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 mol. 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
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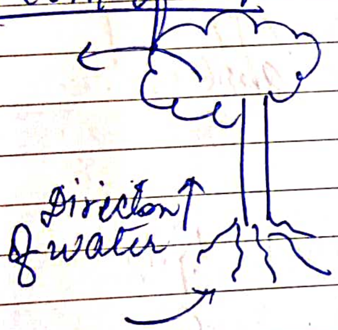
Ascent of SAP



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.

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]

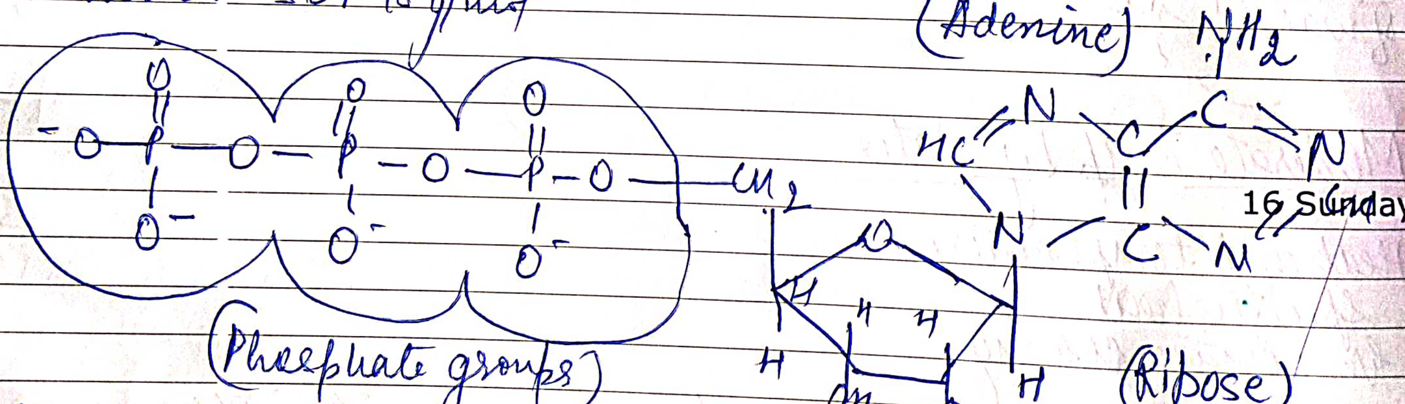
Ch-3

APPOINTMENTS

Adenosine Triphosphate (ATP)

09
10 Adenosine triphosphate is a nucleoside triphosphate used in
11 cells as a 'coenzyme'. It is often called the molecular unit of
12 currency of intracellular energy transfer. ATP
13 transports chemical energy within cells for metabolism.
14
15 Formula: $C_{10}H_{16}N_5O_{13}P_3$
16 mass: 507.18 g/mol
17
18

PHONES



16 Sunday

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

AUGUST							2011
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32		1	2	3	4	5	6
33	7	8	9	10	11	12	13
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35	21	22	23	24	25	26	27
36	28	29	30	31			

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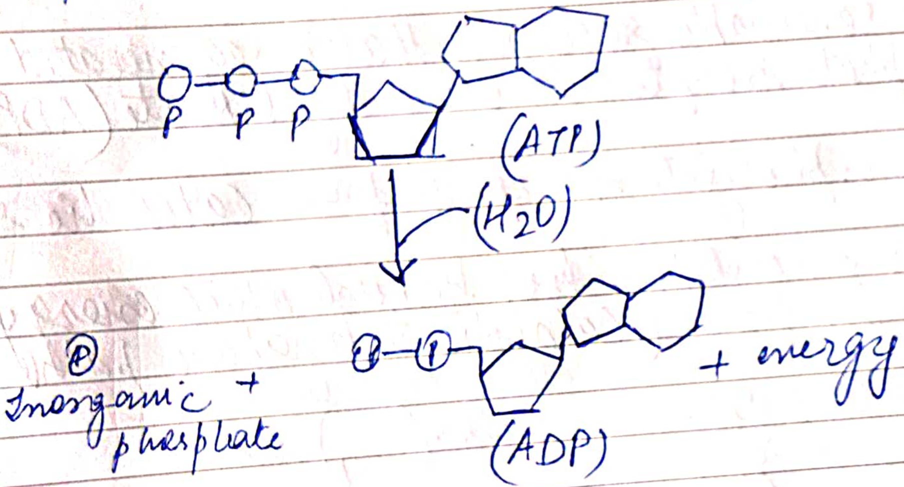
36					1	2	3
37	4	5	6	7	8	9	10
38	11	12	13	14	15	16	17
39	18	19	20	21	22	23	24
40	25	26	27	28	29	30	

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

The Regeneration of ATP

APPOINTMENTS

09 • The ATP is a renewable resource that is regenerated by addition of a phosphate group to adenosine diphosphate (ADP)

10

11 • The energy to phosphorylate ADP comes from catabolic reactions

12 in the cell.

13 • The ATP cycle is a revolving door through which energy passes

14 during its transfer from catabolic to anabolic pathways.

15

16 LIPIDS, PHOSPHOLIPIDS.

$ATP + H_2O$ → $ADP + P$

17

18 [oils and fats] (makes up the cell membrane)

PHONES

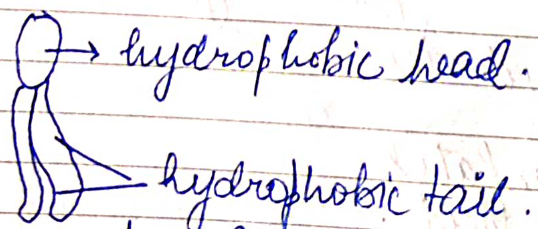
Fats

- 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 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

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

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 acqueous 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.



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.

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WORK TO DO

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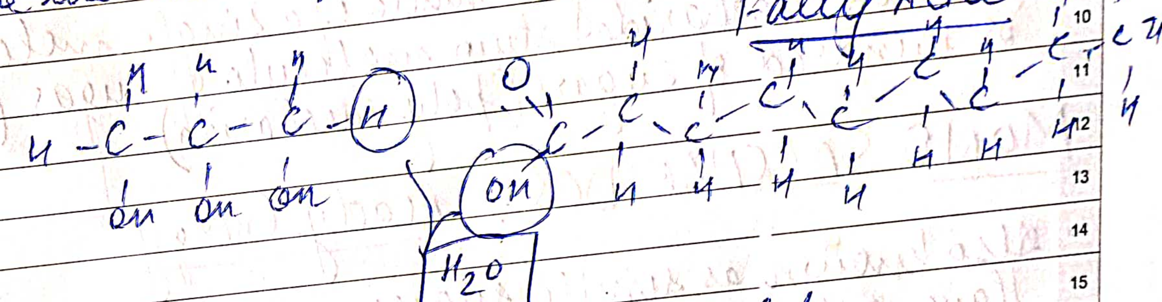
APPOINTMENTS

Glycerol

Fatty Acid



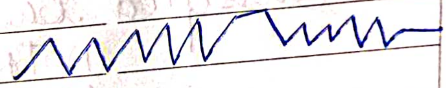
09 10 11 12 13 14 15 16 17 18

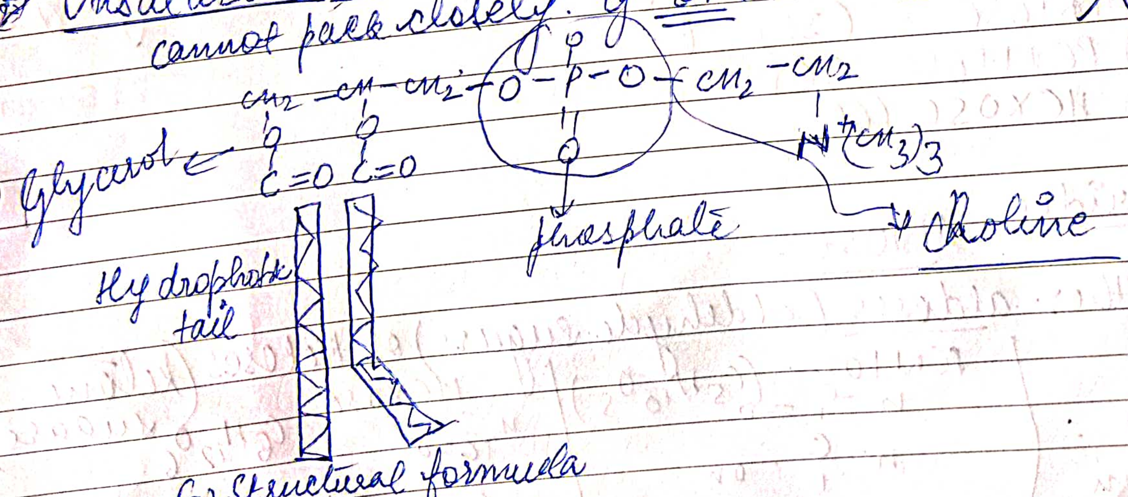
(1) Saturated Fat

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

⇒ 

PHONES

(2) Unsaturated Fat
cannot pack closely. Eg- oil due to kinks 



(a) Structural formula

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42	9	10	11	12	13	14	15
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44	23	24	25	26	27	28	29

NOVEMBER 2011							
Wk.	S	M	T	W	T	F	S
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46	6	7	8	9	10	11	12
47	13	14	15	16	17	18	19
48	20	21	22	23	24	25	26
49	27	28	29	30			

... 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

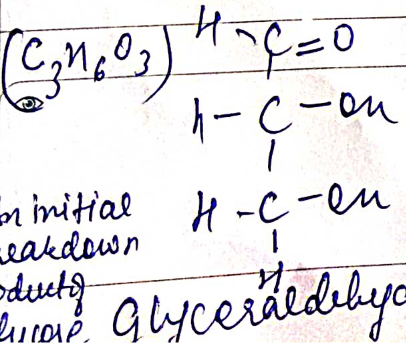
- Classified based on number of C
  (1) TRIOSE (3C)
  (2) PENTOSE (5C)
  (3) HEXOSE (6C)

23 Sunday

Mono-saccharides ALDOSES

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

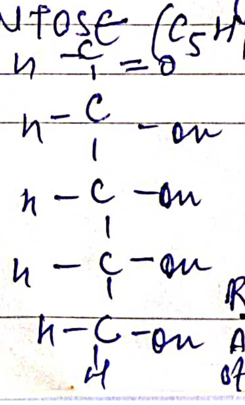
TRIOSE ($C_3H_6O_3$)



An initial breakdown products glucose

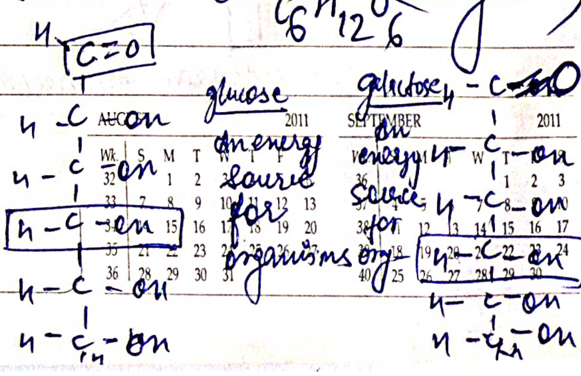
Glyceraldehyde

PENTOSE ($C_5H_{10}O_5$)



Ribose. A comp. of RNA

HEXOSE $C_6H_{12}O_6$

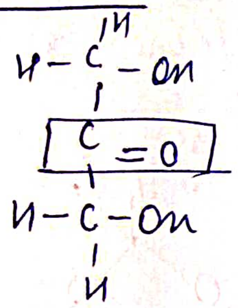


glucose an energy source for organisms

galactose an energy source for organisms

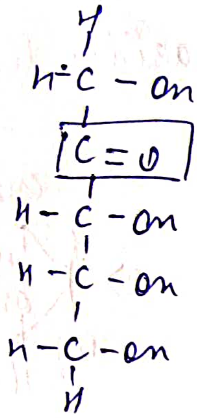
AUGUST 2011 SEPTEMBER 2011

KETOSES



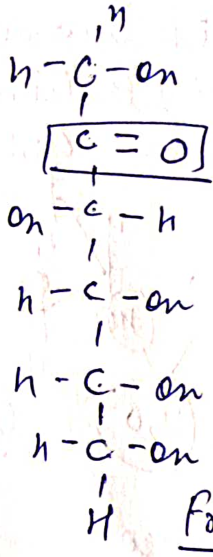
Dihydroxyacetone

An initial breakdown product of glucose



Ribulose

An intermediate in photosynthesis

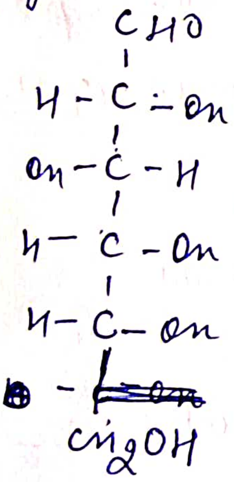


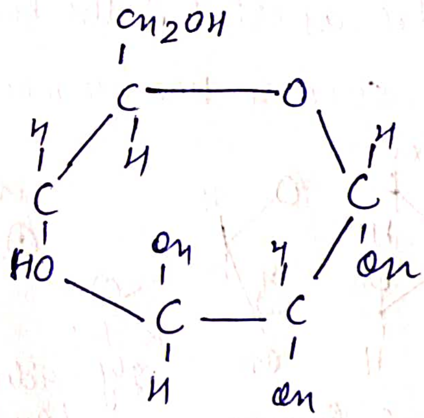
Fructose

An energy source for organisms.

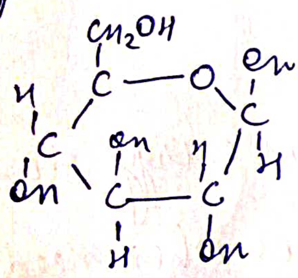
Glucose [$C_6H_{12}O_6$]

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

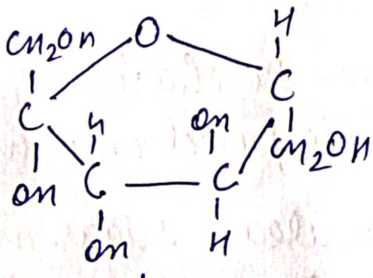




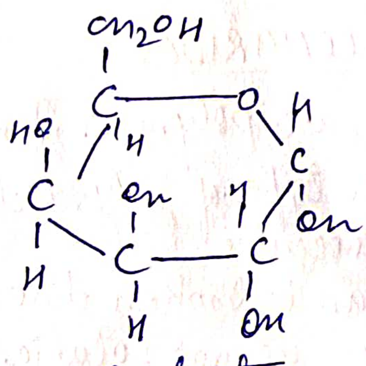
- Glucose has several isomers



glucose



Fructose

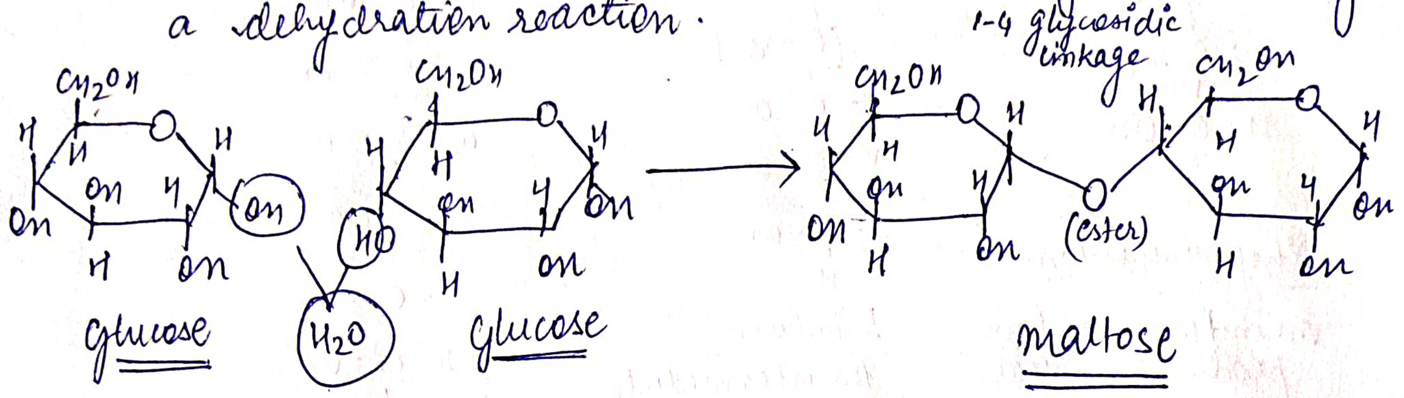


Galactose

- 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

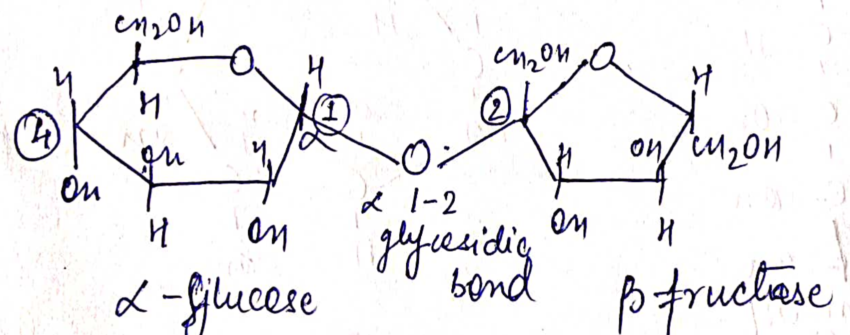
• contains two mono-saccharides that have joined during a dehydration reaction.



- 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 $C_{12}H_{22}O_{11}$



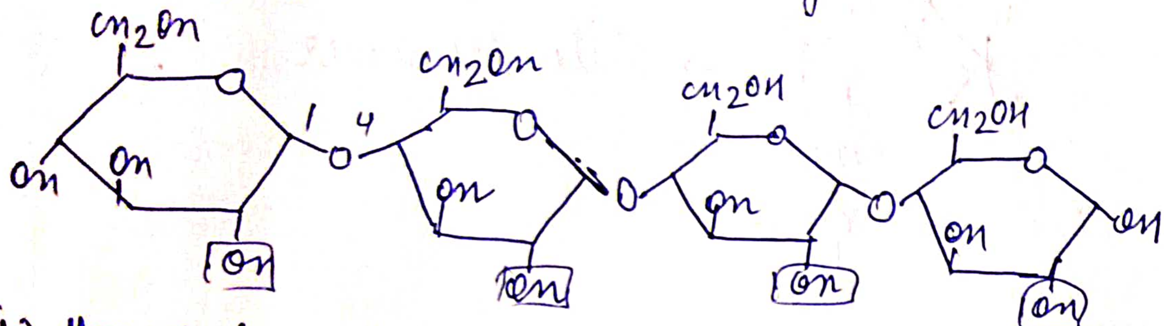
[SUCROSE]

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.

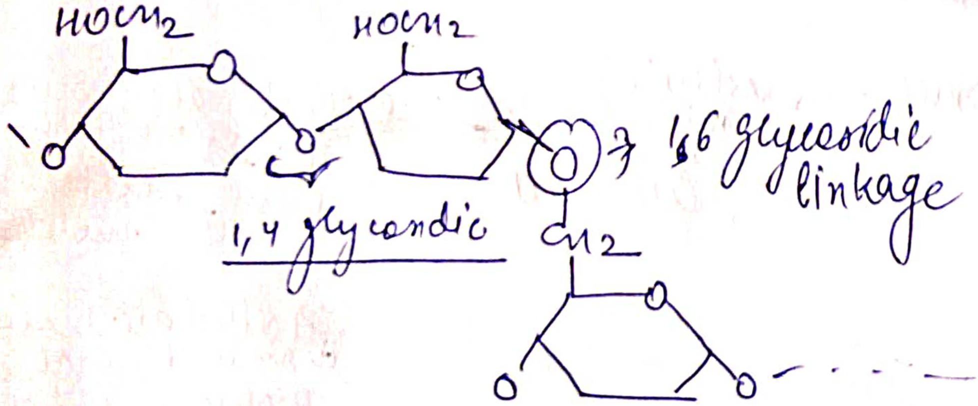


(b) Starch : 1-4 linkage of α glucose monomers. All monomers are in the same orientation. Compare the positions of the -OH groups highlighted in yellow with those in cellulose (C)

Polysaccharides - glycogen

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

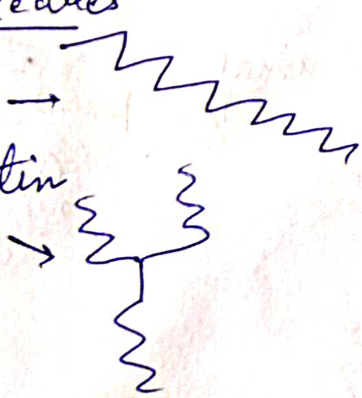
GLYCOGEN



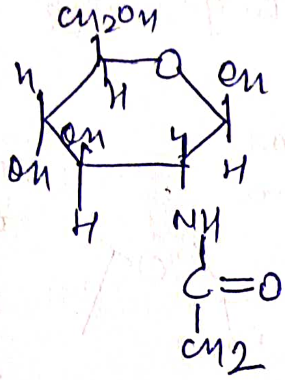
STARCH - There are two types of molecules

Linear → Amylose →

Branched → Amylopectin



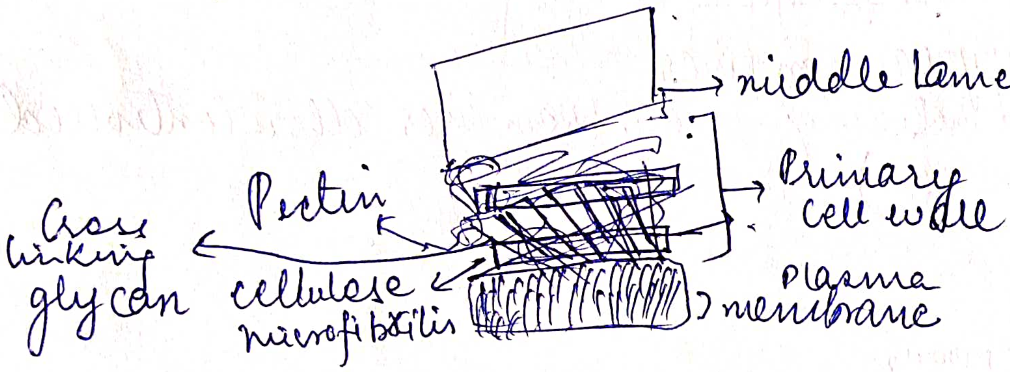
Chitin is found in fungal cell walls and in the exoskeletons of crabs and related animals, such as lobsters, scorpions and insects.

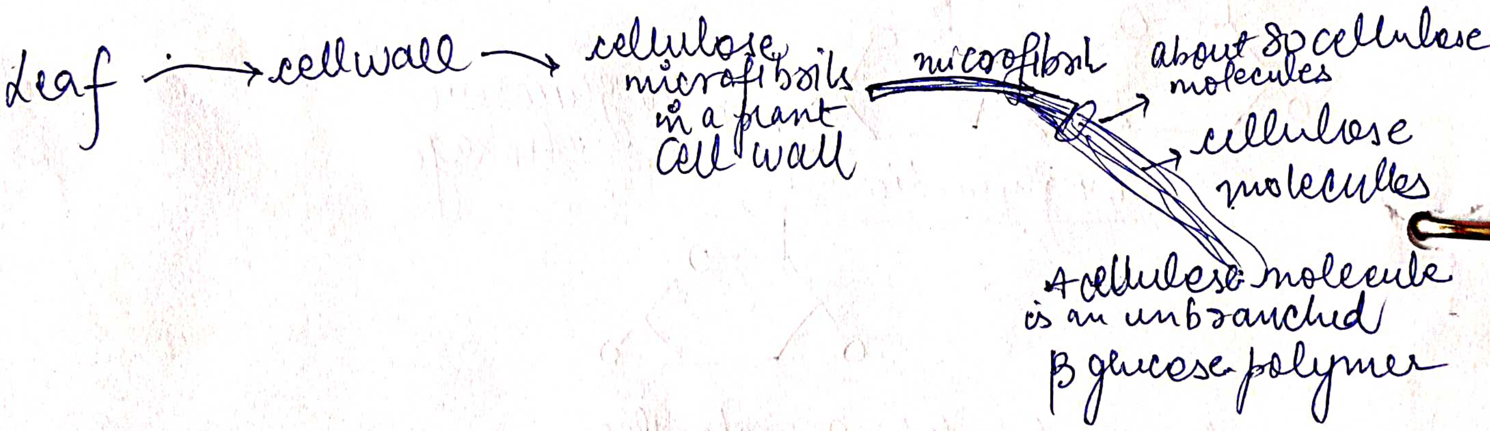


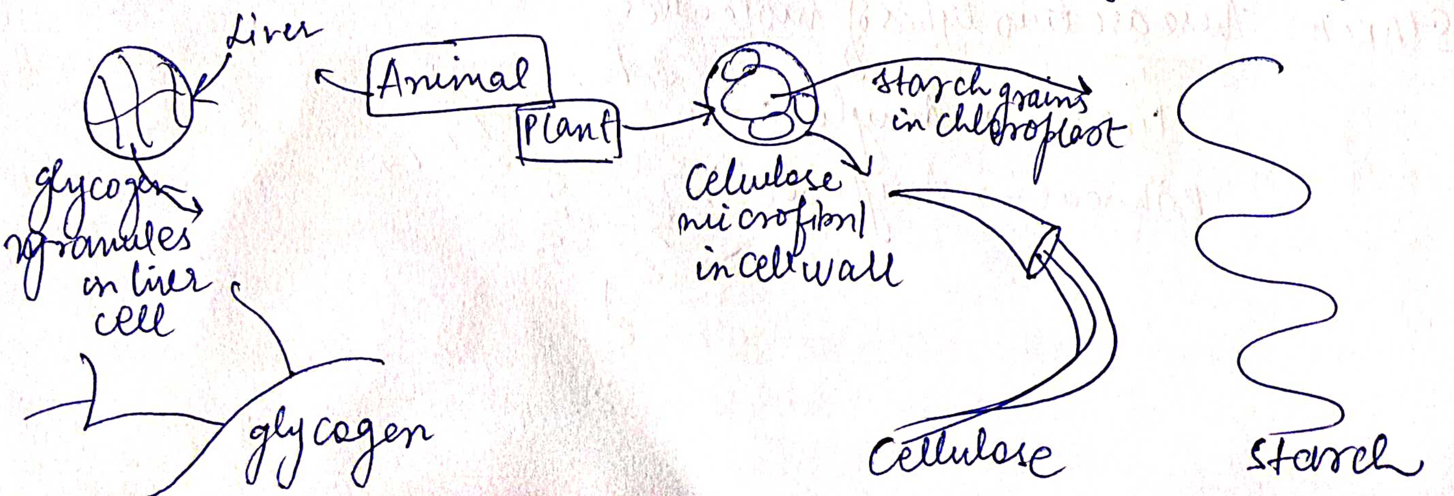
→ chitin Monomer

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 gives strength to ligaments, skin.
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.

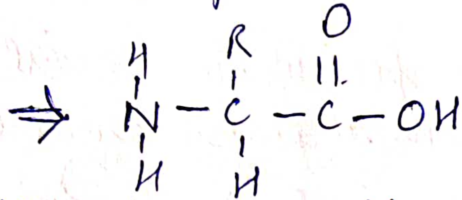
(1) Light produced by fireflies is a result of reaction involving the protein luciferin and ATP, catalyzed by enzyme luciferase

(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.

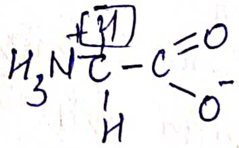


- Amino acids differ according to their particular R group.

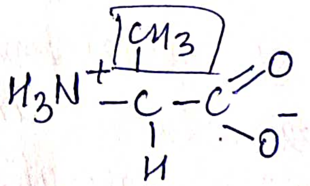
→ there are 20 diff kinds of amino acids based on type of R group.

Amino Acids : Types [NOT TO MEMORIZE]

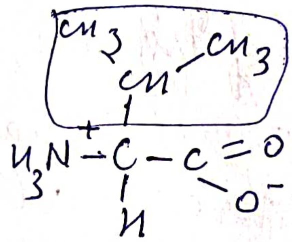
Non-polar



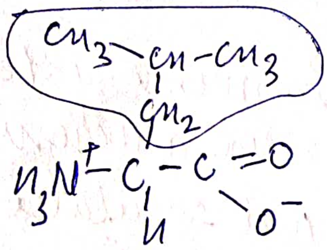
(glycine)



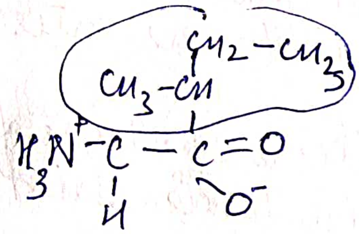
(Alanine)



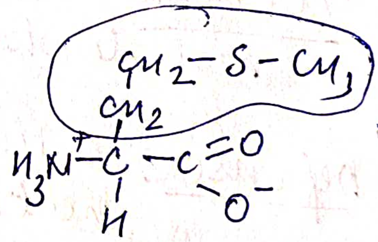
(valine)



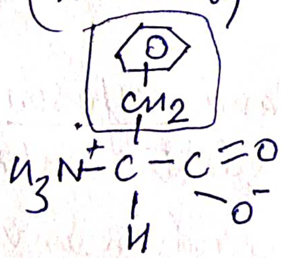
(Leucine)



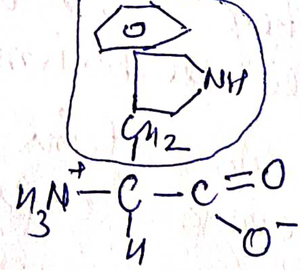
Isoleucine



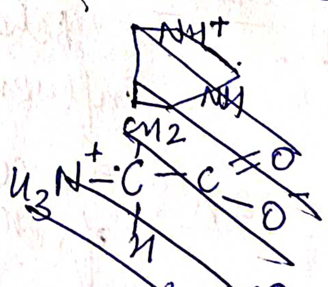
Methionine



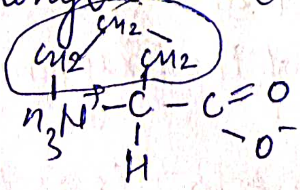
phenylalanine



Tryptophan



Histidine



Proline

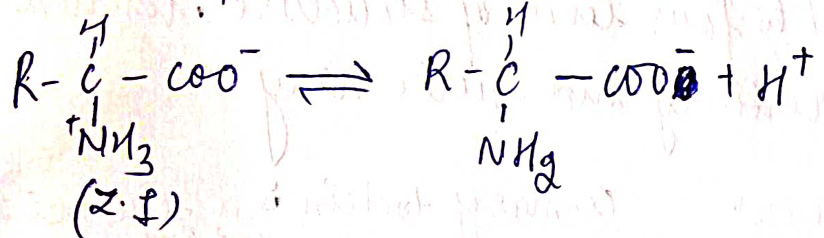
Amino Acids differ by the 'R' group (white) attached to the central carbon.

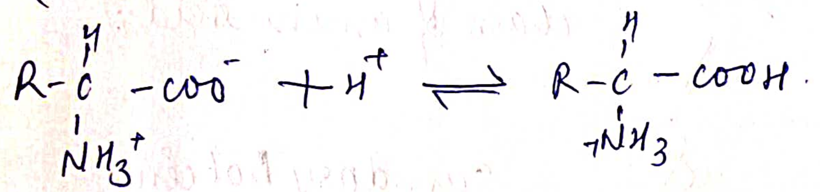
Amino Acids :- Types

Polar, Electrically

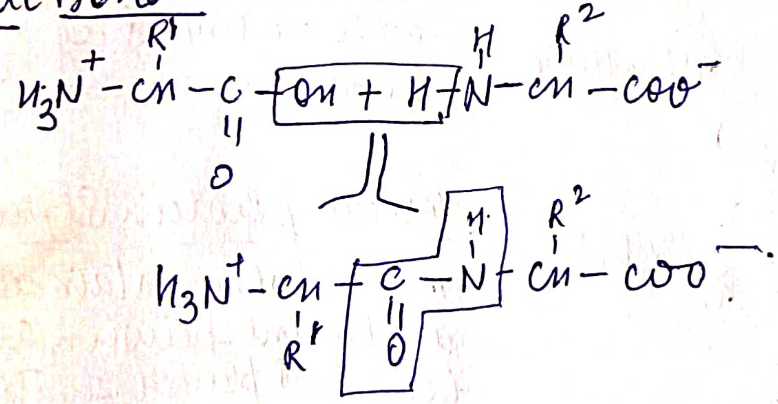
Properties of Amino Acid

Dipolar ions (Zwitter ions) → which contain both +, - charge COO^-, NH_3^+.
Amphoteric → Both Acidic & Basic
Isoelectric point



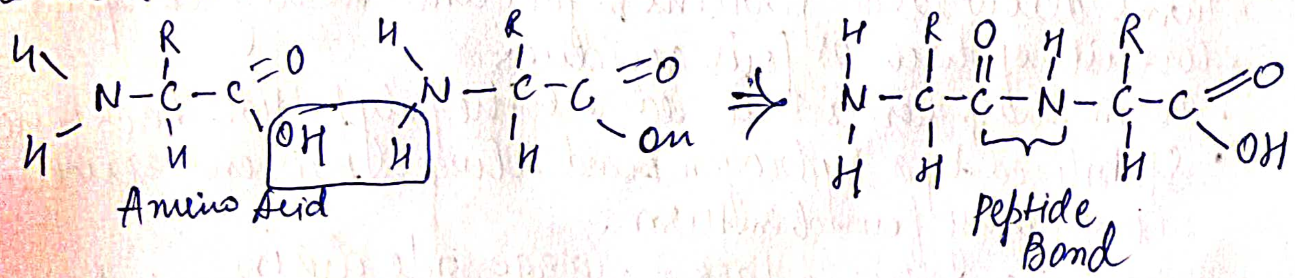


Peptide Bond



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.



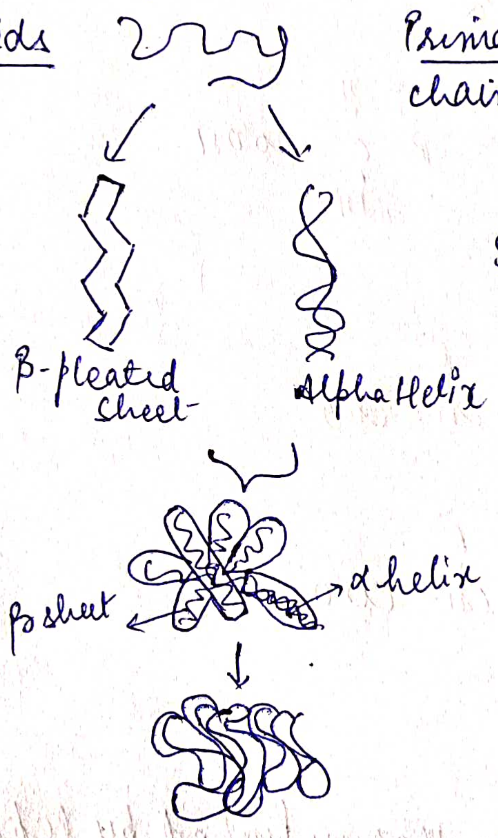
Structure of Proteins

- 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

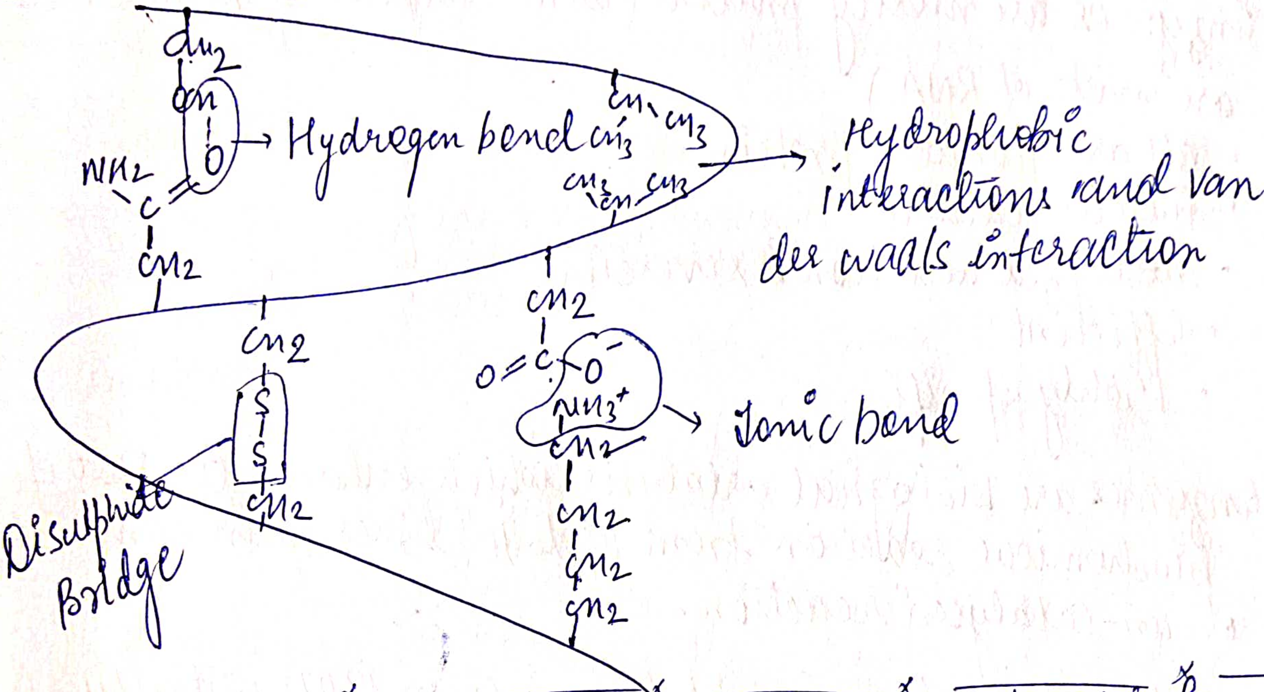
Quaternary Protein Structure
Is protein consisting of more than one amino acid chain.

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

β 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 occurring peptides have only a few amino acid residues. Some proteins are composed of several non-covalently associated polypeptide chains, called Subunits. 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.

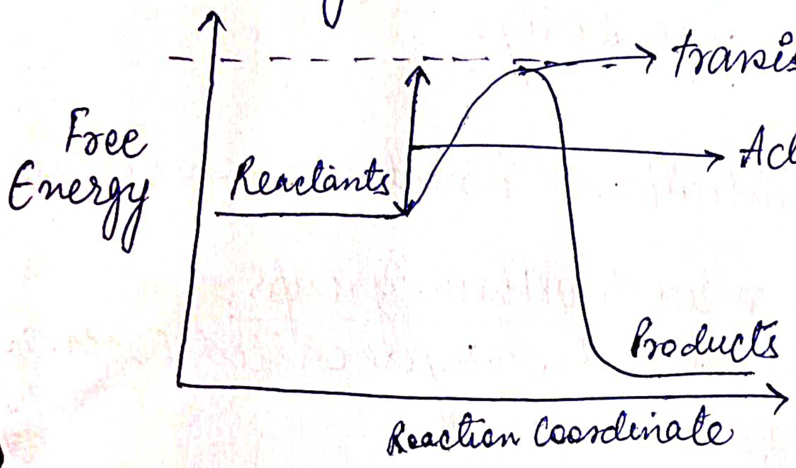
Speed: up to 10^6 times faster reaction rate.

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.

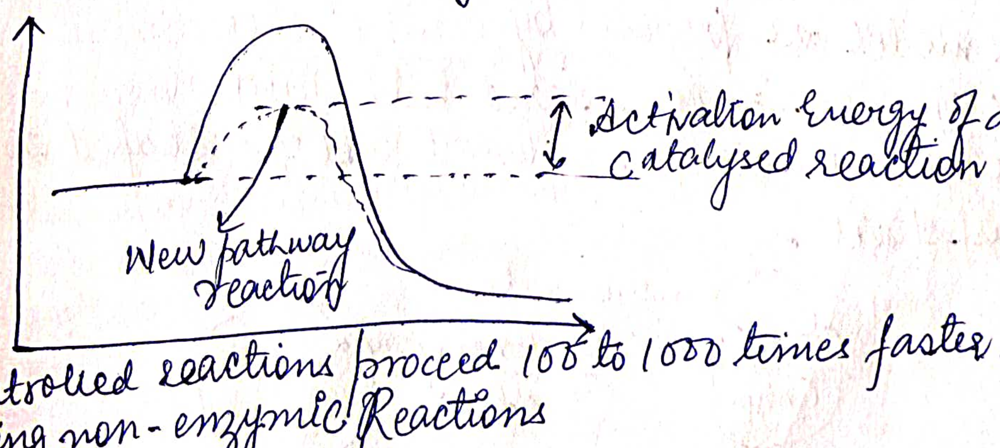
Reaction Pathway



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.

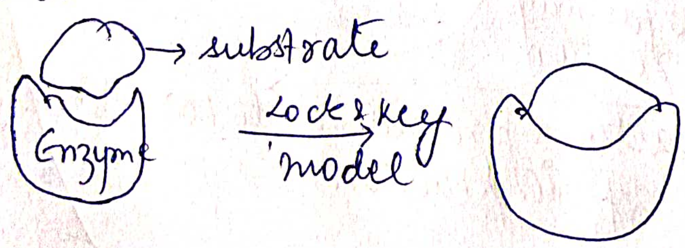
eg- Nitrogenase enzyme with Fe, Mo, ADP cofactors

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.

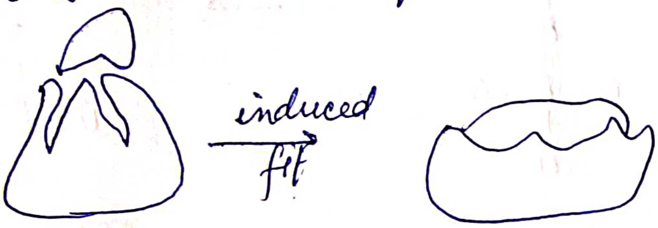
A. The LOCK & KEY or TEMPLATE model

- 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 induces a conformational change in the enzyme

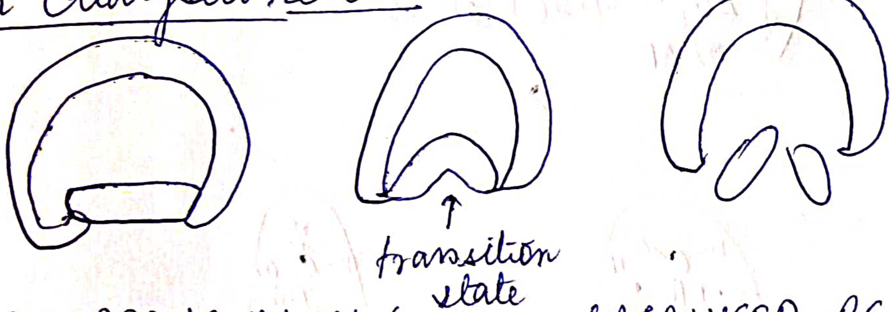


Substrate and enzyme distorted to transition state conformation

The enzymes will have substrate specificity and orientation specificity

(1) In Uncatalyzed reaction

(2) In catalysed reaction



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

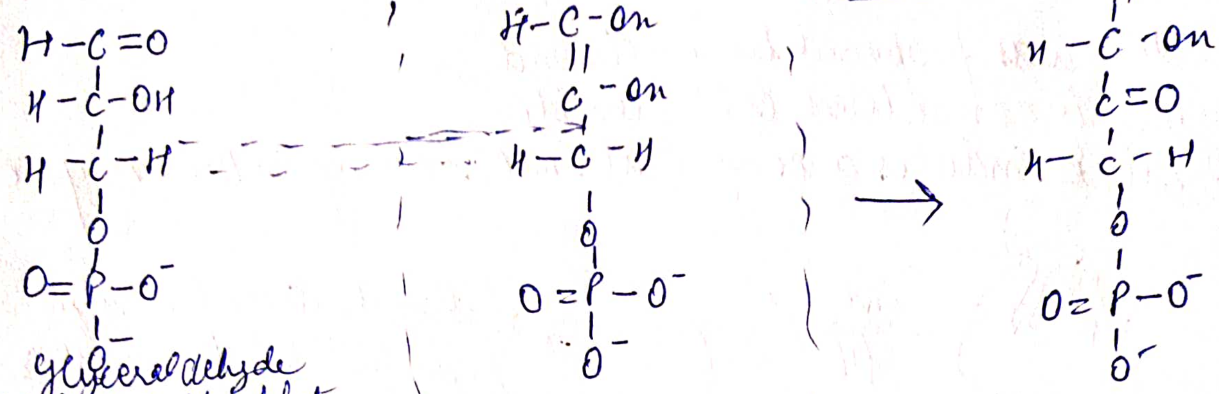
(1) [E] kinds to [S] to form [ES] complex (rate k_1)

(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 toransition state keeps a constant.

(4) At equilibrium [S] and [P] remains constant.

Cis enediol



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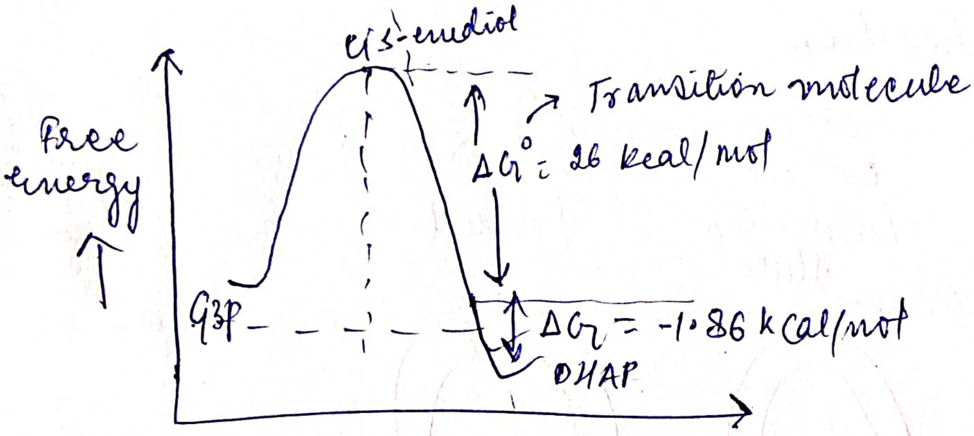
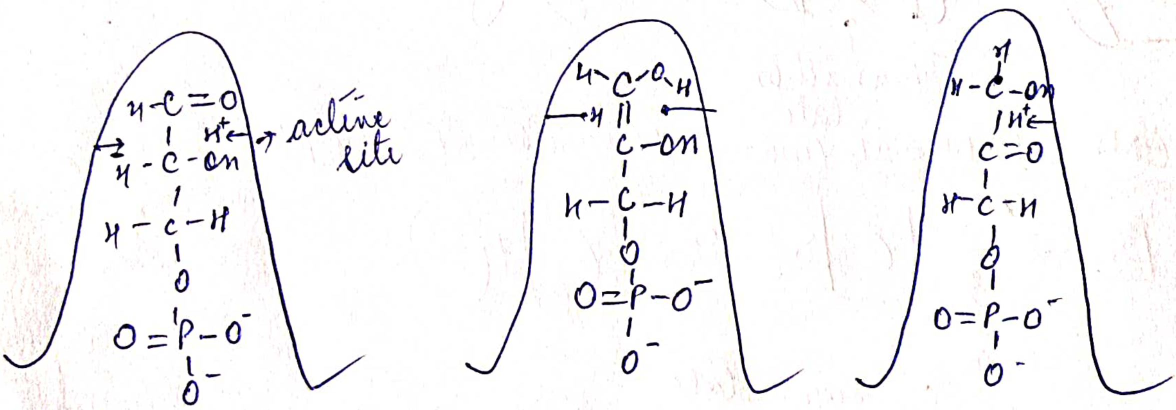
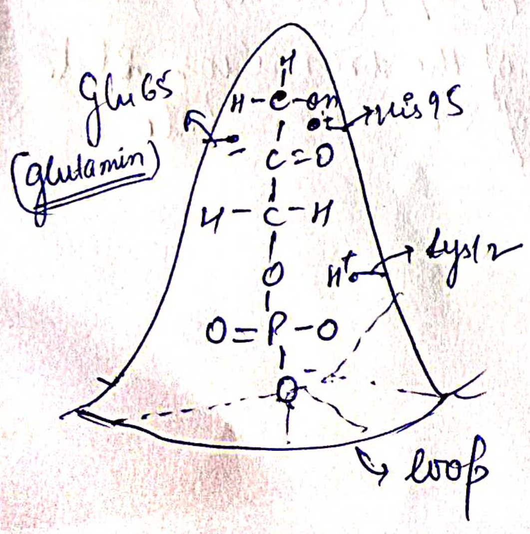




Step. 2



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

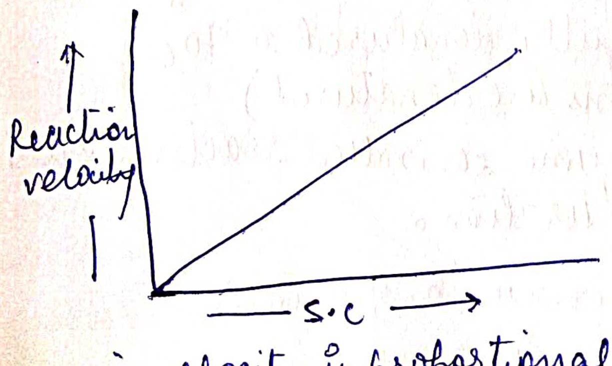
1) Concentration of Enzyme

* 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.

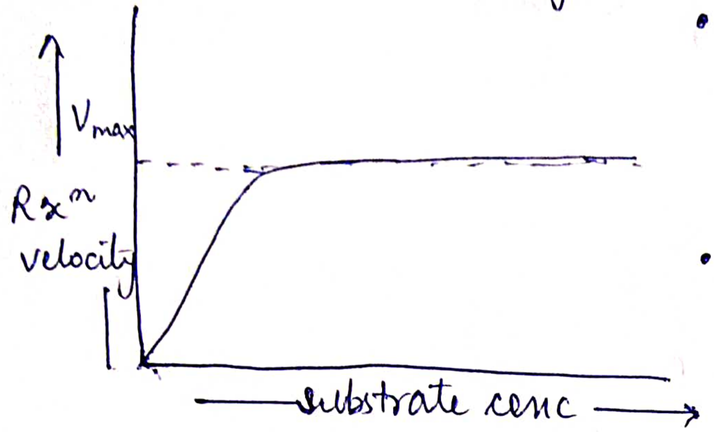
- Enzymes are specific to their substrates.
- The specificity is determined by the active site.

Substrate Concentration : Non enzymic reactions



- The increase in velocity is proportional to the substrate concentration

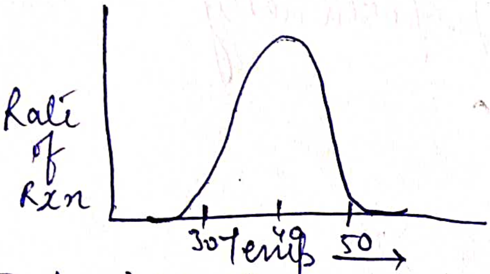
Substrate concentration : Enzymic Reactions



- 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 – optinum 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

- Inhibitors are chemical that reduce the rate of enzymic reactions and they work at low concentrations.
- 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 inhibitors actions is proportional to its concentration.
Resembles the substrates structure closely.

$E + I \rightleftharpoons EI$ → enzyme inhibitor complex.
Reversible Rxn

2. <u>Non Competetive</u> : 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.

<u>Factors/ Effect of Product Concentration</u>

- 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) <u>Effect of Activators</u>

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.

* <u>metal activated enzymes</u> : Enzyme is tightly held by the enzyme

Eg ; ATPase (Mg^{2+} and Ca^{2+})

* <u>metalloenzymes</u> : Enzymes hold the metals tightly. Eg ; alcohol dehydrogenase, carbon anhydrase.

7) <u>Effect of light and radiation.</u>

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

<u>ENZYME KINETICS</u>

- 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

Bioenergetics

- Living organisms carry out energy transductions, conversions of one forms to another.
- modern organisms use chemical energy in fuels (carbohydrates, lipids) to bring about the synthesis of complex macromolecules from simple precursors.
- They also convert the chemical energy into concentration gradients and electrical gradients, into motion and heat, and in a few organisms into light (fireflies, some deep sea fishes)
- Biological energy transductions obey the same physical laws that govern all other natural processes.
- Bioenergetics is the quantitative study of the energy transductions that occur in living cells and of the nature and function of the chemical process underlying these transductions.

Metabolism, the sum of all the chemical transformations taking place in a cell or organism.

Reactions occurs through a series of enzyme catalyzed reactions that constitute metabolic pathways

Heterotrophs	Autotrophs
→ feeds on other plants and animals (consumers) → depends on autotrophs	prepare their own food through process of photosynthesis.

Glycolysis harvests chemical energy by oxidizing glucose to pyruvate

- Glycolysis. ("splitting of sugar") breaks down glucose into two molecules of Pyruvate.
- Glycolysis occurs in the cytoplasm and has two major phases.
  - Energy investment phase
  - energy payoff phase.
- Glycolysis occurs whether or not O_2 is present

[Cell macromolecules]

(1) proteins
(2) polysaccharides
(3) Lipids
(4) Nucleic Acids

[Energy containing nutrients]

(1) Carbohydrates
(2) Fats
(3) Proteins

Catabolism

Anabolism

$ADP + HPO_4^{2-}$
NAD^+
$NADP^+$
FAD

ATP
NADH
NADPH
$FADH_2$

chemical energy

[Precursor molecules]

(1) Amino Acids
(2) Sugars
(3) Fatty acids
(4) Nitrogenous bases.

[energy depleted end products]

CO_2
H_2O
NH_3

* Stages of Cellular Respiration –

A preview

- Harvesting of energy from glucose has 3 stages
- glycolysis → (breaks down glucose into two molecules of pyruvate)
- The citric Acid cycle (completes the breakdown of glucose)
- Oxidative phosphorylation (accounts for most of the ATP synthesis)

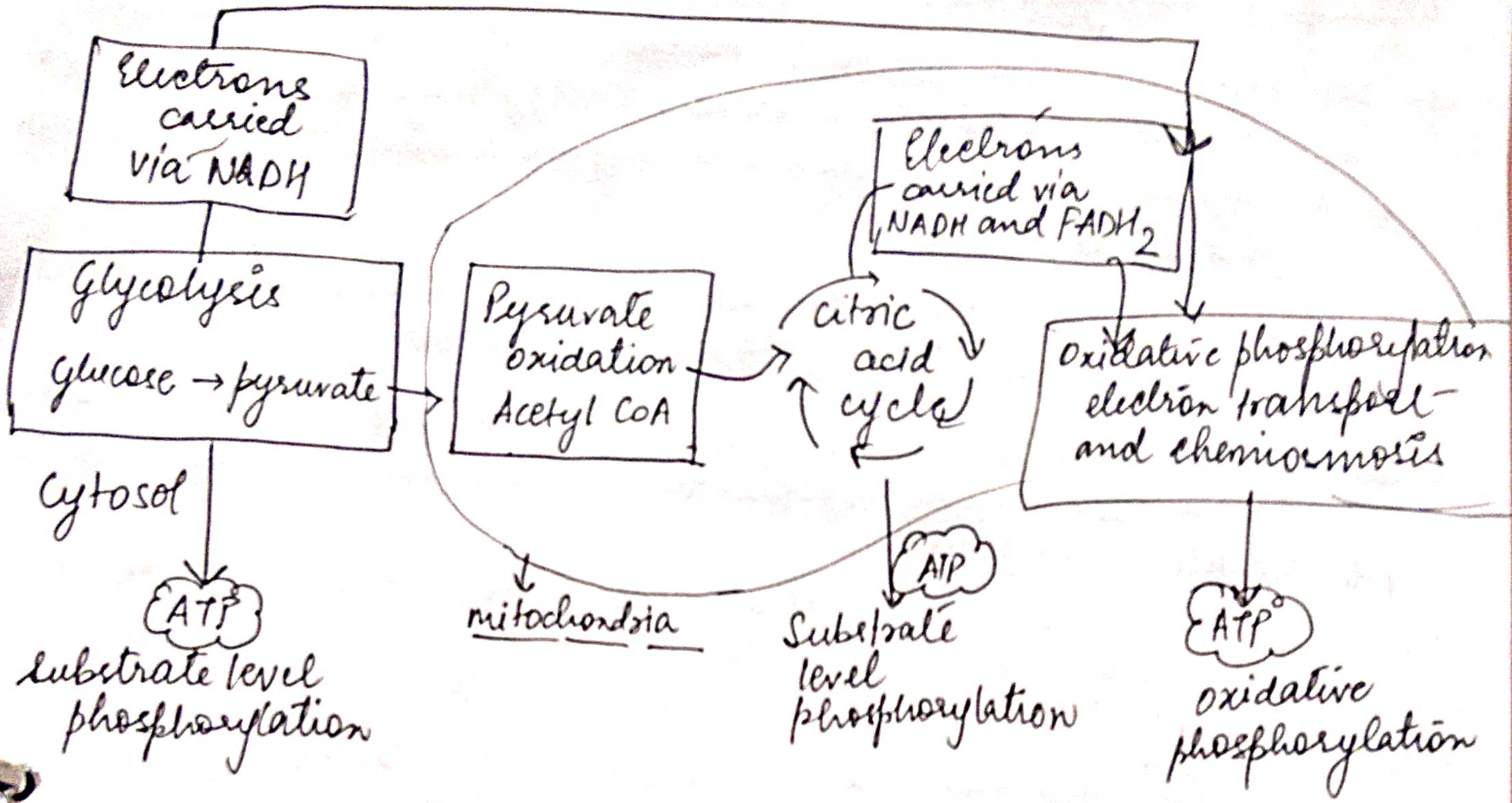
[1 Glucose] $\xrightarrow{\text{glycolysis}}$ [10 successive reactions] [2 Pyruvate]

anaerobic conditions → [2 Lactate] Fermentation to Lactate in vigorously contracting muscle, erythrocytes, some other cells and in some microorganisms

anaerobic conditions ↓ [2 Ethanol + $2CO_2$] Fermentation to alcohol in yeast

aerobic conditions $2CO_2$ → [2 Acetyl-CoA]

citric Acid cycle → [$4CO_2 + 4H_2O$] Animal, plants, and many microbial cells under aerobic conditions



Energy Investment Phase

glucose

$2\,ADP + 2\,P \leftarrow 2\,ATP$ used

Energy Payoff Phase

$2\,ADP + 4\,P \longrightarrow 4\,ATP$ formed

$4\,NAD^+ + 4e + 4H^+ \longrightarrow \boxed{2\,NADH} + 2H^+$

$\longrightarrow 2$ Pyruvate $+ 2\,H_2O$.

Net

glucose $\longrightarrow$ 2 pyruvate $+ 2\,H_2O$

4 ATP formed + 2 ATP used $\longrightarrow$ 2 ATP

$2\,NAD^+ + 4e^- + 4H^+ \longrightarrow 2\,NADH + 2H^+$

Bioenergetics

Biological energy transductions obey laws of Thermodynamics

Laws of Thermodynamics

(1) For any physical or chemical change, the total amount of energy in the universe remains constants, energy may changed from or it may be transported from one-region to another, but it can not be created or destroyed.

(2) The universe always tends towards increasing disorder: in all natural processes, the entropy of the universe increases.

- The reacting system may be an organism, a cell or two reacting compounds. The reacting system and its surroundings together constitute the universe.
- In the laboratory some chemical or physical processes can be carried out in closed systems and no material or energy is exchanged with the surroundings.
- However living organisms are open systems, they exchange both material and energy with surroundings.
- Living systems are never at equilibrium with their surroundings.

→ [Gibbs Free Energy] (G) → expresses the amount of energy capable of doing work during a reaction at constant temperature and pressure

- When a reaction proceeds with the release of free energy (that is, when system changes so as to possess less free energy) ΔG has a negative value and the reaction is said to be exergonic
- In endergonic reactions the system gains free energy and ΔG is positive.
- The unit of ΔG is joules/mole or calories/mole.
- ~~When a reaction proceeds with the release of free energy (that is, when the system changes so as to posses less free energy) ΔG has~~

Cells require sources of free energy

- Living organisms acquire free energy from nutrient molecules. Cells transform this free energy into ATP and other energy-rich compounds.
- They are capable of providing energy for biological work at constant temperature.

The composition of a reacting system tends to continue changing until equilibrium is reached. At the equilibrium the rates of the forward and reverse reaction are equal and no further change occurs in the system

- The Keq is defined by the molar concentrations of products and reactants at equilibrium.

$$aA + bB \rightleftharpoons cC + dD$$

$$K_{eq} = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

Energetics of cell reaction

Because biological systems are generally held at constant temperature and pressure, it is possible to predict the direction of a chemical reaction from the change in the free energy G, (named J.W Gibbs) who showed ("all systems change in such a way that free energy [G] is minimized".)

In the case of a chemical reaction, reactants ↔ products, the change in free energy ΔG is given by,

$$\Delta G_{products} - \Delta G_{reactants}$$

ΔG = 0, during equilibrium

The relation of ΔG to the direction of any chemical reaction can be summarized in 3 statements.

- If ΔG is (-ve), the forward reaction (from left to right) will tend to occur spontaneously
- If ΔG is positive, the reverse reaction (from right to left as written) will tend to occur.
- If ΔG is 0, both forward and reverse reactions occur at equal rates, the reaction is at equilibrium.

[ΔG°, predicts direction of reaction]

The standard free energy change of a reaction $\Delta G'^{\circ}$ is the value of the change in free energy under the conditions of 298 K (25°C), 1 atm pressure, pH 7.0 (as in pure water), and initial concentrations of 1 M for all reactants and products

The actual change in free energy ΔG during a reaction is influenced by temp, pressure, and initial concentrations of reactants and products and usually differs from $\Delta G'^{\circ}$. Most biological reactions like others that take place in aqueous solutions - also are affected by the pH of solution

We can estimate free energy changes for different temperatures and initial concentrations, using the equation.

$$\Delta G = \Delta G^{\circ\prime} + RT \log [Q]$$

$$\Delta G^{\circ\prime} + RT \log \frac{[Produce]}{[Reactant]}$$

where R is gas constant of 1.987 cal/(degree mol), T is temperature (in degrees kelvin) and Q is the initial concentration ratio of products to reactants.

[1 atm, 298 K]

- An Unfavorable chemical Reaction can proceed if it is directly coupled with an Energetically Favourable Reaction.
- An Unfavourable chemical Reaction can proceed if it is indirectly coupled with an energetically favourable Reaction.

→ [Preparatory phase → phosphorylation of glucose and its conversion to glyceraldehyde 3 phosphate

→ [Payoff phase → oxidative conversion of glyceraldehyde 3 phosphate to pyruvate and the coupled formation of ATP and NADH.

Energetics and products of glycolysis:

From one molecule of Glucose:

$$1\,Gl + 2ATP + 2NAD^+ + 4ADP + 4Pi = 2\text{ pyruvate} + 2NADH + 4ATP + 2ADP + 2Pi$$

After Balancing: $1\,Gl + 2NAD^+ + 2ADP + 2Pi = 2\text{ pyruvate} + 2ATP + 2NADH$

2 molecules of ATP generated can directly be used for doing work or synthesis.

The 2 NADH molecules are oxidised in mitochondria under aerobic conditions and the free energy released is enough to synthesize 6 molecules of ATP by oxidative phosphorylation.

Under the aerobic condition pyruvate is catabolized further in mitochondria through pyruvate dehydrogenase and cytric acid cycle where all the carbon atoms are oxidized to CO_2. The free energy released is used in the synthesis of ATP, NADH and FADH2.

Under anaerobic conditions: Pyruvate is converted to lactate in homolactic fermentation or in ethanol in alcoholic fermentation

Regulation of glycolysis

Two types controls for metabolic reactions:

(a) Substrate limited: when concentrations of reactants and products in the cell are near equilibrium then its availability of substrate which decides the rate of reaction.

(b) Enzyme limited: When concentration of substrate and products are far away from equilibrium, then the activity of enzyme that decides the rate of reaction. These reactions are the one which control the flux of the overall pathway.

* There are three steps in Glycolysis that have enzymes which regulate the flux of glycolysis.

(1) The hexokinase (HK)
(2) The phosphofructokinase (PFK)
(3) The pyruvate kinase

Glycolysis and the citric acid cycle connect to many other metabolic pathways.

→ ~~ATP~~ → 1 ATP gives 7.32 calories
∴ 38 ATP = 7.32 × 38
= ≃ 250 calories

- Glycolysis and the citric acid cycle are major intersections to various catabolic and anabolic pathways.
- Catabolic pathways funnel electrons from many kinds of organic molecules into cellular respiration.
- Glycolysis accepts a wide range of carbohydrates.
- Proteins must be digested to amino acids; amino groups can feed glycolysis or the citric acid cycle.
- Fats are digested to glycerol (used in glycolysis) and fatty acids (used in generating acetyl CoA)
- Fatty acids are broken down by beta oxidation and yield acetyl CoA.
- An oxidised gram of fat produces more than twice as much ATP as an oxidized gram of carbohydrate

PH :

[negative log of $\frac{1}{H^+}$]

→ [tells the acidic and basic thing]

Acid, Bases & PH Scale

[$H_2O \rightarrow H_3O^+ + OH^-$]

→ At equilibrium, the concentration water molecules exceeds the concentration of H^+ and OH^-

In pure water only one water molecule in every 554 million is dissociated.

The concentration of each ion in pure water is 10^{-7} M at 25°C.

$$[H^+] = [OH^-] = 0.0000001\ M = 10^{-7}\ M = \boxed{PH = 7}$$

H^+ and OH^- ions are very reactive ~~and~~ changes in the concentration drastically affect a cell's proteins and other complex molecules.

Adding acids or bases can disrupt the balance of H^+ and OH^-

WHAT IS AN ACID ?

① An acid is a substance which, when dissolved in water, releases protons.

② The extent of dissociation, that is the amount of protons released compared to the total amount of compound, is a measure of the strength of the acid.

③ For example HCl (Hydrochloric Acid) is a strong acid, bcz it dissociates completely in water, generating free $[H^+]$ and $[Cl^-]$.

④ Acidity can be measured on a scale called pH ("the negative logarithm of the hydrogen ion Concentration")

WHAT IS A BASE ?

- The substance that reduces the hydrogen ion Concentration is known as a base.
- Some reduces the H^+ concentration by accepting H^+ example NH_3
- NaOH reduces the H^+ concentration by increasing the concentration of OH^-.
- Strong acid and base completely dissociate in water
- Weak acid and bases are reversible reactions (binding and release of hydrogen ions)

WHAT IS A WEAK ACID ?

- Some substances, like Acetic Acid (vinegar) dissociate poorly in water.
- Thus, they release protons, but only a small fraction of their molecules dissociate (ionize).
- Such compounds are considered to be weak acids.
- Thus, while 1M HCl is pH = 0 (why?), 1M acetic Acid is only pH = 2.4.

Weak Acid are in equilibrium with their ionized species: Governed by Law of Mass Action, and characterized by an equilibrium constant:

$$HA \leftrightarrow H^+ + A^-$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

+ Comparative Equilibrium constants

water = $K_a = 1.8 \times 10^{-16}$

Acetic Acid = $K_a = 1.7 \times 10^{-5}$

+ How can you actually determine the pH of a Solution?

(1) Use a pH meter - read the number

(2) Use pH paper (color patterns indicate pH)

(3) Titrate the solution with precise amounts of base or acid in conjunction with a soluble dye, like phenolphthalein, whose color changes when a specific pH is reached.

The conceptual problem with pH

- Every factor of 10 difference in $[H^+]$ represents 1.0 pH units and
- Every factor of 2 difference in $[H^+]$ represents 0.3 pH units
- Therefore, even numerically small differences in pH, can have profound biological effects.

THE pH SCALE GOES FROM 0 TO 14 - because $[H^+][OH^-] = 10^{-14}$

battery Acid → ~~0~~ -1.0

Gastric Fluid → 1.2

carbonated bvg → 2.6

vinegar → 3.0

orange juice → 3.6

beer → 4.4

coffee → 4.9

egg yolks → 5.6

milk → 6.5

blood → 7.4

milk of magnesia → 10.7

lemon juice → 2.2

pure rain → 5.6

distilled water → 7

sea water → 8

baking soda → 9.2

NH_3 → 11.4

bleach → 12.8

NaOH solution → 13.6

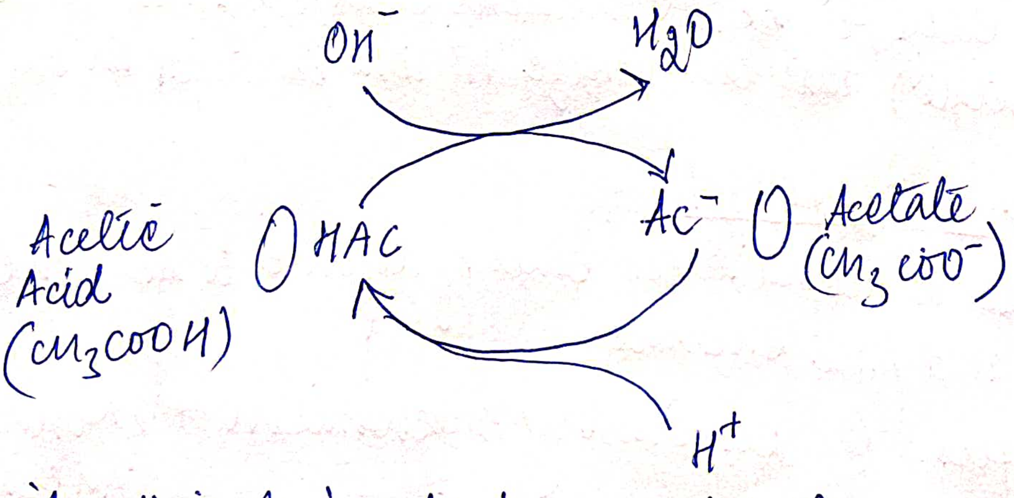
Most living cells have a very narrow range of tolerance for pH.
i.e [H^+]

- The [H^+] concentration will be important for many other topics in Biology.
- [H^+] is controlled in all biological organisms, and in virtually all biochemical experiments.
- Each pH unit represents a factor of 10 difference in [H^+]

BUFFERS

- A buffer is a solution of a weak acid and its conjugate base that resists changes in pH in both directions - either up or down.
- A buffer works best in the middle of its range, where the amount of undissociated acid is about equal to the amount of the conjugate base.
- One can soak up excess protons (acid), the other can soak up excess hydroxide. (base)

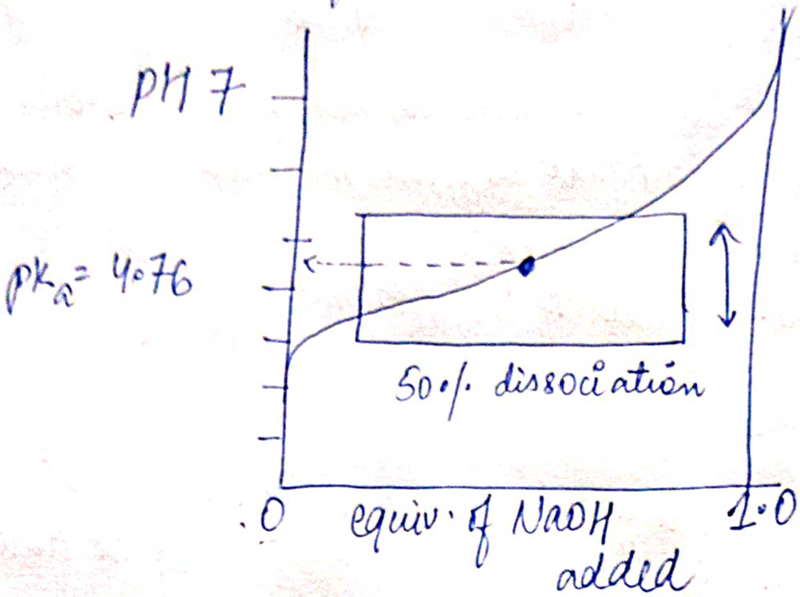
IONISATION OF ACETIC ACID.



Weak Acids, their Conjugate bases and buffers

- Weak Acids have only a modest tendency to shed their ~~[illegible]~~ protons.
- when they do, the corresponding negatively charged anion becomes a willing proton acceptor, and is called the conjugate base.
- The properties of a buffer rely on a balance between a weak acid and its conjugate base.

and titration curve of acetic Acid with Sodium Hydroxide



Buffering range: only small. pH changes result from addition of base or acid.

For Biological system

- Ionization of a strong acid is too big
- Ionization of water itself is way very little
- Ionization of a weak acid is just right

[Production of bases by body → A vegetarian diet has alkalizing effect on body, since it contains salts of organic Acids. (Sodium Lactate) that can utilize H^+ ions produced in the body

Maintenance of Blood pH

- The body has developed three lines of defense to regulate the body's acid base balance.

(1) Blood Buffers (2) respiratory mechanism (3) Renal (kidney) mechanism

Blood Buffer

- Buffer: Resists the change in pH
- Blood contains 3 buffer systems.

→ Bicarbonate buffer ($NaHCO_3$) – (H_2CO_3), most predominant buffer of ECF)

- Phosphate buffer ($NaH_2PO_4 - Na_2HPO_4$, ICF)
- Protein buffer (Plasma protein and hemoglobin, accounts only for 2% of total buffering of ECF)

Respiratory mechanism

- Rapid but short term mechanism of pH
- By regulation of carbonic acid (H_2CO_3) in blood
- cellular metabolic activity leads to release of large volumes of CO_2, which acidifies blood.
- CO_2 is eliminated from the body in the expired air via the lungs
- Rate of respiration is controlled by respiratory center of Brain
- Any decrease in blood pH causes hyperventilation to expel CO_2.

The Hydration of CO_2 in H_2O.

$$CO_2 + H_2O$$
$$\downarrow$$
$$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

As CO_2 goes into solution, carbonic acid is formed, which partially dissociates, liberating protons (H^+) and thus causing the sol^n to become more acidic i.e lowering the pH.

What if you could reverse By removing the CO_2?

$$H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O.$$

As CO_2 leaves the solution, carbonic acid is used up which by the Law of Mass Action shifts the equilibrium to the left, using up protons (H^+) and thus causing the solution to become less acidic i.e raising the pH.

How does this work?

Here, the addition of excess bicarbonate will soak up many of the free protons, and drive the equilibrium to the left. This will reduce the acidity, increasing the pH and the carbon dioxide produced will be blown off in the lungs.

Renal Mechanism

- It is permanent solution to acid - base disturbance
- pH of Urine : Normally acidic (6.0)
- Enzyme carbonic anhydrase plays a important role in renal regulation of pH.

Disorders of Acid-Base balance

Mainly classified as;

- Acidosis → A decline in blood pH.
  → metabolic acidosis - due to a decrease in bicarbonate.
  → respiratory acidosis - due to increase in carbonic acid.
- Alkalosis → A rise in blood pH
  → metabolic alkalosis - due to an increase in bicarbonate.
  → Respiratory alkalosis - due to a decrease in 'Carbonic Acid'.

ONLY FOR INFO.

Metabolic acidosis	Respiratory acidosis
Diabetes mellitus	Severe asthma.
Renal failure	Pneumonia
Lactic acidiosis	Cardiac arrest
Severe diarrhea	obstruction in airways
Renal tubular acidosis	chest deformities
	Depression of respiratory center.