketone functional group.
- **Fischer Projection**: A way of representing carbohydrate structure
- **Haworth Projection**: A way of representing a cyclic (closed chain) carbohydrate substituents can either point up or down on this ring.
- **Furanose**: A five-member closed chain form of a monosaccharide.
- **Pyranose**: A six-member cyclic form of a monosaccharide.
- **Anomeric carbon**: The carbon atom that becomes a new asymmetric center in cyclic form.
- **Anomers**: The configuration around the anomeric carbon (Carbonyl group)

OH group down = α isomer & OH group up = β isomer



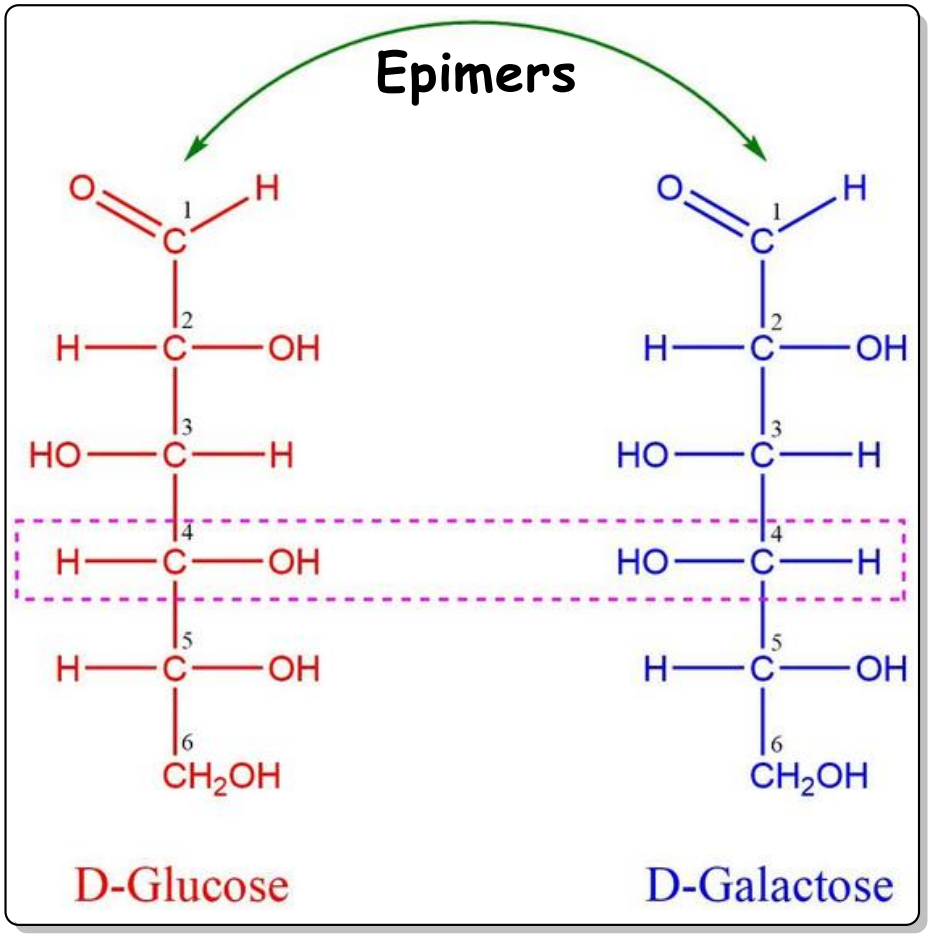
α-D-glucopyranose



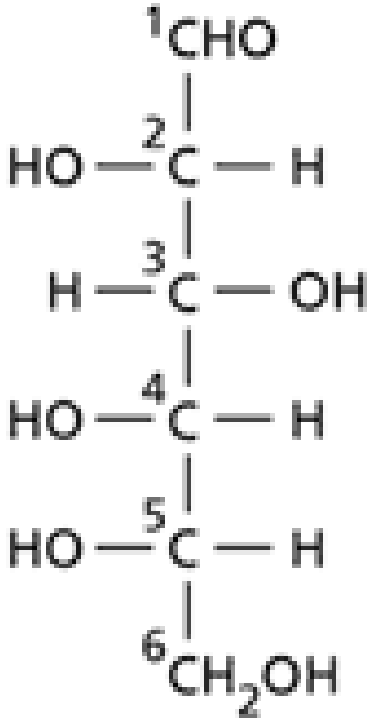
β-D-glucopyranose

➢ **Epimers** :- Differ at only one chiral center, not the anomeric carbon.

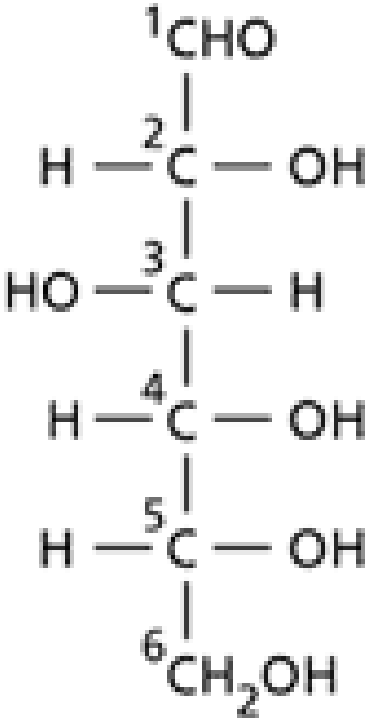
[Ex:- glucose & galactose at C_4]



➢ **Enantiomers**:- D- and L isomer "Mirror image"

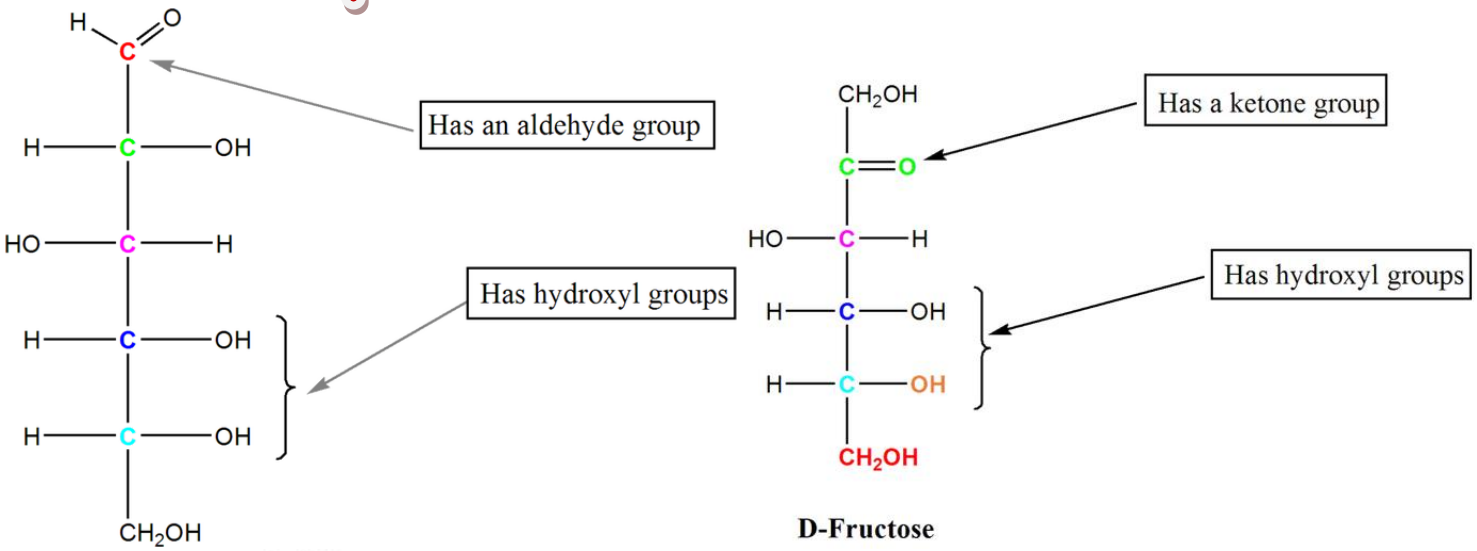


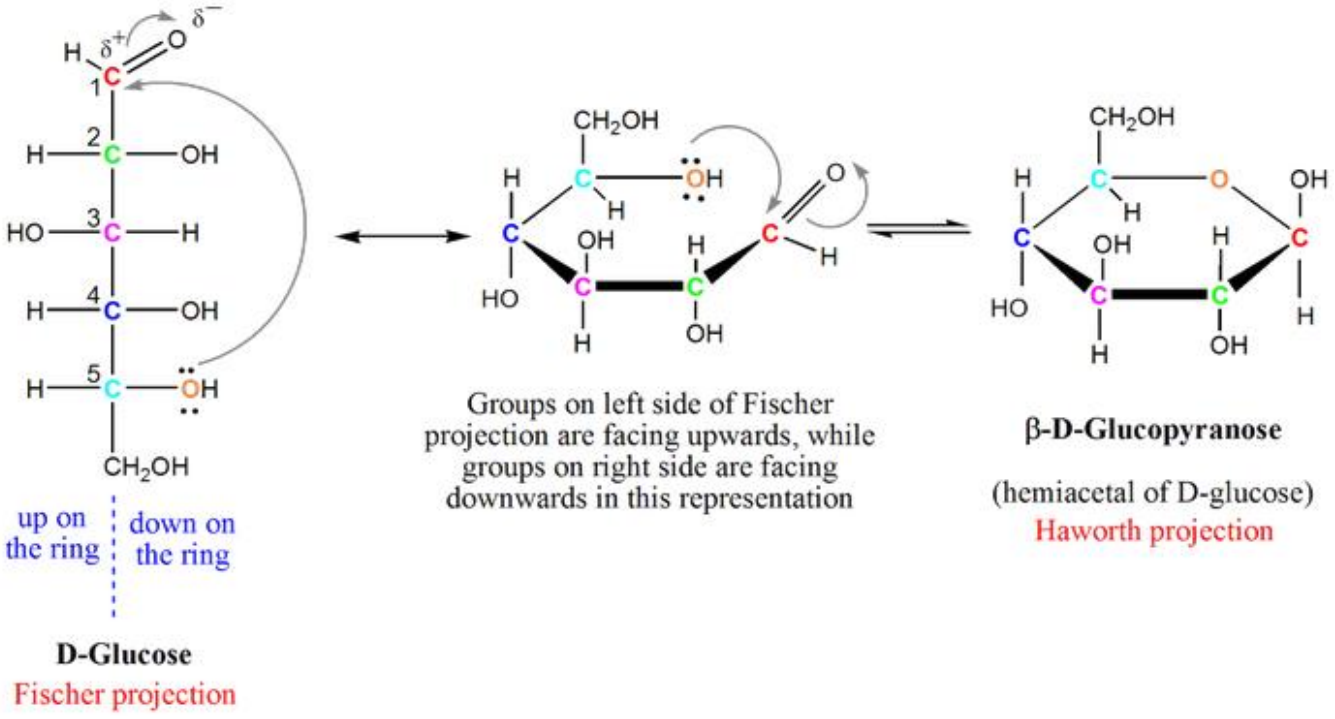
L-Glucose

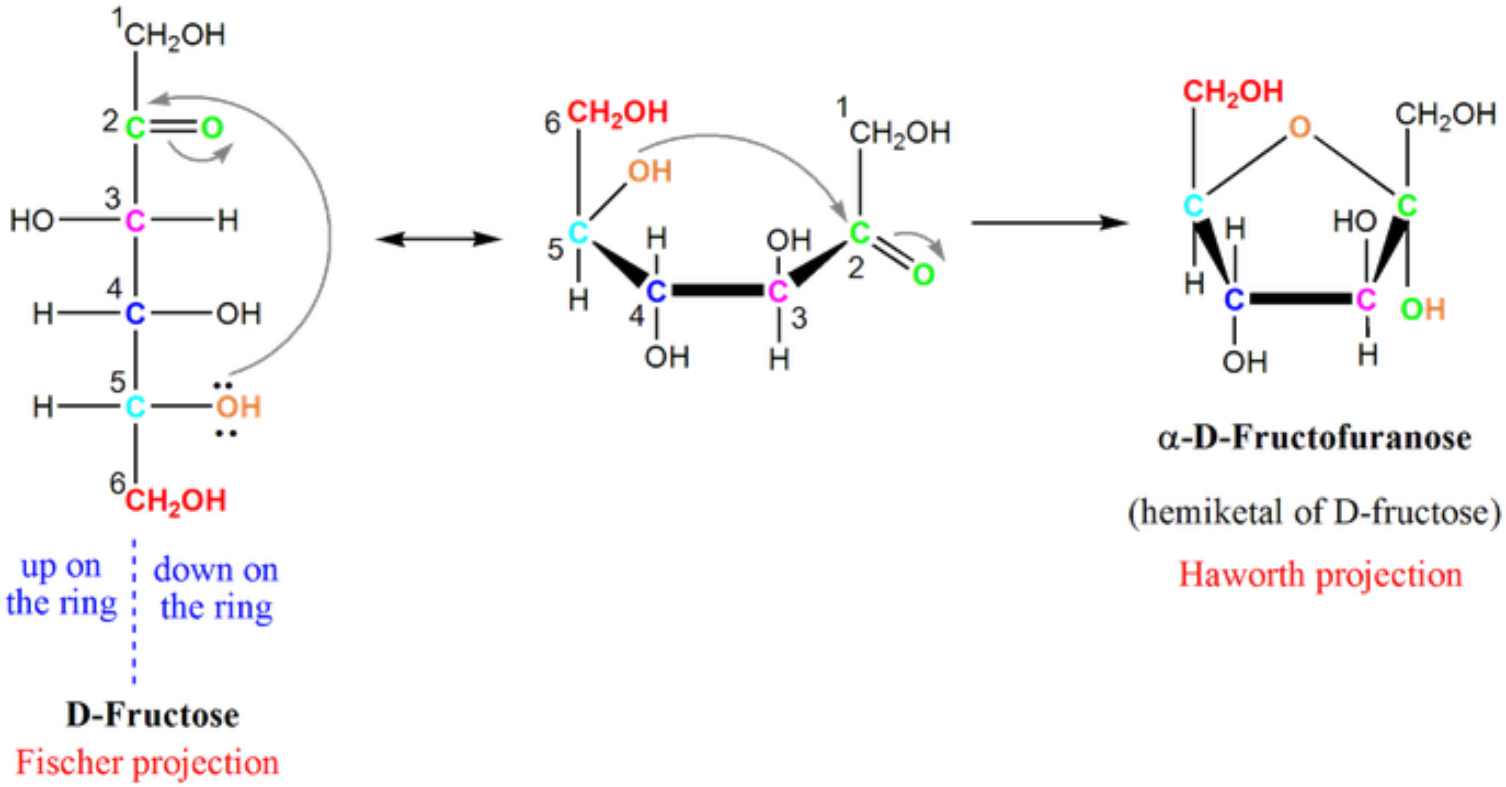


D-Glucose

Drawing Haworth projection



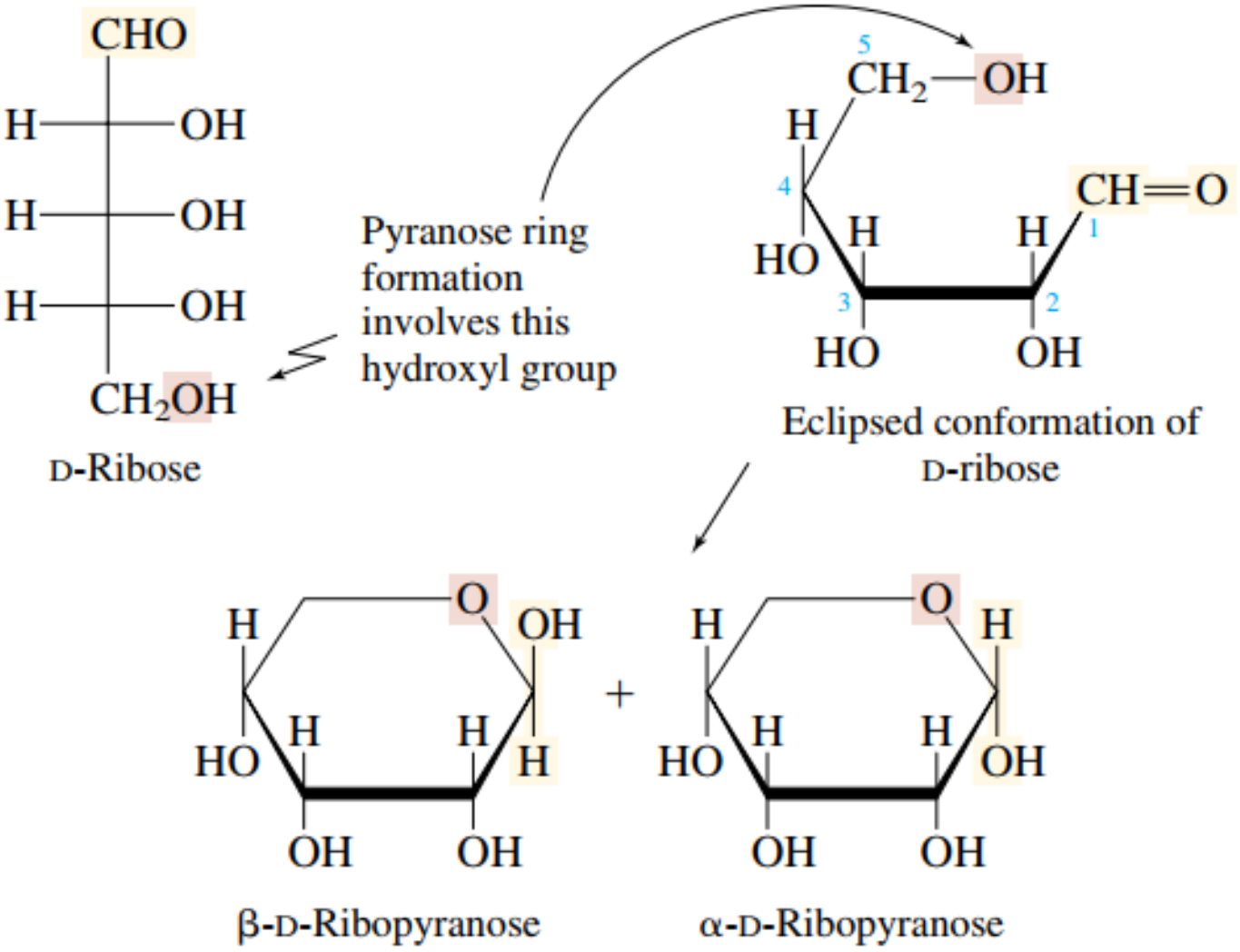



1 CH2OH
2 C O
HO 3 C H
H 4 C OH
H 5 C OH
6 CH2OH
up on the ring
down on the ring
D-Fructose
Fischer projection
6 CH2OH
OH
5 C
H
H
4 C
OH
OH
C 3
H
1 CH2OH
C 2
O
CH2OH
O
CH2OH
C
H
HO
C
H
C
C
OH
OH
H
α-D-Fructofuranose
(hemiketal of D-fructose)
Haworth projection

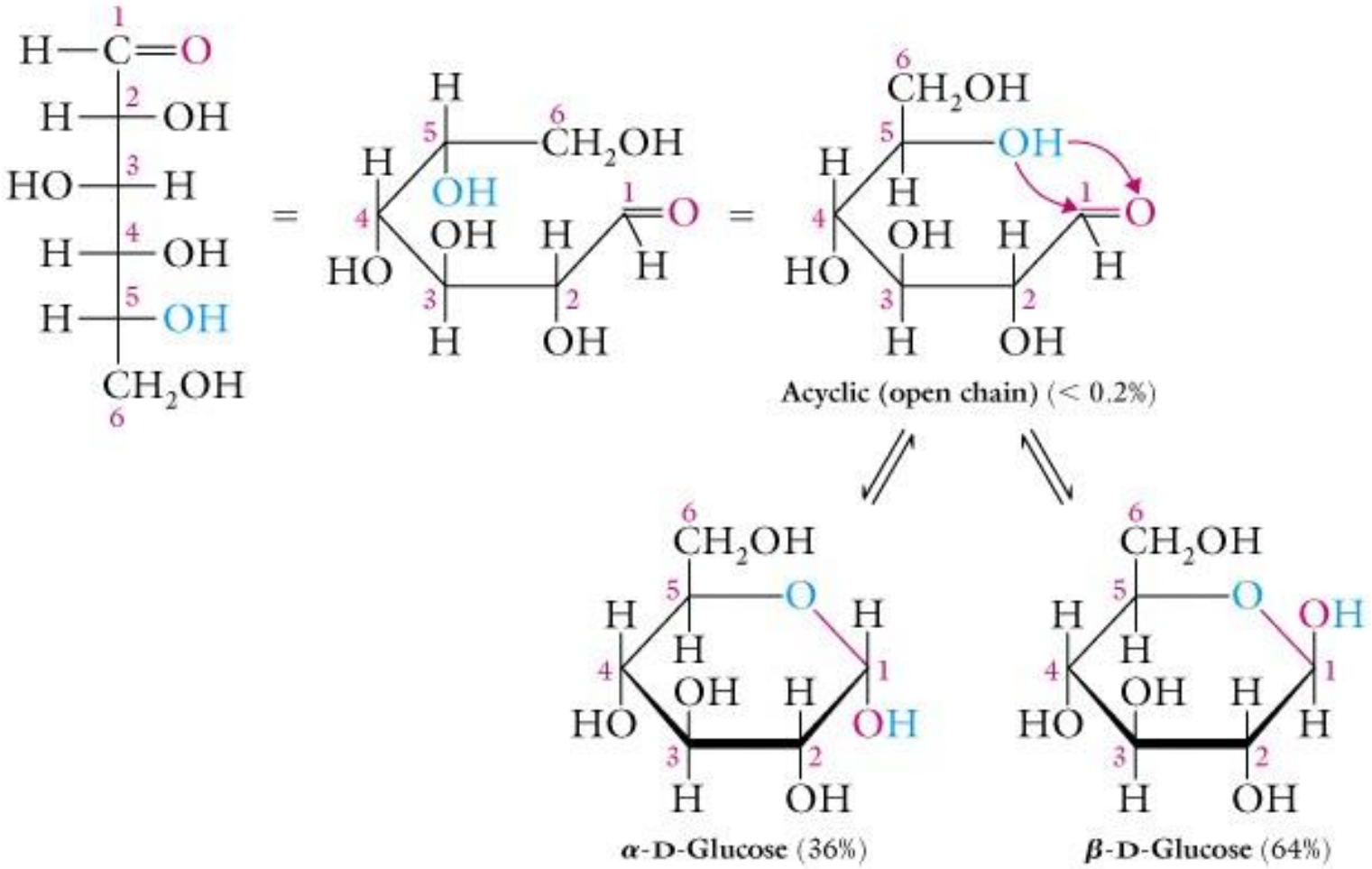
Detailed examples

Write Haworth formulas of each of the following carbohydrates:

i-D-ribose



ii- Glucose



Monosaccharides of Biological Importance

Glucose

a) Major source of energy for humans and animals tissues.

(Some cells and tissues e.g. brain and erythrocytes depend mainly on glucose because they cannot oxidize alternative fuels.)

b) The body maintains a fairly constant blood glucose level of 70–140 mg/dl at all times.

c) Most ingested carbohydrates are absorbed in the form of glucose.

d) Glucose can be converted into other sugars in the liver and other tissues

[e.g. galactose, fructose, ribose and glycogen.]

Galactose

a) It is synthesized in mammary gland to form the disaccharide lactose (sugar of milk)

b) Presents in tissues as a constituent of galactolipid and glycoproteins.

Fructose

a) It is present in semen and is a constituent of disaccharide sucrose

b) Seminal fluid is rich in fructose that is formed from glucose and sperms utilize fructose for energy.

Ribose

a) Ribose and deoxy-ribose form part of the structural backbone of nucleic acids RNA and DNA respectively.

b) Ribose enters in the structure of high-energy phosphate compounds (e.g. ATP) and also in the structure of coenzymes such as (e.g. NAD).