Unit-1

Ch-2 Biology Carbon as Backbone

WORK TO DO

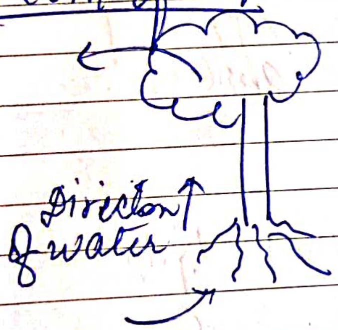
H = valence-1 H·
O valence-2 :O:
N valence-3 ·N·
C valence-4 ·C·

Properties of Water

Cohesion of water molecules → water not. tend to stay together and develops Surface Tension
Moderation of temperature → water properties change, After every 4° expand
Expansion on freezing →
The solvent of life

APPOINTMENTS 09 10 11 12 13 14 15 16 17 18

Ascent of SAP



PHONES

Moderate Temp by Water

Heat and temperature
Specific heat
Evaporative cooling

The liquid that is a completely homogenous mixture of two or more substances is called a Solution.
The dissolving agent of a solution is the solvent.
The substance that is dissolved is the Solute
In which water is solvent known as Aqueous solution.

15 SATURDAY
DAY (288-077)

October
WEEK-42

WORK TO DO

Hydrophilic and hydrophobic substances.

Any substance that has an affinity for water is said to be hydrophilic

Any substance that do not have an affinity for water is hydrophobic

Some substances can be hydrophilic without dissolving [colloids]

Ch-3

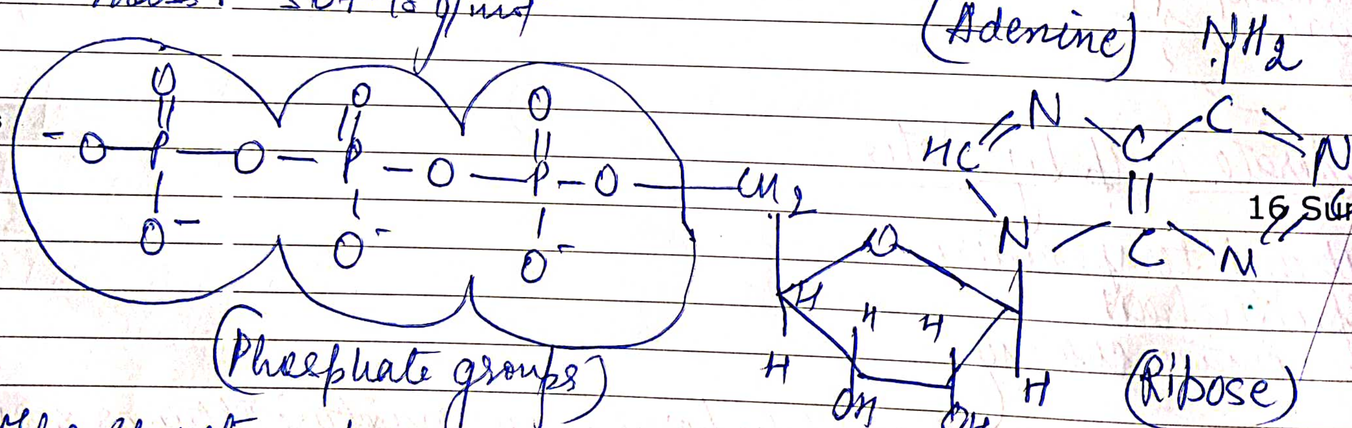
APPOINTMENTS

Adenosine Triphosphate (ATP)

Adenosine triphosphate is a nucleoside triphosphate used in cells as a 'coenzyme'. It is often called the 'molecular unit of currency' of intracellular energy transfer. ATP transports chemical energy within cells for metabolism.

Formula: $C_{10}H_{16}N_5O_{13}P_3$
mass: 507.18 g/mol

PHONES



(a) The structure of ATP. In the cell, most hydroxyl groups of phosphates are ionized

16 Sunday

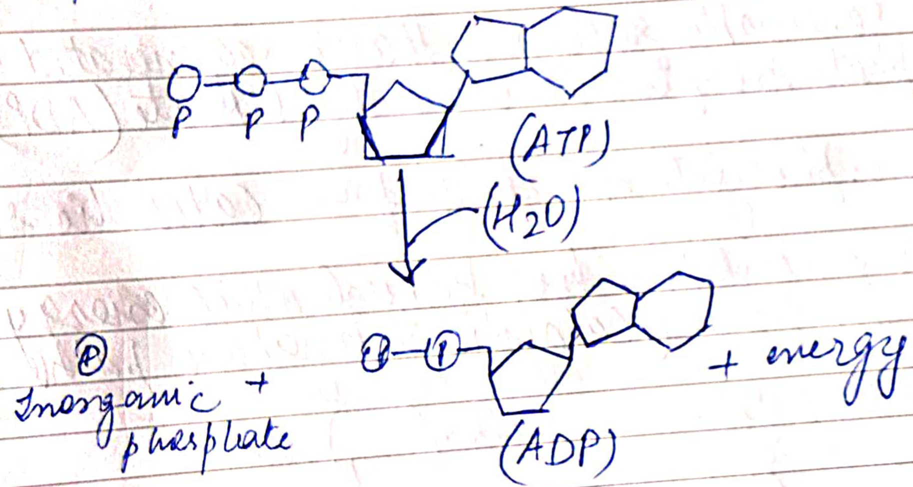
AUGUST							2011
Wk.	S	M	T	W	T	F	S
32		1	2	3	4	5	6
33	7	8	9	10	11	12	13
34	14	15	16	17	18	19	20
35	21	22	23	24	25	26	27
36	28	29	30	31			

SEPTEMBER							2011
Wk.	S	M	T	W	T	F	S
36					1	2	3
37	4	5	6	7	8	9	10
38	11	12	13	14	15	16	17
39	18	19	20	21	22	23	24
40	25	26	27	28	29	30	

When ATP breaks, energy is released, one phosphate bond breaks and ADP is formed.

Hydrolysis of ATP

- ATP drives endergonic reactions by phosphorylation, transferring a phosphate group to some other molecule, such as a reactant.
- The recipient molecule is now called a phosphorylated intermediate



How hydrolysis of ATP performs Work.

- The bonds between the phosphate groups of ATP's tail can be broken by hydrolysis.
- Energy is released from ATP when the terminal phosphate bond is broken.
- This release of energy comes from the chemical change to a state of lower free energy, not from the phosphate bonds themselves.

$$ATP + H_2O \rightarrow ADP + (P)_i$$

$$\Delta G = 7.3 \text{ kcal/mol}$$

WORK TO DO

- The three types of cellular work (mechanical, transport, and chemical) are powered by the hydrolysis of ATP.
- In the cell, the energy from the exergonic reaction of ATP hydrolysis can be used to drive an endergonic reaction.
- Overall, the coupled Reactions are exergonic

<u>The Regeneration of ATP</u>

APPOINTMENTS

- The ATP is a renewable resource that is regenerated by addition of a phosphate group to adenosine diphosphate (ADP)
- The energy to phosphorylate ADP comes from catabolic reactions in the cell.
- The ATP cycle is a revolving door through which energy passes during its transfer from catabolic to anabolic pathways.

$ATP + H_2O$

$ADP + Ⓟ$

LIPIDS, PHOSPHOLIPIDS.

[oils and fats]

(makes up the cell membrane)

PHONES

<u>Fats</u>

- Fats are large molecules assembled from smaller molecules
- A fat is constructed from two kinds of smaller molecules glycerol and fatty acids.
- Glycerol is an alcohol containg three carbons attached with a hydroxyl group.
- A fatty acid has a long carbon skeleton, usually 16 or 18 Carbon atoms in a length.
- The relativety non-polar C-H bonds in the hydrocarbon chains of fatty acids are the reasons fat are hydrophobic.

Phospholipids

WORK TO DO

- Phospholipids are essential for cells because they make up cell membranes.
- Phospholipid is similiar to a fat molecule but has only two fatty acids attached. The third hydroxyl group of glycerol is joined to a phosphate group, which has a negative electrical charge in the cell.
- Additional small molecules, which are usually charged or polar can be linked to the phosphate group to form a variety of phospholipids.

APPOINTMENTS

09

- The two ends of phospholipids show different behaviour towards water.

11

12

13

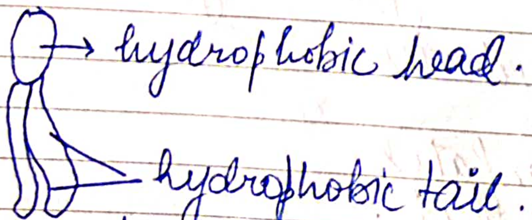
15

16

18

At the surface of a cell, phospholipids are arranged in a similiar bilayer. The hydrophobic ~~tails~~ heads of the molecules are on the outside of bilayer, in contact with the aqueous solution inside and outside the cell. The hydrophobic tails point towards the interior of the bilayer, away from water. The phospholipid bilayer forms a boundary between the cell and its external environment; in fact cells could not exist without phospholipids.

PHONES



In between layers there are proteins.

Cholesterol within the animal cell membrane. Cholesterol reduces membrane fluidity at moderate temperature by reducing phospholipid movement, but at low temperatures it hinders solidification by disrupting the regular packing of phospholipids.

WORK TO DO

Biological Molecules

→ Our food is mainly made up of these macromolecules
→ when we digest food, we break them into smaller molecules, utilize them for energy production and building of required types of molecules.

→ A bacterium, plant and human are different because of their structure and functionality --- but are made of same building blocks!

APPOINTMENTS

→ Macromolecules are polymers of the similar or identical small molecules linked by covalent bonds.

→ Small molecules that serve as the building blocks of polymer are smaller molecules called monomers.
→ Monomers are connected by a dehydration reaction to form a polymer.
→ Polymers are disassembled to monomers by hydrolysis.

BIOLOGICAL MOLECULES

- They are building blocks of life

PHONES

- Life is made of mainly four types of blocks

(1) Carbohydrates
(2) Proteins
(3) Lipids or fats &
(4) Nucleic Acid.

These blocks join in different combinations to produce different structures which can carry out different functions.

WORK TO DO

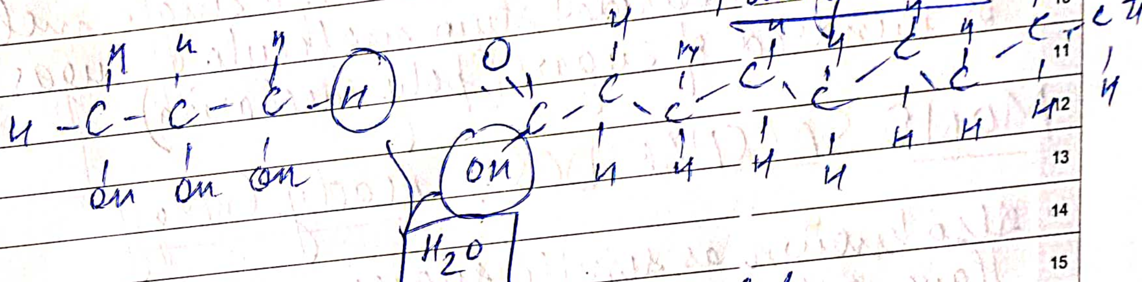
FATS

- Fats are large molecules assembled from smaller molecules
- A fat is constructed from two kinds of smaller molecules glycerol and fatty acids.
- Glycerol is an alcohol containing three carbons attached with a hydroxyl group.
- A fatty acid has a long Carbon skeleton, usually 16 or 18 Carbon atoms in length.
- The relatively non-polar C-H bonds in the hydrocarbon chains of fatty acids are the reason fats are hydrophobic.

APPOINTMENTS

09 10 11 12 13 14 15 16 17 18

Glycerol



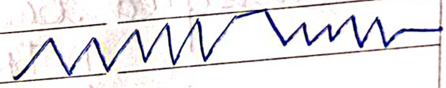
(1) Saturated Fat

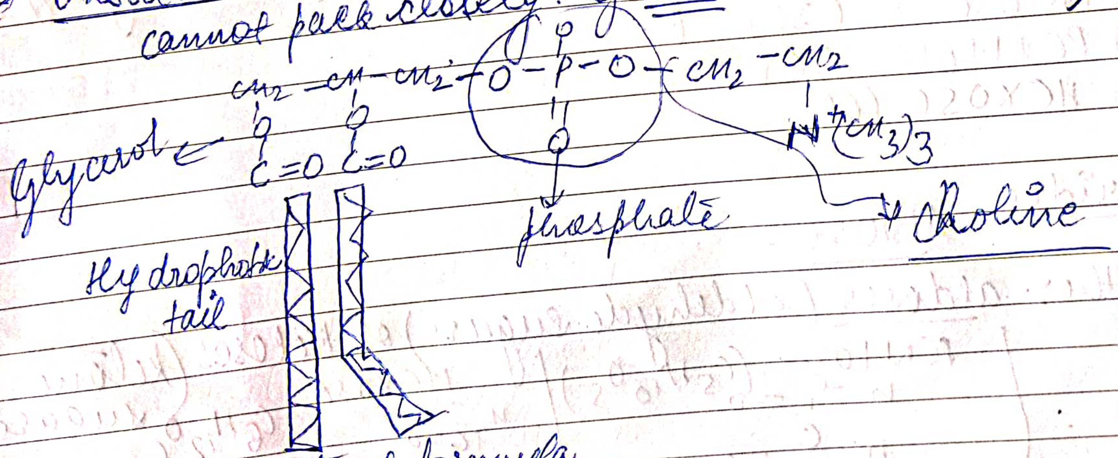
In room temp, fat are packed closely packed forming a solid. eg- butter

(2) Unsaturated Fat

cannot pack closely. Eg- oil due to kinks

PHONES





(a) Structural formula

... broken down and converted into chemical energy (ATP) ... respiration

WORK TO DO

Carbohydrates

- Almost universally used as an immediate energy source in livings things.
- Also pay as structural element in many organisms
- The majority of carbohydrates have a C:H:O ratio of 1:2:1 - eg - glucose $C_6H_{12}O_6$

APPOINTMENTS

- Carbohydrates may be made of a single molecule of sugar (mono-saccharide), two molecule of sugar (di-saccharide) or hundred of sugars (poly saccharide)

MONO SACCHARIDES - Ready Energy

- Also known as simple sugars
- Have only a single sugar molecules
- molecular formula of simple sugar : CH_2O
- Every carbon atom is bond to an -H and an -OH (carbonyl group)
- Sugars can have a Carbon backbone of three to seven carbons

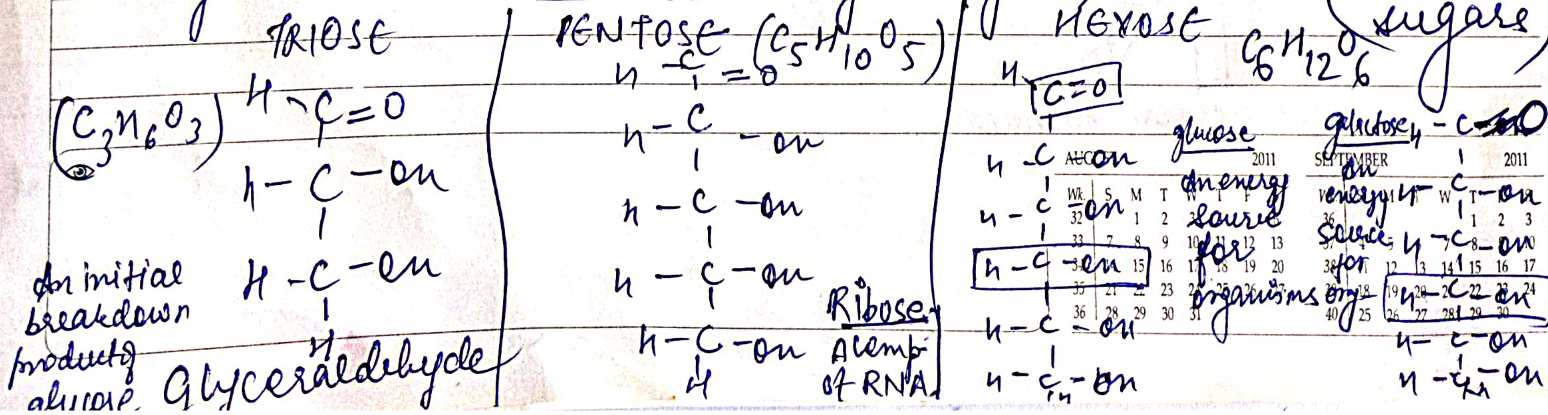
PHONES

- Classified based on number of C
  (1) TRIOSE (3C)
  (2) PENTOSE (5C)
  (3) HEXOSE (6C)

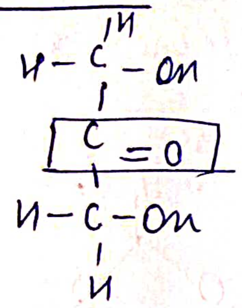
23 Sunday

Mono-saccharides ALDOSES

- They can be either aldoses (aldehyde sugars) or Ketoses (ketone sugars)

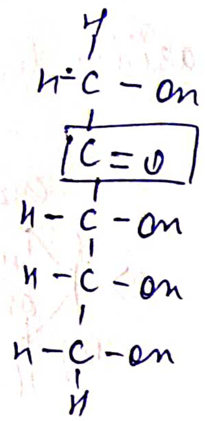


KETOSES



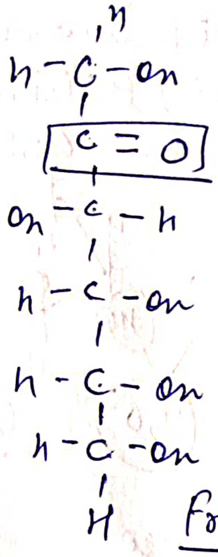
Dihydroxyacetone

An initial breakdown product of glucose



Ribulose

An intermediate in photosynthesis

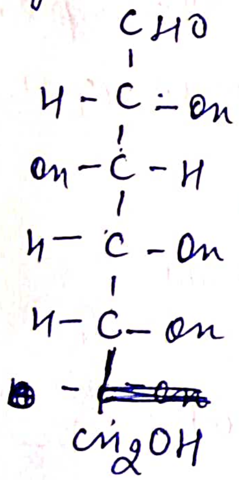


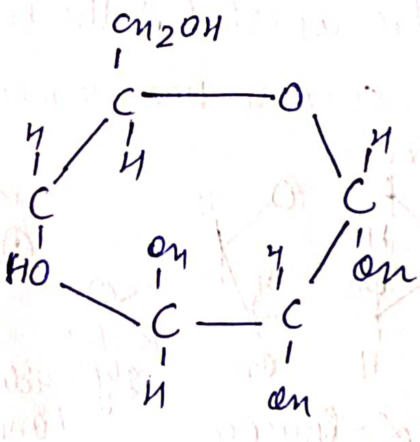
Fructose

An energy source for organisms.

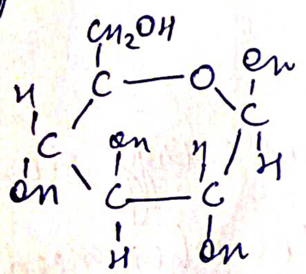
Glucose [$C_6H_{12}O_6$]

- Glucose with 6 carbons atom is a hexose sugar
- It can exist in a linear (straight chain), but normally form ring in water.

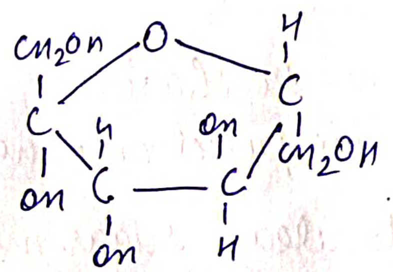




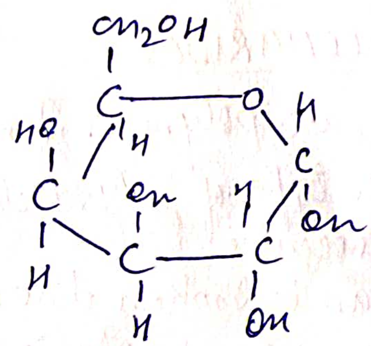
- Glucose has several isomers



glucose



Fructose

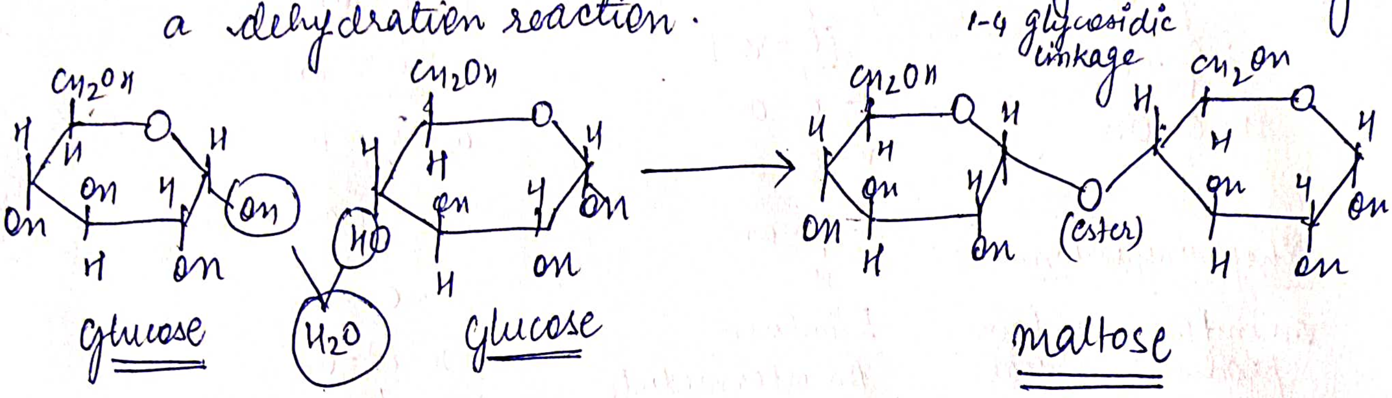


Galactose

- Glucose is critical to biological function
- It is the major source of cellular fuel for all living things.
- It is transported in the blood of animals.
- Glucose is broken down and converted into chemical energy (ATP) during respiration

Di-saccharides

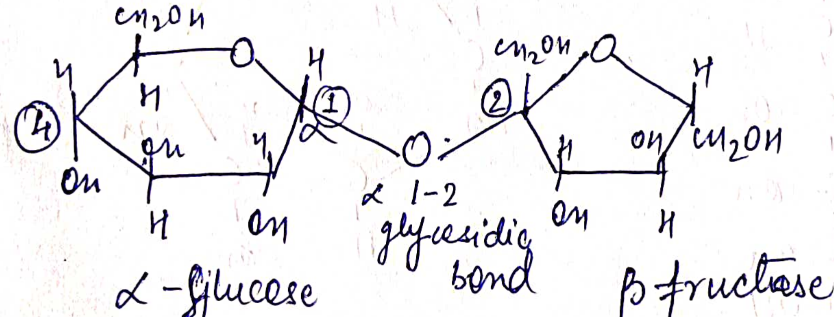
- contains two mono-saccharides that have joined during a dehydration reaction.



- Glucose + Glucose → Maltose (used in brewing)
- Glucose + fructose → Sucrose (house hold sugar)
- Glucose + galactose → Lactose (milk sugar)

- Sucrose is another disaccharide is the sugar we use at home to sweeten our food.
- Sugars are transported in the form of sucrose in plants.

SUCROSE HAS THE MOLECULAR FORMULA $C_{12}H_{22}O_{11}$



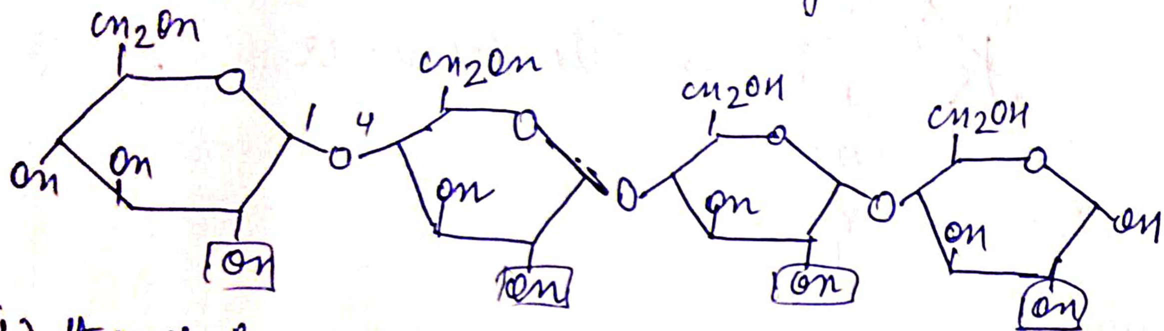
[SUCROSE]

POLYSACCHARIDES

- They are polymers of mono-saccharides
- Some type of polysaccharides function as short term energy storage molecules.
- It can be broken down to release sugar molecules when needed
- They are not soluble in water and are much larger than a simple sugar.
- They cannot easily pass through plasma membrane.
- They also act as structural molecules.

Polysaccharides - Starch

- Plants store glucose as starch
- The cells of a potato contains starch granules.

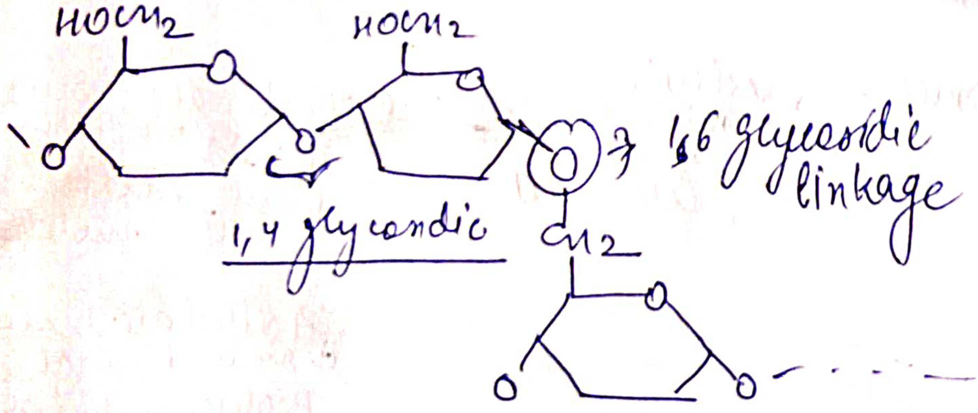


(b) Starch : 1-4 linkage of α glucose monomers. All monomers are in the same orientation. Compare the positions of the -OH groups highlighted in yellow with those in cellulose (C)

Polysaccharides - Glycogen

- Animals store glycogen in liver
- The storage and release of glucose from liver cells is controlled by hormones (insulin)

GLYCOGEN

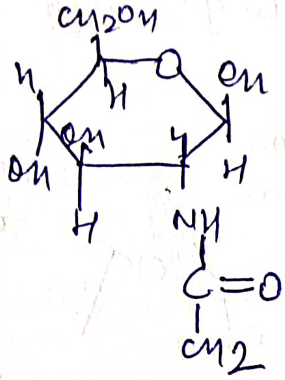


STARCH - There are two types of molecules

Linear → Amylose →

Branched → Amylopectin →

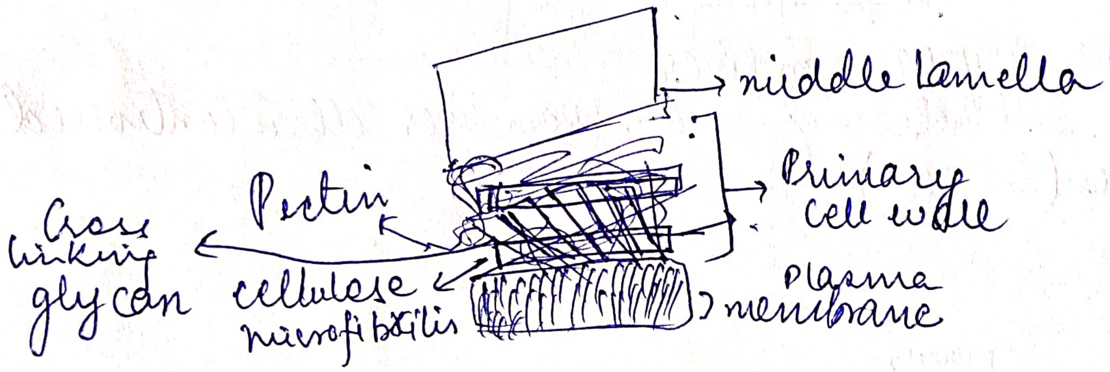
Chitin is found in fungal cell walls and in the exoskeletons of crabs and related animals, such as lobsters, scorpions and insects.

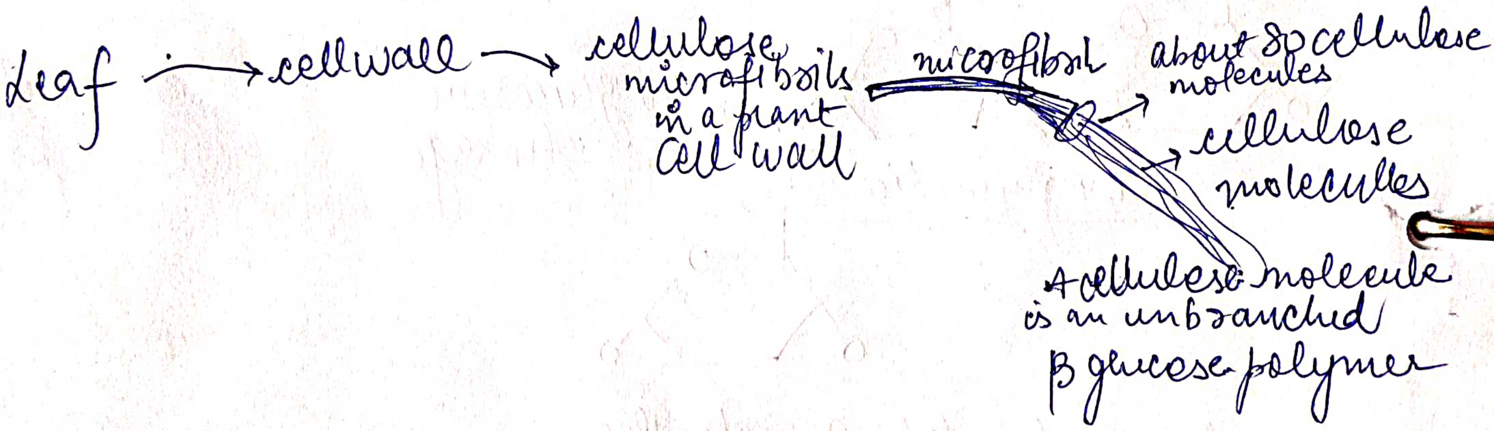


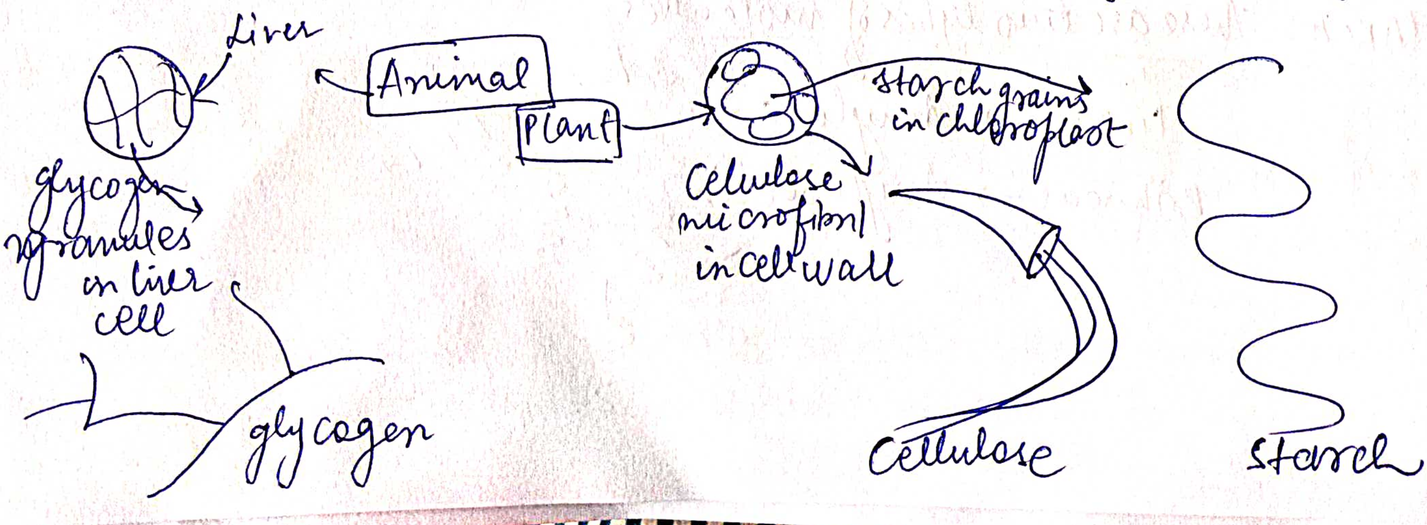
→ chitin Monomer

Cellulose

- is the most abundant carbohydrate
- microorganisms, but not animals are able to digest the bond between glucose in cellulose.







PROTEINS

- Proteins are of primary importance to the structure and function of cells.
- Consists nearly 50% of the dry weight of most cells
- Following are their many functions in animals;

Metabolism : enzyme proteins speed up biochemical reactions in cell. Highly specific and functions at physiological conditions.

Functions of Proteins

Support : Proteins has structural function
For exe - collagen : gives strength to ligaments, skin.
keratin : makes up hair and nails.

Transport : Channel and Carrier proteins in plasma membrane regulate what substances enter and exit the cell.

Defense : antibodies are proteins of our immune system that neutralize foreign substances called antigens.

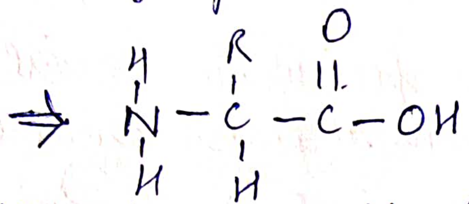
Regulation : Some hormones are proteins that regulates how cells behave. They serve as intracellular messengers that influence cell metabolism.

motion : The contractile proteins actin and myosin allow parts of cell to move and cause muscle to contract.

(1) Light produced by fireflies is a result of reaction involving the protein luciferin and ATP, catalyzed by enzyme luciferase
(2) Erythrocytes contain large amounts of the oxygen transporting protein hemoglobin.
(3) The protein keratin, formed by all vertebrates is the chief structural component of hair, scales, horn, wool, nails, feather

Amino Acids : Protein monomers

- Amino Acids are building blocks of proteins.
- Amino acids have ;
  - NH_2 (amino group)
  - $COOH$ (an acid group) and
  - R group.

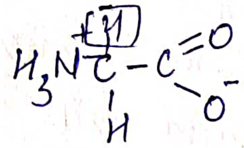


- Amino acids differ according to their particular R group.

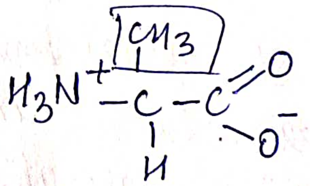
→ there are 20 diff kinds of amino acids based on type of R group.

Amino Acids : Types [NOT TO MEMORIZE]

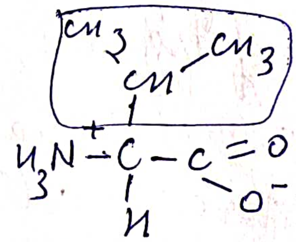
Non-polar



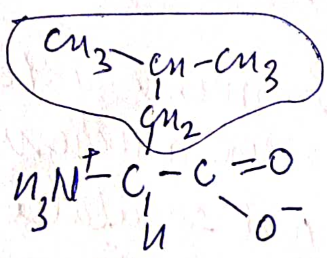
(glycine)



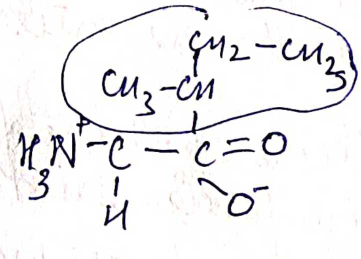
(Alanine)



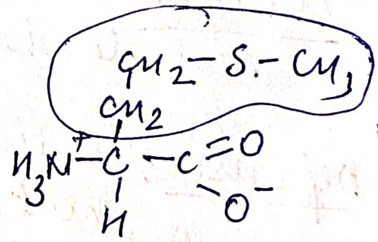
(valine)



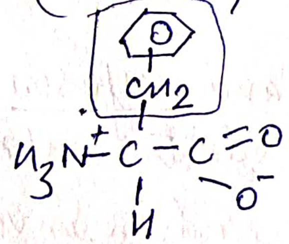
(Leucine)



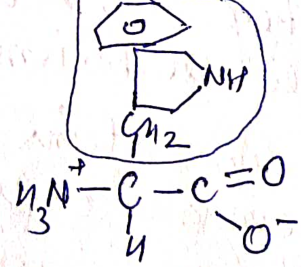
Isoleucine



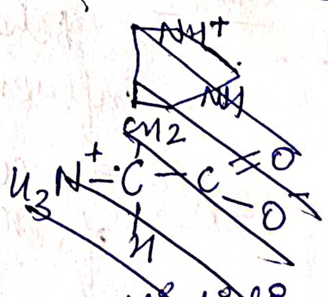
methionine



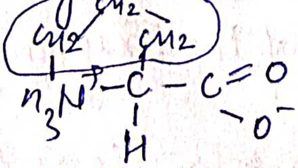
phenylalanine



Tryptophan



Histidine



Proline

Amino Acids differ by the 'R' group (white) attached to the central carbon.

Amino Acids :- Types

Polar, Electrically

Properties of Amino Acid

Dipolar ions (zwitter ions) → which contain both +, - charge COO^-, NH_3^+.

Amphoteric → Both Acidic & Basic

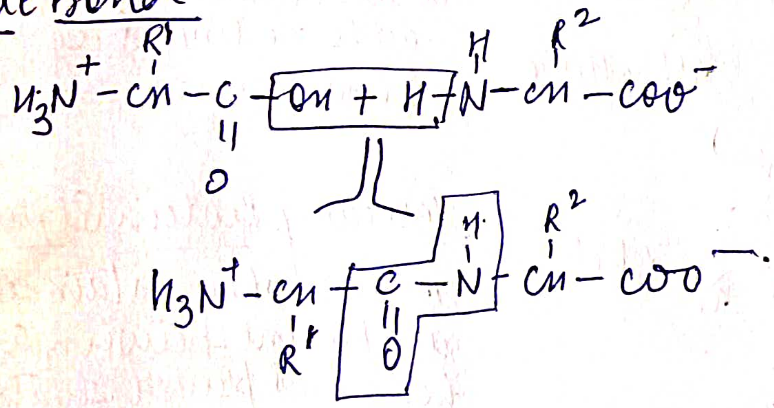
Isoelectric point

$$R-\underset{^{+}NH_3}{\overset{H}{\underset{|}{\overset{|}{C}}}}-COO^- \rightleftharpoons R-\underset{NH_2}{\overset{H}{\underset{|}{\overset{|}{C}}}}-COO^- + H^+$$

(Z.I)

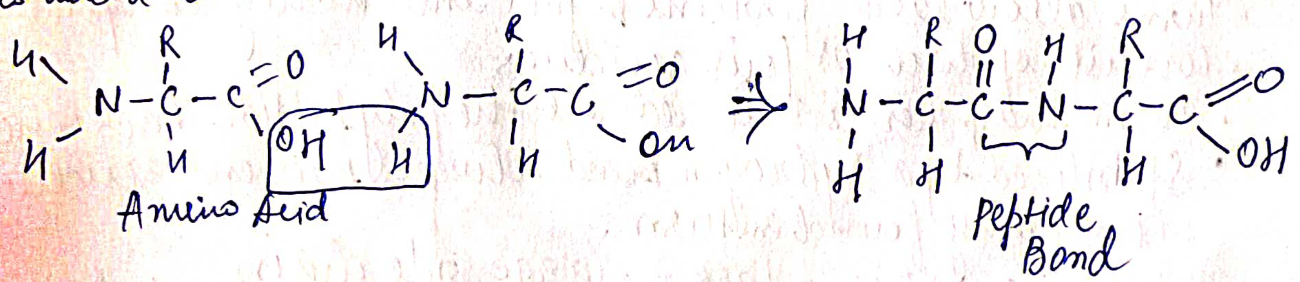
$$R-\underset{NH_3^+}{\overset{H}{\underset{|}{\overset{|}{C}}}}-COO^- + H^+ \rightleftharpoons R-\underset{^{+}NH_3}{\overset{H}{\underset{|}{\overset{|}{C}}}}-COOH.$$

Peptide Bond



Structure of Proteins

- Proteins are made up amino Acids that are linked by peptide bonds
- Following dehydration reaction, a peptide bond joins two amino acids and a water molecule is released.



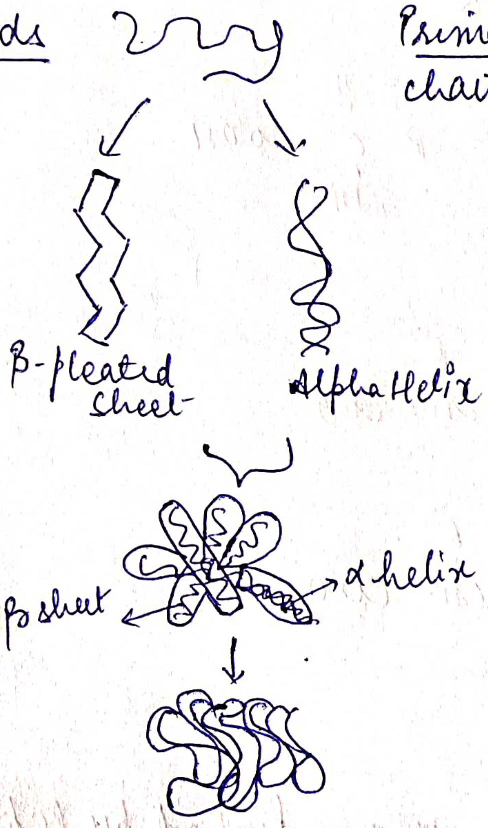
Structure of Proteins

- A peptide is two or more amino Acid bonded together
- A polypeptide is a chain of many amino Acid joined by peptide bonds.
- A protein is a polypeptide that has been folded into a particular shape and has function.
- Some proteins may consist of more than one polypeptide chain
- The sequence of amino acids greatly influences the three dimensional structure and function of proteins.

Shape of Protein

- The protein can have up to four levels of structure, termed Primary, Secondary, tertiary and quaternary

→ Amino Acids



Primary Protein is a sequence of a chain of amino Acid.

Secondary Protein

occurs when the sequence of amino acids are linked by hydrogen bonds.

Tertiary Protein Structure

Occurs when certain attractions are present between alpha helix and pleated sheets

Quaternary Protein Structure

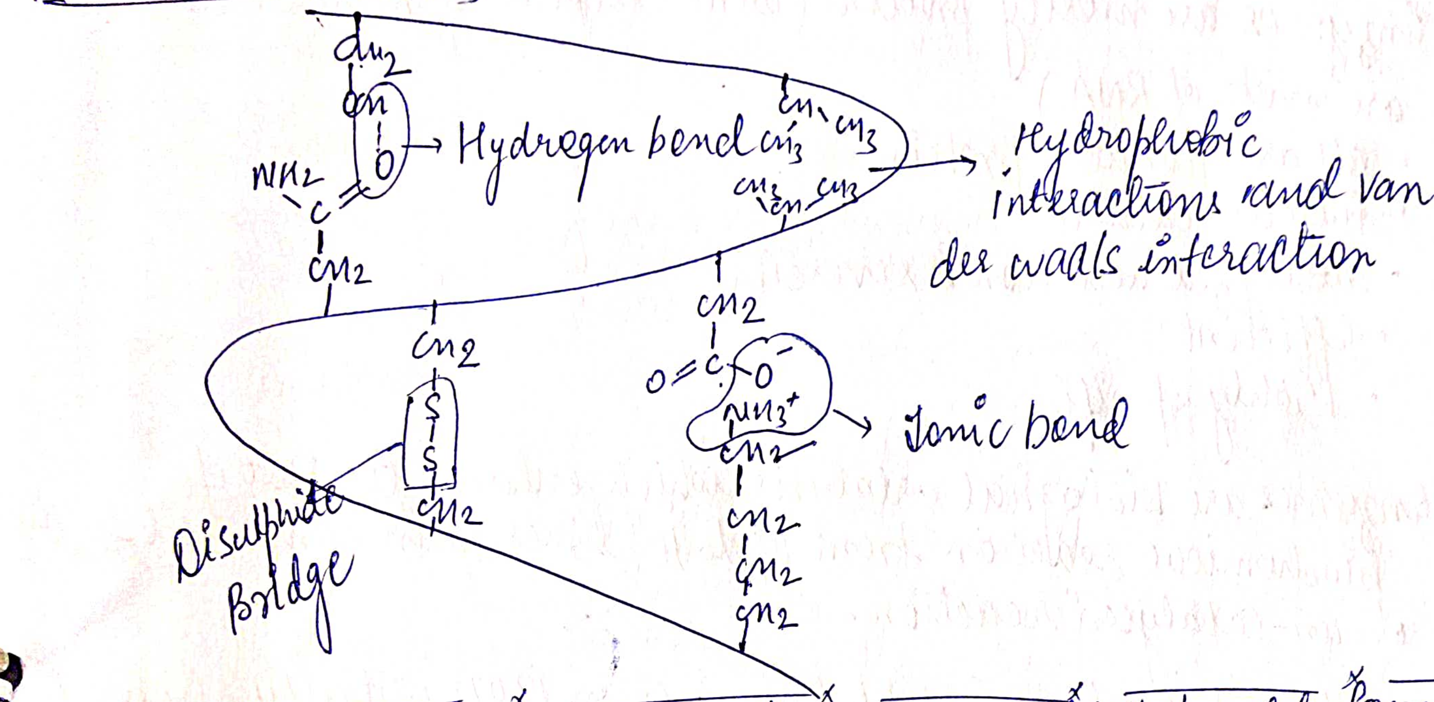
is protein consisting of more than one amino acid chain.

TURNS

- Turns allow large proteins to fold into highly compact
- Consists of three or four residues
- Form sharp bends that redirect the polypeptide backbone.
- Stabilized by a hydrogen bond between their end residues.
- Commonly found in turn.
- Glycine - due to lack of a large side chain
- Proline - due to the presence of a built in bend

Secondary Structure

$\boxed{\beta \text{ sheet - (Plane)}}$



- Amino Acids can be joined covalently through peptide bond to form peptides and proteins. Cells generally contain thousands of different proteins, each with a different biological activity.
- Proteins can be very long polypeptide chains of 100 to several thousand amino acid residues. However, some naturally occuring peptides have only a few amino acid residues. Some proteins are composed of several non-covalently associated polypeptide chains, called <u>Subunits</u>. Simple proteins yield only amino acid on hydrolysis, conjugated proteins contain in, addition some other component, such as metal or organic prosthetic group.
- The sequence of amino acids in a protein is characteristic of that protein and is called Primary Structure. This is one of four generally recognized levels of protein structure.

ENZYMES

A protein with catalytic properties due to its power of specific activation
Enzymes are mostly proteins (with exception of Ribosomes which are made of RNAs)

- All are globular protein
- They are Catalyst
- Catalyzed reaction is reversible
- Efficient
- Highly specific

- Enzymes are biological catalysts which enhance the rate of biochemical reaction from 10^6 to 10^{16} times when compared to those of un-catalysed reaction.

- Edward Buchner (Noble Prize in Chem 1907) initially showed that the fermentation can be done by yeast juice rather than yeast itself. The word 'enzyme' came from a Latin word 'zyma' means yeast and enzyme means something in yeast.

- James Sumner, an american chemist in 1926 for the first time isolated and crystallized Urease
- He also showed through chemical tests that enzyme are proteins.
- He was given noble prize in 1946.

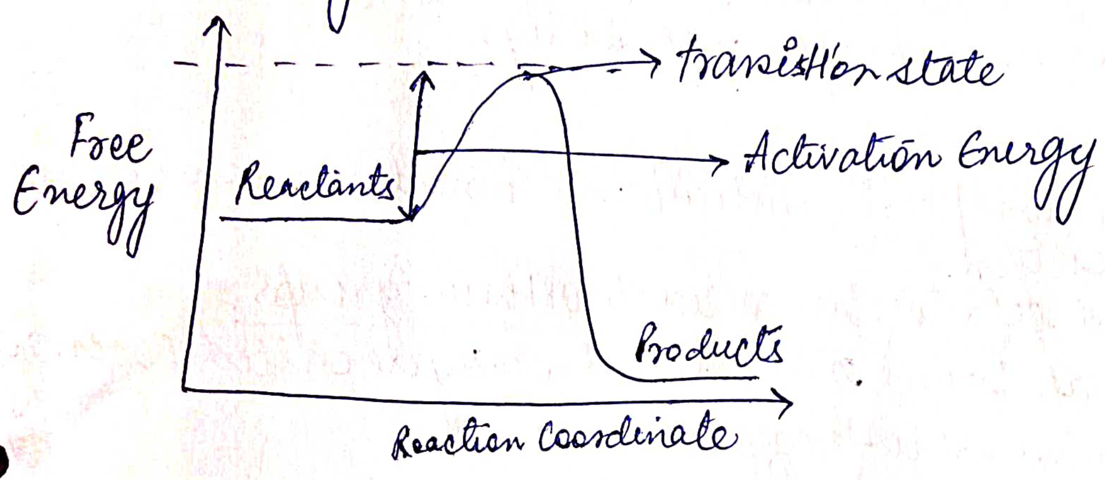
Speed: up to 10^6 times faster reaction rate.

Specificity: only the desired reaction occurs. Hence high quality products, fewer by products, & the purification process becomes much easier.

- Permit reaction under mild conditions.
- Enzyme Carries out its activity without being consumed in the reaction, Hence a minute amount of enzyme can act on large amount of substrate.
- Enzymes can be classified into different groups based on the chemical reactions that catalyzes. eg: Oxidoreductase, isomerase, hydrolase, transferase, lyases, ligases

- Chemical reactions need an initial input of energy = THE ACTIVATION ENERGY.
- During this part of the reaction the molecules are said to be in a transition state.

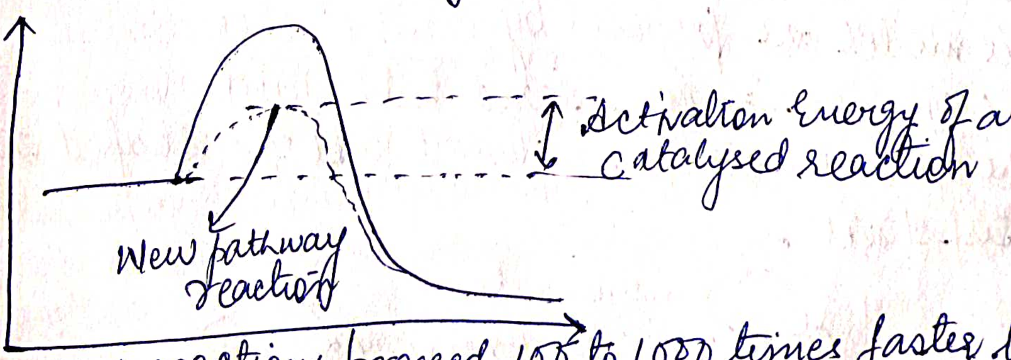
Reaction Pathway



Making Reactions go faster

- Increase the temperature make molecules move faster.
- Biological system are very sensitive to temperature changes.
- Enzymes can increase the rate of reactions without increasing the temperature.
- They do this by lowering the activation energy.
- They create a new reaction pathway known as 'Short Cut'

An Enzyme Controlled Pathway



Enzyme controlled reactions proceed 100 to 1000 times faster than corresponding non-enzymic Reactions

- Enzymes are proteins
- They have a globular shape
- A complex 3-D structure.

THE ACTIVE SITE

- one part of an enzyme, the active site, is particularly important.
- The shape and chemical environment inside the active site permits a chemical reaction to proceed more easily.

COFACTORS

- An additional non-protein molecule that is needed by some enzymes to help the reaction.
- Tightly bound cofactors are called prosthetic groups.
- Cofactors that are bound and released easily are called Co-enzymes.
- Many Vitamins are Co-enzymes.

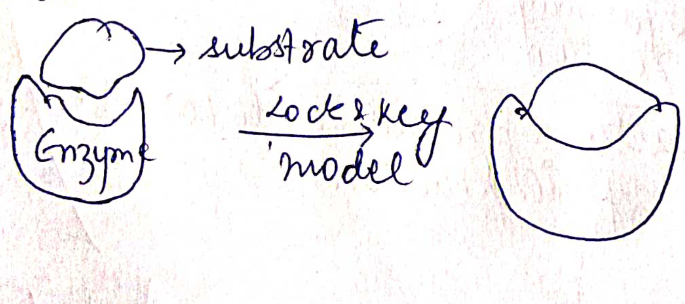
eg- Nitrogenase enzyme with Fe, Mo, ADP cofactors

CATALYTIC SITE OF ENZYME

- Usually the size of the enzyme is bigger than that of substrate.
- Enzyme binds to substrate at least in three different regions called as catalytic sites.
- Different models were proposed regarding how enzyme binds to substrate.

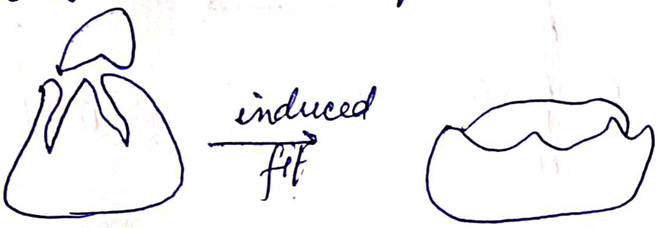
A. The LOCK & KEY or TEMPLATE model

- This model was proposed by Emil Fischer
- The enzyme is considered to be rigid.
- The catalytic site is presumed to be pre-shaped to fit the substrate.



B. The 'Induced Fit' Model

- This model was proposed by Koshland
- The enzyme is considered to be flexible
- The substrate ~~is~~ induces a conformational change in the enzyme



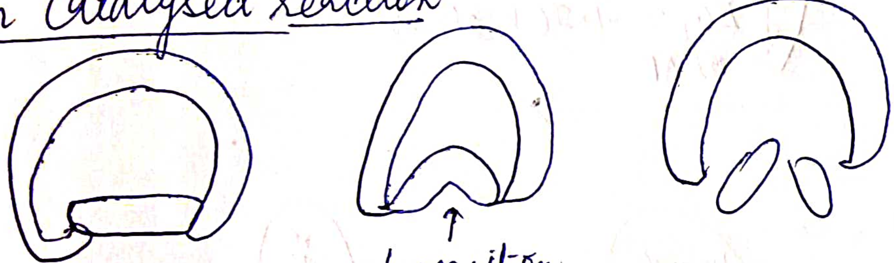
Substrate and enzyme distorted to transition state conformation

The enzymes will have substrate specificity and orientation specificity

(1) In Uncatalyzed reaction

substrate | Transition state | Product.

(2) In catalysed reaction



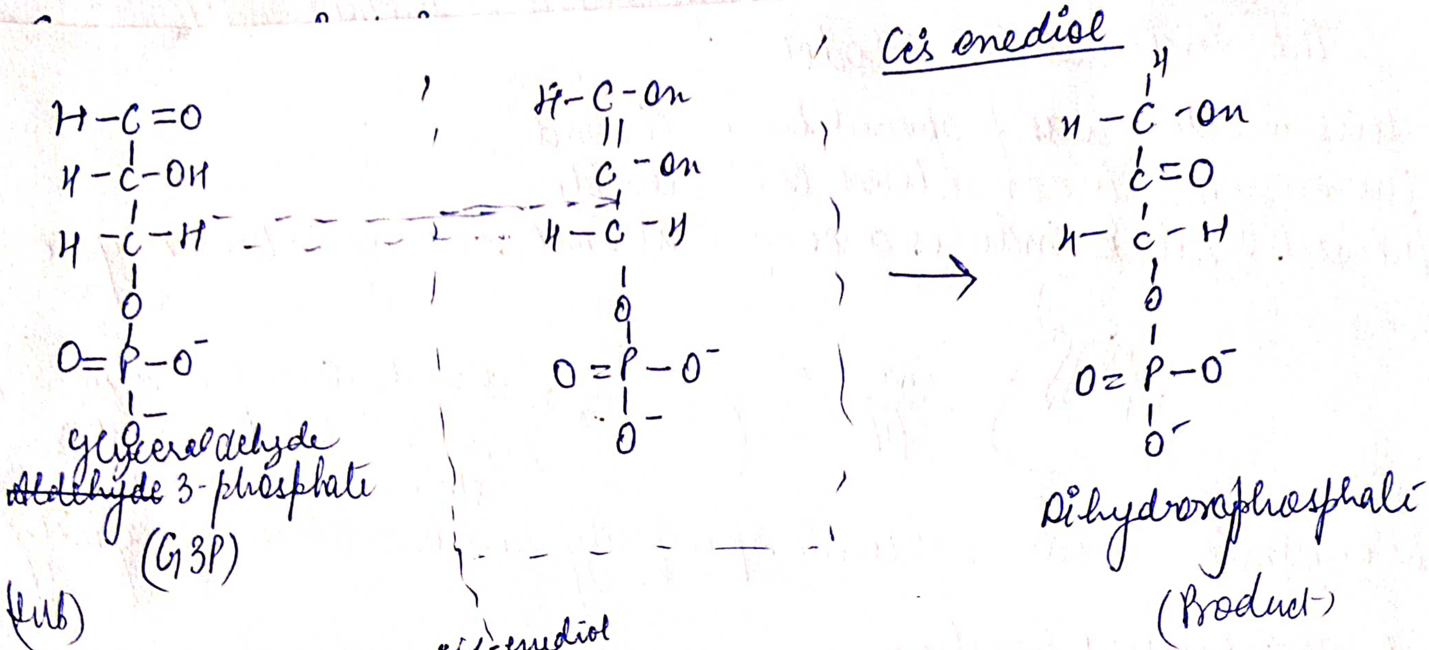
transition state

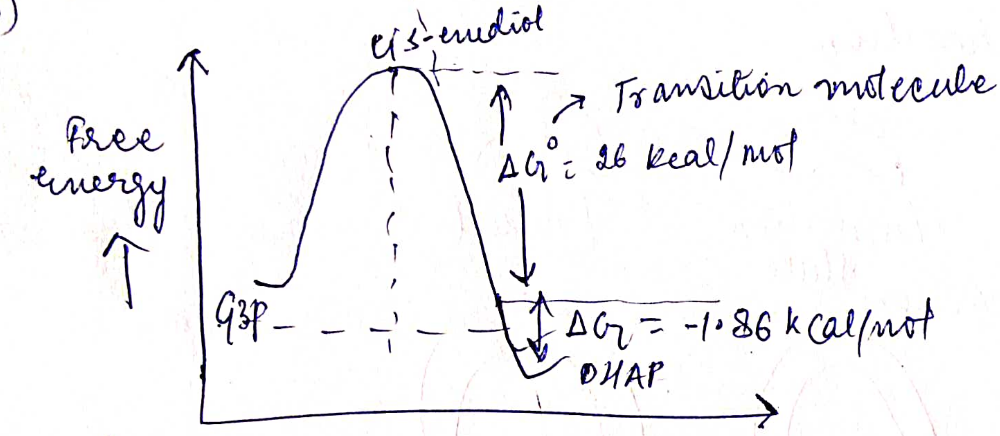
WHAT HAPPENS IN AN ENZYME CATALYSED REACTION

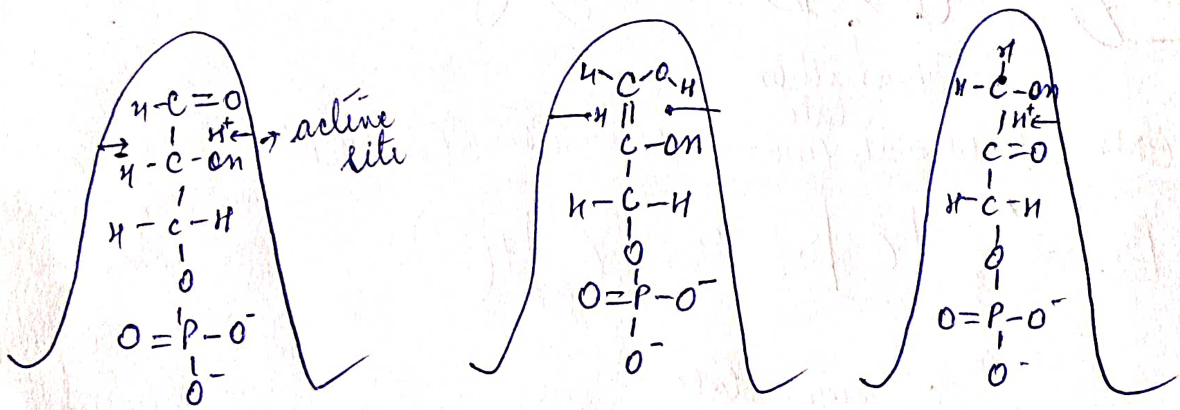
$$\boxed{E} + \boxed{S} \underset{k_3}{\overset{k_1}{\rightleftharpoons}} \boxed{E}\boxed{S} \xrightarrow{k_2} \boxed{E} + P$$

Transition state

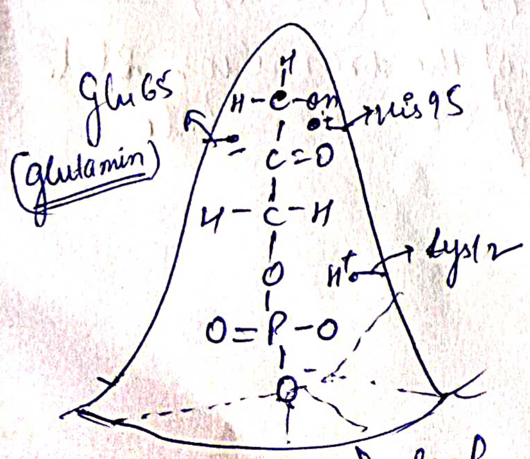
(1) [E] binds to [S] to form [ES] complex (rate k_1)
(2) [ES] can release substrate (rate K_3) or convert [S] to [P] (rate K_2)
(3) In steady state, the production and consumption of the transition state proceed at the same rate. So the concentration of transition state keeps a constant.
(4) At equilibrium [S] and [P] remains constant.


Cis enediol
Glyceraldehyde
~~Aldehyde~~ 3-phosphate
(G3P)
(Sub)
Dihydroxyphosphate
(Product)


Cis-enediol
Transition molecule
Free energy
$\Delta G^{\circ} = 26$ kcal/mol
G3P
$\Delta G = -1.86$ kcal/mol
DHAP


active site

Step 2


Glu 65
(glutamin)
His 95
Lys 12
loop

Factors Affecting enzyme action

1. Concentration of enzyme
2. Substrate concentration
3. Temperature
4. pH
5. Effect of product concentration
6. Effect of activators
7. Effect of light and radiation

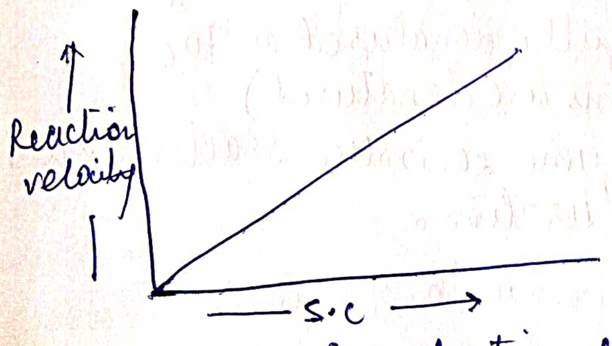
1) Concentration of Enzyme

* As the concentration of enzyme increases the rate of enzyme catalysed reaction increases proportionally.

2) The Substrate of an enzyme are the reactants that are activated by the enzyme.

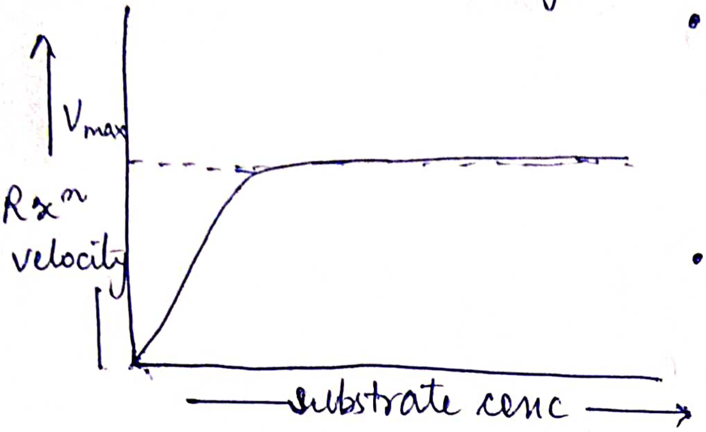
- Enzymes are specific to their substrates.
- The specificity is determined by the active site.

Substrate Concentration : Non enzymic reactions



- The increase in velocity is proportional to the substrate concentration

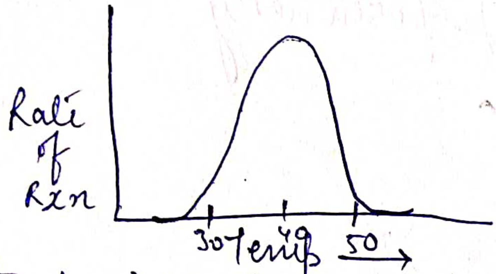
Substrate concentration : Enzymic Reactions



- Faster reaction but it reaches a saturation point when all the enzyme molecules are occupied.
- If you alter the conc of the enzyme then V_{max} will change too

3) Temperature

- Enzyme functions slowly at sub freezing temperatures
- optimal activity between 30-40°C
- Denatures above 45°C



- Increase in temp will lead to an increase in reaction rate, but it also can lead to denaturation of enzyme
- usually the rate of reaction will double for every 10°C rise in temp, thus speeding up the process.
- For most enzymes the optimum temp is about 30°C
- many are a lot lower, cold water fish will die at 30°C because their enzymes denature.
- A few bacteria have enzymes that can withstand very high temperatures up to 100°C.
- Most enzymes however are fully denatured at 70°C (at high temp proteins are denatured)
- The optimum temp for an enzyme controlled reaction will be a balance between the Q10 and denaturation.

4) pH (negative log concentration of H^+ ion)

- extremes generally inactivates enzyme
- pH optimum
- Maximum activity of most enzymes between pH 4.5 to 8.0.
- Narrow pH range

- exceptions
  - Pepsin – optimum pH is 1.8
  - Trypsin – optimum pH is 9.8
- extreme pH levels will produce denaturation
- The structure of the enzyme is changed.
- The active site is distorted and the substrate molecules will no longer fit in it.
- At pH values slightly different from the enzyme's optimum value, small changes in the charges of the enzyme and its substrate molecules will occur.
- This change in ionisation will affect the binding of the substrate with active site.

Inhibitors

- Inhibitors are chemical that reduce the rate of enzymic reactions
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- They are usually specific and they work at low concentrations.
- They block the enzyme but they do not usually destroy it.
- Many drugs and poisons are inhibitors of enzymes in the nervous system.

The effect of enzyme inhibition

- Irreversible inhibitors: Combine with the functional groups of the amino acids the the active site, irreversibly.
- Reversible inhibitors: These can be washed out of the solution of enzyme by dialysis.

There are two categories

(1) Competetive: These compete with the substrate molecules for the active site.
The inhibitor's actions is proportional to its concentration.
Resembles the substrate's structure closely.

$$E + I \rightleftharpoons EI$$

Reversible Rxn — enzyme inhibitor complex.

2. Non Competetive : These are not influenced by the concentration of the substrate. It inhibits by binding irreversibly to the enzyme but not at the active site.

Eg - Cyanide combines with the iron in the enzyme cytochrome oxidase.

- Heavy metals Ag or Hg, combine with -SH groups.

These can be removed by using a chelating agent such as EDTA.

Factors/ Effect of Product Concentration

- The accumulation of products generally decreases the enzyme velocity.
- For certain enzymes, the product combine with the site of enzyme and form a loose complex, and thus inhibit enzyme activity. (Feed back mechanism)

6) Effect of Activators

Some of the enzymes require certain inorganic metallic cations like Mg^{2+}, Mn^{2+}, Zn^{2+}, Ca^{2+}, Co^{2+}, Cu^{2+}, Na^{2+}, K^{+} etc. for optimum activity.

* metal activated enzymes: Enzyme is tightly held by the enzyme
  Eg ; ATPase (Mg^{2+} and Ca^{2+})
* metalloenzymes : Enzymes hold the metals tightly. Eg ; alcohol dehydrogenase, carbon anhydrase.

7) Effect of light and radiation.

exposure of enzymes to ultraviolet, gamma / x rays may inactivate certain enzymes due to formation of peroxides

ENZYME KINETICS

- Chemical Nature of the catalysis carried out-
  - Oxidation / Reduction/ Hydrolysis/ Isomerisation.
- Nature of enzyme - substrate reaction
  - Type of substrate involved.
  - Type of product formed.

Industry break up based on applications

Food and feed → 17%
Leather and paper → 8%
Pharmaceuticals → 41%
Textile processing → 17%
Detergent manufacturing → 17%

Biologically active enzymes are extracted from any living organisms.

* selection of source of enzymes influences.
  - Type of extraction and purification process.
  - stability of enzyme and cost of enzymes.

Enzyme	Plant Source	Industrial Use
Actinidin	Kiwi fruit	Food
a-Amylase	Malted barley	Brewing
b-Amylase	malted barley	Brewing
Bromelain	Pinapple latex	Brewing and Therapeutic
Lipoxygenase	Soy beans, citrus fruits	Food
Papain	Paw paw latex	Meat

Enzyme	Animal source	Industrial Use
Catalase	liver	Food
chymotrypsin	Pancreas	Leather
Lipase	Pancreas	Food
Rennet	Stomach	cheese
Trypsin	Pancreas	Leather

Enzyme	Bacterial Source	Industrial Use
a-amylase	Bacillus	Brewing
b-amylase	Bacillus	Brewing
Asparaginase	E. coli	Health
Glucose isomerase	Bacillus	Fructose syrup
Protease	Bacillus	Detergent