

NOTES ON

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BIOCHEMISTRY

(1st prof)

- ENZYMES
- LIPIDS
- PROTEINS
- CARBOHYDRATES
- CYCLES
- AMINO ACIDS

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BIOCHEMISTRY

DEFINITION: The branch of science which deals with structure, composition and properties of substance and of the transformation that they undergo.

VITAMINS:

They are called as a mean essential to life.

DEFINITION: Vitamins are defined as

"plant organic compounds which are found in foods in minute and minute quantity to enable growth, health and life to be maintained." Vitamins are abbreviated from "Vital amines".

CLASSIFICATION OF VITAMINS:

"Vitamins are usually classified according to their solubility. There are two common classes:

- (i) Fat soluble vitamins (ii) Water soluble vitamins

FAT SOLUBLE VITAMINS:

- (i) Vitamin-A (ii) Vitamin-D
(iii) Vitamin-E (iv) Vitamin-K

They are collectively called as "ADEK".

VITAMIN-A

Vitamin-A is a complex alcohol and is now-a-days called "Retinol". Sometimes it is also called "Xerophthol". Vit. A is necessary for maintenance of vision & epithelia and for skeletal growth.

* CHEMISTRY: Vitamin-A has two isomers i.e. Vit. A₁ and A₂. They are also called retinol, and retinol₂. β -carotene

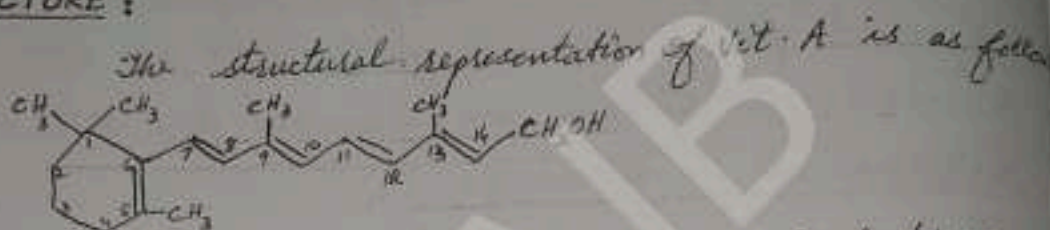
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is a precursor of Vit. A. It is readily transfer in the cells of intestinal wall into Vit. A.

* FORMULA:

The molecular formula of Vit. A is $C_{20}H_{30}OH$

* STRUCTURE:



* OCCURRENCE: Vit. A naturally occurs in the animal tissue. It is found in milk products like butter & cream. It is present in eggs in a very large amount. It is found in high concentration in fish liver oils especially in cod liver oil. Generally, marine fishes contain Vit. A, & fresh water fishes contain Vitam. A₂.

Another important source of Vit. A is the plants which contain carotenoids β -caroten, a yellow pigment contained in corn, sweet potatoes, carrots, tomatoes etc.

* REQUIREMENTS: per day Vit. A is required in international unit of Carotene from 5000 to 6000. In pregnancy this is required up to 8000 I.U.

* FUNCTIONS: It is important for infections. It is used to cure "Measles". It is particularly important for the normal formation and function of epithelial tissue. It also plays a primary role in the synthesis of glycoproteins. It is a fairly

has been found to result in retardation of growth accompanied by defects in bone development. The pressure of deformed skull bones on the CNS may produce nerve degeneration & paralysis.

(V) TOOTH CHANGES: A defective formation of the tooth takes place and this may lead to abnormalities of dentine.

(VI) NIGHT BLINDNESS: Night blindness is the earliest symptom of Vit. A deficiency followed by degenerative changes in retina.

(VII) FAILURE OF REPRODUCTION: Vit. A deficiency leads to the failure of reproduction. Males become sterile. Females although deficient are able to conceive, but are unable to survive due to placental defects.

(VIII) LOW RESISTANCE TO INFECTIONS: Vit. A deficiency in man lowers resistance to common infections.

* HYPERVITAMINOSIS: (Excess of vitamin)

Excessive intake of Vit. A in man produces a number of symptoms. After taking a very high dose of Vit. A, headache, nausea, vomiting, peeling of the skin takes place. Due to excess of Vit. A painful swelling over long bones occurs. Excess of Vit. A intake may lead to skeletal deformation take place in fetus. The serum alkaline phosphatase level is raised in many cases. Due to hypervitaminosis of Vit. A, a condition Anorexia takes place in which loss of appetite occurs.

(4)

good therapy for some type of Anemia. It may reduce the transmission of AIDS virus from mother to foetus. It also used to save the children to become blind. It plays important role in the stability of cell membrane especially of Mitochondria & Lysosomes. It prevents the condition known as Urolithiasis (A condition in which kidney stones formation take place).

* HYPOVITAMINOSIS: (Deficiency of Vitamin).

(i) EFFECTS ON EPITHELIUM: The deficiency of Vit. A leads to the loss of goblet mucous cells along with proliferation of basal cells of the skin and the normal epithelium is replaced by a stratified and dry epithelium; the epithelium becomes susceptible to irritation and infection.

(ii) EYE CHANGES: Due to deficiency of Vit. A following conditions of the eyes occur.

(a) Xerophthalmia: In this case the conjunctival changes occur in which small triangular white patches on the outer and inner side of the cornea covered by a material resembling white foam, these patches are termed "Bitot's spots".

(b) Keratomalacia: In this case prolapse of Iris and loss of lenses occur. The cornea becomes dull and insensitive. Keratomalacia occurs usually in the first year of life.

(iii) SKIN CHANGES: Dryness of skin takes place, due to deficiency of Vit. A. a condition known as "Toad skin".

(iv) EFFECTS ON BONES: In growing animals Vit. A deficiency

DEFINITION:

"The potentiality in various health and PROVITAMIN."

"The"

on hydro

cholesterol

the later

CLASS

These

(i)---

(1) Fat

or oil

(2) WA

wa

VI

in

VITAMINS

DEFINITION:

Vitamins are derived from "vital amines".

"The potent organic compounds which are found in food in variable and minute quantity to enable growth, health and life to be maintained" are called vitamins.

PROVITAMINS:

"The compounds which are converted into vitamins on hydrolysis are called provitamins. e.g. β -carotene and cholesterol. Formar is hydrolysed to Vit. A in the liver and the later is converted into Vit. D by Sunlight.

CLASSIFICATION OF VITAMINS:

Vitamins are classified on the basis of solubility.

There are two types of vitamins.

(i)..... Fat Soluble Vitamins. (ii)..... Water soluble vitamins.

① FAT SOLUBLE VITAMINS:

These are the vitamins which are soluble in fats or oils. These include Vit A, D, E & K.

They are collectively known as ADEK.

② WATER SOLUBLE VITAMINS:

These are the vitamins which are soluble in water. These include Vit C, P and B-complex.

VITAMIN B-COMPLEX:

It is a large group of vitamins. It is divided into subgroup vitamins which are as follows:

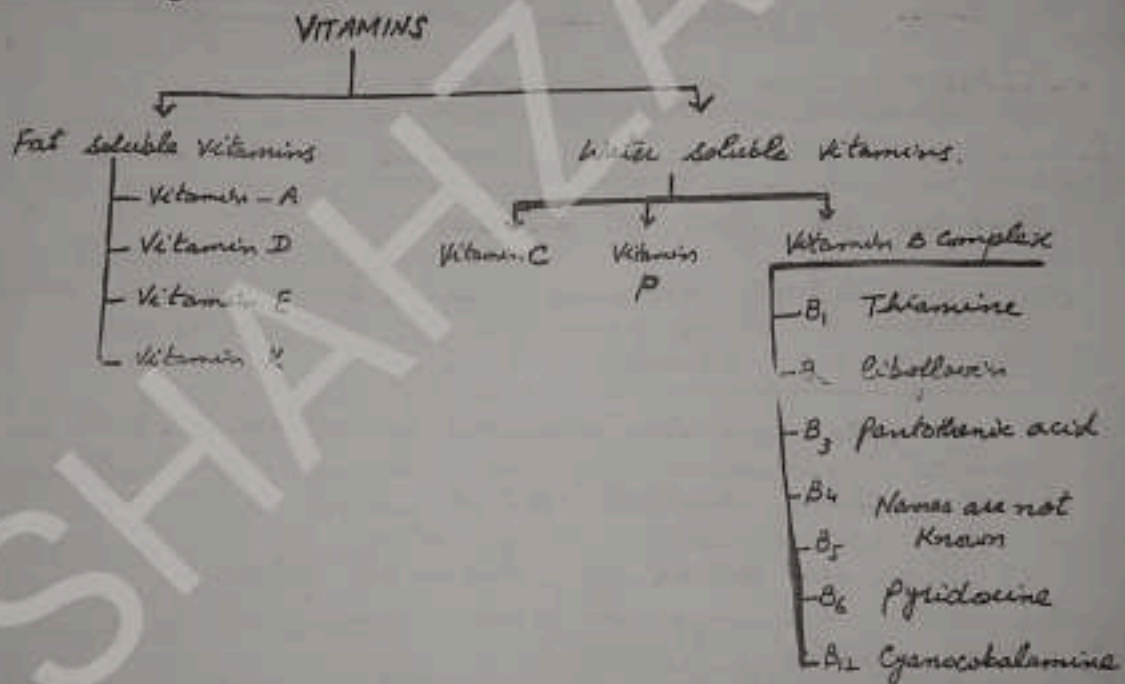
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Vitamin B₁ → Thiamine , Vitamin B₂ → Riboflavin
Vitamin B₃ → Pantothenic acid , Vitamin B₄ & B₅ → Names are not known
Vitamin B₆ → Pyridoxine , Vitamin B₁₂ → Cyanocobalamin.

VITAMIN LIKE SUBSTANCES:

There are some substances which have vitamin like actions and functions but they are not classified as vitamins. They are also called as SMALLER MITES:

The classification of vitamins can be summarised as below:



VITAMIN LIKE SUBSTANCES (SMALLER MITES)

- Nicotinic acid.
- Folic acid.
- Para-Amino Benzoic acid
- Lipoic Acid.
- Biotin (Vit. H)
- Choline
- Inositol.

(7)

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VITAMIN-D

Vitamin-D is a fat soluble vitamin. They are steroids or activated steroids.

It is also called as Anti-Ricket factor. Because it prevents and cure Ricket.

The basic ring structure found in Vitamin-D is perhydrocyclopentanophenanthrene.

*CHEMISTRY:

There are two kinds of Vit. D.

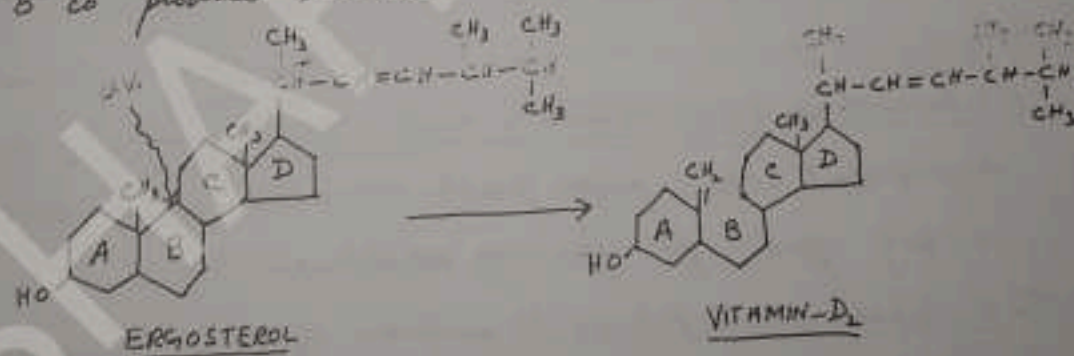
(i)..... Vitamin D₂

(ii)..... Vitamin D₃

(1) VITAMIN D₂:

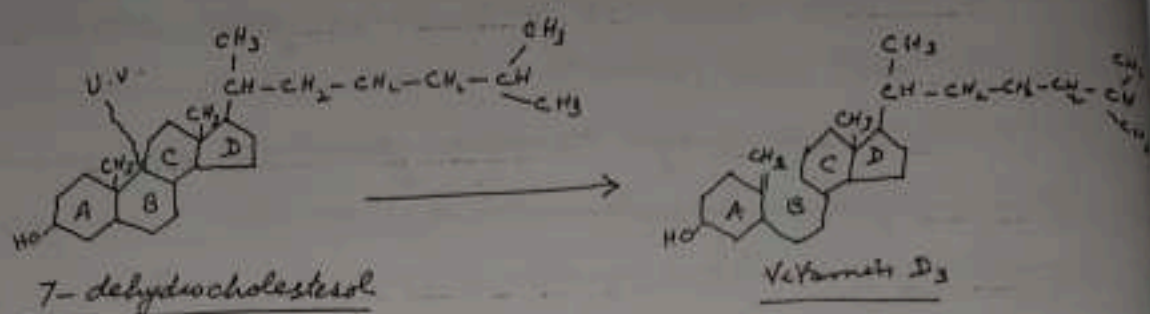
The provitamin of D₂ is the Ergosterol. It is found only in lower plants.

The ultraviolet rays act on ergosterol and opens the ring 'B' to produce Vit. D₂.



(2) VITAMIN-D₃:

The provitamin of D₃ is the 7-Dehydrocholesterol which is present at the surface of skin. It is activated by U.V. rays of Sun to form Vit. D₃ by opening the B ring.



► SOURCES:

ANIMAL SOURCES: Cod and other fish liver oils are best source of Vit. D. It is present in cow milk and other milks. It is present in egg yolk. The provitamins are largely concentrated in skin and they are activated to Vit. D by Sunlight.

PLANT SOURCES: It is present in yeast and irradiated yeast.

✱ DAILY REQUIREMENTS: For adult 250 I.U., pregnant women 500 I.U.
For children 500 I.U./day.

✱ FUNCTIONS:

- ① Development of bones & teeth: Vit. D help in the development and proper growth of bones and teeth. It is very good for growing children.
- ② Calcium equilibrium: It maintain eq^m b/w blood calcium and bone calcium.
- ③ Reabsorption of calcium and phosphorus: It helps for the reabsorption of calcium and phosphorus from intestine into the blood.



- ④ Effect on Parathyroid: Vit. D also influence the activity of parathyroid.
- ⑤ Excretion: It helps in the excretion from intestine and kidney.

* HYPOVITAMINOSIS: Deficiency of Vitamin-D cause the following diseases.

(i)....Rickets: In growing children vit-D deficiency cause rickets. Overgrowth of cartilage occur at the end of bones. Growth is also stunted.

(ii)....Osteomalacia: In adults, due to deficiency of vit-D, there occur adult rickets known as Osteomalacia. It mainly effect the weight bearing bones. It is found in p.women having undergone repeated cycles of pregnancy and lactation.

* HYPERVITAMINOSIS: The increased amount of vit-D brings about an increased absorption of Ca^{2+} and P_i from the intestine and an increased blood level of these minerals. Thus Hypercalcemia & Hyperphosphatemia may occur. The symptoms are thirst, vomiting, nausea and diarrhea and ultimately loss of weight take place.

VITAMIN-B₆ (PYRIDOXINE)

Vitamin B₆ (Pyridoxine) is also called as Rat anti-inflammatory factor.

* CHEMISTRY:

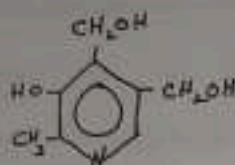
Chemically it is a pyridine derivative. The formula of pyridine is as follows.



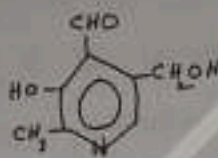
Pyridine

Vitamin B₆ is a collective term for

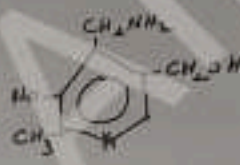
- (i).... Pyridoxine.
- (ii).... Pyridoxal.
- (iii).... Pyridoxamine.



Pyridoxine

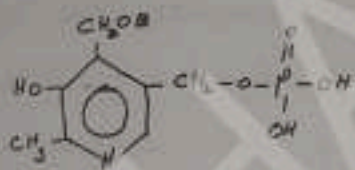


Pyridoxal

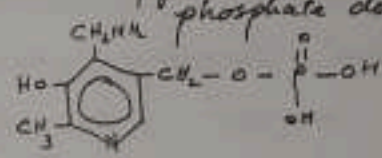


Pyridoxamine

They occur in nature in the form of phosphate derivatives which are the co-enzymes of this vitamin. Only pyridoxal & pyridoxamine occur as phosphate derivatives.



Pyridoxal phosphate



Pyridoxamine phosphate

* PROPERTIES:

- ① It is water soluble.
- ② It is heat stable in both acidic & alkaline sol.
- ③ It is a colourless crystal.
- ④ Resistant to light & U.V. rays.

* SOURCES:

Animal Sources: Kidney, liver, muscle, egg, milk, yolk, meat, fish in animal kingdom.

Plant Sources: Cabbage, wheat, corn, leafy vegetables and yeast in plant kingdom.

* REQUIREMENTS: For adult 2 mg/day
For infants 0.3 mg/day

* FUNCTIONS:

- (i)---The physiological active form is pyridoxal phosphate. It act as co-enzyme for many important reaction such as
 - (a) Transamination. (b) Decarboxylation (c) Racemization.
- (ii)--- Vit B₆ is an important factor to regulate the metabolism of aminoacids & Ketoacids.
- (iii)--- It helps in the synthesis of proteins & carbohydrates.
- (iv)--- It takes part in normal cytoplasm metabolism.
- (v)--- Vit. B₆ helps in the entry of aminoacids and K⁺ into the cell against a concentration gradient.

* HYPVITAMINOSIS:

- ① Dermatitis skin infection
- ② Reduced growth
- ③ Degeneration of nerves
- ④ Reproductive failure.
- ⑤ Weakness of muscles.
- ⑥ Anemia may occur.

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VITAMIN B₁₂ (CYANOCOBALAMINE)

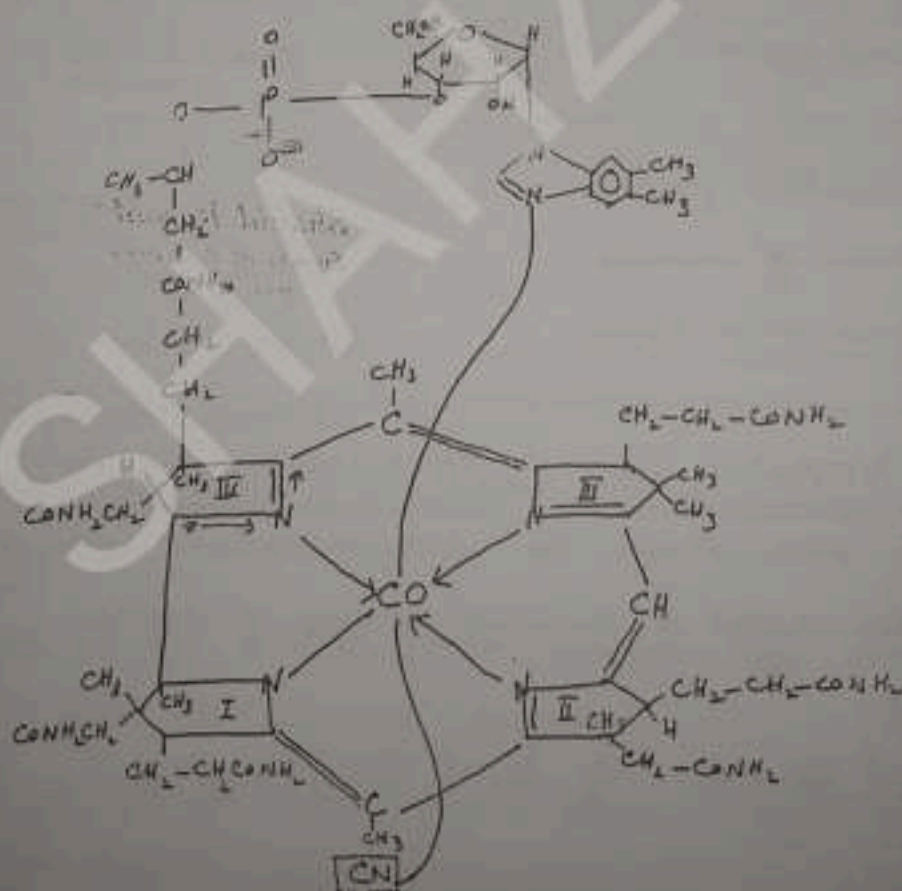
It is also known as Antipernicious anemia factor.
It is also called as extrinsic factor of Castle.

* CHEMISTRY:

Empirical Formula: $C_{63}H_{88}N_{14}O_{14}PCO$

STRUCTURE:

Chemically, it consists of a central corrin ring system which comprises of four pyrrole rings surrounding a single cobalt atom. Ring I and Ring IV joined directly with a common corrin ring which is attached to 5,6-dimethyl benzimidazole which in turn is attached to a ribose. The ribose in turn is attached to phosphate & phosphate is attached to aminopropion to the pyrid ring. A cyanide ion is directly attached to a cobalt atom to form CYANOCOBALAMIN.



CYANOCOBALAMIN

* PROPERTIES:

- ① They are water soluble.
- ② It is a red crystalline substance.
- ③ It is labile to heat, acids, alkalis & light.

* SOURCES:Animal Sources:

Kidney, muscle, egg, yolk, liver, cheese, fish, chicken etc. It is synthesized by micro-organisms.

Plant Sources:

Vit. B₁₂ is not present in plants.

* REQUIREMENTS:

For adults 1 µg / day

For pregnant & lactated mother 6 µg / day.

* FUNCTIONS: To remember (color) ① Maturation of R.B.C.

It is essential for maturation of RBCs.

② W.B.C. & Platelet count:

It increases the W.B.C. & Platelets count.

③ Synthesis of Nucleic acid:

It is important for synthesis of Nucleic acid.

④ Normal activities of Nervous system:

It is essential for normal activities of nervous system.

⑤ Formation of Lipids From Carbohydrates:

Formation of lipids from carbohydrates is influenced by this vitamin.

⑥ Growth of Microorganisms:

It helps in the growth of microorganism called Lactobacillus Lactis.

⑦ Cure of Hyperglycemia:

It can also cure hyperglycemia.

⑧ Help in Transmethylation:

It also help in Transmethylation.

⑨ Purines and Pyrimidines metabolism:

It is also involved in purine and pyrimidine metabolism.

ABSORPTION:

Absorption of Vit. B₁₂ occur from ileum but requiring intrinsic factor and hydrochloric acid contributed by stomach.

STORAGE:

Vit B₁₂ is stored principally in liver for long period.

EXCRETION:

Vit. B₁₂ is excreted in feces (represent unabsorbed vitamin).

HYPOVITAMINOSIS:

- ① Pernicious anemia.
- ② Hyperglycemia
- ③ There may occur nervousness.
- ④ There is slow growth.
- ⑤ Weakness of muscles.

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DEFINITION

"Carbohydrate compounds"

"Carbohydrate between"

not called

Saccharide

GENERAL

The

Carbohydrate

(i) - M

(ii) - M

(iii) - P

(iv) - D

(i) MO

"Monosaccharide"

broken

Monosaccharide

PROPE

(i) The

(ii) Full

CARBOHYDRATES:

DEFINITION:

"Carbohydrates are polyhydroxy aldehydes and ketones or the compounds which yield these substances on hydrolysis."

OR

"Carbohydrates are the compounds of C, H & O and the ratio between H & O is the same as in water."

All carbohydrates are hydrocarbons but all hydrocarbons are not carbohydrates. Carbohydrates are also called "Saccharides" word Saccharide is derived from "Saccharon" a Greek word meaning 'Sugar'.

GENERAL FORMULA:

The General formula for carbohydrates is $C_x(H_2O)_y$.

CLASSIFICATION OF CARBOHYDRATES:

Carbohydrates are classified into following main classes:-

- (i) --- Monosaccharides.
- (ii) --- Disaccharides.
- (iii) --- Polysaccharides.
- (iv) --- Derived carbohydrates.

(i) MONOSACCHARIDES:

"Monosaccharides are the carbohydrates which cannot be further broken down into simpler units by acid hydrolysis."

Monosaccharides have General Formula $C_n(H_2O)_n$.

PROPERTIES OF MONOSACCHARIDES:

- (i). They are sweet in taste.
- (ii) Further, Hydrolysis is not possible.

- (i) Many monosaccharides unite to form complex carbohydrates.
- (ii) The pentose sugar ribose is important compound of RNA.
- (iii) Another pentose sugar - deoxyribose is constituent of DNA.
- (iv) They are easily soluble in water but after dissolution, they take the form of ring.

(v) Glucose a hexose sugar is primary source of energy for cells.

ALDOLASE: A monosaccharide derived from aldehyde is called 'Aldose'.

Ketolase: A monosaccharide derived from ketone is called 'Ketolase'.

NOMENCLATURE: Aldolase can be converted to ketolase by action of enzyme in the human body.

Monosaccharides are named according to a system that uses the number of carbon, as 'tri', 'tetra', 'penta' and 'hexa' as a 'suffix'. For example, Glucose is an aldose as well as a hexose, it is therefore, an aldohexose. Fructose on the other hand, is a ketohexose.

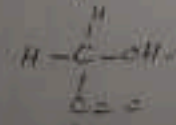
CLASSIFICATION OF MONOSACCHARIDES

Monosaccharides are Trioses, Tetroses, Pentoses, Hexoses etc.

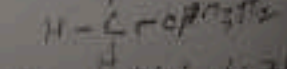
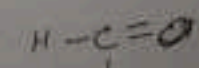
TRIOSES:

- These are monosaccharides with 3-carbon.
- Their general formula is $C_3H_6O_3$.
- These are simplest carbohydrates.
- They contain either an aldehyde group or a ketonic group.
- Trioses are present in straight chain form.

Examples: Aldotriose $\Rightarrow$ Glyceraldehyde



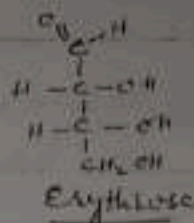
$\Rightarrow$ Dihydroxy acetone phosphate



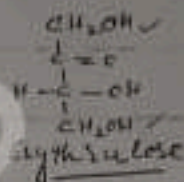
Glyceraldehyde $\Rightarrow$...

TETROSES:

- These are monosaccharides with 4-carbons.
- Their general formula is $C_4H_8O_4$.
- These are in straight chain form.
- Tetroses are also aldehyde or ketonic group.



Examples: Aldotetrose $\Rightarrow$ Erythrose.
Ketotetrose $\Rightarrow$ Erythrulose.

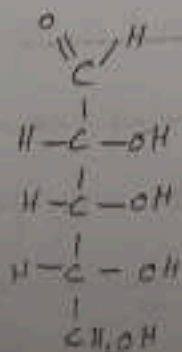
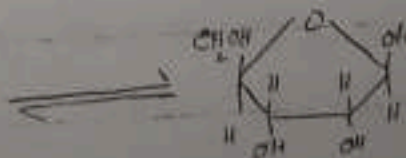
PENTOSE:

- These are monosaccharides with 5-carbons.
- Their general formula is $C_5H_{10}O_5$.
- When ever they are in fluid they form a ring shaped structure. They are in straight chain structure when they are synthesized but later on when they are present in fluid such as human body fluids they are always in ring shaped structure.
- They may be aldoses or ketoses.
- They possess strong reducing properties.
- 5-carbon ring is called "Furan".

Examples: Aldopentose $\Rightarrow$ Ribose.
Ketopentose $\Rightarrow$ Ribulose.



Furan

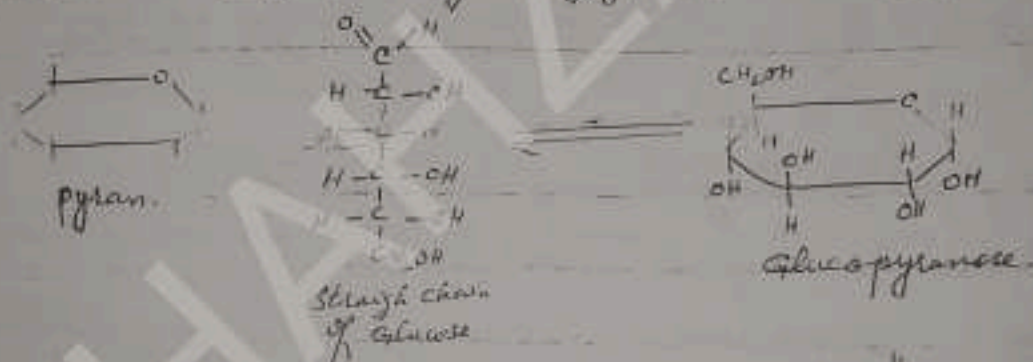
Straight chain
of RiboseRing Structure
of Ribose

HEXOSES:

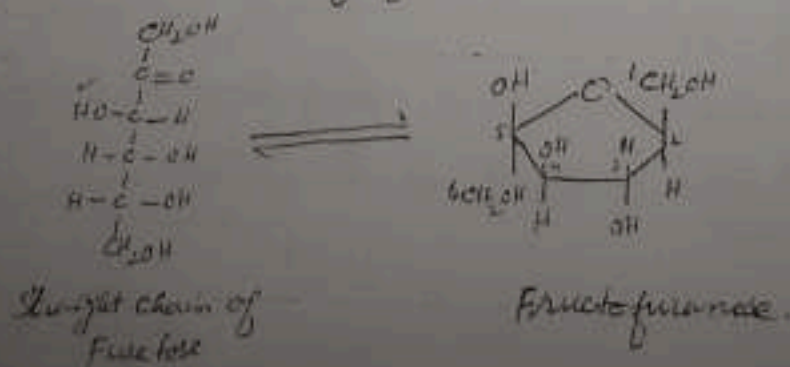
- ... These are monosaccharides with 6 carbons.
- ... Their general formula is $C_6H_{12}O_6$
- ... When present in fluid medium (ICF & ECF) they make cyclic ring structure. But when synthesized they are in straight chain.
- ... Hexoses are ketone derivative or aldehyde derivative.

SOME IMPORTANT HEXOSES:

- (i) GLUCOSE: It is the most abundant monosaccharide. It is also called grape sugar and dextrose. It is commonly obtained from starch. Glucose molecule make 5 cornered ring structure (furan) or 6-cornered ring structure (pyran). But generally glucose make 6 cornered ring.



- (ii) FRUCTOSE: It is also called as fruit sugar. It is ketohexose. It is found in plant kingdom as such or combined with glucose in sucrose. Fructose molecule is always in 5-cornered ring structure. 6-cornered structure of fructose is rare.



- Some other hexoses are
- (iii) Galactose
- (iv) Mannose

(ii) OLIGOSACCHARIDES:

These are the carbohydrates which on hydrolysis yield 2 to 10 and according to some 2 to 6 molecules of monosaccharides.

PROPERTIES OF OLIGOSACCHARIDES:

- (i) They are comparatively less soluble in water.
- (ii) They are also sweet in taste.
- (iii) Most oligosaccharides are composed of hexose sugars.
- (iv) If all the monomers are identical, the substance is called homogenous oligomers.
- (v) If all the monomers are different, the substances are called heterogenous oligomers.
- (vi) They are also source of energy.

TYPES OF OLIGOSACCHARIDES:

Oligosaccharides are of following types:-

- (a) Disaccharides.
- (b) Trisaccharides.
- (c) Tetrasaccharides etc.

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(a) DISACCHARIDES:

Two monosaccharides units unite to form a disaccharide, through a glycosidic linkage.

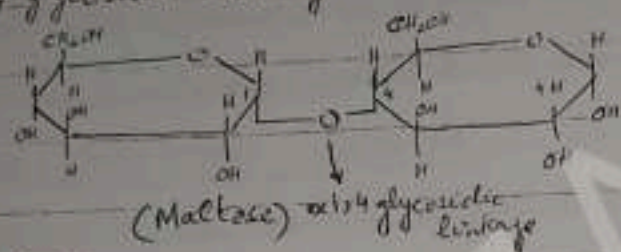
On hydrolysis a disaccharide give 2 monosaccharide units.

Important monosaccharides are

- (i) Maltose
- (ii) Sucrose
- (iii) Lactose.

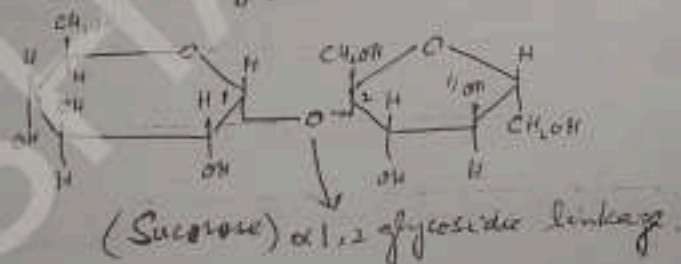
(i) MALTOSE: It is formed by the glycosidic linkage between one molecule of alpha D-glucose with another molecule of alpha

D-glucose with the elimination of water molecule. It is formed by digestion of starches. It is present in various baby foods. Carbon 1 of one alpha D-glucose is attached to carbon 4 of another D-glucose through an oxygen bridge. Such a linkage is termed α -1,4 glycosidic linkage.



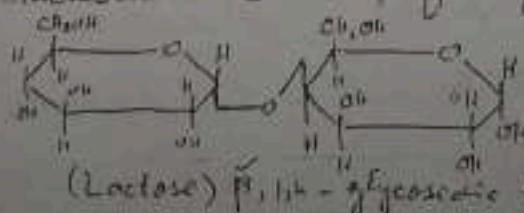
(ii) SUCROSE:

It is a common table sugar. It is also known as cane sugar. It is a disaccharide which on hydrolysis yields 1 mole of each of D-glucose & D-fructose. In its molecule carbon 1 of alpha D-glucose is connected to carbon 2 of beta D-fructose through glycosidic linkage. The linkage is α -1,2 glycosidic linkage.



(iii) LACTOSE: It is called milk sugar. It is also a heterodisaccharide with 2 different monosaccharides units which are glucose & galactose.

D-glucose carbon 1 is attached with carbon 4 of D-galactose through 1,4-glycosidic linkage.



(A) TRISACCHARIDES: These contain 3-monomers. e.g. Raffinose. ($C_{18}H_{32}O_{16}$)

(B) TETRASACCHARIDES: These contain 4-monomers. e.g. Stachyose. ($C_{26}H_{44}O_{21}$)

(iii) POLYSACCHARIDES

"Polysaccharides are the products of condensation of monosaccharides."

PROPERTIES OF

(i) They have

(ii) These are

(iii) One of the

cells, thus

(iv) Another

(v) They are

(vi) On hydrolysis

General

is (C)

oligosaccharides

(a) Homopolysaccharides

(b) Heteropolysaccharides

(a) Homopolysaccharides

type

$\Rightarrow$

STARCH

polysaccharide

glycosidic linkage

(a)

AND POLYSACCHARIDES:

"Polysaccharides are the carbohydrates which are formed by the natural condensation of a very large number of molecules of monosaccharides."

PROPERTIES OF POLYSACCHARIDES:

- (i) They have high molecular weight & are insoluble in water.
- (ii) These molecules can be hydrolysed into simpler sugar.
- (iii) One of the polysaccharide, Starch is storage material of plant cells, thus serve as reservoir of energy.
- (iv) Another polymer, cellulose provides mechanical support to cell walls.
- (v) They are less sweet in taste.
- (vi) On hydrolysis they yield large no. of monomers.

General Formula: General formula is derived from hexoses is $(C_6H_{12}O_5)_n$.

CLASSIFICATION OF POLYSACCHARIDES:

Polysaccharides are of 2 types.

(a) Homopolysaccharides.

(b) Heteropolysaccharides.

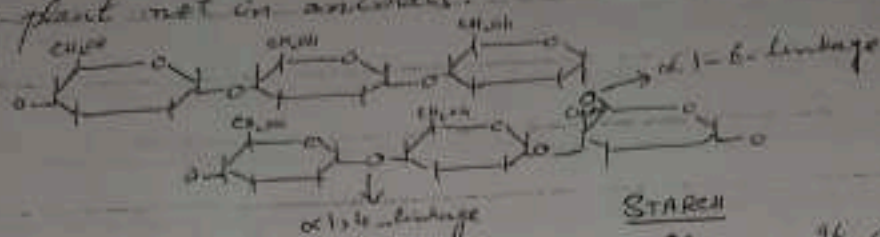
(a) HOMOPOLYSACCHARIDES:

These are polysaccharides which on hydrolysis yield only one type of monosaccharides unit.

⇒ These include Starch, Glycogen, cellulose & dextrins.

STARCH: It is homopolysaccharide of Glucose. We can say that it is a polymer of Glucose in which glucose units are attached via α -1-4 glycosidic linkage (forming straight chain) and α -1-6 glycosidic linkage (at branching point). The straight chain part is called Amorphous.

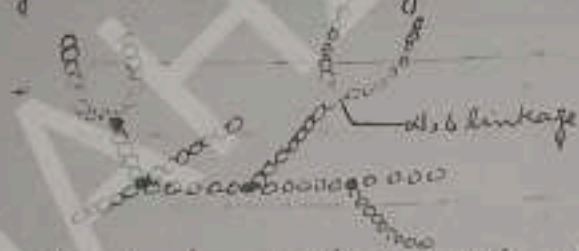
but branching part is called Amylopectin. Starches are formed in plant not in animals.



STARCH

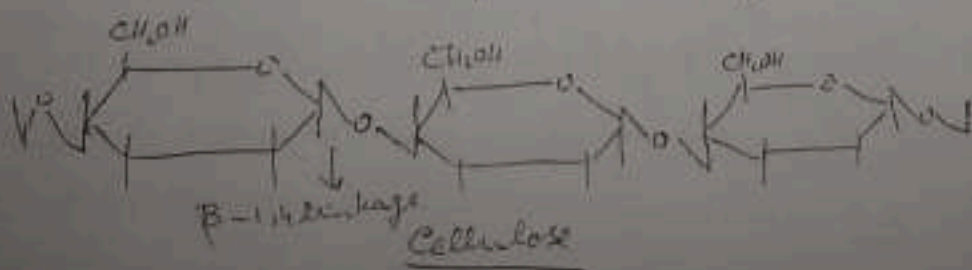
GLYCOGEN: It is homopolysaccharide of Glucose. It resembles in structure with starch. It is also a polymer of Glucose in which glucose units are attached by α -1,4 and α -1,6 linkages. The difference between Starch & Glycogen is that

- 1. Glycogen is storage form of Glucose in animals while Starch in plants.
- 2. Glycogen has extensive branches but not the Starch.
- 3. Glycogen can store more glucose than Starches.



Glycogen

CELLULOSE: It is homopolysaccharide, like glycogen & Starch. It is also polymer of Glucose. It is a straight chain polymer in which glucose units are bonded through β -1,4 linkage, no branch is there. It is not digested in the human GIT because man lacks the cellulose digesting enzyme cellulase. It is chief organic matter in the world and is present mainly in plant kingdom. (cotton, wood)



Cellulose

DEXTRINS: These are the intermediate products in the hydrolysis of starch. Dextrins consists of a very complex mixture of molecules of different sizes & structures. They generally have sweet taste.

(b) HETEROPOLYSACCHARIDES:

These are polysaccharides which on hydrolysis yield two or more different types of monosaccharides unit.

⇒ It can be divided into following subgroups.

(i) Mucopolysaccharides

(ii) Mucilages.

(iii) Hemicellulose.

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(i) MUCOPOLYSACCHARIDES:

These include hyaluronic acid, heparin, chondroitin sulphates, blood group polysaccharides & serum mucoids. These substances, in addition to containing carbohydrate parts, also contain acid groups. Mucopolysaccharides combine with protein to form mucoproteins.

(ii) MUCILAGES:

These include agar, vegetable gums and pectins. All of these are plant origin.

(iii) HEMICELLULOSE:

It is also a heteropolysaccharide occurring in plant kingdom.

DERIVED CARBOHYDRATES:

These are derived from carbohydrates by various chemical reactions.

These include following:

(i) Oxidation Product: Various sugar acids e.g. gluconic acid, glucuronic acid, glucaric acid are derived from glucose on

(29)

its oxidation. Ascorbic Acid (Vit C) is also on oxidation production of Glucose and is produced in the bodies of many animals but not in man.

(ii) Reduction products:

These are polyhydric alcohols e.g. glycerol and ribitol derived from glyceraldehyde & ribose respectively.

(iii) Amino Sugars:

These have $-NH_2$ group at C No-2 and include glucosamine, mannosamine, galactosamine derived from glucose, mannose & galactose respectively.

(iv) Deoxy Sugars:

These have less no of oxygen atoms than other sugars. An important example is deoxyribose that is present in DNA molecule.

In addition to this, carbohydrates are also found in combination. e.g.

Glycoprotein: Carbohydrates & Proteins.

Glycolipids: Carbohydrates & Lipids.

X

X

STRUCTURE OF GLUCOSE

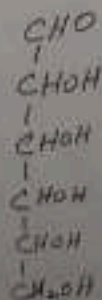
Glucose is one of the most important monosaccharides which plays a very important role in biochemical processes involved in the physiological systems.

The following tests and properties of glucose molecule help to establish its chemical structure.

- (i) When pure sample of Glucose is tested for the detection of elements, it is found that Glucose molecule contains only carbon, hydrogen and oxygen.
- (ii) Quantitative estimation reveals that empirical formula of Glucose is CH_2O .
- (iii) Molecular weight of Glucose was found to be 180 so its molecular formula comes out to be $\text{C}_6\text{H}_{12}\text{O}_6$.
- (iv) Glucose forms an osone with NH_2OH and reduces the Benedict's solution, which shows that glucose molecule contains $>\text{C=O}$ group which may be aldehyde and ketone.
- (v) Glucose forms a pentaacetate with acetic anhydride which indicate the presence of five free hydroxyl groups.

STRAIGHT CHAIN STRUCTURE:

All these facts show that Glucose molecule is a straight chain compound with CHO group on one side and CH_2OH group on other side and thus structure of Glucose is written as



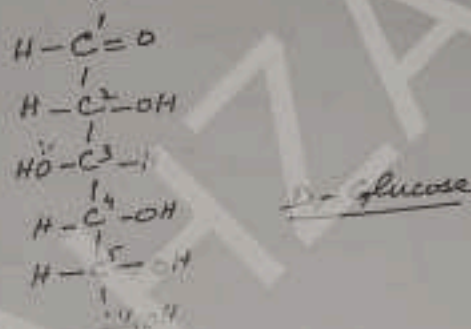
Glucose

Straight chain structure of Glucose has two its stereoisomers.

(a) D-GLUCOSE:

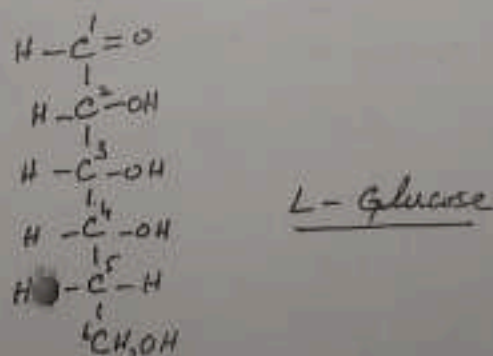
The orientation of H and OH groups around the carbon atom adjacent to the terminal primary alcohol carbon (carbon-5 in Glucose) determines whether sugar belong to D or L series.

When the OH group is attached to the right side of this carbon, then sugar is a member of D-series.



(b) L-GLUCOSE:

When the OH group on C-5 is on the left, it is L-Glucose.



The presence of asymmetric carbon atoms also confers OPTICAL ACTIVITY on the compound. When a beam of plane-polarized light is passed through a solution of an

optical isomer it will be rotated either to the right dextrorotatory (d) (+), or to the left levorotatory L(-). A compound may be designated D(-), D(+), L(-) or L(+).

CYCLIC STRUCTURE OF GLUCOSE :

The following facts about glucose are strong enough to consider glucose as a cyclic compound.

- (i) Glucose does not give certain tests characteristic of aldehyde group. Glucose gives the Benedict's test. This shows that glucose exists partially as an open chain and partially as a cyclic structure.
- (ii) Penta-acetate derivative of glucose does not form an osime with NH_2OH . This means that CHO -group is absent from this glucose derivative.
- (iii) Aldehyde normally react with alcohol (two molecules) to form acetal derivatives but aldehydes react with one molecule of alcohol to form hemiacetal derivatives.
- (iv) It has been observed that ring formed in the glucose by the formation of 1:4 bridge and 1:5 bridge which is the basis of pyranose and furanose structure of glucose.

PYRANOSE STRUCTURE OF GLUCOSE : (i)

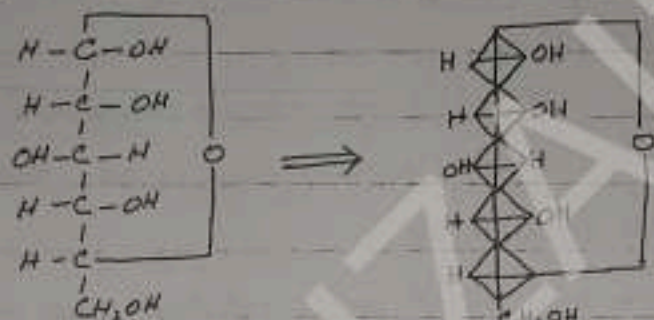
From the structural consideration, it is evident that the sugars are closed chain or cyclic compounds. Due to this reason, the sugars are not represented by old conventional formula. All monosaccharides are considered to be the derivatives of pyran or furan. The structure of pyran is



The Monosaccharides having pyranose structure are also called Pyranoses. Glucose is a derivative of pyran structure. It is obtained by condensing together a certain no. of pyran rings.

FISCHER'S PROJECTION FORMULA :

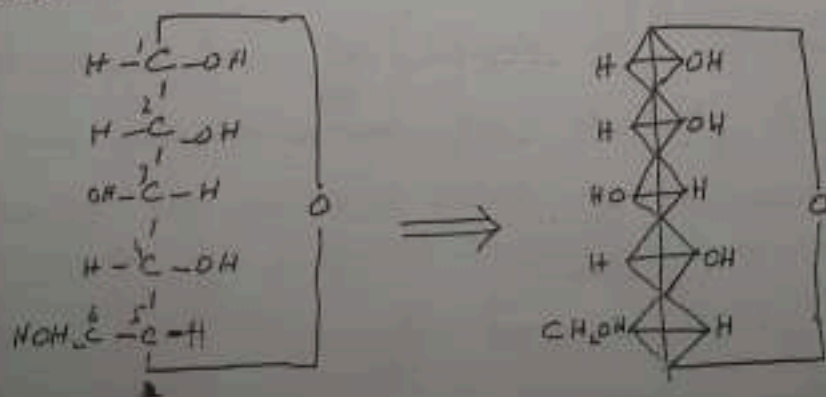
The conventional formula of α -D-glucose is shown below. This formula is known as Fischer's projection formula.



(I) α -D-Glucose

(II)

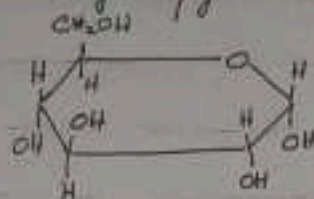
(II) shows the tetrahedral linkages of all the carbon atoms. The tetrahedral representation shows that the point of attachment of oxide ring at C_1 is below and at C_5 is above the plane of paper. On rotating C_5 tetrahedron taking C_5 as centre, the point of attachment of ^{oxide} ring goes below the paper both at C_1 and C_5 . It is shown below.



Fischer's projection formula.

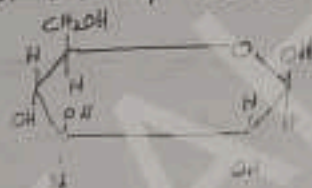
HAWORTH'S PROJECTION FORMULA

All the five carbon atoms and one oxygen atom form a hexagon in the plane of paper and thus form a pyran ring. All the groups which are on the left in fisher's formula are placed above and those on the right are placed below the carbon atoms. Thus the structure formed is called α -D-glucopyranose as shown below.



α -D-glucopyranose

This is called pyranose structure of glucose. As it was proposed by Haworth so it is called Haworth's projection formula. β -D-glucopyranose is obtained by interchanging the H and OH at C₁, as shown below.



β -D-glucopyranose

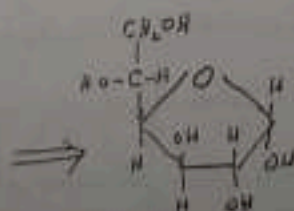
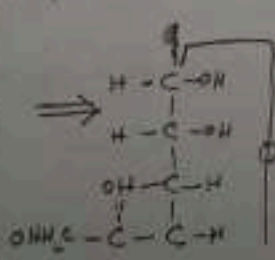
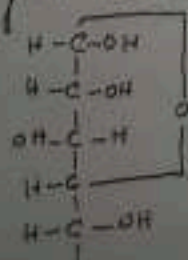
FURANOSE STRUCTURE OF GLUCOSE:

As in the case of pyranose structure, glucose can be considered as a derivative of furan. The structure of furan is as



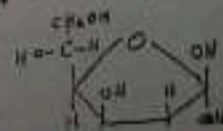
Furan (Five cornered ring)

The structure of α -D-glucofuranose with fisher projection formula are given below.



α -D-glucofuranose

β -D-glucofuranose can be obtained by interchanging H & OH at C₁.



β -D-glucofuranose

FUNCTIONS OF CARBOHYDRATES:

carbohydrates perform a variety of function in the body.

(i) SOURCE OF ENERGY: First and foremost function of the carbohydrate is that they yield a large amount of energy by oxidation in different processes going on at cellular or sub-cellular level. They provide 4.1 Kcal/mole energy.

(ii) MECHANICAL SUPPORT: Cellulose is the most abundant carbohydrate. It is present in the cell walls of plant cells and provide mechanical support to cells.

(iii) NUCLEIC ACIDS FORMATION: Nucleotides are basic building blocks of nucleic acids. A nucleotide consists of 3 parts a nitrogen base, pentose sugar (Ribose or deoxyribose) and phosphoric acid.

(iv) STORED ENERGY: Glucose is utilized for energy but excess of this is stored in the form of glycogen in liver and muscles.

(v) GROWTH MEDIUM: Agar is growth medium for many algae which is also a carbohydrate.

(vi) HORMONES: Some of the hormones are protein and carbohydrate in nature.

(vii) GROWTH OF INFANTS: Mother's milk is rich in carbohydrates which is very important for the growth of infants.

(viii) IMPORTANCE OF GLUCOSE: Glucose is very important carbohydrate. All the carbohydrates are absorbed and eventually of them are converted into glucose in the liver.

(ix) MAINTAIN SUGAR LEVEL: Carbohydrates maintain the sugar level in blood.

DEFINITION:

"These group (NH₂) other side carbon."

Amino

STRUCTURAL

The

Here R

forming ac

NUMBER

in the

A

① Glycine

② Leucine

③ Tyrosine

④ Glutamine

CLASSI

classified

(i) Ess

(ii) Non

AMINO ACIDS

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DEFINITION:

"There are the organic compounds which contain amino group (NH_2) on one side and carboxyl group ($-\text{COOH}$) on the other side bounded to the same carbon atom called alpha (α) carbon."

Amino acids are the building blocks of proteins.

STRUCTURAL FORMULA:

The General formula of an amino acid is given below.



$\alpha \rightarrow$ Alpha carbon

Here R is variable chain length and is different for different amino acids.

NUMBER OF AMINO ACIDS:

Usually 20 different kinds of amino acids are involved in the formation of proteins.

A list of 20 amino acids is as follows.

- (1) Glycine (2) Alanine (3) Serine (4) Threonine (5) Valine
- (6) Leucine (7) Isoleucine (8) Cysteine (9) Methionine (10) Phenylalanine
- (11) Tyrosine (12) Tryptophan (13) Aspartic acid (14) Asparagine (15) Glutamic acid
- (16) Glutamine (17) Lysine (18) Arginine (19) Histidine (20) Proline. $\Rightarrow$ Imino acid (No α carbon)

CLASSIFICATION OF AMINO ACIDS:

Nutritional point of view, amino acids are classified into two groups.

(i) Essential Amino acids.

(ii) Non essential Amino acids.

They are described on the basis of Nutrition. This

(32)

Classification was done by BLOCK & BOLLING.

(1) ESSENTIAL AMINO ACIDS:

These are the amino acids which are not synthesized by the body and they are essential to be supplied through the diet for proper growth.

Essential amino acids are also called INDISPENSABLE.

Names of Essential A.A.: (T.M. Villeplante)

There are 8 essential amino acids which are as follows:

- | | |
|----------------------|--------------------------|
| (1) <u>Threonine</u> | (2) <u>Methionine</u> |
| (3) <u>Valine</u> | (4) <u>Isoleucine</u> |
| (5) <u>Leucine</u> | (6) <u>Phenylalanine</u> |
| (7) <u>Lysine</u> | (8) <u>Tryptophan</u> |

Another amino acid Histidine is essential for infants.

Previously Arginine was also considered essential for infants but now it is not considered so. It is however claimed

that the lack of Arginine in adult causes Oligospermia (deficiency of spermatozoa in semen). These amino acids must be ingested by man.

CLASSIFICATION OF ESSENTIAL A.A:

According to SCHOENHEIMER and others E.A.A are classified into two classes.

(1) Class I includes Leucine and Histidine which continue yield and accept nitrogen. In such amino acids carbon chain is essential but H₂ group can be introduced if required. (LH) (Intercourse)

(2) Class II includes Lysine and Threonine (LT) which form a single essential chemical unit which has to be supplied as such to the animals. Do not take part in nitrogen transfer.

REQUIREMENTS

normal
For Example

adults

SEMI-ESSENTIAL

amongst

can span

(2) ...

by the

Names of

To ...

(1) Glycine

(5) Tyrosine

(1) Hydroxy

in

BIO

(1) T

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a

EXP

Re

REQUIREMENTS OF ESSENTIAL AMINO ACIDS

The requirement of essential amino acids to maintain a normal nitrogen equilibrium is not same at different ages. For example, Infants need 9 amino acids in their diet while adults need 8 amino acid (Histidine not needed)

SEMI-ESSENTIAL AMINO ACIDS

Some authorities include Cystine and Tyrosine amongst semi-essential amino acids because these amino acids can spare methionine and phenyl alanine respectively.

② NON ESSENTIAL AMINO ACIDS

These are the amino acids which are synthesized by the body and their presence in the diet is not essential.

Names of Non-essential A.A.:

Non-essential A.A. includes

To remember $\Rightarrow$ - 1st minor $\Rightarrow$ i-Val - i-Asp - i-Glu - i-His - i-Ile - i-Phe

- ① Glycine
- ② Alanine
- ③ Serine
- ④ Cystine
- ⑤ Tyrosine
- ⑥ Aspartic acid
- ⑦ Glutamic acid
- ⑧ Citrulline
- ⑨ Hydroxy proline
- ⑩ proline

BIOCHEMICAL REACTIONS OF AMINO ACIDS IN THE BODY

BIOLOGICAL PROPERTIES OF AMINO ACIDS

① TRANSAMINATION

Definition: "Transamination is the reaction between an amino acid and a keto acid to interchange their $>NH_2$ and $-C(=O)-$ groups".

Amino Acid $\rightleftharpoons$ Keto-Acid

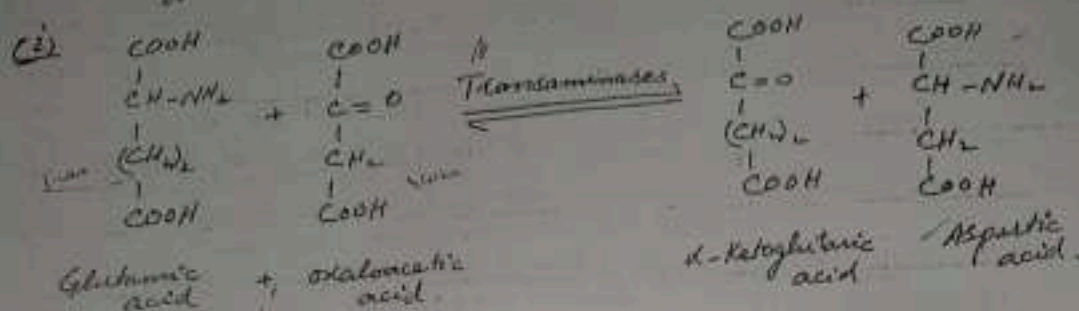
EXPLANATION:

In this an amino acid is decarboxylated to form a keto acid and the NH_2 group liberated from amino acid.

amidates the ketoacid to form an amino acid.

EXAMPLES:

Different examples of Transamination are as follows



The reaction is catalysed by Transaminases present in the animal tissue especially in heart, kidney, liver & brain.

The reaction is reversible and keto acid can be changed into amino acids by reversal of reaction.

IMPORTANCE:

The role of transamination in the metabolism of amino acids and proteins is as follows.

(i) It provides a mechanism for interconversion of amino acids via keto acids.

(ii) It provides a mechanism for transamination.

(2) TRANS METHYLATION:

Definition

"In these reactions, the methyl group of a methyl donor is transferred to other substances which act as methyl acceptors."

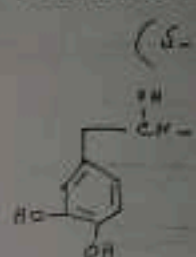
The methyl group which can take part in

the trans methyl group

EXAMPLES:

(i) In trans its -CH₃ group methionine methyl donor not -adenine

Adenosine



(ii) Another of choline

(3) DEAMINATION

Definition

amino acid

keto acid

It

mainly

(i) Oxidative

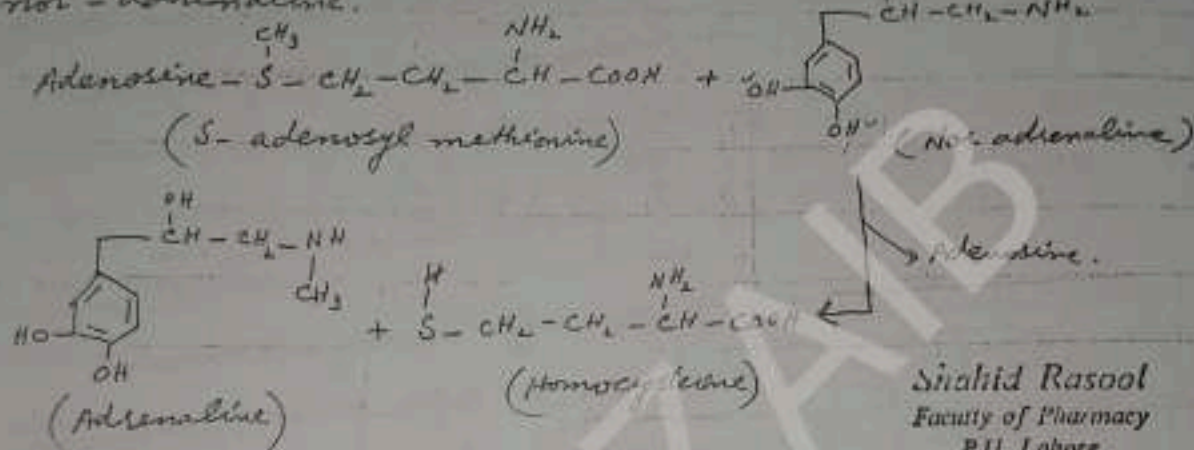
(ii) Non oxidative

(i) -- OXIDATIVE

In the transmethylation reactions is termed as "labile methyl group" and is represented by $\sim\text{CH}_3$.

EXAMPLES:

(i) In transmethylation, methionine can not directly supply its $\sim\text{CH}_3$ group but first it is converted into active methionine i.e. S-adenosylmethionine then it act as methyl donor. e.g. in the formation of adrenaline from nor-adrenaline.



(ii) Another important example of transmethylation is the formation of choline from dimethylaminoethanol and a methyl group.

(3) DEAMINATION: removal

Definition: "It is the removal of NH_2 from an amino acid resulting in the formation of corresponding keto acid."

It mainly takes place in liver. It is of two main types.

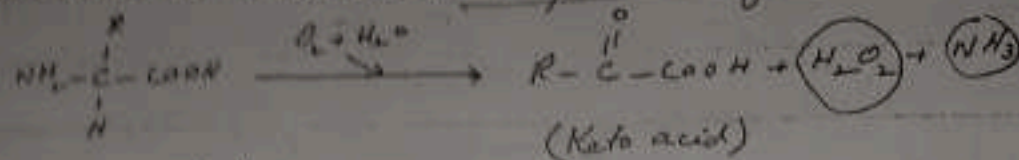
(i) Oxidative deamination.

(ii) Non oxidative deamination.

(i) OXIDATIVE DEAMINATION:

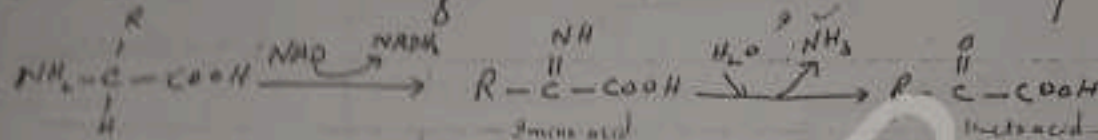
This process is catalysed by enzymes called

Amino acid oxidases in the presence of O_2 .



(Amino acid)

Some amino acids (e.g. Glutamate acid) are deaminated by amino acid dehydrogenases enzymes and not by oxidases. An IMINO ACID is formed as an intermediate product.



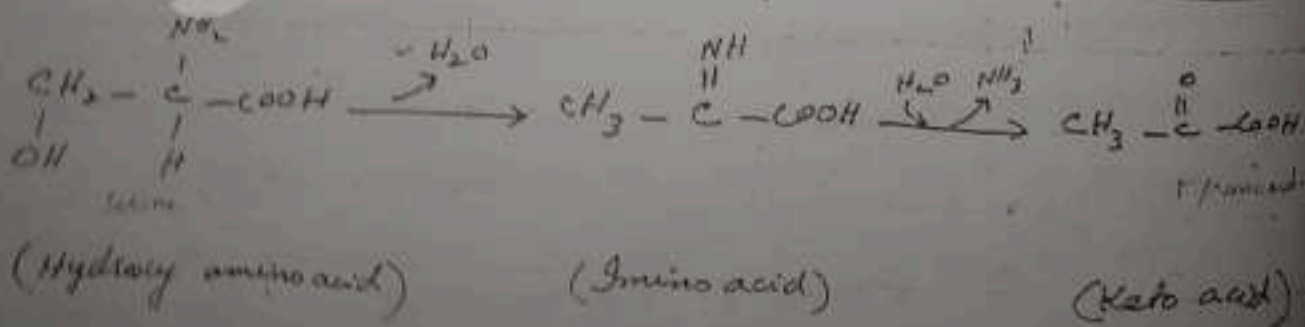
Another type of oxidative deamination involves specific amino acid oxidases. e.g. Glycine is deaminated by the enzyme Glycine oxidase.



dehydrogenase

NON OXIDATIVE DEAMINATION:

The hydroxy amino acids i.e. Serine and threonine are deaminated by specific enzymes called dehydrogenases which catalyze the removal of H_2O from their molecules. This is followed by spontaneous deamination.



PROTEINS:

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MEANINGS:

The word "Protein" has been derived from Greek word "proteios" which means first formed compound.

DEFINITION:

Proteins are the complex nitrogenous compounds which are formed by the condensation of large no. of amino acids through peptide bond.

Proteins are composed of C, H, O, N in addition to that some proteins contain S & P.

PEPTIDE BOND:

"The bond formed between the α -NH group of one amino acid and C of COOH group of another amino acid by the elimination of water molecule is called peptide bond."



CLASSIFICATION OF PROTEINS:

Proteins are classified into three main classes which are further subdivided into subclasses.

- i) Simple proteins.
- ii) Compound or conjugated proteins.
- iii) Derived proteins.

1) SIMPLE PROTEINS:

These are the proteins which on hydrolysis yield only amino acids or their derivatives. They are further classified into following classes:

HISTONES:

They are soluble in H_2O . (ii) They are insoluble in NH_3 .
 (iii) They are not coagulated by heat. (iv) They are rich in arginine
 these in combination with DNA form nucleoprotein more
 exactly nucleohistones which occur in cell nuclei forming
 chromatin material. (vi) They are basic proteins.

Examples: Globin of Haemoglobin, Thymus histones.

PROTAMINES:

(i) They are soluble in H_2O . (ii) They are basic proteins and
 resemble histone. (iii) These are present in sperm cells.

Like histones, they form nucleoproteins.

They are rich in Arginine.

Examples: Salmine of Salmon sperm, Protamine of other species.

GLOBINS These are rich in histidine but they are not basic.

These proteins unite with haem to form Haemoglobin.
 Haemoglobin of different species differ only with
 respect to globins and haeme part is the same in all cases.

ALBUMINIDES:

(i) They are also called as scarcely proteins.

(ii) They are soluble in H_2O . (iii) They are found in animals.

(iv) They are soluble in dil. sol. of acids and alkalis.

Examples: Keratin of hair, Horn hoof, Nails, Collagen of bone, silk etc.

COMPOUND OR CONJUGATED PROTEINS:

These are the proteins which are conjugated with
 some non-proteinous substance called as prosthetic group
 and are of great importance.

Different classes of this type are given below.

(1) NUCLEO PROTEINS: These are composed of simple protein and nucleic acid. These are obtained as the products of glandular tissue and from sperm oil.
 Examples: Nucleohistone, Nucleoprotomere.

(2) LIPO PROTEINS: These are composed of simple protein and lipids such as lecithin, caplain, fatty acid etc.
 Examples: Lecithoprotein, See Lecithoprotein.

(3) PHOSPHO PROTEINS: These are composed of simple protein and phosphate containing substances such as lecithin, caplain.
 Examples: Casein of milk and Vitellin of egg yolk.

(4) CHROMO PROTEINS: These are composed of simple protein and a coloured prosthetic group.
 Examples: A few important examples of chromoproteins with their prosthetic groups are given below.

- (i) Haemoglobin ✓ Haeme
- (ii) Cytochromes ✓ Haeme
- (iii) Flavoprotein ✓ Riboflavin
- (iv) Catalase ✓ Haeme

(5) METALLO PROTEINS: These are composed of simple proteins and metal containing prosthetic group. Common metals are Fe, Co, Mn, Zn & Mg.
 Examples: Haemoglobin, Cytochromes.

(6) GLYCO PROTEINS: These are composed of simple proteins and carbohydrates through glycoside linkage.
 Examples: Mucin of saliva, Albumin of egg, Globulin of blood.

(7) MUCO PROTEINS: These are composed of simple proteins and mucopolysaccharides.
 Examples: Gonadotropic hormones such as Interstitial cell stimulating hormone (ICSH), Follicle stimulating hormone (FSH).

DERIVED PROTEINS:

These are the proteins which are derived from simple and conjugated (compound) proteins.

Derived proteins are further classified into primary derived proteins & secondary derived proteins.

(a) PRIMARY DERIVED PROTEINS: No. Hydrolytic Cleavage Occurs.

These are the derived proteins in which there is no or little hydrolytic cleavage of peptide bond or in these are further divided into following subclasses. ^{These are 1. conjugates with water protein.}

(i) Proteins: These are formed by the action of water & acids and enzymes on simple and conjugated proteins in a short time.

Examples: Myosin obtained from myosin.

(ii) Metaproteins: These are formed by further action of acids and alkalies on simple proteins. They are generally soluble in acids and alkalies.

Examples: Acid albuminates & alkali albuminates.

(iii) Coagulated Proteins: These are the product of coagulation of proteins by action of heat. They are actually denatured proteins and denaturation takes place due to loosening of structure.

Examples: Cooked meat (e.g. albumin), cooked meat protein, Fried Egg.

(b) SECONDARY DERIVED PROTEINS: Hydrolytic Cleavage Occurs

These are the derived proteins in which there is hydrolytic cleavage of peptide bond occur. They are further classified into following groups.

(i) Proteoses: They are soluble in water. They are not coagulated by heat. They are precipitated from their sol. by saturation with ammonium sulphate. The mol. with large mol. wt. are called as Primary Proteoses & molecules with smaller mol. wt. are called as Secondary Proteoses.

(ii) Peptones: They are of simple structure than proteins. They are soluble in H₂O. They are not coagulated by heat. They are not precipitated by ammonium sulphate. They are precipitated by phosphotungstic acid.

(iii) Peptides: These are the condensation products of two or more than two amino acids through peptide bond. They are called "dipeptides", "tripeptides" and "tetrapeptides" depending upon the no. of amino acids in them. They are also referred as "POLYPEPTIDES". The hydrolysis of protein is given as:



* LEVELS OF STRUCTURAL ORGANIZATION OF PROTEINS

Proteins are made up of amino acids which are linked to each other through peptide bond.

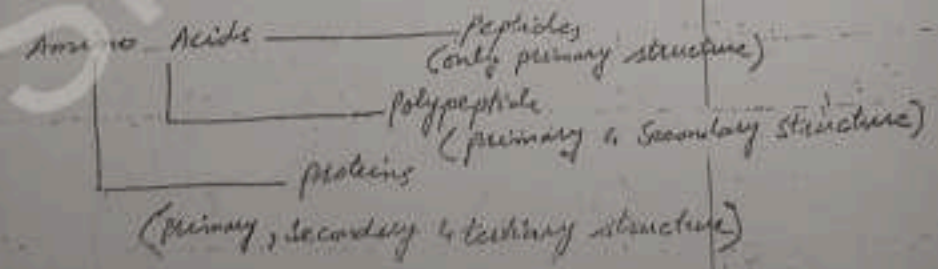
Proteins assume at least three levels of structural organization. These are known as P. S. T. O.

- (i) Primary Structure
- (ii) Secondary Structure
- (iii) Tertiary Structure

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Some proteins also possess a fourth structure called quaternary structure.

BY GENE OPERATION



PRIMARY STRUCTURE:

The sequence of amino acids along the peptide chain is called the primary structure of the peptide.

... of peptide ... amino acids ...
... the total no. of ...
... amino acids ...
... primary structure ...
... the number ...
... from the amino ...
... primary structure of ...
... are given ...
... OF INSULINE ...
... Insulin has 51 ...
... in two chains, C ...
... contains 30 amino ...
... disulphide linkage ...
... at 6' ...
... linkage. The ...
... OF HAEMOGLOBIN ...
... Hemoglobin ...
... four chains ...
... amino acids and ...

EXPLANATION: There are 20 amino acids which enter into the formation of peptide through peptide bond. The formation of peptide from amino acids can be compared with the formation of words from alphabets.

✓ The total no. of amino acids, type of amino acids and sequence of amino acids give rise to the primary structure of proteins.

⇒ The primary structure of proteins is regulated by respective genes on specific chromosomes. By convention the numbering of amino acid in a peptide chain starts from the amino acid containing free -NH group.

EXAMPLES:

The primary structure of large no. of proteins has been found. Some of them are given below.

Insulin → 51 ✓

Oxytocin → 9 ✓

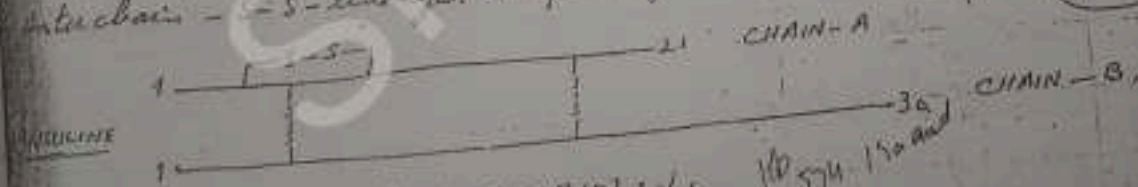
Haemoglobin → 54 ✓

Gluconic acid → 29 ✓

51 ✓

STRUCTURE OF INSULINE:

Insulin has 51 amino acids of 16 different kinds arranged in two chains, chain A contains 21 amino acids while chain B contains 30 amino acids. The two peptide chains are linked through disulphide linkage (-S-S-) to each other. Chain A has an interchain -S-linkage. Its primary structure was found by SANGER.



STRUCTURE OF HAEMOGLOBIN: ✓ 110 574 150 and 141 amino acids
Haemoglobin has 574 amino acids of 19 kinds. There are four chains in Haemoglobin. Two alpha chains each containing 141 amino acids and two beta chains each containing 146 amino acids.

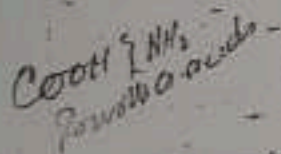
SECONDARY STRUCTURE:

The primary structure of protein shows that peptide chains are quite straight and extended. But X-ray diffraction experiments on peptides show that polypeptide chains tend to twist or coil upon themselves in a characteristic manner.

The folding of the polypeptide chain into a specific folded structure held together by hydrogen bond is called the secondary structure.

Secondary Structure includes (i) α helix structure (ii) β -pleated structure

① α -HELIX STRUCTURE: It is a clockwise spiral and is formed by linking the chains through H-bonding which is formed between the -COOH group of an amino acid and -NH₂ group of amino acid that is situated 4 amino acids ahead i.e. amino acid no. 1 forms bond with 4, 2 with 5 & 3 with 6 and so on.



H-bonds



α -helix structure.

Advantages

The helical structure give stability to peptide molecule. Proteins containing alpha helix show great strength and elasticity. The helix may be right handed or left handed coiled but right handed helix is more stable.

② β -PLEATED STRUCTURE:

This is not very common and is found in some proteins including globulin and fibrous proteins. This is also formed due to H-bonding.

It is of two types.

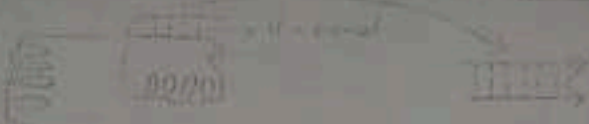
(i) Parallel β -pleated

(ii) Antiparallel β -pleated.

X-ray Diffraction

Protein p-phenol

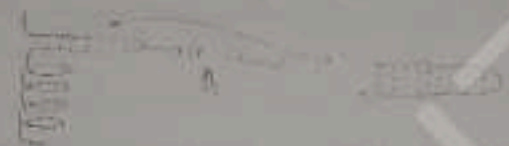
In protein p-phenol structure of chain is too long
hydrophobic side of the chain protein molecule are parallel
each other and hydrogen bonds are formed between them.



(Protein p-phenol structure)

(ii) Anticancer p-phenol

In anticancer p-phenol structure of chain is too long
hydrophobic side of the chain protein molecule are parallel
to each other and hydrogen bonds are formed between them.



(Anticancer p-phenol structure)

Protein structure is shown as a zigzag line with side chains. The side chains are represented by small circles. The zigzag line represents the backbone of the protein.

The structure of the protein is shown as a zigzag line with side chains. The side chains are represented by small circles. The zigzag line represents the backbone of the protein.

The structure of the protein is shown as a zigzag line with side chains. The side chains are represented by small circles. The zigzag line represents the backbone of the protein.



Tertiary structure of myoglobin.

The tertiary structure is mainly maintained by the following factors:

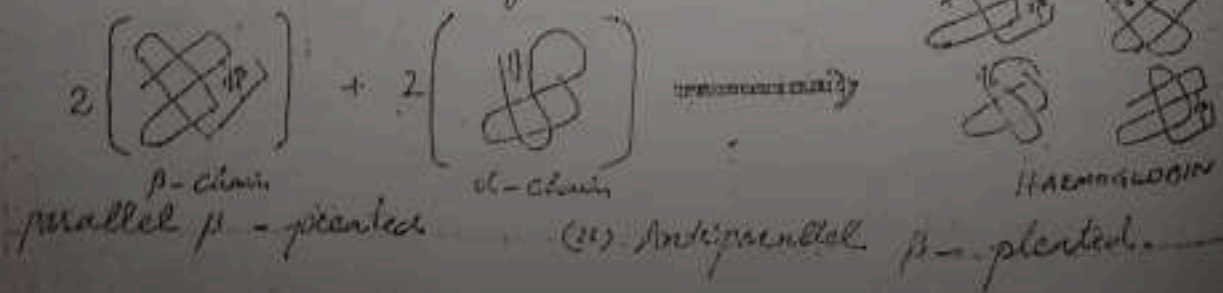
- (i) The disulphide linkage - S-S- between the polypeptide chains stabilize it.
- (ii) The ester linkage between a carboxyl group and hydroxyl group on two different amino acids.
- (iii) The attraction between the negatively charged amino group and positively charged amino group of amino acids.
- (iv) Vander Waal's forces between non-polar side chains of amino acids also provide stability to the molecule.

④ QUATERNARY STRUCTURE:

"The Quaternary structure is the manner in which the protein subunits called proteins fit into each other to form polymers." proteins subunits proteins combine to form polymers. Quaternary

This is seen in those cases in which a protein molecule is made up of more than one peptide chain subunits, each of which has its own primary, secondary and tertiary structure.

EXAMPLES: (i) STRUCTURE OF HAEMOGLOBIN: Haemoglobin has four peptide chains. Two α chains each containing 146 amino acids and two β chains each containing 146 amino acids. The way, these four subunits polymerize to form Haemoglobin is called its Quaternary structure.



the only assembly of represents



DEFINITION:

of two or more

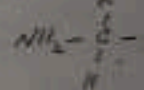
PEPTIDE BOND

of one amino acid by

PEPTIDE C

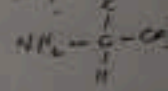
DIPEPTIDE

peptide



TRIPEPTIDE

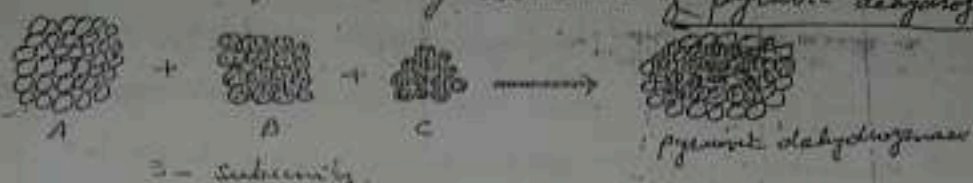
peptide



POLYPEP

through

The enzyme pyruvate dehydrogenase is produced by the assembly of 3 subunits. Their association with each other represents the quaternary structure of pyruvate dehydrogenase.



PEPTIDES

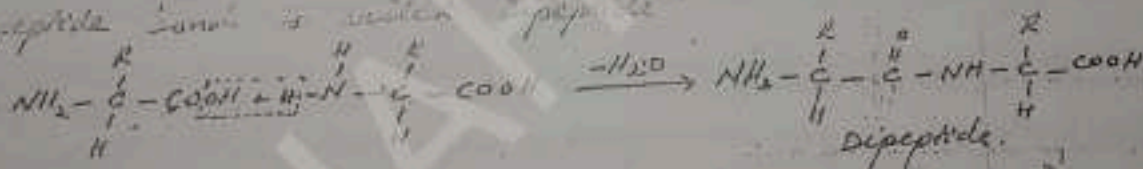
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Faculty of Pharmacy
P.U. Lahore

DEFINITION: "Peptides are the compounds formed by the condensation of two or more than two amino acids through peptide bond."

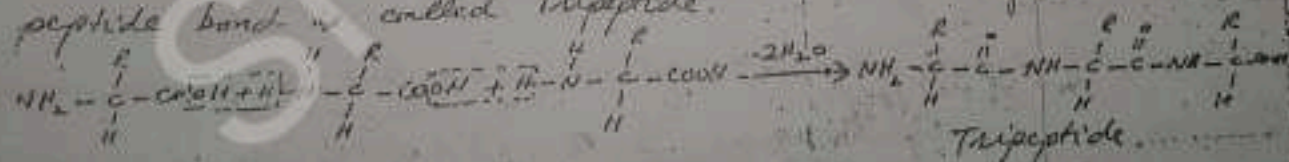
PEPTIDE BOND: "The bond formed between the N of $-NH_2$ group of one amino acid and C of $-COOH$ group of another amino acid by the elimination of H_2O molecule is called Peptide Bond."

PEPTIDE CHAIN: "A chain consisting of peptide bond between amino acids."

DIPEPTIDE: "A chain containing two amino acids and one peptide bond is called peptide."



TRIPEPTIDE: "A chain containing three amino acids and two peptide bond is called Tripeptide."



POLYPEPTIDE: "A chain containing many amino acids linked through peptide bond is called polypeptide."

They are described on the basis of Nutrition. This

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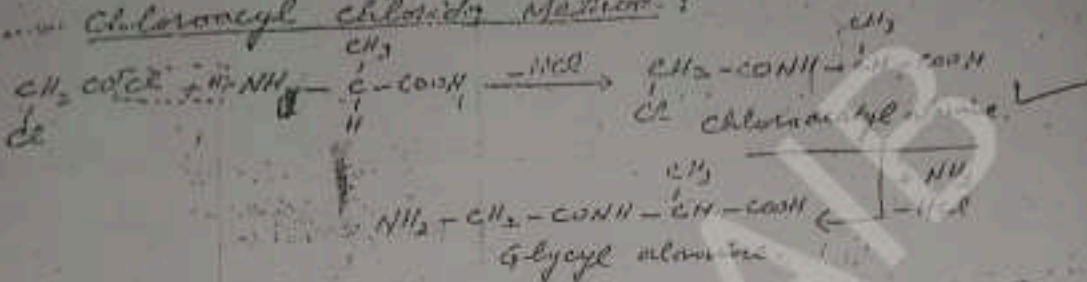
Faculty of Pharmacy

P.O. Lahore

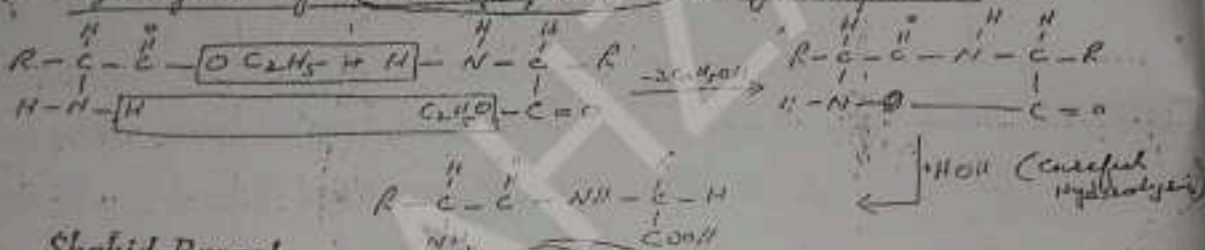
LABORATORY SYNTHESIS OF PEPTIDES

Biochemists have failed to synthesize naturally occurring protein in vitro but they have been able to synthesize a few polypeptide hormones. A few methods are given below:

(1) Chloranil Chloride Method:



(2) Hydrolysis of Diketopiperazine Ring Compound:



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BIOLOGICAL IMPORTANCE / SIGNIFICANCE OF PROTEINS: (FUNCTIONS OF PROTEIN)

- ① Source of energy: 1g = 0.1 kcal energy when oxidized in body.
- ② Hereditary function: Nucleoprotein.
- ③ STRUCTURAL PROTEIN: Cell membranes.
- ④ STORAGE PROTEIN: Egg, Milk, Wheat.
- ⑤ Enzymes: All enzymes are protein in nature and play important role without them life will not possible.
- ⑥ Hormones: Chemical messengers e.g. Insulin.
- ⑦ Antibodies: play important role in immunity as protein.
- ⑧ Clotting of Blood: Fibrinogen (clotting protein).
- ⑨ Respiration: Haemoglobin carry O_2 & CO_2 .
- ⑩ Contractility: Actin & Myosin (contractile protein).
- ⑪ Toxins: Most of proteins are toxins & are secreted by microorganisms.
- ⑫ Pathological importance: proteins are integral part of all viruses which are very important from pathogenic point of view.

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DEFINITION:

"These are water but benzene, acet"

Lipids

(b) Simple

(ii) Com

(iii) Der

(1) SIMPLE

"A

Simple

Simple

(a) Fats &

(a) FATS &

"ster

Fats &

A new

of trigl

Fa

C

C

C

C

C

C

(b) WAXE

"The

DEFINITION:

"These are the substances which are sparingly soluble in water but readily soluble in organic solvents e.g. chloroform, benzene, acetone etc."

CLASSIFICATION OF LIPIDS

Lipids are classified into following three types.

- (i)..... Simple lipids.
- (ii)..... Compound lipids.
- (iii)..... Derived lipids.

(1) SIMPLE LIPIDS:

"Esters of fatty acids with α -alcohol are called Simple lipids."

Simple lipids are again subdivided into two groups.

- (a) Fats or oils
- (b) Waxes.

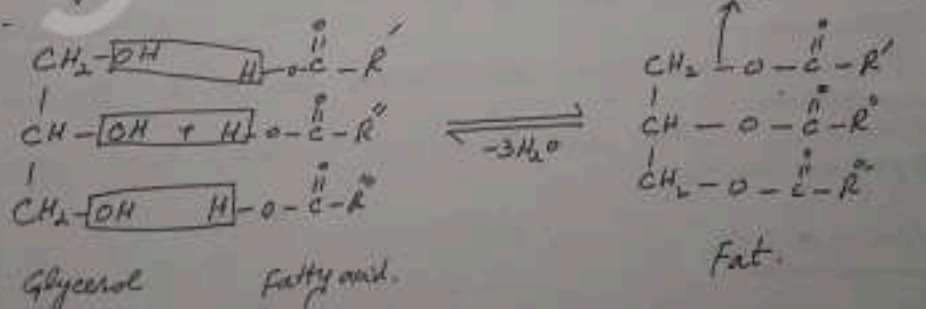
(a) FATS & OILS:

"Esters of fatty acids with glycerol are called Fats."

Fats are also called as Neutral Fats or Triglyceride.

A new term triglycerol is being used now a days instead of triglyceride.

Fatty acid + Glycerol $\longrightarrow$ Fat.



(b) WAXES:

"These are the esters of fatty acids with alcohol other than glycerol."

(30)
The most important constituent alcohol of the molecules of waxes is the cholesterol e.g. Bees wax.

Waxes are commonly known as "Lubricants".

SIGNIFICANCE: Waxes are of great importance.

- (i) They serve as protective coatings on the surface of animals & plants.
- (ii) They protect plants from water loss.
- (iii) Skin and feathers are not wetted due to wax.
- (iv) Many fruits are prevented from infections.
- (v) Industrial waxes are commonly called Lubricants e.g. candle, Crutone.

(3) COMPOUND LIPIDS:

These are also known as complex lipids.

"These are the esters of fatty acids containing groups in addition to alcohol and fatty acids."

Other groups are phosphoric acid, Nitrogen Bases and

many other groups.

Compound lipids are divided into following types.

- (i) ... phospholipids.
- (ii) ... Glycolipids.
- (iii) ... Sphingolipids.
- (iv) ... Gangliosides.
- (v) ... Lipoproteins.
- (vi) ... Lipopolysaccharides.



(i) PHOSPHOLIPIDS:

These lipids have fatty acid, alcohol and phosphoric acid. We can say that these are esters of fatty acids with an alcohol which is generally glycerol and rarely sphingosine and a phosphoric acid is attached to it.

These are

phospholipids
below



Phospholipids

(i) Glycolipids

(ii) Sphingolipids

(iii) GLYCEROL

glycerol

as in

Glycerol

(a) Phospholipids

(b) Phospholipids

(c) Phospholipids

(d) Phospholipids

(e) Phospholipids

(f) Phospholipids

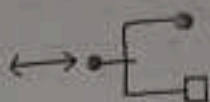
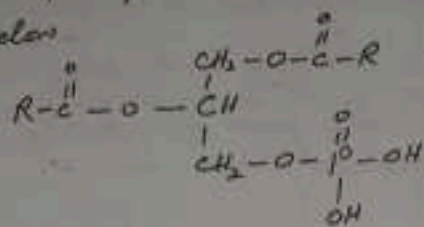
(a) Phospholipids

as in

Nitrogen

These are richly found in brain and nerves.

Phosphatidic Acid is the mother compound of phospholipids. The structure of phosphatidic acid is given below



● = Fatty acid chain
 □ = phosphate acid.

phosphatidic acid

Phospholipids are of 2 types.

(i) Glycerophospholipids.

(ii) Sphingophospholipids.

(i) GLYCEROPHOSPHOLIPIDS: These are phospholipids which have glycerol as alcohol. These occur in all cells plants as well as in animals. They are not fully soluble in water.

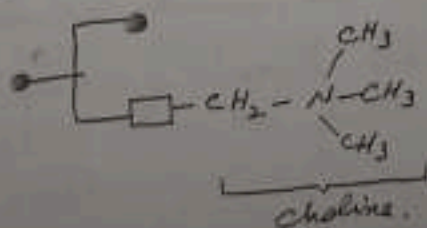
Glycerophospholipids include:

- Phosphatidyl Choline.
- Phosphatidyl Ethanolamine.
- Phosphatidyl Serine.
- Phosphatidyl Threonine.
- Phosphatidyl Inositol.
- Plasmalogen.

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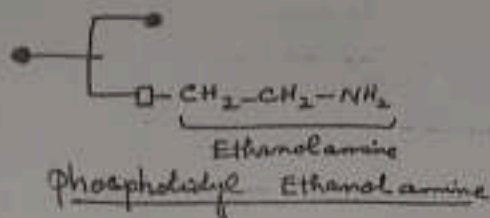
(C#ST.11)

(a) PHOSPHOTIDYL CHOLINE: It is also known as lecithin. It is mainly found in association with cell membranes. In it, Nitrogen base choline is attached with phosphatidic acid.

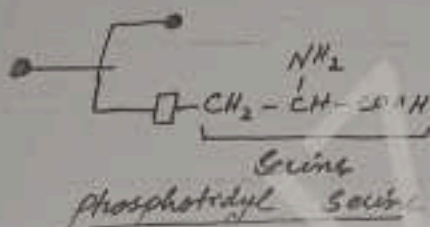


phosphatidyl choline

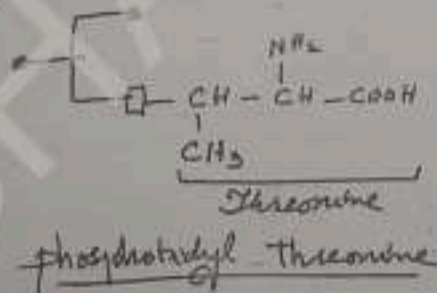
(b) PHOSPHOTIDYL ETHANOLAMINE: It is also known as cephalin and differs from phosphatidylcholine only that ethanolamine replaces choline. It act as 2nd messenger and present in smooth muscle cell membrane. They take part in clotting of blood.



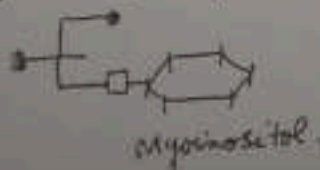
(c) PHOSPHOTIDYL SERINE: These are present in skeletal muscle and act as 2nd messenger. In it serine is attached with phosphoric acid.



(d) PHOSPHOTIDYL THREONINE: These are also found at neuromuscular junctions in relation with phosphatidyl Serine.



(e) PHOSPHOTIDYL INOSITOL: In muscles alcohol can be derived in the form of Myo-inositol. Inositol is stereoisomer of Myoinositol.

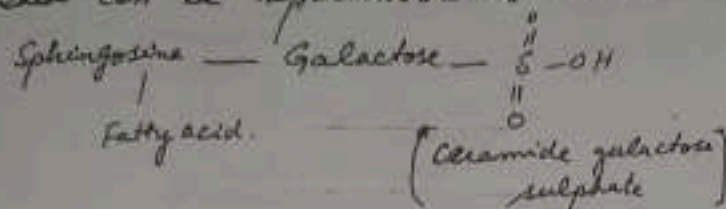


(f) PLASMALEGEN: These constitute about 10% of phospholipids of brains and muscles. Structurally there is an ether linkage.

(iii) SULPHOLIPIDS:

These contain sphingosine, a fatty acid and a sulphated hexose. They also occur in white matter of Brain.

These can be represented as below.

(iv) LIPOPROTEINS:

These are also called complex compounds. These are lipids containing proteins. They may be water soluble or fat soluble. These are very huge in structure and carry lipids from one place to other. This is also present in membrane of mitochondria, endoplasmic reticulum and nucleus.

(i) LIPOPOLYSACCHARIDES:

The exact chemical nature of these compounds is not known. They occur in the cell wall of some bacteria. β -hydroxy myristic acid occurs in some of them in addition to glucosamine and phosphate groups.

DERIVED LIPIDS

These are substances which are either derived from simple or compound lipids by their oxidation or any other mechanism. These include: Fatty acids, Steroids, Terpenoids, cholesterol etc.

STERIODS: The common steroids of animal cells are the sex hormones, Vit. D and bile acid.

TERPENOIDS: These are very large and important group of compounds. They are formed by repeating units called isoprenoid units. e.g. Rubber, Terpenoids etc.

Definition:

"These are carbonyl group at the end of"

EXPLANATION:

Fatty acid. All the neutral

1-12

13-18

19-20

are in

small

in the

carbon

fat

(i) Saturated

(ii) Unsaturated

(iii) Bile

(iv) Cy

(v) H

(vi)

FATTY ACIDS

Definition:

"These are water insoluble, long chain hydrocarbons having carbonyl group on one end and methyl group on the other end of the chain."

EXPLANATION:

Fatty acids in human body are of great variety. All the Fatty acids are building blocks of lipids including neutral fats, phospholipids, glycolipids, cholesterol, waxes etc.

Fatty acids having carbon atoms from 1-12 are called short chain fatty acids.
13-18 are called moderate chain fatty acids.
19- ∞ are called long chain fatty acids.

In the body short chain fatty acid with 2 carbon are in abundance and with 4, 6 and 8 are present in very small amount. Moderate chain fatty acids are also in abundance in human body. The most frequent is 16 carbon palmitic acid.

CLASSIFICATION OF FATTY ACIDS

Fatty acids are classified according to the no. of carbon atoms present in it.

Fatty acids are classified as

- (i) Saturated Fatty acids.
- (ii) Unsaturated Fatty acids.
- (iii) Branched chain fatty acids.
- (iv) Cyclic fatty acids.
- (v) Hydroxy and ketoderivatives.

(1) SATURATED FATTY ACIDS:

These are the fatty acids which contain only

single bond and no double bond is present."

The saturated fatty acid usually contain even no. of carbon atoms. However some fatty acids having odd no. of carbon atoms have also been discovered in plants and also in animal fats.

The most common member of even carbon fatty acid is palmitic acid found in great extent in every fat.

Examples:

Name	Formula	Symbol
Butyric acid	C_4H_8COOH	4:0
Palmitic acid	$C_{16}H_{32}COOH$	16:0
Stearic acid	$C_{18}H_{36}COOH$	18:0

The symbol has two no. first is the no. of C-atoms and second is no. of double bonds.

* NON ESSENTIAL FATTY ACIDS:

From dietary point of view, saturated fatty acids are synthesized by human body. $\therefore$ they are not so essential as unsaturated. So they are called Non-essential fatty acids. Saturated Fatty acids $\rightarrow$ Non essential.

(2) UNSATURATED FATTY ACIDS:

These are the fatty acids which contain one or more double bond. Thus they are more reactive than saturated fatty acids. They are further classified as

(a) Monoenoic: These have only one double bond in their structure e.g. Oleic acid $C_{17}H_{33}COOH \Rightarrow 1\Delta 9$

The symbol Δ represent double bond. 1 means one double bond at carbon no. 9.

(b) Di-Enoic: These have two double bonds in their structure e.g. Linoleic Acid $C_{18}H_{32}COOH$

(c) Tri-Enoic: These have three double bonds in their structure.
e.g. Linolenic acid $C_{11}H_{21}COOH$

(d) Poly-Enoic: These have more than three double bonds.

* ESSENTIAL FATTY ACIDS:

From dietary point of view, unsaturated fatty acids must be taken by human because these fatty acids cannot be synthesized in the body. So they are very essential that is why they are called Essential fatty acids.

There are three (3) essential Fatty acids.

(i) Linoleic acid (ii) Linolenic acid (iii) α -linolenic Acid.

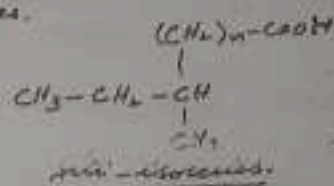
(3) BRANCHED CHAIN FATTY ACIDS:

In these fatty acids, the branched chain are present. Branched chain fatty acids are more often present in waxes than fat. These are further divided into two classes.

(i) Isoseries.

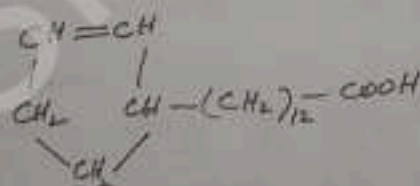


(ii) Anti-isoseries.



(4) CYCLIC FATTY ACIDS:

Fatty acids having cyclic structure are rare but have been identified to be present in certain seed oils. The ring structure is at the end of fatty acid chain:



Tri-Decanoic Acid

(5) HYDROXY AND KETO DERIVATIVES:

The hydroxy derivatives of C_2 , C_3 and C_4 fatty acids do not exist to an appropriate extent in lipids. Many hydroxy derivatives of higher acids are known.

PHYSICAL PROPERTIES OF FATTY ACIDS:

(2) MELTING POINT:

The melting point of fatty acids depend upon the chain length and degree of unsaturation.

Chain length: The longer is the chain, the higher is melting point and vice versa. e.g. The melting point of butyric acid is -8°C while the melting point of palmitic acid is 62°C and 70°C for stearic acid.

Unsaturation: The greater the no. of double bond, the lower the melting point. e.g. The melting point of oleic acid is 14°C while Linolenic acid have -10°C .

That is why the acids with small chain length and with high unsaturation are generally liquids at room temperature.

(3) SOLUBILITY:

Solubility of fatty acids in water also depend upon the chain length and degree of unsaturation.

(i) CHAIN LENGTH: The solubility of fatty acids decreases with increase in chain length. e.g. Butyric acid is more soluble than palmitic acid.

(ii) DEGREE OF UNSATURATION: Solubility of fatty acids increases with increase in double bond. e.g. palmitoleic acid is more soluble than palmitic acid.

(3) ISOMERISM OF FATTY ACIDS:

It is of several types.

(a) Saturated Fatty acid: There may be straight chain or branched.

e.g. $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{COOH}$
(Normal butyric acid)

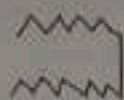
$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH} - \text{COOH} \\ | \\ \text{CH}_3 \end{array}$ (Isobutyric acid)

(i) UNSATURATED FATTY ACIDS

For unsaturated fatty acids, the isomerism is of two types.

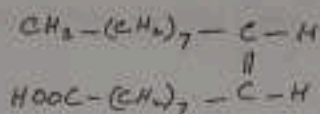
(a) CIS - ISOMERISM:

These chains have a turn on the same side as shown



Cis-form.

e.g. Structure of Cis oleic acid is as follows.



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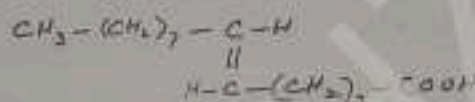
(b) TRANS - ISOMERISM:

These chains have a turn on opposite side as shown.



Trans-form

e.g. Structure of Trans oleic acid is as follows.

CHEMICAL PROPERTIES OF FATTY ACIDS:(1) FORMATION OF SALT:

Fatty acids when reacted with alkalis form their salts.



SOAP: Metallic salts of higher fatty acids are called

Soap. These may be the salts of sodium, potassium, Mg & Ca.

Sodium and potassium salts are soluble and are good emulsifying agents, while Mg and Ca salts are insoluble in water.

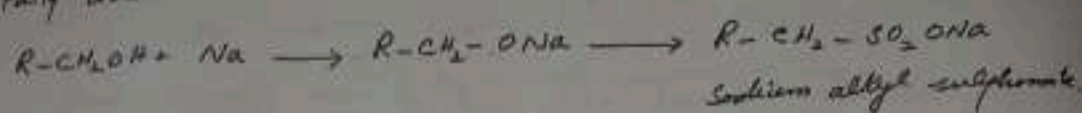
(2) FORMATION OF DETERGENTS:

~~from~~ Reduction of carbonyl group of fatty acids

produces alkyl alcohols which can be sulphated or sulphonated to form alkyl sulphates or sulphonates which act as "Detergents".



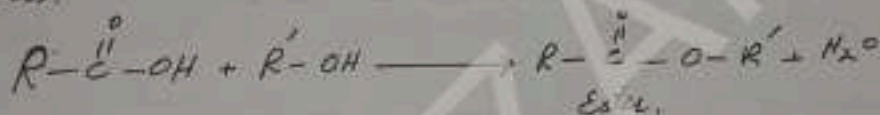
Fatty acid



Unlike soaps the detergents are stable and do not form insoluble salts with Ca & Mg .

(3) FORMATION OF ESTERS:

When Fatty acids react with alcohol, they form esters.



(4) FORMATION OF PROSTAGLANDINS:

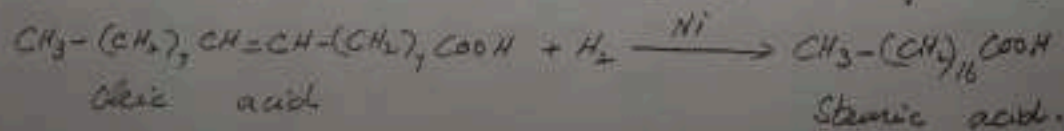
Prostaglandins are derivatives of a 20-C unsaturated fatty acid termed the prostanoic acid. They possess very important physiological properties.

(5) RANCIDITY:

Rancidity is a chemical change that results in an unpleasant odour and taste in fats. The oxygen of air is believed to attack the double bond in fatty acids to form a peroxide linkage.

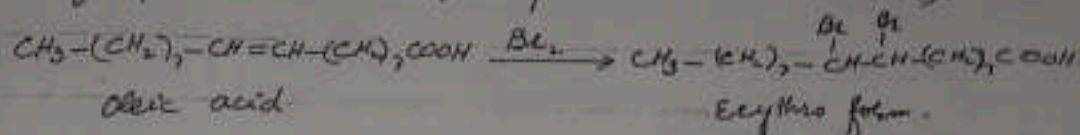
(6) HYDROGENATION:

The hydrogenation of fatty acids (unsaturated) results in production of more saturated fatty acid by adding H_2 across the double bond.



(1) HALOGENATION:

Halogens are readily added to double bonds and form Erythro form of product (i.e. Halogen is present on the same side)

(2) OXIDATION:

The unsaturated fatty acids are much more easily oxidized than saturated fatty acids. It is a complicated process.

FUNCTIONS OF LIPIDS:

Lipids have variety of functions. Shalini Arora
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(1) ENERGY SOURCE:

Lipids are good source of energy and provide large amount of energy. It provides 9.1 Kcal/g energy.

(2) ENERGY RESERVOIR:

In liver 2-3% of fat is stored which is used in many metabolic processes.

(3) TRANSPORT OF MATERIAL:

Many compounds are soluble in fats so they transport them in the plasma.

(4) HORMONES:

Many hormones like sex hormones are lipid in nature.

(5) IMPORTANT CELLULAR CONSTITUENT:

Lipids are important cellular components. They take part in the formation of plasma membrane present around

the whole cell, nucleus and membranes around organelles.

(6) INSULATORS:

Lipids act as

- (a) Electrical insulator.
- (b) Heat insulator.
- (c) Chemical insulator.
- (d) Mechanical insulator.

(7) PREVENTION FROM WATER LOSS:

They prevent water losses from skin in animals and plants. They also protect fruits from infections.

(8) ESSENTIAL FATTY ACIDS:

The lipid contents of food provide an essential supply of essential fatty acids to the body.

(9) DIETARY LIPIDS:

Many lipids increase gastric motility and secretions and have a high satiety value.

(10) TRANSMISSION OF NERVE IMPULSES:

The sphingolipids containing lipids have a role in the transmission of nerve impulses in the body.

ENZYMES

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MEANINGS:

The word "Enzyme" means "derived from yeast." As it was used when catalytic properties of the yeast were discovered.

DISCOVERY OF ENZYMES:

Enzymes were discovered by Payon and Percey.

The first enzyme, which was discovered was "DIASTASE".

Many enzymes have been crystalline in pure form. URASE was the first enzyme to be crystalline discovered by UMNER.

DEFINITION:

"Enzymes are specific protein molecules generated by gene operation which can speed up a biochemical reaction."

In other words enzyme is a "Biological catalyst".

"A catalyst is an agent which in minute amount ~~increases~~ increases the velocity of a reaction without appearing in the final product of the reaction."

PROPERTIES OF ENZYMES:

- (i) They are protein in nature.
- (ii) They are specific in action.
- (iii) They control the reaction rates.
- (iv) They guide the reaction in specific direction.
- (v) They complete the reaction.

* NOTE: It should clearly understood that enzyme only accelerate the rate of a biochemical reaction but do not initiate it. In other words, the reaction can take place even without enzyme but in this case rate of reaction is extremely slow.

Occurance: Enzymes generally occur in all living cells, in tissues and in glands.

SOME TERMS RELATED TO ENZYMES:

① APOENZYME:

"Enzymes may be entirely a protein or an enzyme may consists of a protein part and non protein part. The protein part is called APOENZYME."

② PROSTHETIC GROUP:

"Enzymes are mostly protein but in some cases an enzyme may consists of a protein part and non protein part. The non protein part is called PROSTHETIC GROUP."

EXPLANATION:

So an enzyme consist of a protein part i.e. Apoenzyme and an a nonprotein part i.e. prosthetic group which are covalently bonded.



⇒ Apoenzyme is heat labile while prosthetic group is heat stable.

③ CO-ENZYME:

"If prosthetic group is not tightly bonded to apoenzyme covalently and can be dialysed out, it is called CO-ENZYME."

EXAMPLES: Some examples of CO-enzymes are

- (i) NAD (Nicotinamide adenine dinucleotide)
- (ii) FAD (Flavin adenine dinucleotide)
- (iii) FMN (Flavin Mono nucleotide)

PROPERTIES:

- (i) They are heat stable.
- (ii) Their size is smaller than enzyme.
- (iii) They help the enzyme to speed up chemical reaction.
- (iv) They are non protein in nature.
- (v) Most of co-enzymes play role in electron transport chain.

④ HOLOENZYME:

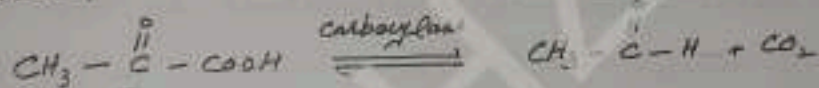
"The enzyme formed by the conjugation of co-enzyme (non protein part) and Apoenzyme (protein part) is called HOLOENZYME."

* HOLOENZYME = CO-ENZYME + APoenzyme

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EXAMPLE:

An example of such an enzyme is the enzyme Carboxylase which is responsible for the conversion of pyruvic acid into ethanal.



Carboxylase is formed by conjugation of thiamine pyrophosphate (TPP) with a protein.

⑤ PRO ENZYME:

"The substance going to be enzyme is called

PROENZYME or ZYMOGEN.

PROPERTIES: (i) They are inactive form of enzyme.

(ii) They are converted into active enzyme after activation.

(iii) Those which activate them are called their CO-FACTORS.

EXAMPLES: Following proenzymes along with their co-factor are important.

(i) Trypsinogen $\xrightarrow{\text{Enterokinase}}$ Trypsin.

(ii) Pepsinogen $\xrightarrow{\text{HCl}}$ Pepsin.

⑥ CO-FACTORS:

"The substances which convert inactive form of enzyme (pro-enzyme) into active form of enzyme are called their co-factors."

EXAMPLES:

(i) Trypsinogen $\xrightarrow{\text{Enterokinase}}$ Trypsin

Here Enterokinase is the co-factor of Trypsinogen.

(ii) pepsinogen $\xrightarrow{\text{HCl}}$ pepsin.

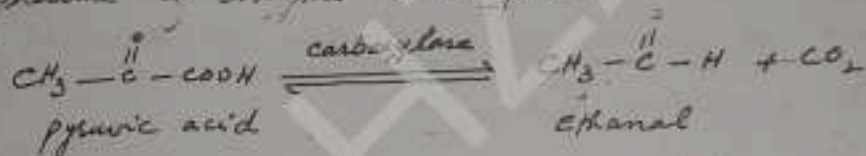
Here HCl is the co-factor of pepsinogen.

⑦ SUBSTRATE:

"The substance on which enzyme act and it show reaction is called Substrate."

EXAMPLE:

pyruvic acid is converted into ethanol in the presence of enzyme carboxylase.



Here pyruvic acid is the Substrate.

PROPERTIES:

- (i) They play important role in the functioning of enzyme.
- (ii) Enzyme have many active sites which react with substrate to form enzyme substrate complex $E+S \Rightarrow ES$.
- (iii) Just like enzymes, substrate are also specific. e.g. Urease act only on Urea.
- (iv) As compared to enzyme, substrate are smaller.

⑧ ISOZYMES:

"Isomers of enzymes are called as Isozymes."

MECHANISM OF ENZYME ACTION.

Main function of enzyme is to lower the energy of activation of a biochemical reaction.

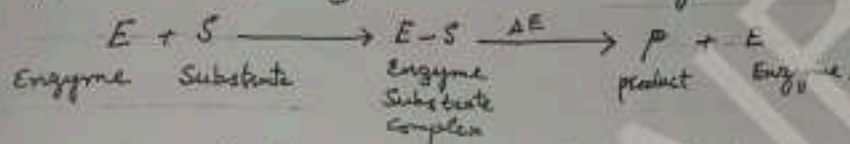
According to M. Menzies theory, there are two steps in all enzyme reactions.

STEP - I $\Rightarrow$ Formation of enzyme substrate complex.

STEP - II $\Rightarrow$ Formation of product with liberation of enzyme.

STEP - I : FORMATION OF ENZYME SUBSTRATE COMPLEX :

Consider an enzyme E comes in close relation with a substrate S. They form a E-S complex and then after getting energy of activation changes into products.



The linkage between the substrate and enzyme is non covalent bond including H-bond, electrostatic force or Vander waal's bond. These very weak bond are involved in binding of enzyme with substrate together. The binding takes place between the substrate molecule and a place over the enzyme called substrate site or Active site.

There are two theories that explain mechanism of E-S complex formation.

(i) Lock and Key theory.

(ii) Induced fit Model.

(i) LOCK AND KEY THEORY:

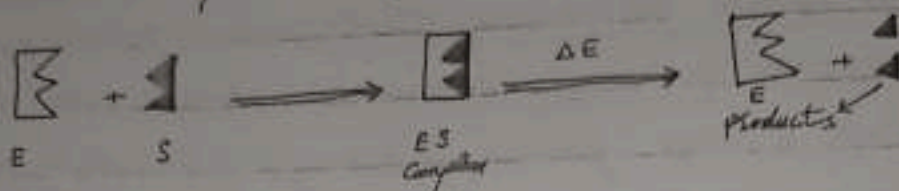
According to this theory

- Enzymes and substrates have structural characteristics which favour E-S complex.
- Enzyme have certain ridges and substrate have reciprocal.

depressions.

(i) As they come close, substrate gets fitted into enzyme preformed structure.

(ii) Then getting the energy of activation, they key the door towards the products by splitting of substrate.

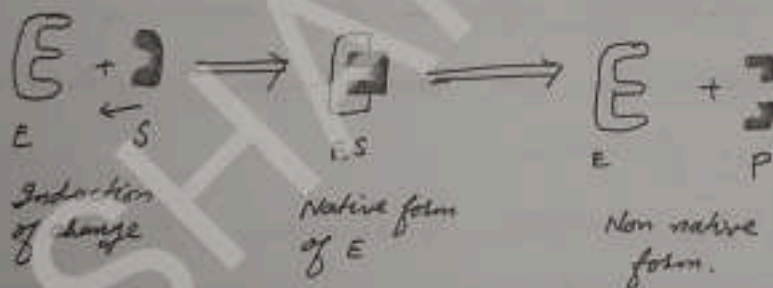


ΔE = Energy of activation

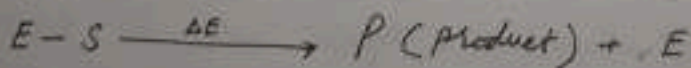
It is quite old theory not applicable now.

(ii) INDUCED FIT MODEL:

According to this theory as S approaches E, it induces a change get fitted into substrate binding site. All enzymes have specific no. of binding sites. This theory is based on fluid structure of protein that is in native or non native form.



STEP-II: FORMATION OF PRODUCT WITH LIBERATION OF ENZYME



Now when Enzyme substrate complex is formed, there need a certain amount of energy to change them into product. This energy is called energy of activation.

It is defined as "The minimum amount of energy

in cal/mole required to be supplied to the reactant in order to start a chemical reaction."

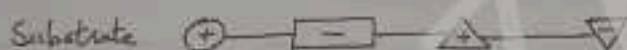
The activation results in rupturing of some of the chemical bond of the substrate molecule, thus causing it to break into certain product.

As soon as the product is formed, the enzyme becomes detached from substrate molecule. Its chemical nature remains unchanged.

ANOTHER WAY:

Enzyme action can also be explained by another way. A substrate has positive and negative charge and the enzyme action upon them will be explained by following diagram.

(i) of



and



The reaction will never occur.

(ii) of



and enzyme



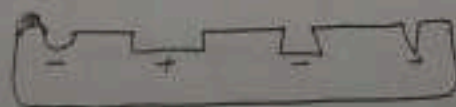
They will form enzyme-substrate complex.

Step-I

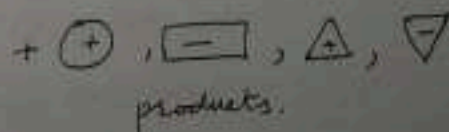


E-S complex.

Step-II



Enzyme



MODERN CLASSIFICATION OF ENZYMES

Enzyme classification presents a number of problems. Many systems of classification have been proposed. The current system of classification and nomenclature of enzyme is devised by the Commission on Enzymes of the International Union of Biochemistry (I.U.B.).

ARTICULAR SYSTEM:

The main features of I.U.B system for classification of enzymes are as follows.

(i) Each enzyme has its trivial name in addition to its systematic name.

e.g. Ptyalin is Trivial name and systematic name is amylase of an enzyme present in saliva.

(ii) Every enzyme has got a suffix -ase.

(iii) Every enzyme has a systematic code number of four digits called Enzyme Commission number as

A : B : C : D

□..... A: First digit indicates the main class of enzyme.

□..... B: Second digit indicates the subclass of enzyme.

□..... C: Third digit indicates the type of reaction or Sub-subclass.

□..... D: Fourth digit indicates the no. of individual enzyme or Sub-sub-subclass.

EXAMPLE: Number 1.1.1.6

Systematic name Glycerol : NAD oxidoreductase.

Trivial name Glycerol dehydrogenase.

Main class Oxidoreductases (1)

Sub-class Oxidoreductases attacking -CHOH group (1.1)

Sub-sub-class Oxidoreductases attacking -CHOH group and linked to NAD as hydrogen acceptor (1.1.1)

Sub-sub-sub-class NAD linked oxidoreductase attacking -CHOH group & attacking glycerol as substrate (1.1.1.6)

Enzymes are classified into 6 main classes according to the reaction they catalysed. Then each class is divided into 4-13 Subclasses.

1- Oxidoreductases.

2- Transferases.

3- Hydrolases.

4- Lyases.

5- Isomerases.

6- Ligases.

(OTHLIL)

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(1) OXIDOREDUCTASES:

DEFINITION: These are the enzymes which are involved in the oxidation reduction reactions.

Dehydrogenases and oxidases are included in this class.

Dehydrogenases remove hydrogen from the substrate.

Oxidases bring about the oxidation in the presence of oxygen.

SUBCLASSES: $\text{S}_{\text{oxidized}} + \text{S}_{\text{oxid}} \rightleftharpoons \text{S}_{\text{oxid}} + \text{S}_{\text{reduced}}$

Some subclasses with their substrate examples are as follows.

⇒ 1.1 : Enzymes acting on the CH-OH groups as donors.

EXAMPLES: (i) 1.1.1.1 → Trivial name: Alcohol dehydrogenase.

Systematic name: Alcohol: NAD oxidoreductase.

- Reaction: $\text{RCH}_2\text{OH} + \text{NAD} \rightleftharpoons \text{RCHO} + \text{NADH} + \text{H}^+$
Alcohol. Aldehyde

(ii) 1.1.1.6 → Trivial name: Glycerol dehydrogenase

Systematic name: Glycerol: NAD oxidoreductase.

⇒ 1.2 : Enzymes acting on the C=O group.

⇒ 1.3 : Enzymes acting on the CH-CH group.

⇒ 1.4 : Enzymes acting on the CH-NH₂ group.

EXAMPLE: 1.4.1.3 → Trivial name: Glutamic dehydrogenase.

Systematic name: Glutamate: NAD(P) oxidoreductase.

⇒ 1.11: Enzymes acting on H_2O_2 group as electron acceptor.

EXAMPLE: 1.11.1.6 → H_2O_2 : H_2O_2 oxidoreductase.

REACTION: $H_2O_2 + H_2O_2 \rightleftharpoons 2H_2O + O_2$.

(B) TRANSFERASES:

DEFINITION: "These are the enzymes which catalyse the transfer of a group or a radical from one organic molecule to another."

These enzymes catalyse transfer of group such as acyl group, amino group and other groups.

SUBCLASSES: [2.3.16], [2.7.12] Temp (CKAP)

Some subclasses with few examples are as follows.

⇒ 2.1: ^{catalyse} Transfer of one carbon group.

⇒ 2.2: ^{catalyse} Transfer of ~~aldehyde~~ or Ketone group.

⇒ 2.3: ^{catalyse} Transfer of Acyl group (Ac : transferases)

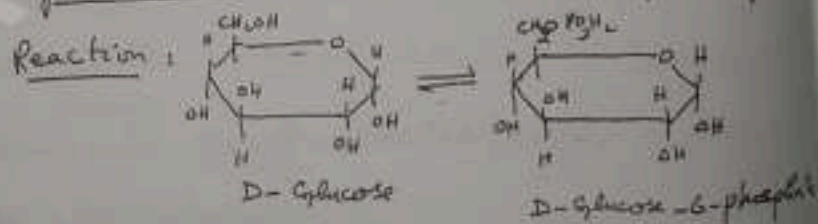
EXAMPLES: 2.3.16. → Trivial name: choline acyltransferase

Systematic name: Choline: O-acetyl transferase.

⇒ 2.7: Catalysing Transfer of phosphorus containing group.

EXAMPLE: 2.7.1.2 → Trivial name: Glucokinase

Systematic name: ATP: D-Glucose-6-phosphotransferase



(B) HYDROLASES:

DEFINITION: "These are the enzymes which cause the hydrolysis of various compounds."

All most all the enzymes of GIT are hydrolases.

SUBCLASSES: [3.1.2.1], [3.2.3.1], [3.4.4.5], [3.5.1.1] (EGOP-H) bond.

Some subclasses with few examples are as follows.

⇒ 3.1.1: Enzymes acting on ester bonds.

EXAMPLE: → 3.1.2.1 →

Trivial name: Acetyl-S-CoA lyase

Systematic name: Acetyl-S-CoA hydrolase

Reaction: $\text{CH}_3\text{-C}(=\text{O})\text{-S-CoA} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{HS-CoA}$

⇒ 3.2: Enzymes acting on glycosyl compounds.

EXAMPLE: 3.2.3.1 →

Trivial name: Amylase

⇒ 3.3: Enzymes acting on other bonds.

⇒ 3.4: Enzymes acting on peptide bond.

EXAMPLE: 3.4.4.4 → Trivial name: Trypsin

Trypsin is secreted by pancreas in an inactive form Trypsinogen. It acts on proteins.

⇒ 3.8: Enzymes acting on Halide Bonds:

EXAMPLE: 3.8.1.1 → Trivial name: Alkyl Halidase.

Systematic name: Alkyl Halide Hydrolase.

Reaction: $\text{CH}_3\text{Cl} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{OH} + \text{HCl}$.

(4) LYASES: [1.12.5], [6.2.1] (C(ONS) Lyase.)

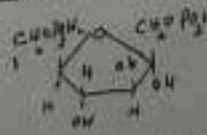
DEFINITION: "These are enzymes which catalyse the reaction of the type $\text{AB} \rightleftharpoons \text{A} + \text{B}$ "

They can decompose the substrate into fragments and from the fragments they can synthesize the substrate.

SUBCLASSES: Some subclasses with examples are as follows.

⇒ 4.1: Carbon-carbon Lyases:

EXAMPLE: 4.1.2.6 → Trivial name: Aldolase

Reaction:  $\rightleftharpoons$ DAP - Glyceraldehyde-3-phosphate

⇒ 4.2: Carbon-oxygen Lyases:

EXAMPLE: 4.2.1.1. Carbonic anhydrase: Reaction: $\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}_2\text{O} + \text{CO}_2$

⇒ 4.3 : Carbon-Nitrogen Lyases.

⇒ 4.4 : Carbon-Sulphur Lyases.

⑤ ISOMERASES: 5.11, 5.211, 5.311.

DEFINITION: "These are enzymes which bring about the isomerization of substrate molecule."

SUBCLASSES: Some subclasses are as follows.

⇒ 5.1 : Racemases and epimerases.

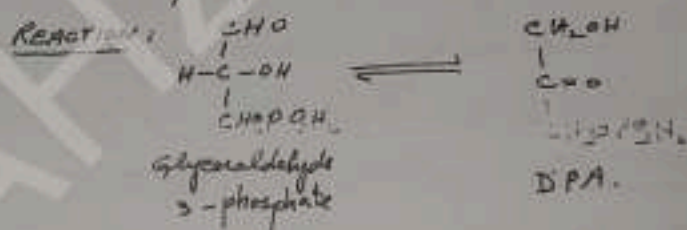
EXAMPLE: 5.1.1.1 → Alanine Racemase.

⇒ 5.2 : Cis-Trans Isomerases.

EXAMPLE: 5.2.1.1 → Maleate Isomerase.

⇒ 5.3 : Interconverting Aldoses & Ketoses.

EXAMPLE: 5.3.1.1 → Triose phosphate Isomerase.



⑥ LIGASES: 6.11, 6.311 C(O3NC) bonds.

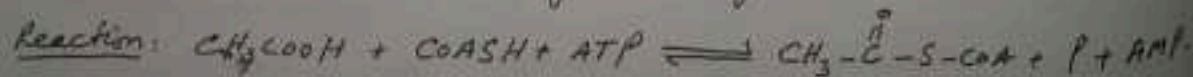
DEFINITION: "These are the enzymes which fix certain fundamental compounds for the synthesis of higher compounds."

SUBCLASSES: Some subclasses with examples are as follows.

⇒ 6.1 : Forming C-O Bonds.

⇒ 6.2 : Forming C-S Bonds.

EXAMPLE: 6.2.1.1 → Acetyl-CoA Synthetase.



⇒ 6.3 : Forming C-N Bonds.

EXAMPLE: 6.3.1.1 → Asparagine Synthetase.

⇒ 6.4 : Forming C-C Bonds. e.g. 6.4.1.1 → Pyruvate Carboxylase.

(75) ENZYME SPECIFICITY

DEFINITION:

"Enzymes are specific in attacking the substrate. The specificity means that a particular enzyme always attacks a particular substrate or a particular kind of substrate."

EXPLANATION:

Specificity is perhaps, the most characteristic property of living machine. The enzyme substrate relationship is an important example of this phenomenon.

TYPES OF SPECIFICITY:

(ABGSR)

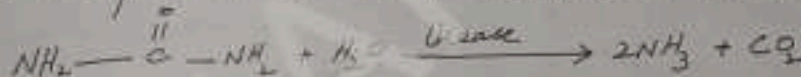
Specificity is of different types.

(i) ABSOLUTE SPECIFICITY:

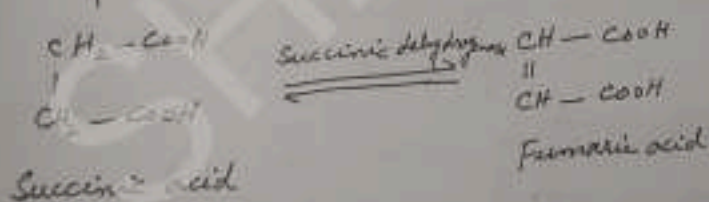
In this type of specificity, certain enzyme attack only a single specific substrate molecule and will never attack any other substrate. This kind of specificity is called absolute specificity.

EXAMPLES:

(a) Urease is an enzyme which attacks only urea and no other compound. It thus exhibits an absolute specificity.



(b) Similarly Succinic dehydrogenase attacks only succinic acid.



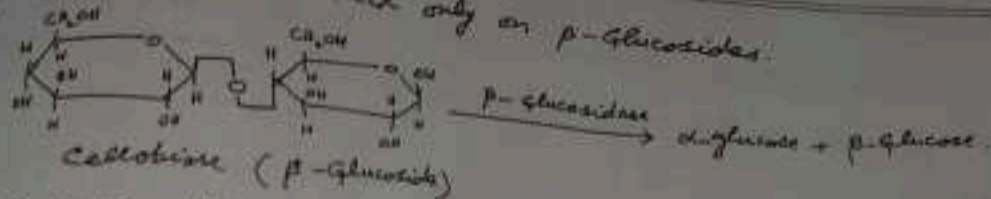
(ii) BOND SPECIFICITY:

In this type of specificity, an enzyme attacks only a specific type of Bonds present in the substrate.

EXAMPLES:

Proteinases attack only peptide bond and glucosidases attack

(b) β -Glucosidases attack only on β -Glucosides.



(v) RELATIVE SPECIFICITY:

There are certain enzymes which attack the same type of substrate at different rates. They are said to possess relative specificity.

EXAMPLE:

An enzyme β -glucosidase attacks on certain β -glucosides at a much faster rate relative to other β -glucosides. Therefore they are said to exhibit relative specificity.

CHEMICAL NATURE OF ENZYMES:

Studies on pure crystalline enzymes have indicated that enzymes have the structure and characteristics of proteins. These properties can be altered by gentle heating, dehydration, change in pH and even by ultraviolet radiations. Such changes are called denaturation and is very much like by other type of proteins such as egg albumin and collagen etc.

On the basis of chemical nature, the enzymes can be put into two categories.

- (i) Simple proteins.
- (ii) Conjugated proteins.

(i) SIMPLE PROTEINS:

These are the enzymes which are purely proteins.

and do not contain any other group in conjugation with proteins.

EXAMPLES: Pepsin, Ribonuclease, etc.

(ii) CONJUGATED PROTEINS

These are the enzymes which are composed of protein and non protein components which are essential for their activity.

The protein component is called Apoenzyme while the non protein component is called prosthetic group.

Unlike apoenzymes which are heat labile, the prosthetic group are heat stable. If the prosthetic group is not tightly bound to apoenzyme and it can be dialysed out, it is called co-enzyme.

The enzyme formed by the conjugation of Apoenzyme and co-enzyme is also called a Holoenzyme.

$$\text{Holoenzyme} = \text{Apoenzyme} + \text{co-enzyme}.$$

An example of Holoenzyme is Carboxylase.

FACTORS AFFECTING ENZYME ACTIVITY

The factors which affect the enzyme activity are as follows.

(1) ENZYME CONCENTRATION:

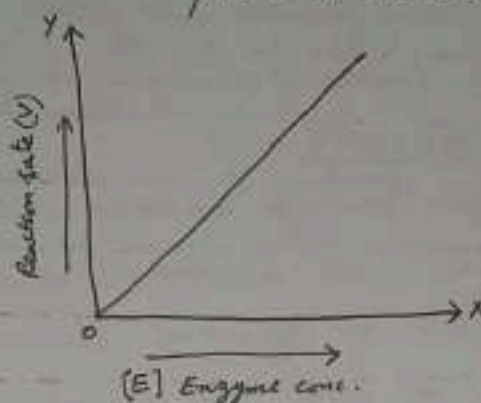
When the concentration of enzyme is increased in a chemical reaction, the rate of reaction is increased. So enzyme conc. is directly proportional to the rate of reaction, i.e.

$$V \propto [E]$$

Where V = Rate of reaction

$[E]$ = Enzyme conc.

In fact when enzyme conc. is increased, it causes the increase in substrate binding sites so more and more substrate is transformed into products hence rate of reaction rises.

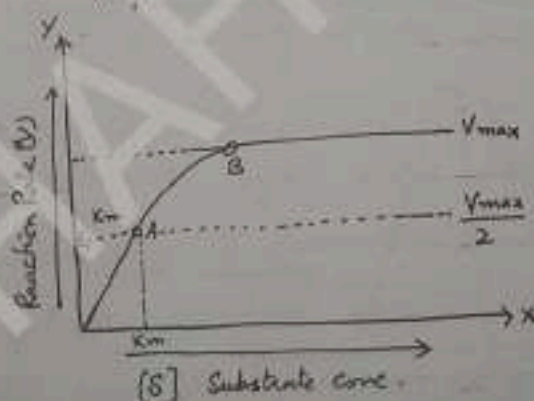


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GRAPH: Effect of increase enzyme conc. on rate of reaction.

(2) SUBSTRATE CONCENTRATION:

When the conc. of substrate increases, the rate of reaction increases rapidly and then become constant as shown in Graph also called M. Menten Graph.



Increasing substrate conc. upto 'B' increases rate of reaction. As $[E]$ rises more and more substrate binds at substrate binding sites giving more and more products. But at 'B' substrate binding site gets fully saturated and reaction proceed at constant rate.

that is maximum speed V_{max} .

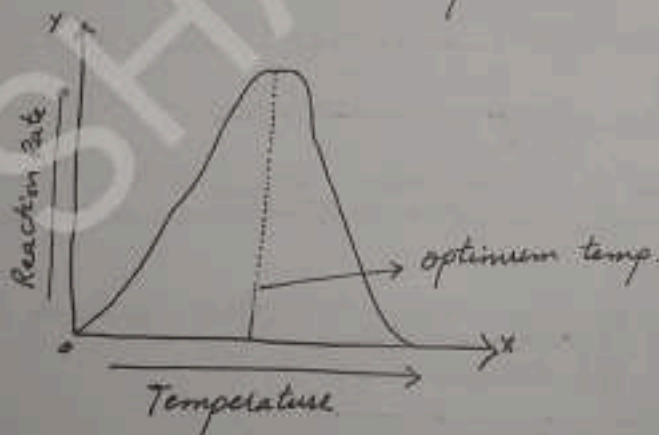
K_m : The conc. of substrate in mol/l at which the velocity of reaction is $\frac{1}{2}$ of maximum velocity is called as K_m .

In fact, at point 'A' amount of substrate is high so forward reaction is favoured. At point 'B' amount of substrate is low so backward reaction is favoured.

(3) EFFECT OF TEMPERATURE:

The enzyme activity increases with an increase in temp. and decreases with a decrease in temp. An increase in temp. increases the no. of effective collisions between the enzyme and substrate to form the activated complex and thus rate of reaction increases. But there is a limit to increase in rate of reaction by increasing temp. After that limit, the reaction rate falls.

OPTIMUM TEMPERATURE: The temp. at which the enzyme activity is max. is called optimum temp.



Rate of reaction decreases after optimum temp. At about 70°C to 80°C majority of enzymes are inactivated.

TEMPERATURE QUOTIENT (Q_{10}): It means that every 10°C rise in temp. causes the rate of reaction some times double and even triple. Majority of enzymes have a Q_{10} value of 3 or lower.

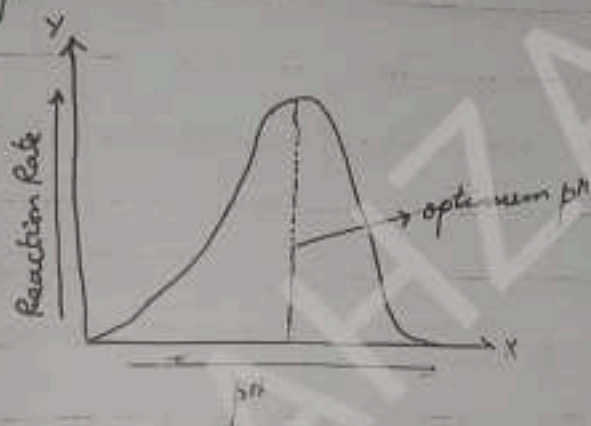
(4) EFFECT OF pH :

Enzyme activity is influenced by the hydrogen ion concentration. Some enzymes are active in acidic medium, some in alkaline medium and others in neutral medium. There is a minimum, an optimum and a max. pH for every enzyme to act favourably.

OPTIMUM pH : The pH at which an enzyme has max. reaction rate is called optimum pH.

e.g. The optimum pH of Salivary amylase is 6.5 to 6.9.

An enzyme is most active when its pH is at or near its isoelectric point.



GRAPH : The effect of changing pH value on rate of enzyme reaction.

(5) EFFECT OF ULTRAVIOLET LIGHT :

Ultraviolet light either destroys or modifies the action of enzymes. The rate of destruction is independent of temp. but is affected by pH etc. Purified enzymes are more easily destroyed by the ultraviolet rays than impure enzymes.

(6) EFFECT OF PRODUCTS OF REACTION :

Suppose an enzyme catalyses the reaction



If products C and D are removed as they are formed, then

reaction will be 100% complete and if they are not removed the reaction will be incomplete. This is due to two reasons. FIRSTLY, the enzymatic reactions are usually reversible and some of A and B are being reformed. SECONDLY, the products of the reaction having some structural resemblance to the substrate will bind some enzyme thus slowing the rate of reaction.

(1) PRESENCE OF INHIBITORS

"The substances which reduce the rate of enzymatic reaction are called Inhibitors" and the effect is called INHIBITION.

TYPES OF INHIBITORS:

There are mainly two types of inhibitors.

- (i) Reversible Inhibitors.
- (ii) Irreversible Inhibitors.

(1) REVERSIBLE INHIBITORS:

These are the inhibitors which do not react covalently with enzyme and are instantaneous inhibitors.

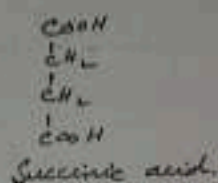
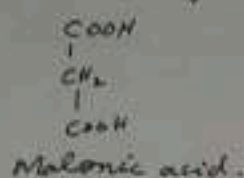
There are three types of reversible inhibitors on the basis of degree of inhibition.

- (a) Competitive inhibitors.
- (b) Non competitive inhibitors.
- (c) Un competitive inhibitors.

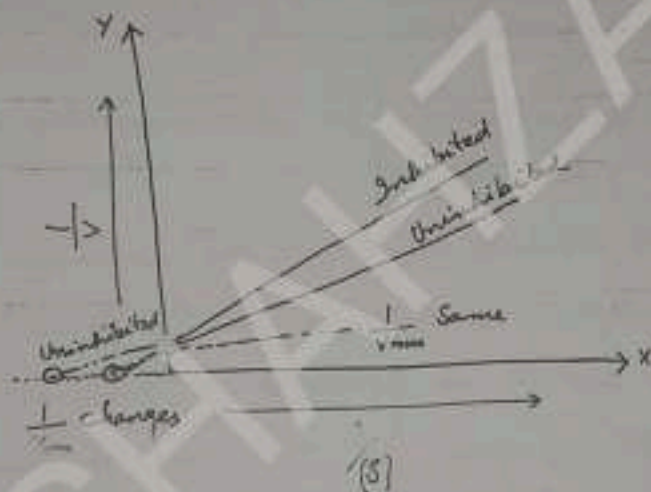
(a) COMPETITIVE INHIBITORS:

These are the inhibitors which compete with substrate for binding sites present on enzyme. When enzyme inhibitor complex is formed. If conc. of substrate is high then the favour is towards the enzyme substrate complex but if conc. of inhibitor is high then favour is towards

the enzyme inhibitor complex formation. The inhibitor and substrate are very similar in structure. e.g. Malonic acid, which resembles succinic acid in chemical structure inhibits succinic dehydrogenase whose true substrate is succinic acid.



For competitive inhibitors K_m increases with increasing inhibitor conc as shown in LINE WEAVER BURK PLOT.



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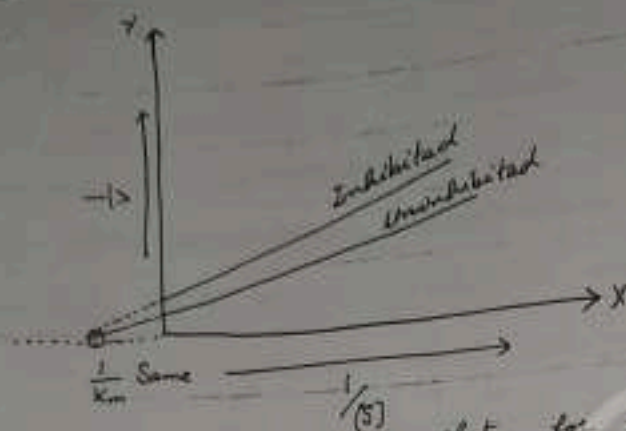
GRAPH: Line Weaver Burk plot for competitive inhibitors.

(b) NON COMPETITIVE INHIBITORS:

These are the inhibitors which do not bind with enzyme at active sites but they bind at some other places. This combination fails the substrate to combine with enzyme at active sites and thus substrate enzyme complex is not formed.

These inhibitors have no structural resemblance with substrate. Such an inhibitory action is produced by ions of heavy metals such as Ag and Hg.

For noncompetitive inhibitors K_m generally remains the same as shown below.



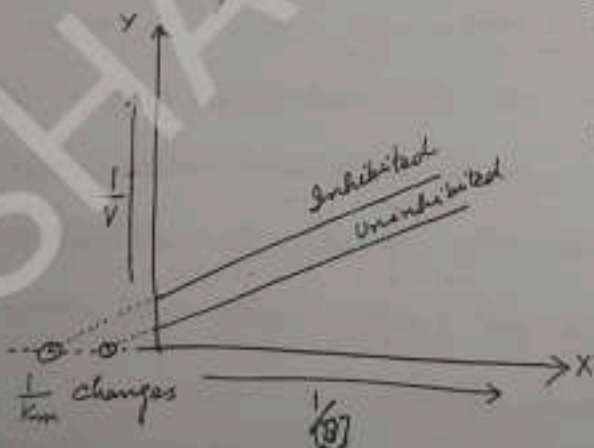
GRAPH: Line Weaver Burk plot for Non-competitive inhibitors.

(C) UN-COMPETITIVE INHIBITORS:

These are the inhibitors in which the inhibitors combine with the enzyme substrate complex to form enzyme substrate inhibitor complex. This results in stoppage of enzyme activity.

Such type of inhibitors are seen in those reactions in which two or more substrates are involved.

For Un-competitive inhibitors K_m generally decreases.



GRAPH: Line Weaver Burk plot for Un-competitive inhibitors.

(C.C) IRREVERSIBLE INHIBITORS:

These are the inhibitors which bind covalently with enzyme so enzyme get inactivated irreversibly, cause enzyme poisoning.

EXAMPLE: Iodoacetate reacts with thiol group of enzyme and produces irreversible inhibition.

CYCLES (BIOCHEMISTRY)

(27)

SHAHID RASOOL

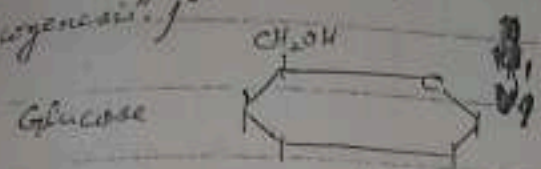
Shahid Rasool
Faculty of Pharmacy
P.U. Lahore.

GLYCOGENESIS:

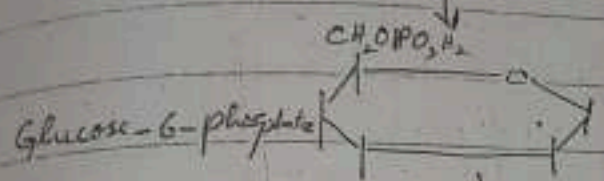
Dr. N.D.Z.H Punjab University
Faisalabad

Definition: It may be defined as

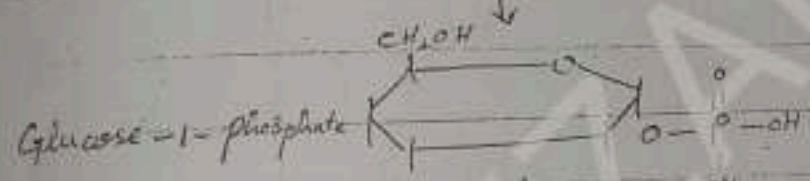
"Formation of Glycogen from Glucose in the liver by action of various enzymes is called Glycogenesis."



Hexokinase
ATP → ADP + P



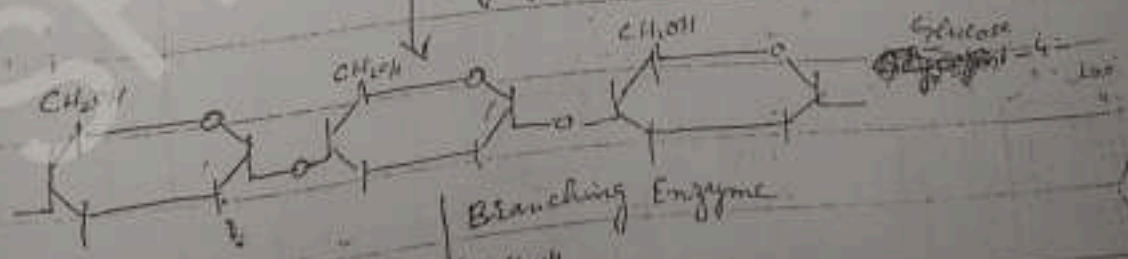
Phosphoglucomutase



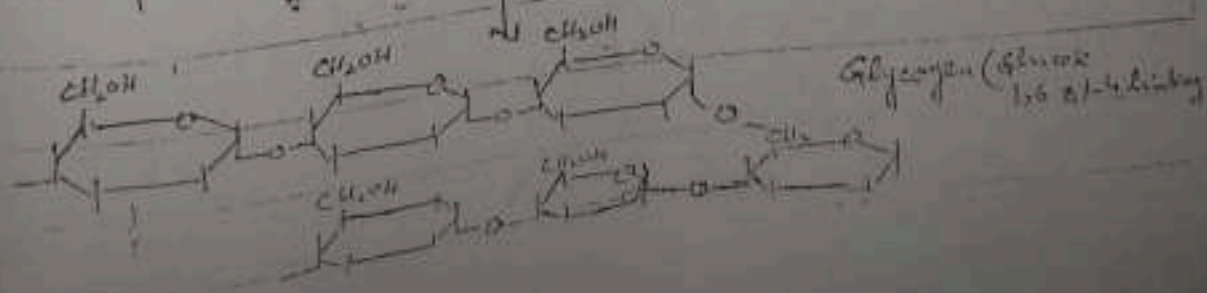
UDP-glucose
iso-phosphorylase



Glycogen Synthetase



Branching Enzyme

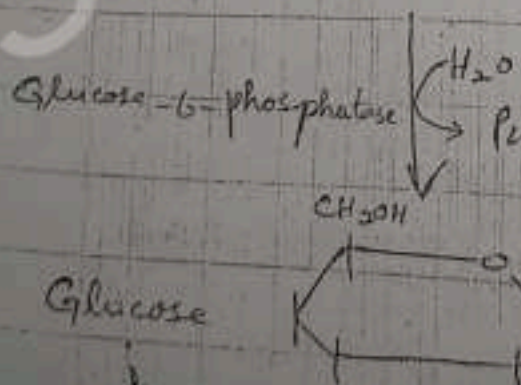
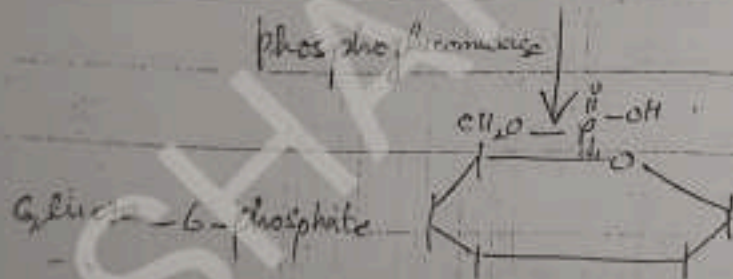
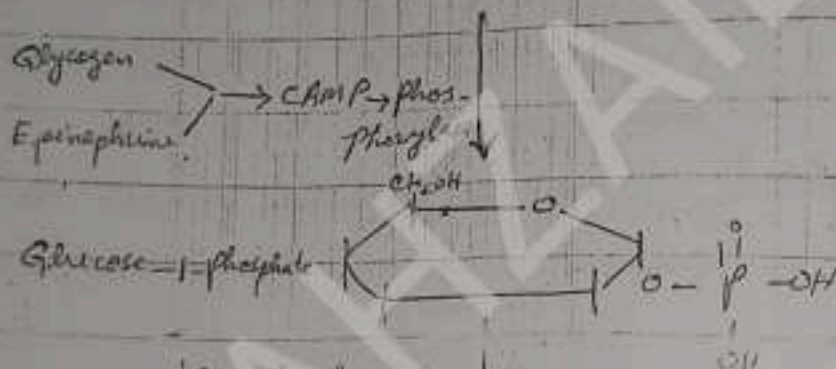
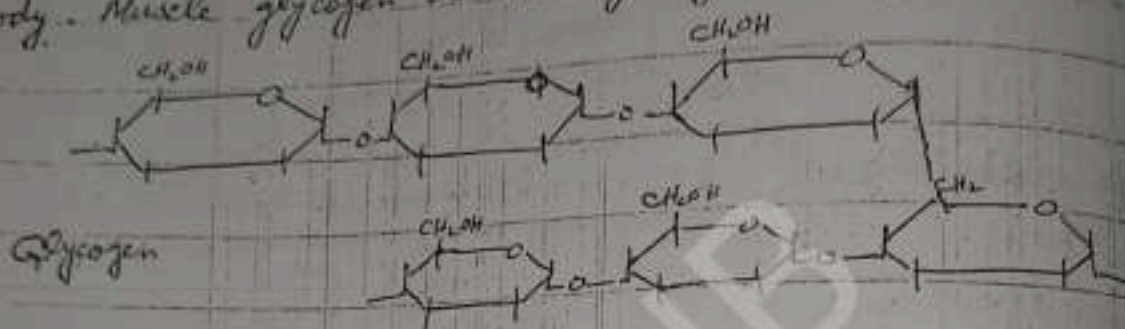


Glycogen (Glucose 1-6 & 1-4 linking)

GLYCOGENOLYSIS:

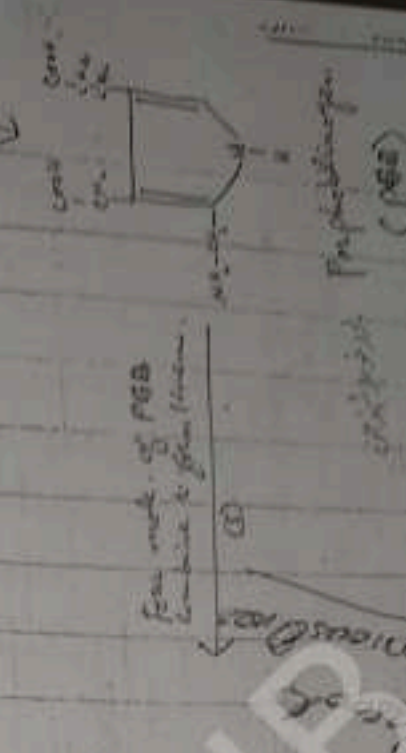
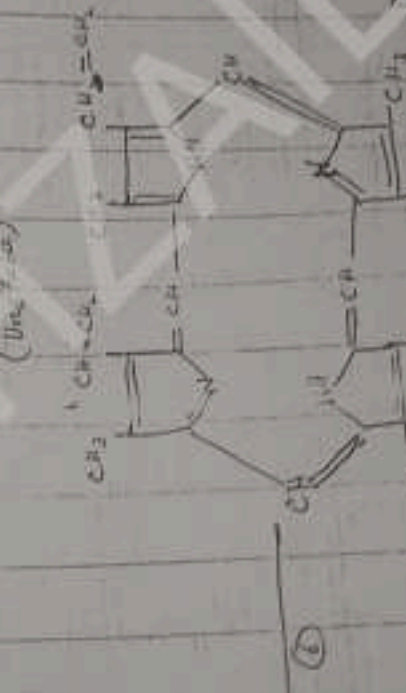
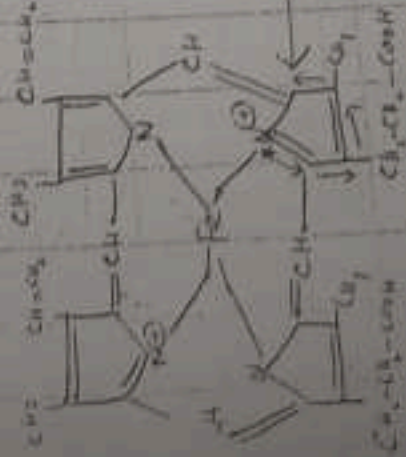
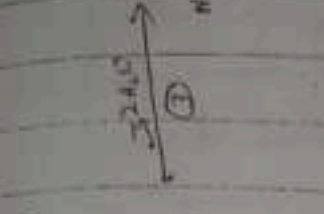
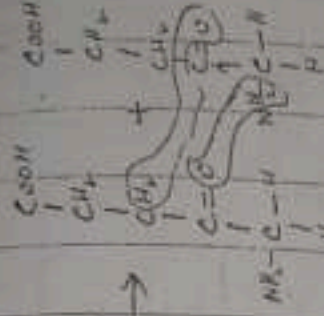
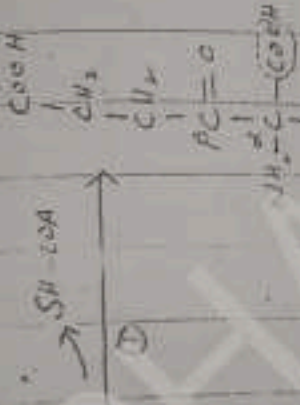
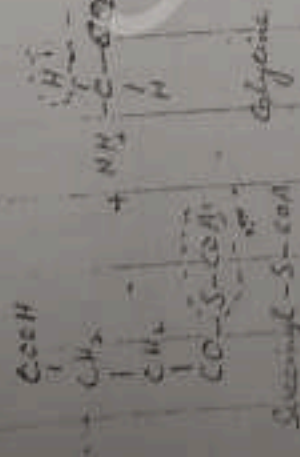
Definition: "The hydrolysis of liver Glycogen to Glucose is called Glycogenolysis."

The liver is the main store house of Glucose in human body. Muscle glycogen is not hydrolysed to glucose.

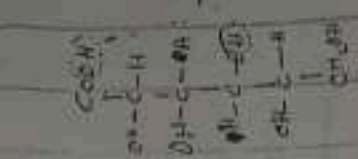
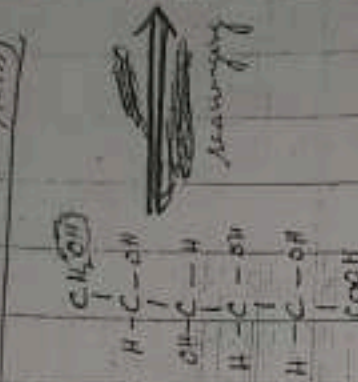
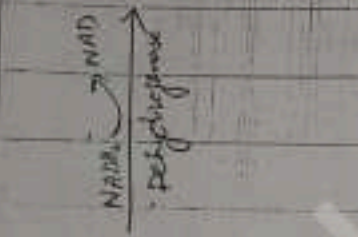
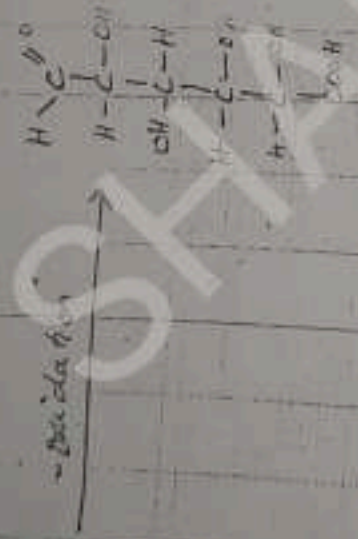
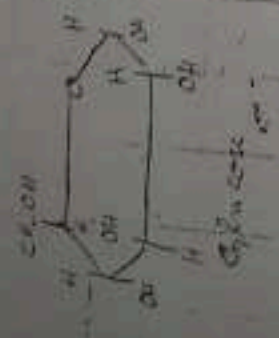


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Faculty of Pharmacy
P.U. Lahore.

BIOSYNTHESIS OF HAEME



BIO SYNTHESIS OF VITAMIN C (ASCORBIC ACID)

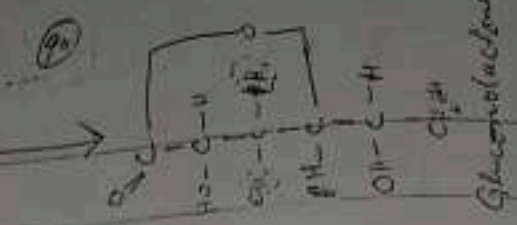
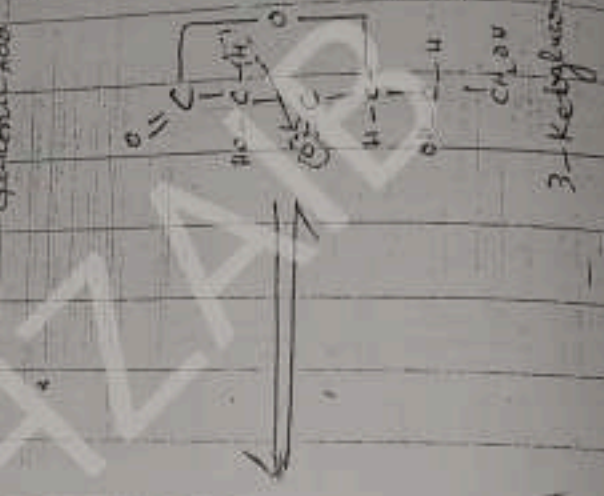
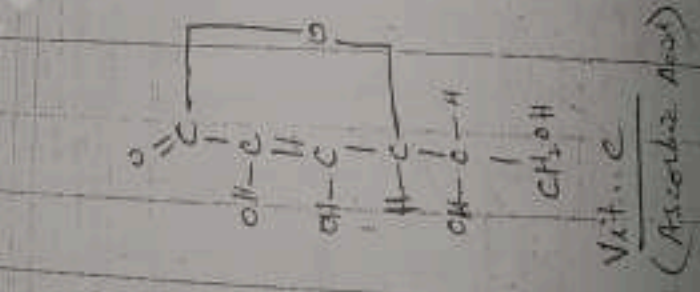


Glucose

Glucose

Glucose

Glucose



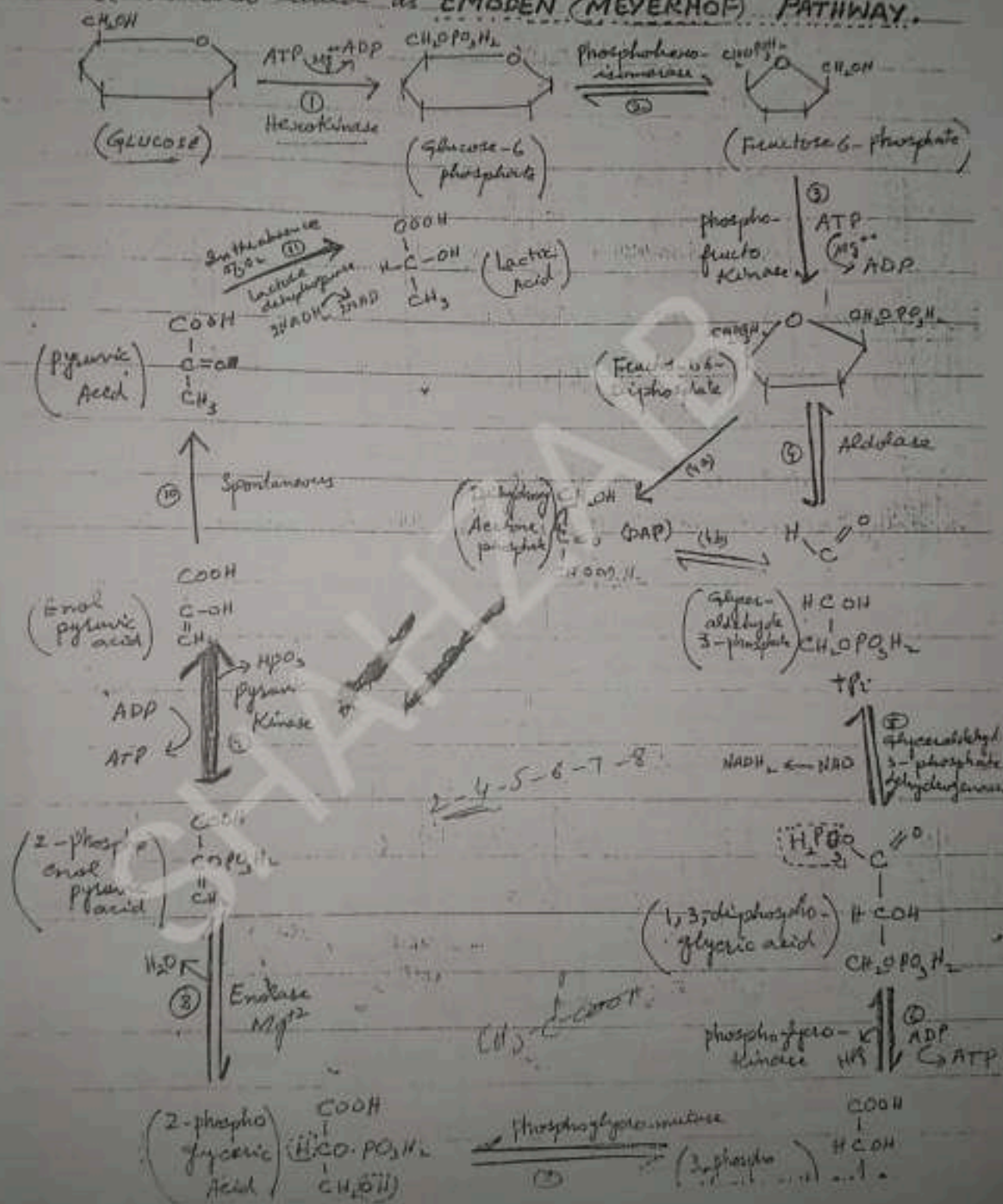
GLYCOLYSIS

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Faculty of Pharmacy
P.U. Lahore.

Definition: "It occurs in cytoplasm."

"Glycolysis is the process in which glucose is converted into 2 molecules of pyruvic acid in the liver and lactic acid in the muscles by the action of enzymes."

It is also called as "EMBDEN MEYERHOF PATHWAY."



ENERGATICS OF GLYCOLYSIS:

⇒ In Aerobic Respiration

ACCORDING TO OLD CONCEPT:

$$\text{Total ATP used} = 2$$

In step ① & ③

$$\text{Total ATP Gained} = 10$$

$$\text{In Step ⑤} = 3 \times 2 = 6$$

$$\text{In Step ⑥} = 1 \times 2 = 2$$

$$\text{In Step ⑨} = 1 \times 2 = 2$$

$$\boxed{\text{NET ATP GAINED} = 10 - 2 = 8}$$

ACCORDING TO NEW CONCEPT:

$$\text{Total ATP used} = 2$$

$$\text{In Step ① & ③}$$

$$\text{Total ATP Gained} = ?$$

According to new concept in Step ⑤ FAD is converted into FADH_2 instead of NAD into NADH_2 . So 2 ATP are gained.

$$\text{In Step ⑤} = 2 \times 2 = 4$$

$$\text{In Step ⑥} = 1 \times 2 = 2$$

$$\text{In Step ⑨} = 1 \times 2 = 2$$

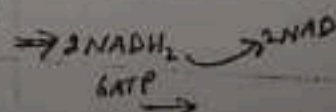
$$\boxed{\text{NET ATP GAINED} = 8 - 2 = 6}$$

⇒ In Anaerobic Respiration:

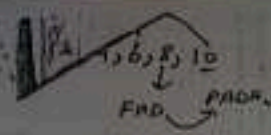
$$\text{No. of ATP Formed} = 8$$

$$\text{Used} = 6$$

$$\boxed{\text{NET ATP FORMED} = 2}$$

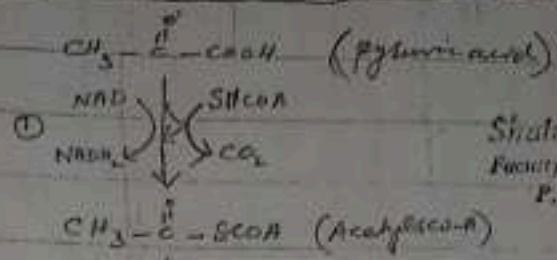


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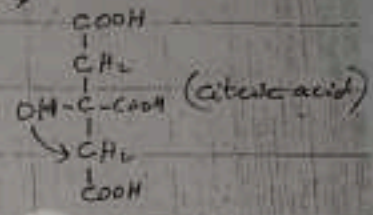
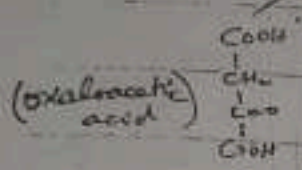
KREB'S CYCLE (TCA CYCLE) (CARBOXYLATE CYCLE)

* Aerobic oxidation of Glucose



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P.O. Lahore.

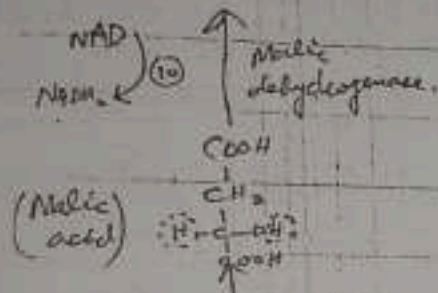
citrate Synthase



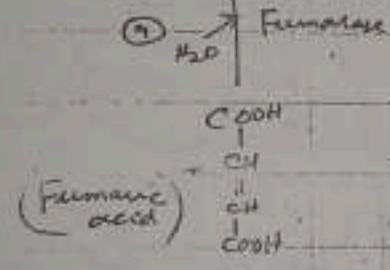
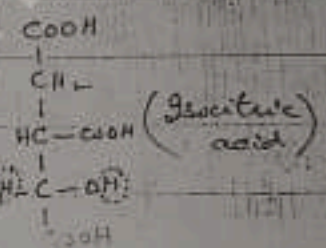
ENERGETICS:

ATP GAINED:

- In step ① = 3
- In step ② = 3
- In step ③ = 3
- In step ④ = 2
- In step ⑤ = 1
- In step ⑥ = 3
- Total = 15
- ∴ (Total TP = 15)



③ Acetate



$15 \times 2 = 30$
 $T = 30$

$T = 30$

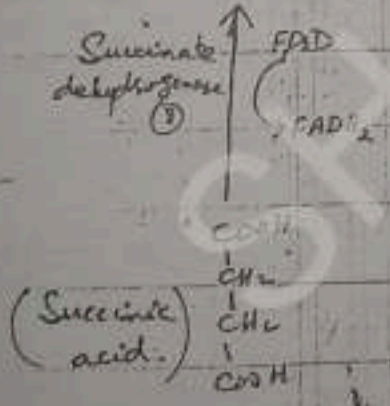
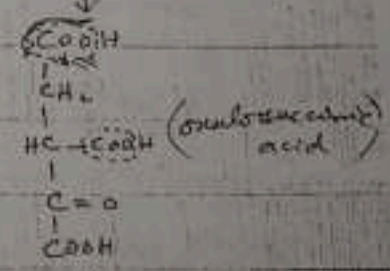
According to old concept:

ATP from Glycolysis = 8
 ATP from Krebs cycle = 30
 Total ATP = 38

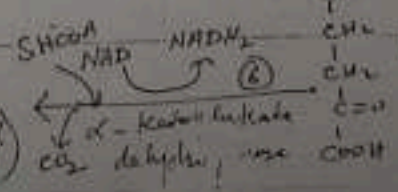
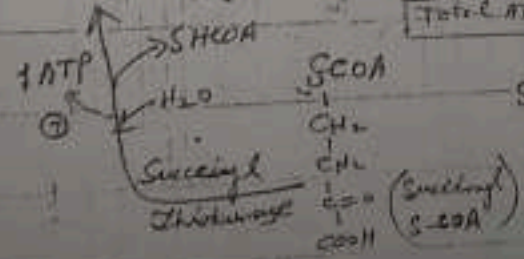
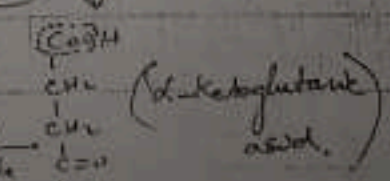
According to new concept:

ATP from Glycolysis = 6
 ATP from Krebs cycle = 30
 Total ATP = 36

④ NAD⁺ Isocitrate dehydrogenase



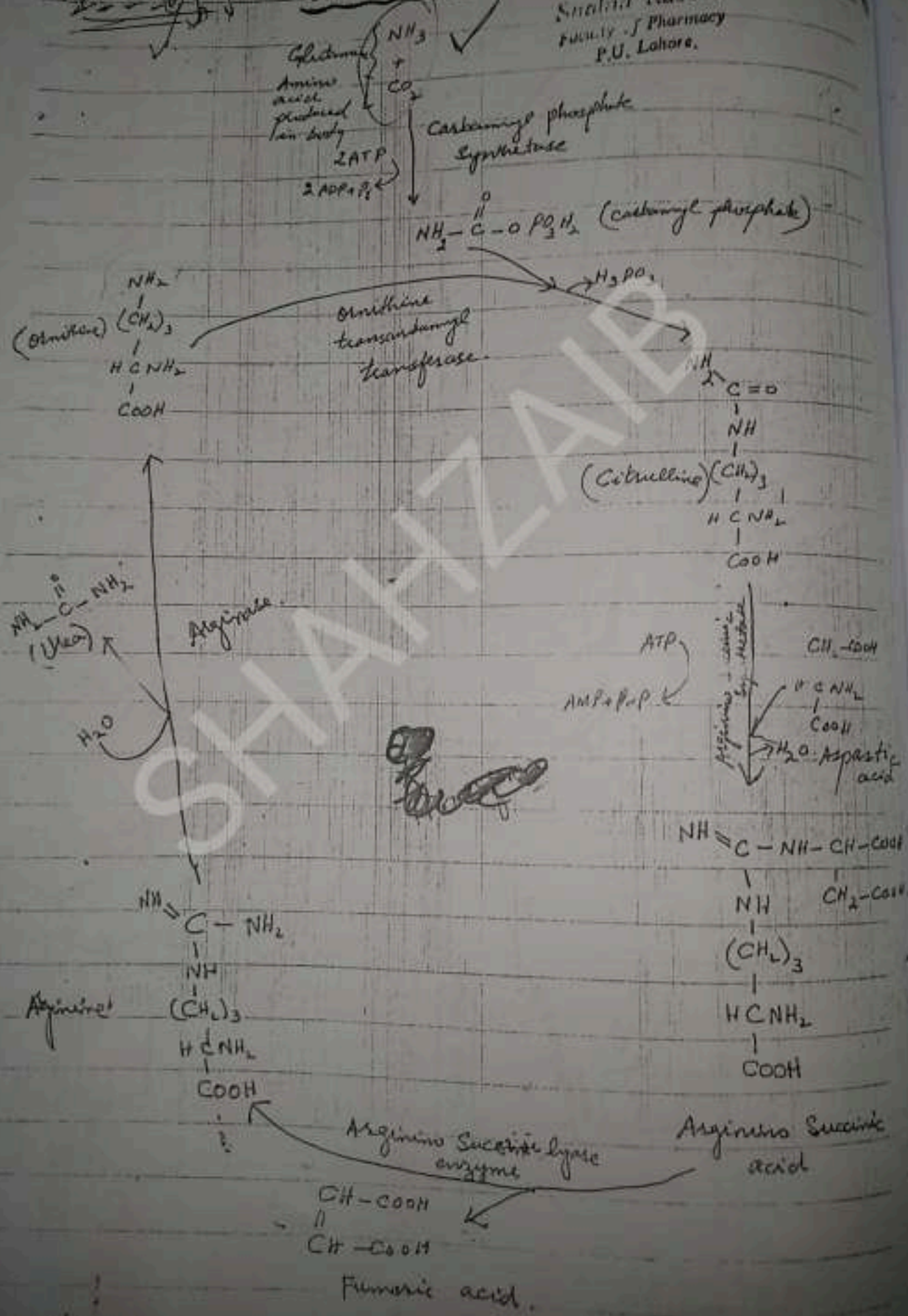
⑤ Spontaneous



GCC 1000

UREA CYCLE

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Faculty of Pharmacy
P.U. Lahore.



UREA CYCLE occurs in

BIOSYNTHESIS OF FATTY ACIDS

The following points are very important in the biosynthesis of Fatty acids.

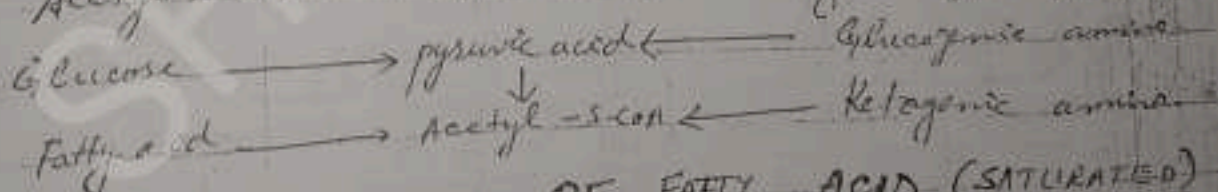
- (i) Biosynthesis must be carried out in the complete absence of dietary fibres.
- (ii) In the biosynthesis, the starting material is acetyl-S-CoA which is formed from glucose via pyruvic acid. Amino acid can also form acetyl-S-CoA. Glucogenic amino is converted into pyruvic acid and then acetyl-S-CoA.
- (iii) Biosynthesis of Fatty acid mostly occurs outside the mitochondria. But β -oxidation of fatty acid occurs inside the mitochondria.

It occurs in three different systems.

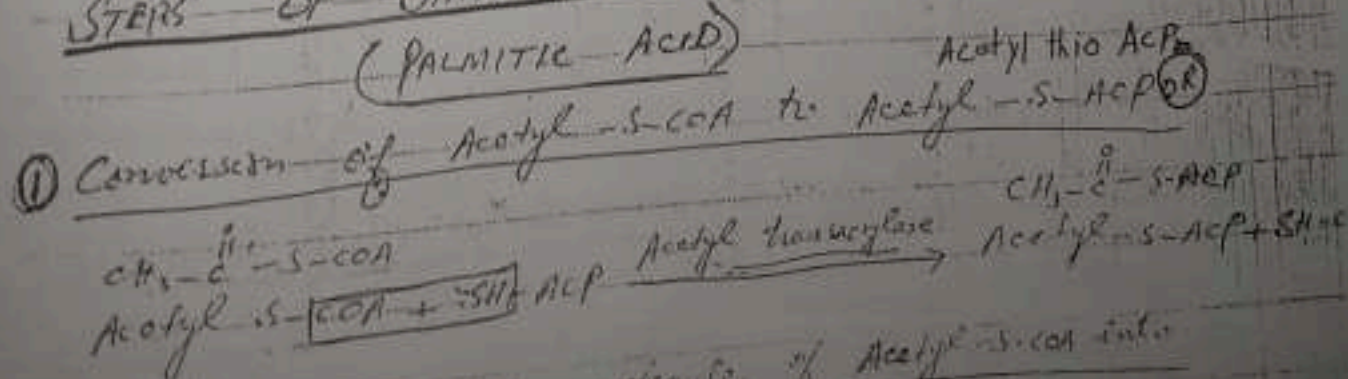
- (a) Cytoplasmic system.
- (b) Mitochondrial system.
- (c) Microsomal system.

The chief site of production of acetyl-S-CoA is cytoplasm.

Acetyl-S-CoA is obtained in the following ways.

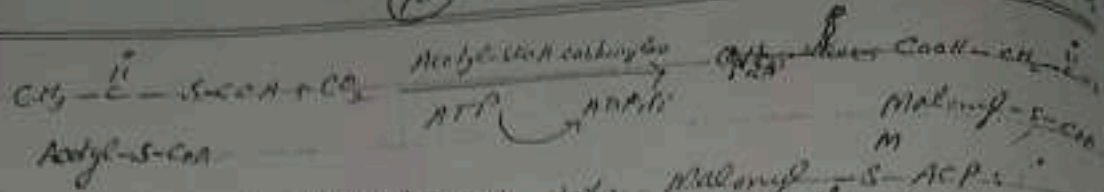


STEPS OF SYNTHESIS OF FATTY ACID (SATURATED) (PALMITIC ACID)

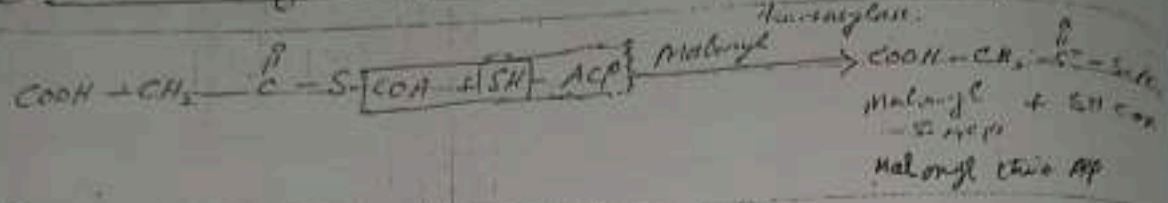


② Conversion of another molecule of Acetyl-S-CoA into Malonyl-S-CoA.

Conversion of Acetyl S-CoA to Malonyl S-CoA
(98)

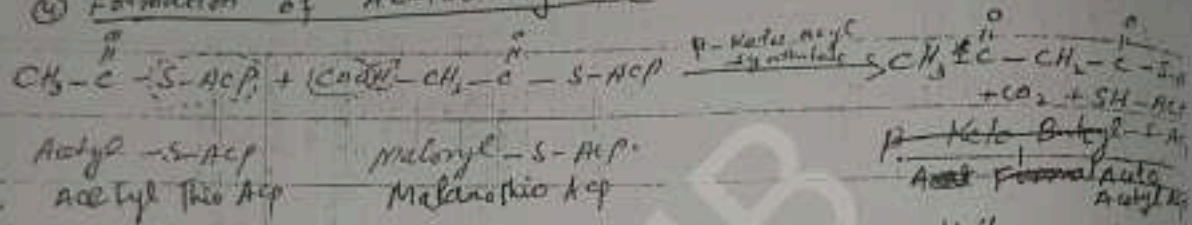


③ Conversion of Malonyl-S-CoA into Malonyl-S-ACP
Malonyl-thio ACP

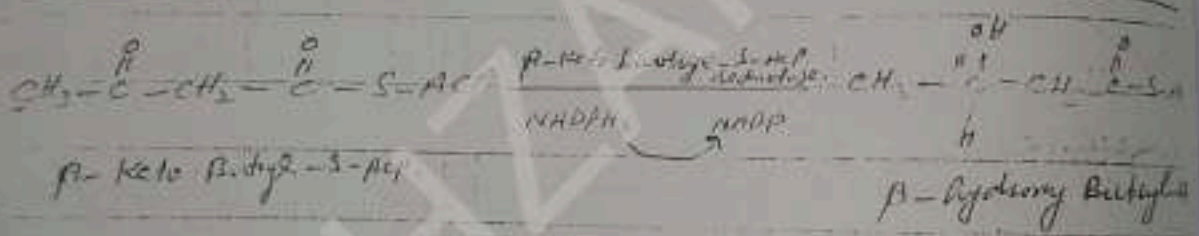


④ Formation of β -Keto-Butyryl-S-ACP

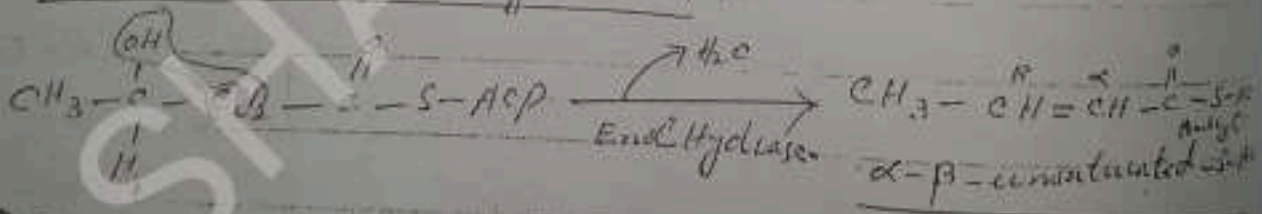
⑤ Formation of Acetoacetyl ACP



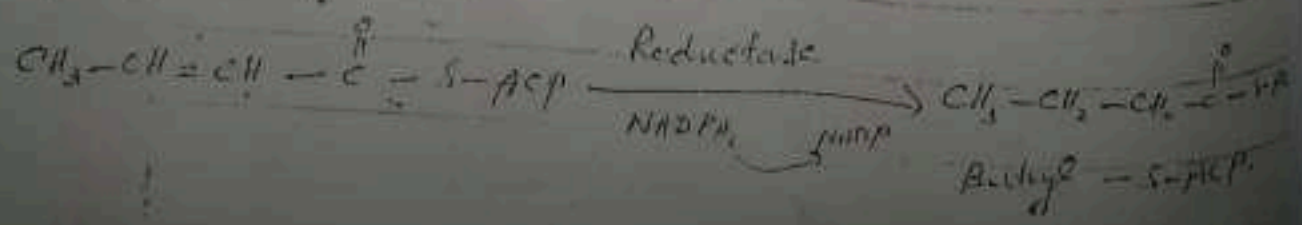
⑥ Reduction of β -Keto Butyryl-S-ACP into β -Hydroxy Butyryl-S-ACP

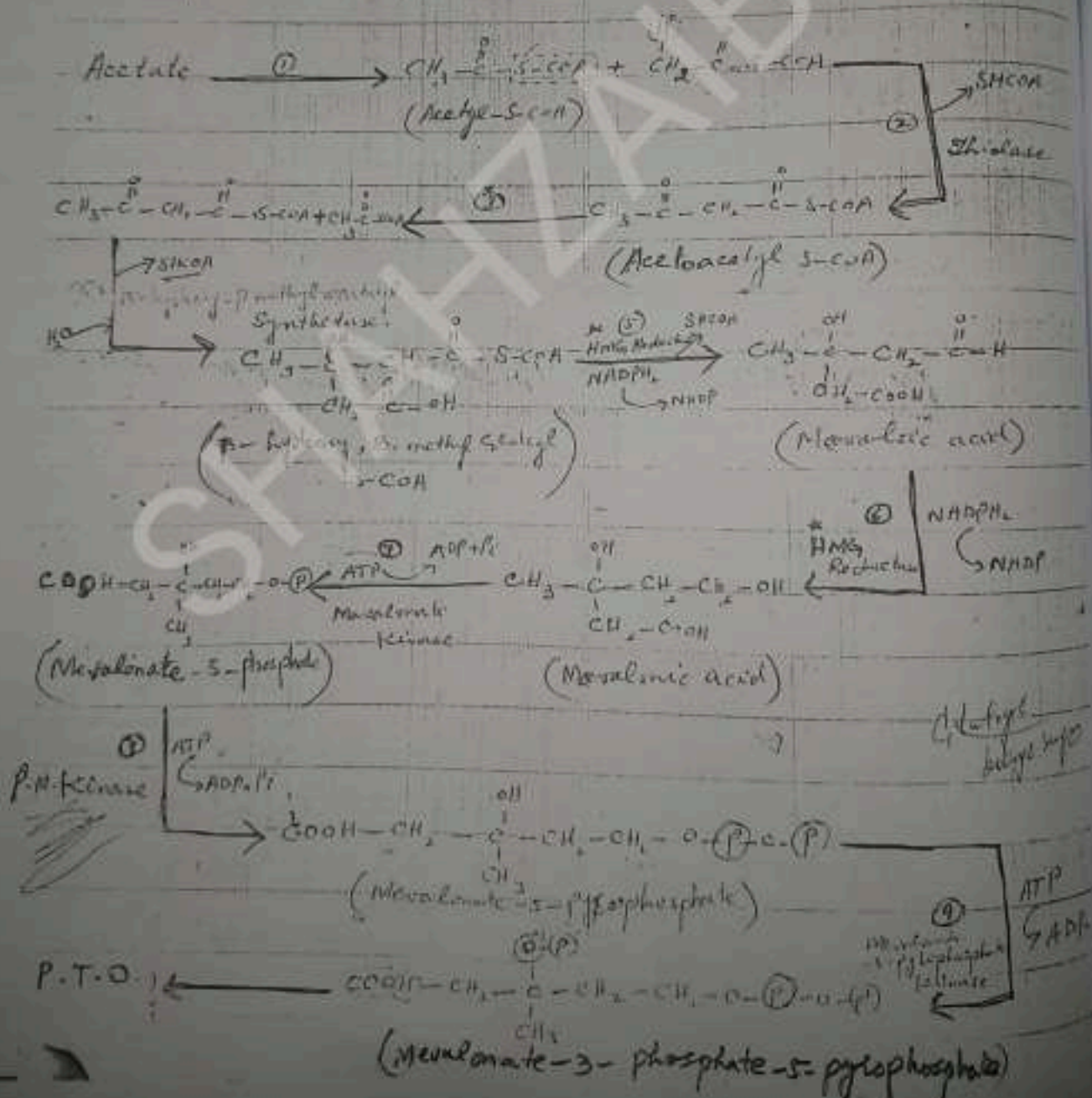


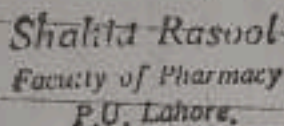
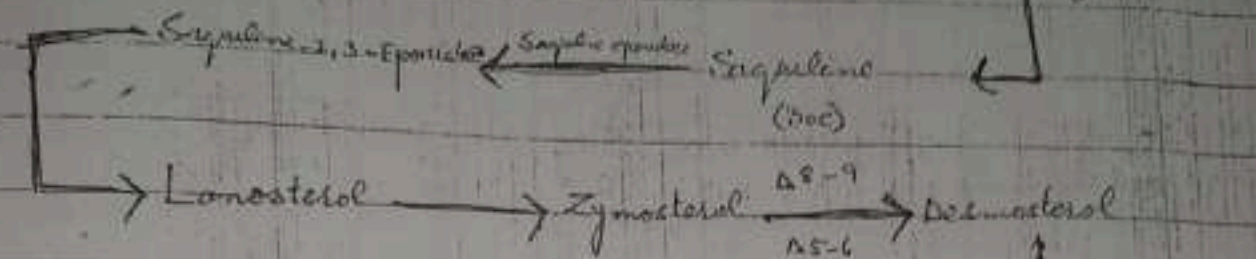
⑦ Dehydration of β -Hydroxy Butyryl-S-ACP into α - β -unsaturated Butyryl-S-ACP



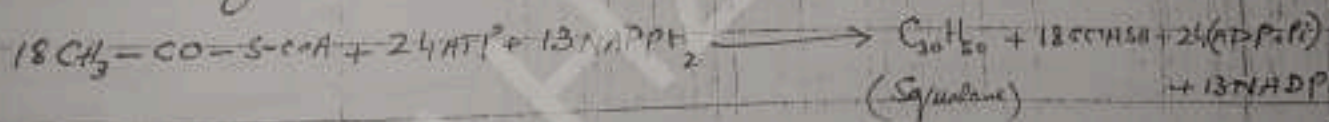
⑧ Reduction of α - β -unsaturated Butyryl-S-ACP into Butyryl-S-ACP







The over all reaction upto the formation of Ergosterol is as follows.



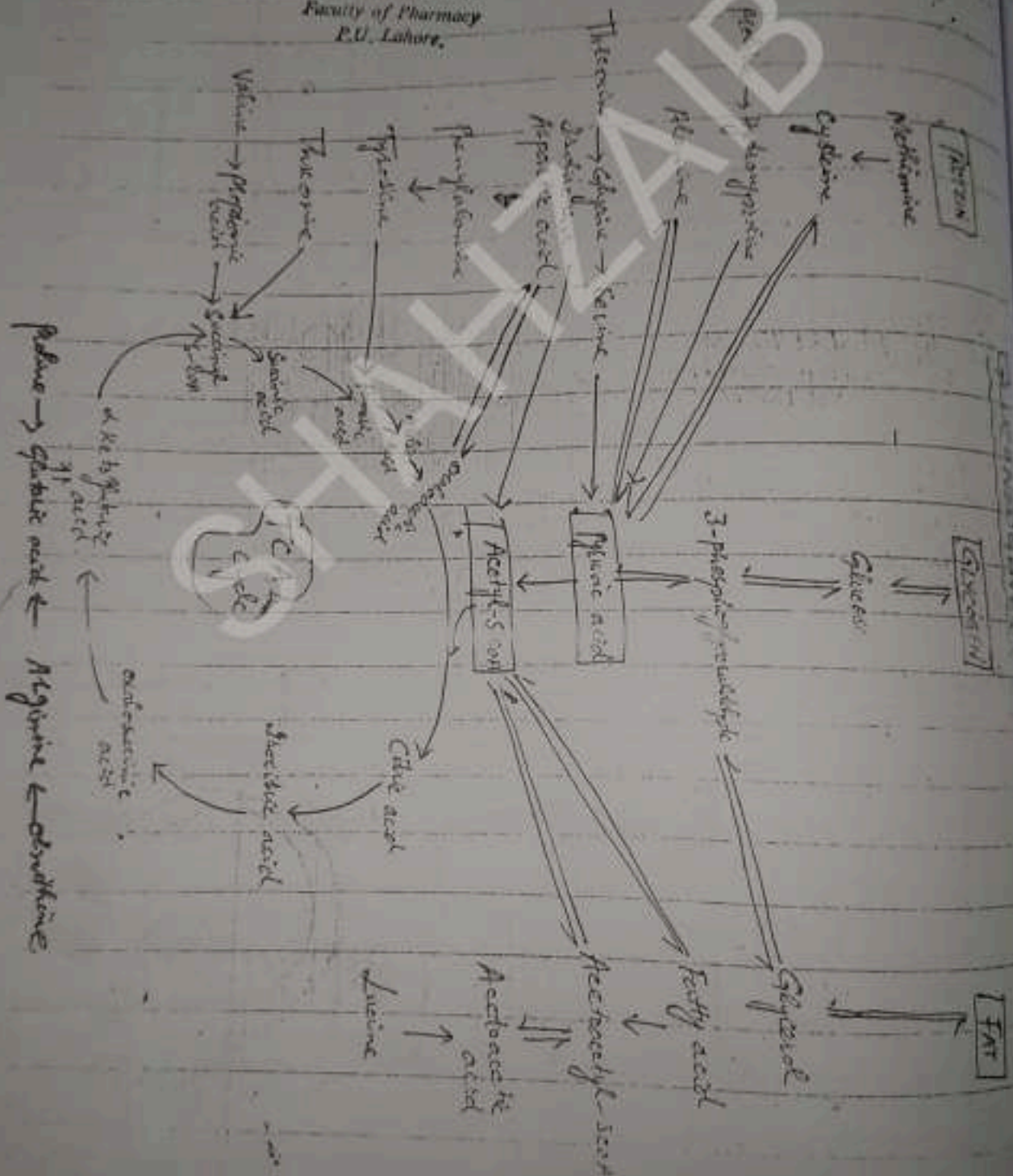
A collection of various handwritten marks, including loops, swirls, and scribbles, scattered across a piece of lined paper. Some marks resemble stylized letters or symbols, while others are more abstract. The marks are drawn in dark ink or pencil.

GLUCONEOGENESIS

of Glutamate from the amino acid
protein amino acid undergo

(10) GLUCONEOGENESIS (antihyperlipid, fat to protein)
Definition: It is the process of synthesis of Glucose from the ^{degradation} of ^{of 100%} catabolic compounds. e.g. Protein amino acid undergo oxidative decarboxylation to give Glucose.

Shahid Rasool
Faculty of Pharmacy
P.U., Lahore.



12/2/2008

Michigan

1

Fig. 1. Diagram of the experimental setup.

140

Metocin $\rightarrow$ Glycine $\rightarrow$ Ne

Japan's

Phenylalanine

Phosphoric —

Bookkeeping

—proliferative
—fresh—

Gallic acid

10

11

Portage

1

1

3

etc

↑

又

10

— 100 —

0

91

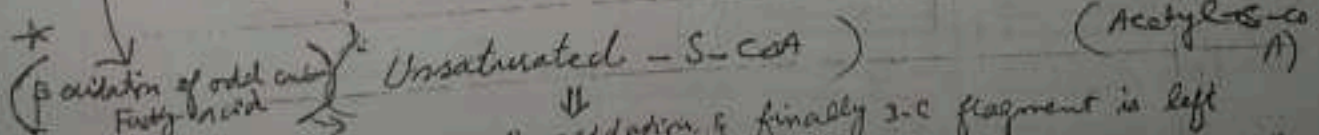
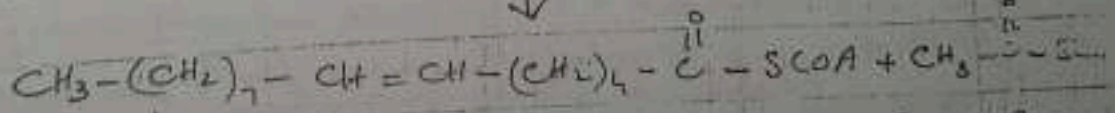
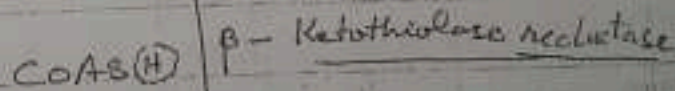
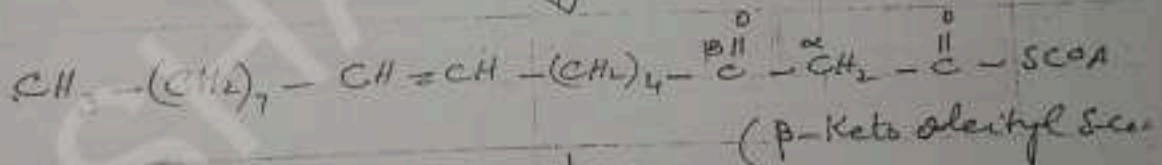
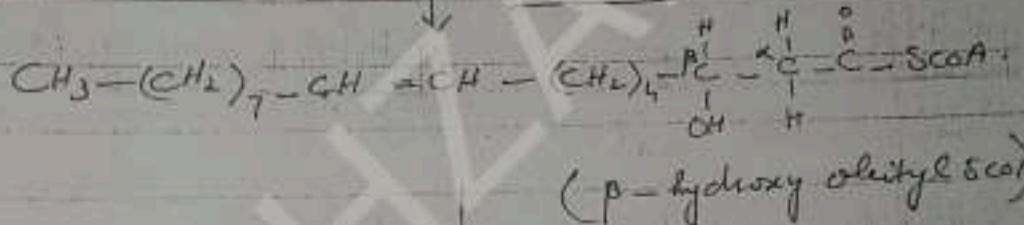
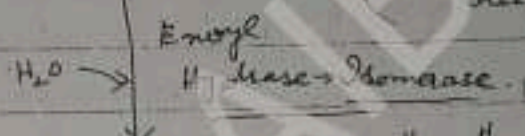
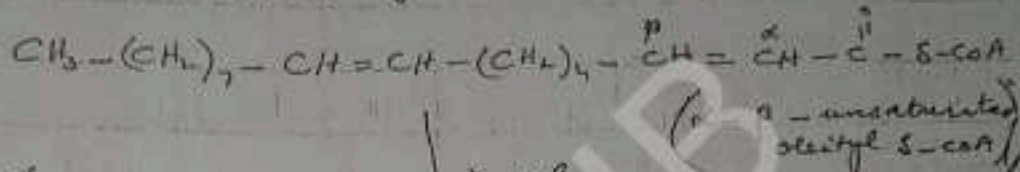
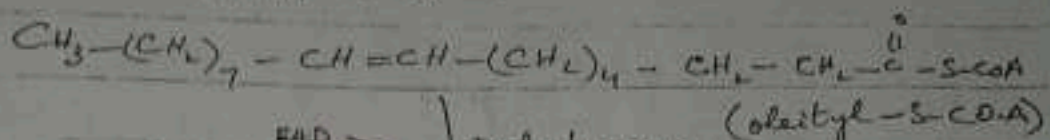
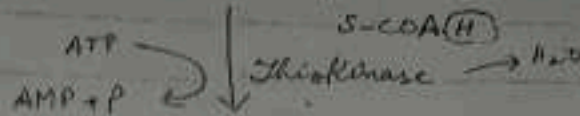
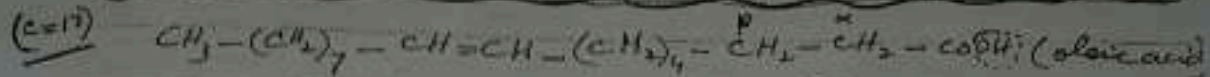
rehabilitate

45

→

James

B- OXIDATION OF FATTY ACIDS (UNSATURATED)



It under goes β oxidation & finally 3-C fragment is left behind in the form of Propionyl-S-CoA which is metabolised in the following way:

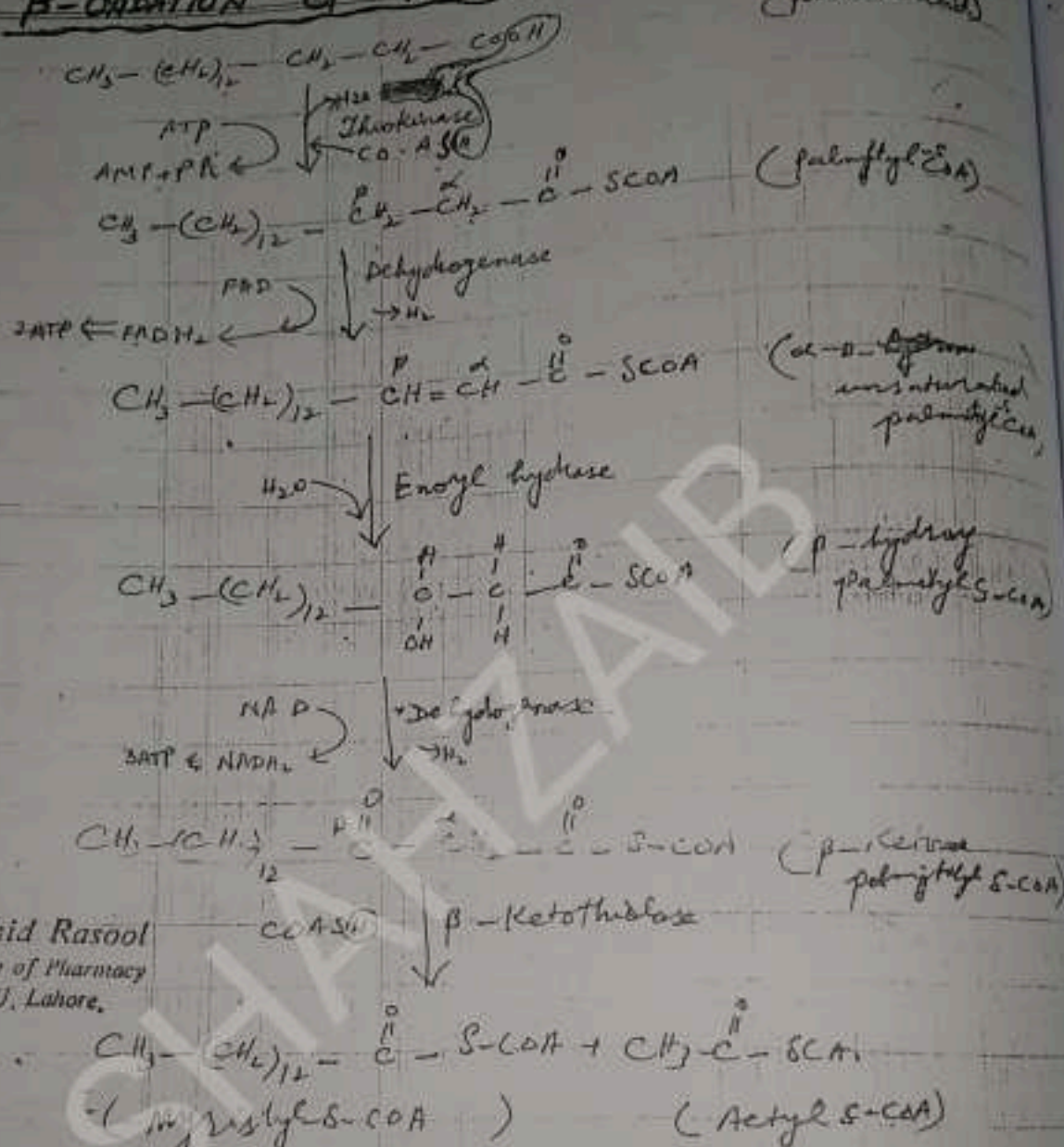
CH₃-CH₂-C(=O)-S-CoA $\xrightarrow{\text{Carboxylase}}$ CH₃-CH₂-C(=O)-S-CoA $\xrightarrow{\text{Isomerase}}$ CH₃-C(=O)-CH₂-S-CoA $\xrightarrow{\text{Methylcrotonyl-CoA carboxylase}}$ CH₃-C(=O)-CH₂-C(=O)-S-CoA

The Succinyl-S-CoA thus produced can enter the TCA cycle.

The process of β -oxidation was described by Knoop

β -OXIDATION OF FATTY ACIDS (SATURATED)

(palmitic acid)

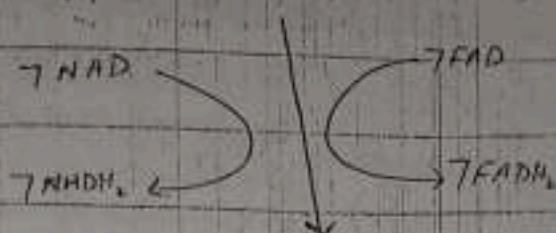
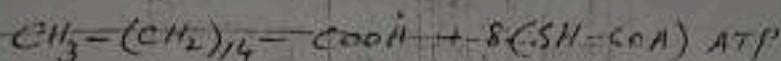


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The myristyl-S-CoA is 14C fatty acid and will undergo β -oxidation in the same way as palmityl-S-CoA and finally form acetyl-S-CoA.

STEPS OF β -oxidation:

- (i) Activation $\rightarrow$ Fatty acid is activated by thioesterase in the presence of CoA-SH and ATP .
- (ii) Dehydrogenation $\rightarrow$ Removal of H_2 . Activate
- (iii) Hydration $\rightarrow$ Addition of H_2O .
- (iv) Dehydrogenation $\rightarrow$ Removal of H_2 .
- (v) Thiolysis cleavage $\rightarrow$ β -keto fatty acid is cleaved at β by P-Ketothiolase .

OVER ALL REACTION:

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ENERGETICS

ATP gained from ^{one} acetyl-CoA (in Krebs cycle) = 12 ✓

So ATP Gained from 8 acetyl-CoA in β -oxidation = 12×8
= 96

ATP Gained from NAD = $3 \times 7 = 21$ ✓

ATP Gained from FAD = $2 \times 7 = 14$ ✓

TOTAL ATP GAINED = 131 ✓

One molecule of ATP is utilized for β -oxidation

So $131 - 1 = 130$

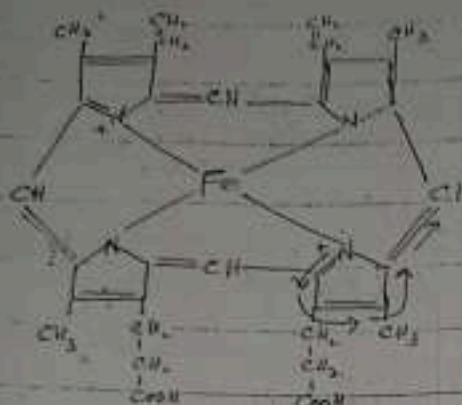
Some times two molecules are utilized

then $131 - 2 = \boxed{129}$

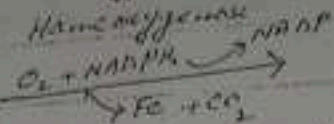
DEGRADATION OF HAEME

Reticuloendothelial system

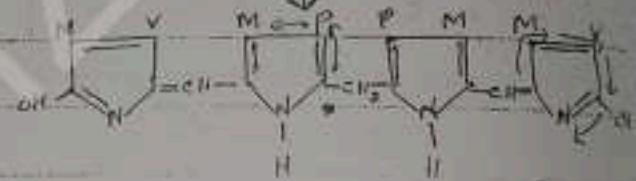
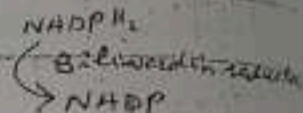
- (i) Formation of Biliverdin
- (ii) Uptake of Biliverdin by the liver
- (iii) Formation of Biliverdin digluconide
- (iv) Secretion of Biliverdin into bile
- (v) Formation of Biliverdin in the intestine



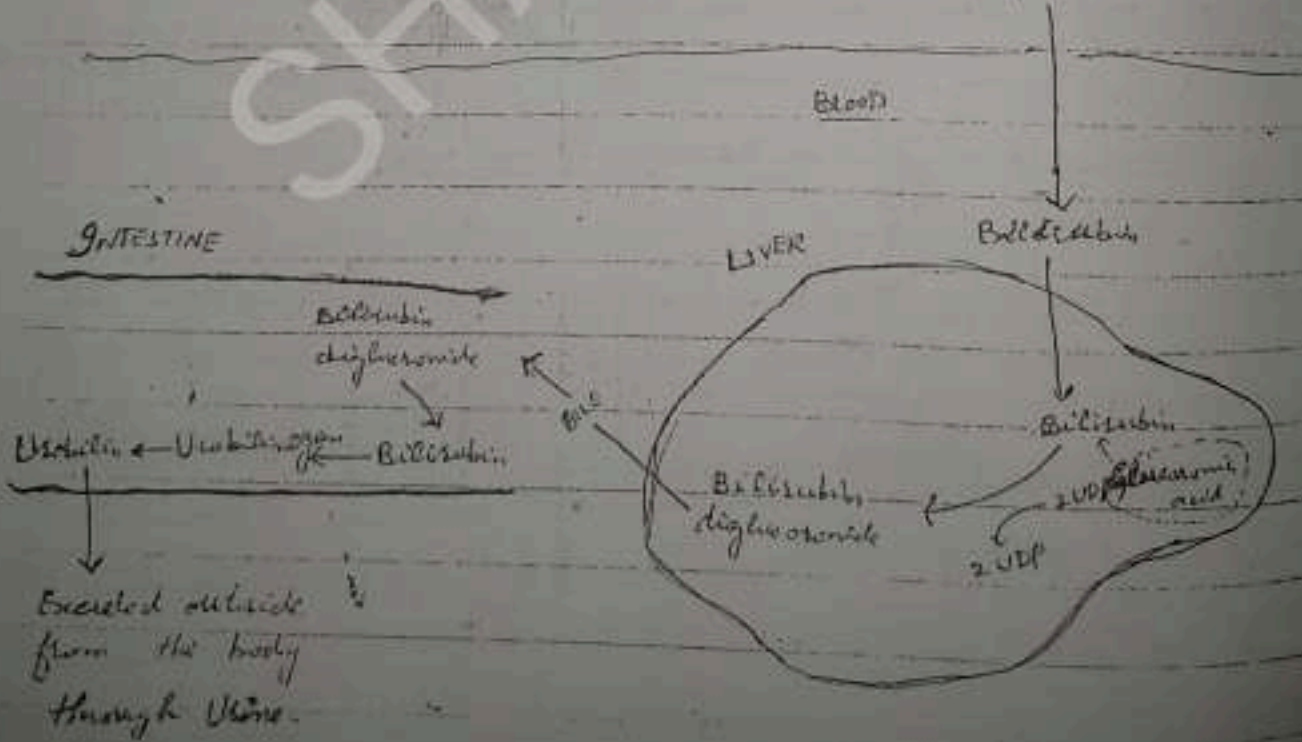
(HAEME)



(BILIVERDIN) → Green



(BILIRUBIN) → Yellow



Degradation of Haeme

ROLE OF PHARMACEUTICAL BIOCHEMISTRY IN HEALTH PROFESSION.

DEFINITION OF BIOCHEMISTRY:

"It is the science which deals with the study of molecules, chemical reactions and process in living cells."

DEFINITION OF PHARM. BIOCHEM.:

"It is the study of molecules, chemical reactions and process in living cells with special reference to pharmaceutical point of view."

IMPORTANCE:

Pharmaceutical Biochem. is very important in health profession in the following two ways:

- (i) For understanding and maintenance of health.
- (ii) For understanding and effective treatment of diseases.
- (iii) For UNDERSTANDING & MAINTANCE OF HEALTH.

HEALTH:

The World Health Organization (W.H.O.) defined health as

"A state of ^{complete} physical, mental and social well being of an individual and not merely absence of diseases".
Health may be considered when all the intracellular and extra cellular reactions are going satisfactory.

One major pre-requisite for the maintenance of health is that there should be optimum no. of ^{chemical} molecules. The chief of chemicals are vitamins, amino acids, minerals, H_2O & certain fatty acids, are much subject

matter of Biochem and nutrition is concerned with the study of various aspects of these chemicals.

CAUSES OF DISEASES:

All diseases are manifestation of abnormalities of molecules, chemical reactions or processes. The major factors responsible for the cause of disease are as follows.

- (i) Physical Agents: e.g. Excess of heat, excess of cold etc.
- (ii) Chemical Agents: e.g. Drugs, poisons.
- (iii) Hereditary Agents: e.g. Haemophilia.
- (iv) Microbial Agents: e.g. Virus, Bacteria, Fungus etc.
- (v) Immunological Agents: e.g. Antigen - Antibodies.
- (vi) Nutritional Deficiency: e.g. Protein, Fat, Carbohydrate etc.

(ii) FOR UNDERSTANDING & EFFECTIVE TREATMENT OF DISEASES:

The use of present Biochem. investigations in relation to disease may be summarized as follows.

- (a) It reveals the causes of diseases.
- (b) Suggest rational and effective treatment of disease.
- (c) Make available of screening tests for early diagnosis.
- (d) Assist in monitoring process.
- (e) Help in assessing response to drugs.

EXAMPLES:

Following examples briefly illustrate the relationships of Biochemistry to the prevention and treatment of diseases.

- (i) It is well known that human must ingest no. of complex organic molecules called Vitamins in order to

maintain normal health. Vitamins are generally converted into more complex molecules (Co-enzymes) in the body that play key role in biological reactions. If a particular vitamin is deficient in diet, a deficiency disease may result e.g. Scurvy & Rickets (Vit. C and D). The vit. play key role in forming their biological derivatives.

(vi) Phenyl Ketoneuria (PKU) is a disease which is caused due to low or absent activity of enzyme that convert phenyl alanine to tyrosine.

As a consequence of enzyme deficiency, CNS is apparently damaged. So it becomes rational to treat the disease by placing effective influence on a diet low in phenyl alanine.

In this way pharmaceutical Biochem. is important for understanding and treatment of diseases.

Q-What are Nucleic Acids? Give their structure and importance in the biosynthesis of protein? Differentiate between DNA & RNA. (20)

1001 NUCLEIC ACIDS:

Definition:

"Nucleic acids are the chains of polynucleotides, in which large no. of mononucleotides are linked by ester linkage."

NUCLEOTIDES:

Nucleotides are basic building blocks of nucleic acids. It will be correct to say that nucleotides polymerize to form nucleic acids.

Each nucleotide is composed up of 3-parts.

- (i) Nitrogen base
- (ii) Sugar.
- (iii) Phosphate group.

(1) NITROGEN BASES: Nitrogen bases are of two types.

(a) Purines: These include Adenine and Guanine.

(b) Pyrimidine: These include Cytosine, Thymine and Uracil.

(2) SUGAR: Sugar in the nucleotide is of two types.

(a) Ribose sugar

(b) Deoxyribose sugar $\Rightarrow$ Having one oxygen less.

(3) PHOSPHATE GROUP: In nucleotide, phosphoric acid is attached.

So A general structure of a nucleotide can be written as



Nucleotide

P = phosphoric acid

N = Nitrogen Base.

S = Sugar.

NUCLEOSIDES: A nucleoside has two parts instead of 3 parts, i.e. Nitrogen Base & Ribose sugar.

It contains no phosphoric acid.



Nucleoside

TYPES OF NUCLEIC ACIDS:

There are two types of nucleic acids.

(1) Deoxyribonucleic Acids (DNA).

(2) Ribonucleic Acids (RNA).

(1) DEOXYRIBONUCLEIC ACIDS: (DNA).

It was discovered by R. Miescher in fish sperm.

Occurance: It occurs in the cells of various groups of animals, plants, bacteria and viruses.

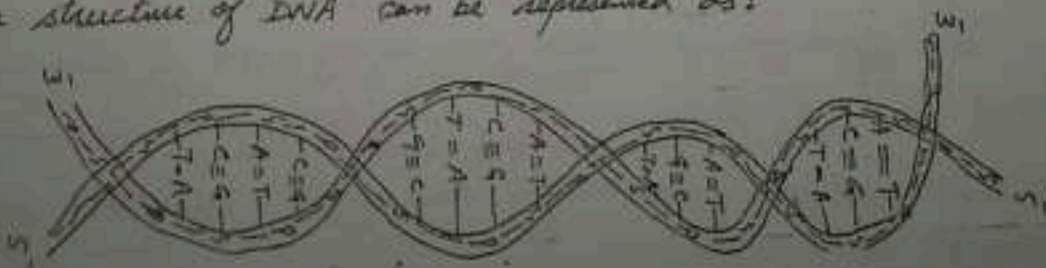
Location: It is located in the nucleus of cell.

Number: In the nucleus of prokaryotic cells, there is single chromosome so there is single DNA while in Eukaryotic cells, there are several chromosomes, so there are several DNA molecules.

STRUCTURE OF DNA:

The structure of DNA was proposed by Watson and Crick in 1953 from the x-ray diffraction obtained by Franklin.

According to them, DNA molecule is a double strand molecule in which two strands are twisted to form a double helix. The sides of strand are composed of Deoxy ribose sugar and phosphoric acid linked to each other by phosphodiester linkage. The rings of strand are composed of Nitrogen Bases which are linked to each other through Hydrogen bonds. 'A' always combine with 'T' and 'C' always combine with 'G'. There is double hydrogen bond between 'A' & 'T' while triple in 'C' and 'G'. The structure of DNA can be represented as:



(2) RIBONUCLEIC ACIDS: (RNA)

LOCATION: They are present in the cytoplasm in Ribosomes.

OCCURANCE: RNA is present in all the plant viruses, bacteria and animals.

NUMBER: The no. of RNA is not fixed in different cells. In most cells there is 5-10 times as much RNA as a DNA.

TYPES: RNA has three types.

(i) Messenger RNA (mRNA).

(ii) Transfer RNA (tRNA).

(iii) Ribosomal RNA (rRNA).

STRUCTURE OF RNA:

RNA is a single strand molecule. In RNA, the sugar is Ribose and instead of the amino nitrogen Base, there is Uracil.

IMPORTANCE OF NUCLEIC ACIDS IN BIOSYNTHESIS OF PROTEIN:

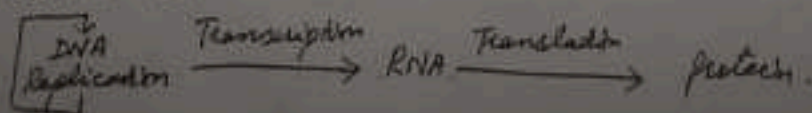
Nucleic Acids have great importance in the biosynthesis of proteins. They play a vital role in the whole process of synthesis.

In the synthesis of protein, both type of nucleic acids are involved i.e. DNA and RNA.

The role of different nucleic acids are as follows.

(i) DNA:

The synthesis of protein from amino acids is directed by DNA present in the nucleus. The process of protein synthesis takes place in three steps i.e. replication, transcription & translation. It can be represented as



So first of all DNA molecule replicate and produce their exact copies to serve as genetic code to send the information through mRNA.

(2) mRNA: The formation of mRNA from DNA is called transcription. When mRNA is formed from DNA, it gets information, leaves the nucleus and enters the cytoplasm where it gets associated with ribosomes and form a codon. There are four types of nitrogen bases in mRNA.

(3) tRNA:

The function of tRNA is to collect the amino acids and transfer them to ribosomes which are the main sites of protein synthesis. The tRNA form an anti codon. In this way it transfer amino acids from cytoplasm to ribosomes.

(4) rRNA:

These are the main sites of protein synthesis. The amino acids are linked through peptide bond with each other at ribosomes and thus a protein molecule is given out.

In this way, nucleic acids play a very important role in the synthesis of protein.

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DIFFERENCE BETWEEN DNA & RNA:

	<u>DNA</u>	<u>RNA</u>
(1) <u>LOCATION</u> :	It is present in the nucleus.	It is present in the cytoplasm.
(2) <u>STRAND</u> :	It is a double strand molecule.	It has single strand.
(3) <u>NITROGEN BASES</u> :	It has four nitrogen bases i.e. Adenine, Guanine, Cytosine and thymine.	It has four nitrogen bases i.e. Adenine, Guanine, cytosine and Uracil.

DNARNA

- ④ PENTOSE SUGAR: It has deoxyribose sugar. It has ribose sugar.
- ⑤ TYPES: It has no type. It has three types
i.e. mRNA, tRNA & rRNA.
- ⑥ GENETIC MATERIAL: It is a genetic material and passed on from one generation to next. It is not a genetic material.
- ⑦ STRUCTURES: DNA has primary, secondary & tertiary structures. RNA has only primary structure.
- ⑧ SOLENOID STRUCTURE: Its specific feature is solenoid structure. It has no solenoid structure.
- ⑨ REPLICATION: It can replicate. It cannot replicate.
- ⑩ FORMATION: It is formed from itself. It is formed from DNA.
- ⑪ AMOUNT OF NITROGEN BASES: In DNA, the amount of nitrogen bases are equal. i.e. Total purines = Total pyrimidines. In RNA, the amount of nitrogen bases varies greatly.
- ⑫ MOLECULAR WEIGHT: Much larger than RNA. Much smaller than DNA.

Chromatography

is of two types

① Paper chromatography

② Thin layer chromatography ✓

It has two phases i.e. (mobile phase) and (stationary phase)
eg. moving solvent while stationary phase
eg. Paper ✓

$R_f \text{ value} = \frac{\text{distance travelled by the solute (sample)}}{\text{distance travelled by solvent (mobile phase)}}$
 R_f should always be less than 1

① Paper chromatography

This technique was introduced by Martin and his co-workers in (1944).
The basic principle of paper chromatography is the "distribution or partition of a solute or substances between two solvents or phases" (one solvent is usually water which is strongly adsorbed on the fibers of cellulose which constitutes the paper. This is fixed or stationary phase).

The mobile phase is the other solvent usually immiscible with water which travels up and down on the paper. Substances which are more soluble in water (eluting solvents) travel faster than the one which are less soluble resulting in separation of components of a mixture.

For separation of mixture of a given sample we use paper chromatography technique.
A large rectangular piece of special filter paper is taken. A pencil



spotting (116)

spotting

A line is drawn on the paper near the bottom. Then a drop of sample soln is placed on this line with the help of capillary pipette tube or fine pipette. This is known as spotting.

① Drops of soln of known substances (standards) believed to be present in sample soln are also placed along the side for comparison.

It is placed vertically that is paper in a glass stand known as chromatography jar. The mobile phase or solvent used for development of chromatogram is introduced into the tanks so that the filter paper dips into solvent but the pencilled line is just at the surface of the solvent. The chromatographic tank is then closed so that it is saturated with the vapours of the solvent.

As the solvent moves upward on the paper (due to capillary action) -

✓ Different substances in the sample are carried with but only to different lengths when the solvent front reaches that is mobile phase almost to the top end of paper. The paper is removed from the tank and the solvent is allowed to evaporate from solvent the spots of adsorbed substances that have ascended the paper within a suitable reagent that reacts with separated substances from coloured spots or bands.

If the unknown substance have travelled the same distance as the standard known substance then this is sufficient for its identification and such identification can be verified by the comparison of Rf value of the sample with that of known substance.

The Rf (Rate of flow) value is defined as

" (Ratio of distance travelled by the substance or solute to distance travelled by solvent mobile)

Applications

- (i) Amino acids eg. aspartic acid, glycine etc and (ii) sugar components like dextrose, fructose and sucrose can be detected by this technique.
- (iii) a mixture of different components of ink can also be detected.

Def

Chromatography is a technique used to separate different components of a mixture on the rate of their absorption (Rf)

- ① Amino acids are detected
- ② Sugar components dextrose, fructose and sucrose are detected
- ③ Ink mixture is also detected

② Thin Layer Chromatography

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This technique was fully developed by E. Stahl in 1926 - based on the combined principle of absorption and partition chromatography. TLC is similar to Paper Chromatography except for the fact that here the paper is replaced by a glass plate or a plastic plate coated with the thin layer of adsorbent like alumina, silica gel, or other foreign materials like starch, cellulose, and Kieselguhr (a fine clay).

- The adsorbent is mixed with a liquid like distilled water to form a slurry which is spread as a uniform thin layer (about 0.25 mm to 20 mm) on a clean glass plate of the size 10-70 cm or 20-20 cm with the help of a roller to remove excess slurry. The glass plate is then dried in a cran.
- ③ A drop of unknown solution or mixture is applied with the help of a micropipette on the layer at a point about 1 cm from the end (from baseline) - Drops of solution of known (standard) substance is believed to be present in sample may also be placed along side for comparison.
- ④ When the solvent has evaporated from the plate, then the plate is kept in a chromatograph chamber of glass containing the solvent. The solvent moves up slowly.

slowly on the plate due to capillary action causing it with a component of the mixture which moves at different rates as in columns of absorption chromatography.

When the solvent front ^(mobile) has travelled almost to the top of plate, the plate is removed from the chromatograph chamber. If coloured substances are involved - then spots of separated compounds will be seen as coloured lines. However, if colourless substances are involved then the plate is developed with the vapours of iodine or soln of $KMnO_4$ or with any other colour producing reagent.

This development serves to be utilized for spots of substance - so that comparison of R_f values may be done for identification purposes.

R_f value can be calculated as

$$\rightarrow R_f = \frac{\text{Distance travelled by solute or sample}}{\text{" " by solvent front (mobile phase)}}$$

R_f value should always be less than one (1).

$$R_f \leq 1$$