CBS Confident Pharmacy Series

Fifth Edition

Biochemistry and Clinical Pathology

for Second Year Diploma in Pharmacy

Course Code: **ER20-23T**

As per the latest syllabus prescribed by Pharmacy Council of India

Including
Board Examination Question Papers and Specimen Answer Papers

VN Raje





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- To the point answers
- Remembering the concepts in the simplest way
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Preface to the Fifth Edition

Fifth edition of this book includes Board Examination Question Papers and Solved Specimen Answer Papers. These additional contents are of great importance about the framework of Question Paper Pattern and Specimen Answers as per the format of Pharmacy Council of India (PCI).

This edition of the book **Biochemistry and Clinical Pathology** builds self-confidence in students which will help them to get success in the examinations. The book has been written to meet the requirements of students of Diploma in Pharmacy (D Pharm) in accordance with the new revised syllabus ER 2020 prescribed by Pharmacy Council of India.

This book is small and a humble effort has been put in for compiling necessary information on the subject. An attempt has been made to demystify and simplify the basic concepts for the students of pharmacy and to enable them get an evergreen success in all the board examinations.

The salient features of the present book are:

- Lucid and easy language
- To the point answers
- Remembering facts in the simplest way
- Infusing confidence in the reader to appear in the board examinations.

Hence, the series is named

CBS Confident Pharmacy Series

I am confident that this book will be useful to both the students and the teachers of Diploma in Pharmacy as well as the candidates desiring to succeed in competitive examinations for better job opportunities in pharmacy profession such as hospital pharmacists in PHCs, civil hospitals, etc.

Raje Vijay N

to

my beloved family

Acknowledgements

I express my heartfelt thanks to Prof Madan Jagtap, Chairman, Gourishankar Education Society, Satara, Maharashtra, for consistent encouragement and inspiration for writing this book.

I wish to acknowledge the prompt and efficient help given by Prof Milind Jagtap, Mr Jaywant Salunkhe, Mr Appa Rajage, Mr Nitin Mudalgikar, and Mr Shrirang Katekar of Gourishankar Education Society, Satara.

I am also thankful to Shri Satish Kumar Jain, Chairman and Managing Director, and Shri Shantanu Sarkar, General Manager, Mumbai Branch, CBS Publishers & Distributors Pvt Ltd, for their sustained efforts and keen interest in the publication of this book.

I wish all my beloved students to have a great success in the board examinations.

Raje Vijay N

Syllabus

(As per PCI New ER 2020)

Biochemistry and Clinical Pathology

Course Code: ER20-23T

1. **Introduction to biochemistry:** Scope of biochemistry in pharmacy; cell and its biochemical organization
2. **Carbohydrates**
   - Definition, classification with examples, chemical properties
   - Monosaccharides—structure of glucose, fructose and galactose
   - Disaccharides—structure of maltose, lactose and sucrose
   - Polysaccharides—chemical nature of starch and glycogen
   - Qualitative tests and biological role of carbohydrates
3. **Proteins**
   - Definition, classification of proteins based on composition and solubility with examples
   - Definition, classification of amino acids based on chemical nature and nutritional requirements with examples
   - Structure of proteins (four levels of organization of protein structure)
   - Qualitative tests and biological role of proteins and amino acids
   - Diseases related to malnutrition of proteins
4. **Lipids**
   - Definition, classification with examples
   - Structure and properties of triglycerides (oils and fats)
   - Fatty acid classification—based on chemical and nutritional requirements with examples
   - Structure and functions of cholesterol in the body
   - Lipoproteins—types, composition and functions in the body
   - Qualitative tests and functions of lipids
5. **Nucleic acids**
   - Definition, purine and pyrimidine bases
   - Components of nucleosides and nucleotides with examples
   - Structure of DNA (Watson and Crick model), RNA and their functions
6. **Enzymes**
   - Definition, properties and IUB and MB classification
   - Factors affecting enzyme activity
   - Mechanism of action of enzymes, enzyme inhibitors
   - Therapeutic and pharmaceutical importance of enzymes

7. **Vitamins**
   - Definition and classification with examples
   - Sources, chemical nature, functions, coenzyme form, recommended dietary requirements, deficiency diseases of fat-and water-soluble vitamins
8. **Metabolism** (study of cycle/pathways without chemical structures)
   - Metabolism of carbohydrates: Glycolysis, TCA cycle and glycogen metabolism, regulation of blood glucose level. Diseases related to abnormal metabolism of carbohydrates
   - Metabolism of lipids: Lipolysis, β-oxidation of fatty acid (palmitic acid), ketogenesis and ketolysis. Diseases related to abnormal metabolism of lipids such as ketoacidosis, fatty liver, hypercholesterolemia
   - Metabolism of amino acids (proteins): General reactions of amino acids and its significance—transamination, deamination, Urea cycle and decarboxylation. Diseases related to abnormal metabolism of amino acids, disorders of ammonia metabolism, phenylketonuria, alkaptonuria and jaundice
   - Biological oxidation: Electron transport chain and oxidative phosphorylation
9. **Minerals:** Types, functions, deficiency diseases, recommended dietary requirements
10. **Water and electrolytes**
    - Distribution, functions of water in the body
    - Water turnover and balance
    - Electrolyte composition of the body fluids, Dietary intake of electrolyte and Electrolyte balance
    - Dehydration, causes of dehydration and oral rehydration therapy
11. Introduction to biotechnology
12. **Organ function tests**
    - Functions of kidney and routinely performed tests to assess the functions of kidney and their clinical significances
    - Functions of liver and routinely performed tests to assess the functions of liver and their clinical significances
    - Lipid profile tests and its clinical significances
13. **Introduction to pathology of blood and urine**
    - Lymphocytes and platelets, their role in health and disease
    - Erythrocytes—abnormal cells and their significance
    - Normal and abnormal constituents of urine and their significance

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Chapter
1

Introduction to Biochemistry

Q.1. Define the terms.

i. *Biochemistry:* Biochemistry is the study of chemistry of living organism and deals with structure of tissues, cells, organelles and individual biomolecules.
ii. *The cell:* The cell is the basic, living, structural and functional unit of living organism.
iii. *Biomolecules:* The living cell is composed of few elements like C, H, O and N that combine to form a great variety of molecules are called biomolecules, e.g. carbohydrates, proteins, fats, nucleic acids, lipids.

Q.2. Give the aims, objectives and importance of biochemistry.

i. Biochemistry is helpful for detailed study of structure and functions of biomolecules like carbohydrates, proteins, lipids, minerals and DNA.
ii. Biochemistry is useful for study of various interactions of different biomolecules.
iii. Biochemistry is useful for study of nature and working of enzymes and study of different types of enzymes.
iv. Study of the energy transformations in living cells and organisms is another objective of study of biochemistry.
v. Heredity and variations possess rational molecular basis. The study of this molecular basis is one of the main aims of biochemistry.
vi. Study of self-replication and duplication processes which maintains the genetic continuity from cell to cell, is main objective of biochemistry.
vii. Knowledge of biochemistry is used to control diseases, abnormal deficiency and treatment of deficiencies.
viii. Metabolic abnormalities can be studied by the knowledge of biochemistry.

ix. Knowledge of biochemistry is helpful for understanding the dynamic changes of cellular systems and corresponding need of nutrients.

Q.3. Define biochemistry and state significance of biochemistry in pharmacy.

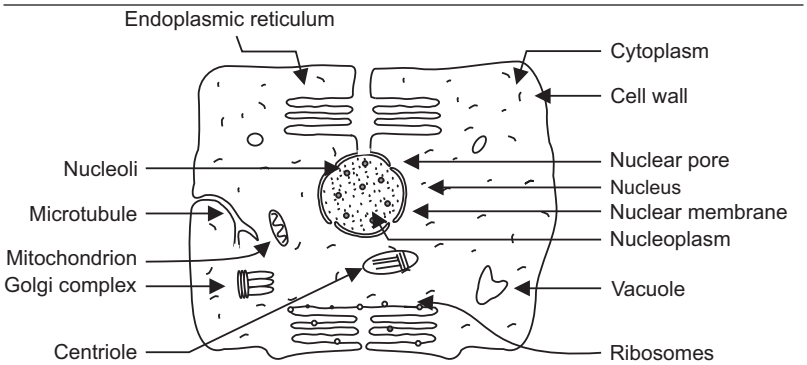
Biochemistry

The study dealing with the chemistry of living organism in its different phases of activity, is called biochemistry.

Significance

1. It deals with study of living system and its working.
2. Study of nature and working of molecules
3. Diagnosis of various metabolic disorders
4. Study of various deficiency diseases
5. Helps in synthesizing new molecules.

Q.4. Discuss major intracellular organs and their functions. OR Describe various parts of cell, draw and label diagram of cell. (S.23, W.23)



The cell

Parts/Components of Cell/Major Intracellular Organs/Organelles

1. *Nucleus:* It is a spherical and largest part of the cell. It contains nuclear membrane, nucleoplasm, nucleoli and genetic material DNA. Nuclear membrane is continuous with endoplasmic reticulum.
   - *Functions:*
     i. It controls all cellular activities.
     ii. It contains DNA, RNA and proteins.
     iii. RNA helps in protein synthesis.

iv. DNA helps in production of chromosomes.
v. Marker enzyme is DNA polymerase which is a site of DNA to RNA synthesis.

2. *Endoplasmic reticulum:* It is a network of membrane continuous with nuclear membrane.
   - *Functions*:
     i. It provides surface area for number of chemical reactions.
     ii. It helps in synthesis of steroids, proteins, etc.
     iii. It provides a pathway for transporting various chemical substances.
     iv. It helps to concentrate the products of synthetic activities of cell.
3. *Ribosomes:* These are tiny granules present in cytoplasm as well as on surface of endoplasmic reticulum. It contains special type of RNA called RNA.
   - *Function:* Ribosomes are the main sites for protein synthesis.
4. *Lysosomes:* These are membranous vesicles, contain powerful digestive enzymes which are capable of breaking down many kinds of molecules.
   - *Functions:*
     i. It helps for intracellular digestion
     ii. Autolysis
     iii. Phagocytosis.
5. *Golgi apparatus:* It consists of 4–8 flattened bag-like channels stacked upon each other. It is located near the nucleus.
   - *Functions*:
     i. It helps in intracellular sorting of proteins
     ii. It helps in packaging of secretory products.
6. *Mitochondria:* There are small intracellular organelles and are known as powerhouse of cells. Each one is bounded by inner folded and other smooth membrane. Inner surface have many cristae and are covered with F_1 particles.
   - *Functions:*
     i. It is the main site for synthesis and storage of ATP.
     ii. It is the site of citric acid cycle, β-oxidation, urea cycle and ETS.
     iii. It contains special DNA and is self-replicative.
     iv. Mitochondrion performs the main function of conversion and transfer of cellular energy.

7. *Cell membrane/plasma membrane:* It surrounds the cell and separates it from other cells and external environment. It is composed of proteins, phospholipids, carbohydrates, minerals, etc.
   - *Functions:*
     i. It involves in transport of molecules in-and-out of the cells.
     ii. It gives shape to the cell.
     iii. It covers and protects the cell and organelles.
     iv. It helps in intracellular adhesion and communication.
     v. It forms channels of ER.
     vi. It forms boundaries to the cytoplasm.
     vii. It can act as a physiological sieve.

Q.5. Explain physiology of cell wall.

Physiology of Cell Wall

The cell wall forms the boundary of the cell, inside which various organelles and protoplasm are present. The cell wall is mainly composed of proteins, carbohydrates, phospholipids, minerals, etc. The cell wall is a semipermeable membrane which acts as a sieve through which certain substances are allowed to enter the cell in the form of excreta.

The substances pass through semipermeable membrane and it depends upon their:

i. Particle size
ii. Concentration
iii. Lipid solubility
iv. Electrical charges
v. Presence of carrier molecules.

Q.6. Why lysosomes are known as 'sulcide bags'/sulcide packets/ digestive apparatus of the cell?

- Lysosomes are membranous vesicles containing powerful digestive enzymes which are capable of breakdown of many kinds of molecules.
- Lysosomes are known as suicide bags of cell because they contain lytic enzymes capable of digesting cells and unwanted materials when lysosomes brust, the lytic enzymes within it spill all over the cell, rupturing the cell membrane or cell wall and inducing the death of cell. This is also known as autolysis.

Q.7. Why mitochondria are called powerhouse/storehouse of cell (energy coin/storehouse of energy)?

- Mitochondria are tiny organelles present inside the cell.
- They are involved in release of energy from food. This is known as cellular respiration.

- They generate energy rich molecules ATP from cellular respiration which are later used for other processes.
- The energy is stored in the form of ATP.
- It is the main site for citric acid cycle, β-oxidation, urea cycle, ETS, etc. where, ATP is generated.
  Hence, mitochondria are called the powerhouse of the cell.

Q.8. What are various stages of cell reproduction or cell division?

Stages of Cell Reproduction

1. Prophase
2. Metaphase
3. Anaphase
4. Telophase

Q.9. Differentiate between eukaryotic and prokaryotic cells.

Eukaryotic cell	*Prokaryotic cell*
1. Cell wall is absent.	1. Cell wall is present.
2. They contain true nucleus, nucleolus and nuclear membrane.	2. They do not contain true nucleus, nucleolus and nuclear membrane.
3. Nuclear material is bounded by nuclear membrane.	3. Nuclear material is scattered.
4. Contains mitochondria or chloroplast	4. Mitochondria or chloroplasts are absent.
5. Capable of pinocytosis	5. Not capable of pinocytosis
6. They are found in almost all plants, animals, fungi and protozoa.	6. They are found in bacteria and blue green algae.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. The spherical and largest part of cell is **nucleus**.
2. **RNA** helps in protein synthesis.
3. **Ribosomes** are the main sites for protein synthesis.
4. **Lysosomes** are called suicidal packets of the cell.
5. Powerhouse/storehouse/energy coin of the cell is **mitochondrion**.
6. **Mitochondria** are the main sites for synthesis and storage of **ATP**.
7. ATP means **adenosine triphosphate**.
8. The **cell** is the basic, smallest, living, structural and functional unit of the living organisms.
9. The tiny granules present on the surface of endoplasmic reticulum are called **ribosomes**.
10. Autolysis and phagocytosis are the functions of **lysosomes**.

Chapter

2

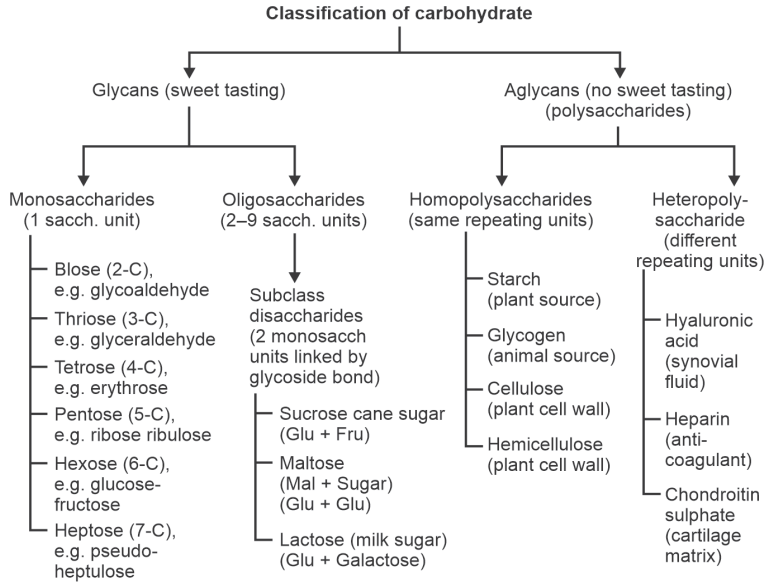
Carbohydrates

Q.1. Define carbohydrates. Classify carbohydrates with examples. (S.23, 24, W.23)

Carbohydrates

"Carbohydrates can be defined as organic compounds which are polyhydroxy aldehydes or polyhydroxy ketones or their derivatives or substances which upon hydrolysis give these derivatives."

Carbohydrates are also called saccharides meaning sugar.



Explanation

A. **Monosaccharides:** These contain one saccharin unit. These are the polyhydroxy aldehydes or ketones, which cannot be further hydrolysed into simple sugar.

The general formula is $C_n (H_2O)_n$.

Sugars containing aldehyde group are called aldoses.

Sugars containing ketone group are called ketoses.

a. *Trioses:* These are the monosaccharides containing three carbon atoms, e.g. glyceraldehyde.
b. *Tetroses:* These contain four carbon atoms in the chain, e.g. erythrose, threose.
c. *Pentoses:* These contain five carbon atoms in the molecule, e.g. ribulose, ribose, xylose, arabinose.
d. *Hexoses:* These contain six carbon atoms in the molecules, e.g. glucose, galactose, mannose and fructose.

B. **Oligosaccharides:** The carbohydrates that hydrolyse to yield 2–10 moles of monosaccharides are called oligosaccharides.

The general formula is $C_n(H_2O)_{n-1}$.

Disaccharides

The sugars that undergo hydrolysis to produce only two moles of monosaccharides are called disaccharides.

Generally, these are sweet, crystalline, water-soluble substances, easily hydrolysed by enzymes and dilute mineral acids, e.g.

Maltose = 1 mol. glucose + 1 mol. glucose
Lactose = 1 mol. glucose + 1 mol. galactose
Sucrose = 1 mol. glucose + 1 mol. fructose

Reducing sugars: Maltose, lactose

Non-reducing sugars: Sucrose

C. **Polysaccharides:** Several monosaccharides combine to form polysaccharides.

Polysaccharides are of two types:

a. *Homopolysaccharides:* These are made-up of several units of one monosaccharide only, e.g. starch, glycogen, cellulose, dextrans, inulin, agar, etc.
b. *Heteropolysaccharides:* These contain more than one monosaccharides, e.g. pectin, mucopolysaccharide, heparin.

Q.2. Give the biological role/function/importance of carbohydrates.

- Carbohydrates work as a main source of energy.
- Glucose is readily available energy source.
- Glucose, fructose and galactose all the three are rich source of energy.
- Glycogen is reservoir of energy and glycogen is stored in the liver and skeletal muscles.
- Carbohydrates are required as structural building blocks for synthesis of polymers or complex carbohydrates.

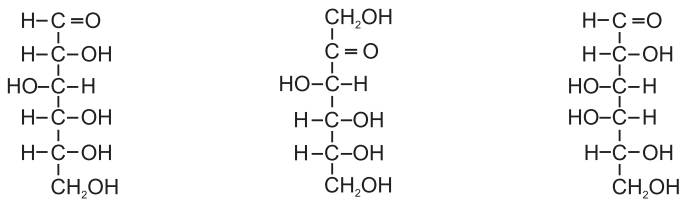
- Cerebrosides are special carbohydrates being provided to the nervous tissue.
- Cellulose and hemicellulose though do not possess energy value, there function is to clean alimentary canal as they possess roughage value.
- Derivatives of glucose and galactose are required to synthesize special polysaccharides as heparin and chondroitin sulphate (part of structure of cartilage).
- Ribose is useful for nucleic acid synthesis.
- Galactose is necessary for forming lactose of milk of glycoproteins.
- Starches are important food reserve for the plant and foodstuff for men and other animals.

Q.3. Explain the terms.

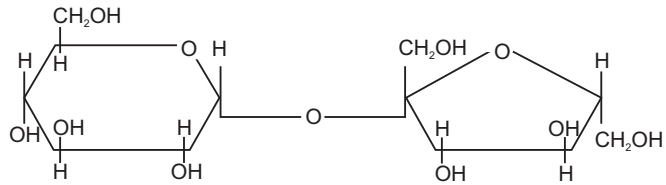
1. *Hyperglycaemia:* It is the condition in which blood sugar level is increased above the normal range. It is observed in diabetes mellitus.
2. *Hypoglycaemia:* It is the condition in which blood sugar level is decreased below the normal range.
3. *Pentosuria:* It means pentose sugars appears in urine. It is the genetic defect in metabolism caused by a deficiency of L-xylulose dehydrogenase. This leads to excretion of as much as 1 g/day of L-xylulose.
4. *Galactosaemia:* It is the condition in which there is an increased concentration of galactose in blood. This is caused due to reduced activity of glucose-1-phosphate uridyl transferase enzyme which is essential for galactose metabolism.
5. *Polyuria*: It is an abnormal condition in which urine output is much higher than the normal urine output, i.e. 3–8 litres of urine per day.

Q.4. Draw the structures of following sugars. (S.23, 24, W.23)

i. Glucose (S23,24) ii. Fructose (W23) iii. Galactose (W23)

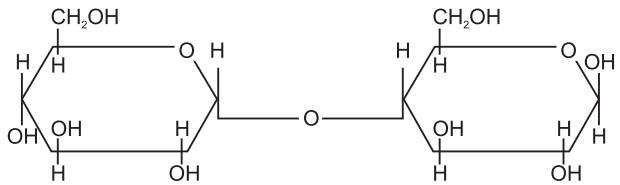


iv. Sucrose



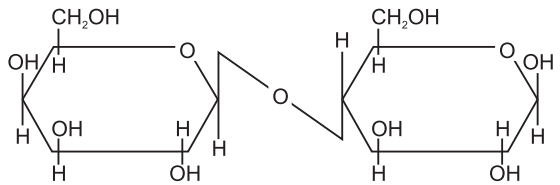
(Glucose) (Fructose)

v. Maltose



(Glucose) (Glucose)

vi. Lactose

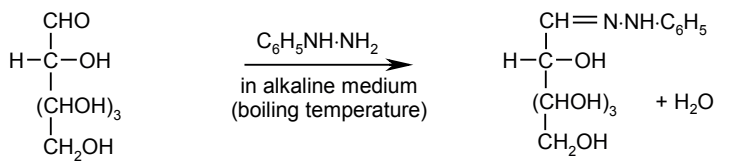


Q.5. Explain osazone test for carbohydrates (glucose). OR What is the action of phenylhydrazine on carbohydrates?

Osazone test is used to detect and distinguish the reducing sugar. When reducing sugar is treated with phenylhydrazine under boiling temperature and alkaline medium, there is a formation of osazone crystals. These crystals are water insoluble and yellow coloured. These are seen under microscope. The shape and arrangement of these crystals for the particular reducing sugar are different.

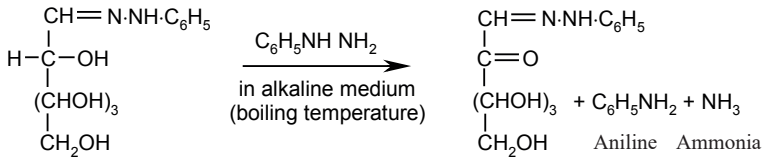
- *Reaction*:

1.



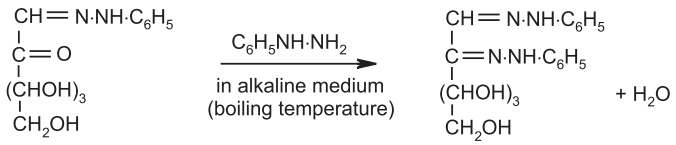
D-glucose Glucose phenylhydrazone

2.



Glucose phenylhydrazone

3.



Glucosazone

- *Mechanism of osazone formation:*
  - i. When reducing sugar is treated with phenylhydrazine, it gives the reaction product phenylhydrazine.
  - ii. The two molecules are heated again with phenylhydrazine, it gives rise to products like aniline, ammonia, and glucosazone.
  - iii. In actual mechanism, three molecules of phenylhydrazine hydrochloride react with one molecule of reducing sugar to produce one osazone crystal of respective reducing sugar, e.g. glucose, fructose, galactose.
- Osazones of different reducing sugars are as follows:

i. Glucose – Glucosazones



(Needle-shaped)

ii. Lactose – Lactosazones



(Balls of prickles-like shape)

iii. Maltosazones – Maltose



(Sunflower shaped)

- *Significance of osazone test:*
  - i. Osazone test helps to differentiate reducing sugars from non-reducing sugars like starch, dextrin, sucrose.
  - ii. Osazone test also helps to differentiate particular type of reducing sugar from other types of reducing sugars.
  - iii. Osazone test is used to identify and confirm reducing sugars, e.g. glucose, fructose, galactose, maltose, lactose (disaccharides).

Q.6. Give the biological role and functions of glucose.

Functions of Glucose

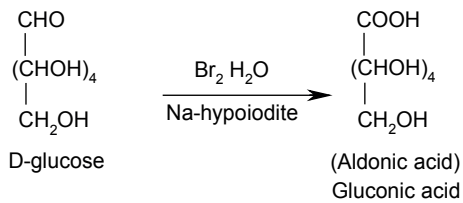
1. Glucose is very easily available and ready to use source of energy for all living cells.
2. Glucose is best suitable transport form of sugar due to its high water solubility.
3. Mainly riped fruits are sweet tasting because they contains glucose.
4. One molecule of glucose after complete oxidation provides 673 kcal energy, equivalent to 38 ATPs. So, glucose is rich and ideal source of energy.
5. Different derivatives of glucose are important intermediates of carbohydrate metabolism.
6. Glucosamine is another important amino sugar of glucose which is structural part of some antibiotics as like erythromycin, streptomycin.
7. Glucose is an important structural part of complex polysaccharides as starch, cellulose, hemicellulose and the glycogen.
8. Glucose is structural unit of biologically important disaccharide as maltose, sucrose and lactose.
9. Glucose can be converted into the water insoluble form called glycogen via glycogenesis process.

Q.7. Write a note on oxidation of glucose.

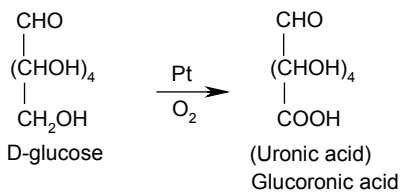
Sugar on oxidation gives acid. The oxidation product depend upon oxidising agent used in the reaction.

Glucose is oxidised to different products with the help of different oxidising agents.

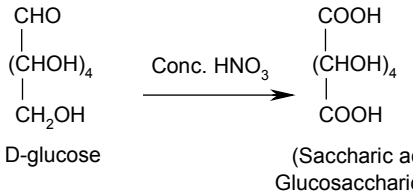
i. Oxidation of 1st carbon



ii. Oxidation of 6th carbon



iii. Oxidation of 1st and 6th carbon



i. *Aldonic acid formation:* When glucose is treated with mild oxidising agents like bromine water and Na-hypoiodite, the product generated is aldonic acid. Here, the 1st carbon from CHO group of glucose is oxidised and replaced by carboxyl (–COOH) group. The product formed is generally called aldonic acid while for glucose it is called gluconic acid.

ii. *Uronic acid formation* (*oxidation at 6th carbon*)*:* When glucose is treated with better strong oxidising agent as platinum and molecular O_2, there is an oxidation of 6th carbon in CH_2OH group of glucose. Hence, oxidation replaces the CH_2OH by –COOH (carboxyl group). In general, product formed is called uronic acid while for glucose it is called glucoronic acid.

iii. *Saccharic acid formation* (*oxidation of both 1st and 6th carbon*)*:* Here, the glucose is treated with very strong oxidising agent as concentrated HNO_3, where both 1st and 6th carbons are oxidised and replaced by carboxyl (–COOH) group. The product formed, in general, is called saccharic acid. While for glucose it is called glucosaccharic acid.

Q.8. What are reducing sugars? Write a note on reducing sugars.

Reducing Sugars

There are the sugars possessing free aldehyde or ketone group in their structure and possess an ability to reduce certain heavy metal ions, e.g. glucose, fructose, galactose, lactose, maltose presence of free aromatic carbon atom possess an ability to reduce certain heavy metal ions. This is called the reducing property of reducing sugars. In this reaction, the precipitation of specific colour is obtained, which can indicate roughly the amount of reducing sugar present, e.g. copper ions present in Fehling and Benedict's reagent can be reduced in alkaline medium at high temperature to form cuprous oxide by reducing ability of monosaccharides. The reactions can be operated as follows:

i. $CuSO_4 \longrightarrow Cu^{2+} + SO_4^{2-}$

ii. Reducing sugar $\xrightarrow[\text{Alkaline medium and high temperature}]{Na_2CO_3}$ Enediol form of reducing sugar

iii. Enediol form of sugar $\xrightarrow{Cu^{2+}}$ Mixture of sugar acids

iv. $Cu^{2+} + OH^{-}$ from sugar acids $\longrightarrow$ CuOH

v. $2CuOH \longrightarrow Cu_2O + H_2O$

This particular mechanism of reaction of metallic ion forms common basis to detect all reducing sugars.

The colour of precipitation obtained in observation, tells about approximate amount of reducing sugar present in corresponding sugar solution.

Colour precipitation	*Approximate % of reducing sugar*
Greenish colour precipitation	0.5 (+)
Green colour precipitation	0.5–1 (++)
Yellow colour precipitation	1–1.5 (+++)
Yellow to orange colour precipitation	1.5–2 (++++)
Dark brick red colour precipitation	>2 (+++++)

Significance

Benedict's qualitative test possesses a diagnostic value, where this test is used to detect roughly the amount of reducing sugar, if present in urine sample, in detectable amount. The abnormal pathological condition indicating presence of reducing sugar in the urine, in the detectable amount is called glycosuria. Very typically, glycosuria is prominent in disease of diabetes mellitus.

Q.9. Write a note on 'diabetes mellitus'. (W.23)

Diabetes mellitus is a condition caused due to raised glucose concentration in the blood due to deficiency of insulin.

Types of Diabetes Mellitus

i. Juvenile-onset type of diabetes mellitus (10–12 years).

ii. Maturing onset type of diabetes mellitus (middle or/later ages).

Symptoms/Characteristics of Diabetes Mellitus

- Hyperglycaemia
- Weakness/tiredness
- Intense thirst (polydypsia)
- Breathlessness
- Reduced visual activity
- Pain in legs
- Dry skin, cracked lips
- Glycosuria
- Loss of body weight
- Dehydration
- Polyuria
- Epigastric pain and vomiting
- Infection of skin, lung and urinary tract
- Rapid pulse, BP is low.

Causes of Diabetes Mellitus

- Genetic factors

- Obesity
- Dietary intake of sugar in excess
- Increased rate of glucose absorption from intestine
- Decreased level of insulin.

Treatment

- Use of oral antidiabetic agents and insulin
- High protein and low carbohydrate and fat diet is advisable.

Q.10. What is glycosuria? (W.23)

Glycosuria

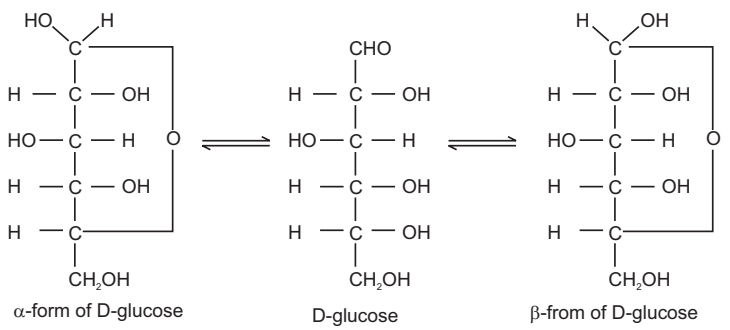
The condition in which an abnormal quantity of glucose is excreted in the urine is called glycosuria. Glycosuria can be classified as follows:

i. *Alimentary glycosuria*: Glucose may appear in urine temporarily due to high intake of carbohydrate, without any defect in blood glucose regulatory mechanism. This is known as alimentary glycosuria.
ii. *Renal glycosuria*: In this case, there are defects in tubular mechanism that lead to glucose excretion in urine.
iii. *Diabetic glycosuria*: This type of glycosuria occurs in diabetes mellitus due to hyperglycemia resulting from insulin deficiency.

Q.11. Write a note on 'mutarotation' of carbohydrates.

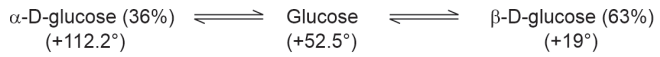
Mutarotation

"The change in specific rotation of plane polarized light by solution of optically active substance but without any change in other properties of that compound, is known as mutarotation."



When a carbohydrate compound carries asymmetric carbon, it shows optical activity, i.e. ability to rotate plane polarized light, e.g. glucose as hexose sugar exists in α- and β-forms as shown above.

When glucose is dissolved in water, optical rotation of solution gradually changes to attend the equilibrium. This change in optical rotation as shown below is called mutarotation.



Equilibrium mixture of α- and β- forms of
D-glucose and with open chain form of glucose

Main reason of mutarotation is formation of cyclic or ring compound from the open chain form of D-glucose. α- and β-forms of D-glucose differ from each other only with respect to rotation. Under such condition, α-form shows optical activity +112.2° and β-form shows optical activity +19°. Initially, in aqueous solution α- and β-forms are in different properties as 36% and 63%, respectively. Later on, in the mixture, equilibrium status of α- and β-forms is achieved. Initially much high percentage of β-form is present because of its stable configuration relative to α-form. Finally, when equilibrium mixture of α- and β-forms is achieved, the optical rotation changes and stabilizes to +52.5°.

In the biological system, i.e. living cells, such mutarotation is carried out by activity of enzyme called *mutarotase*.

Q.12. Write a note on cellulose (location and importance).

Cellulose is a homopolysaccharide. Cellulose is a linear unbranched long chain polymer of D-glucose unit linked by β-1,4-glycoside bond.

Location of Cellulose

i. It occurs in plant tissues but totally absent in the animal tissue.
ii. Actually, in plant tissues cellulose is present as a structural part of cell wall.
iii. Cellulose is distinctly present in the wood and fibrous tissues in one plant body.

Importance of Cellulose

i. For human body, cellulose fibres possess roughage value, i.e. they act as a cleansing plug.
ii. Cotton and filter papers are the examples of true cellulose and are of great commercial value.
iii. Fibres of jute and hemp are of commercial use in cordage industries.

Q.13. Differentiate between starch and glycogen.

Starch	*Glycogen*
1. Storage form of carbohydrate for the plants	1. Storage form of carbohydrate for the animals
2. It is insoluble in water.	2. It is better soluble in water.
3. It shows less branched structure.	3. It shows highly branched structure.

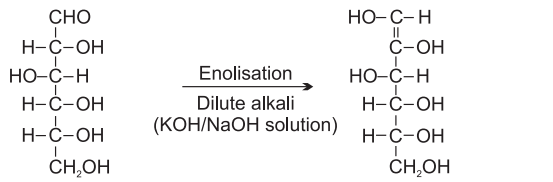
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4. Branching repeats after every 25–30 glucose units.	4. Branching repeats after every 8–10 glucose units.
5. For iodine test it gives dark blue violet colour	5. For iodine test it gives dark pinkish red to brown colour
6. It is digested by action of different digestive enzymes which come from salivary glands, and intestinal mucosa.	6. Metabolism of glycogen occurs by special mechanism called Cori cycle, promoted by pancreas glycogenolysis and enzyme LDH
7. The location for breakdown of starch is cavity within alimentary canal.	7. The location for breakdown of glycogen are mainly skeletal muscle and liver.
8. It is very common part of the human diet.	8. It is a rare part of the human diet.

Q.14. Explain enediol formation/enolisation of carbohydrate. Explain action of dilute alkali on sugars (glucose).

When monosaccharide is heated with dilute alkali like KOH or NaOH solution, there is formation of enediol form of the monosaccharide. Both aldose and ketose (–C=O) type of sugars give this test positive. The enediol form carries C=C in C-1 and C-2 of the concerned monosaccharide. Such process of enediol formation is called enolisation.



(1,2-enediol form of glucose)

Q.15. Explain various qualitative chemical tests for identification of carbohydrates.

Qualitative Tests for Carbohydrates

1. Benedict test
2. Fehling test
3. Barfoed test
4. Molisch test

(Test for reducing sugars)

5. Mucic acid test
6. Seliwanoff test
7. Tollen mirror test
8. Iodine test
9. Osazone test

1. *Benedict test*: This test is positive for all reducing sugars. Benedict reagent contains cupric ions (cupric sulphate) in alkaline medium and different chelating agents to keep the cupric ions in solution. When sugar is heated with Benedict reagent the **cupric ions** are reduced to

cuprous ions which give brick red or yellow precipitate depending upon the concentration of sugar. The brick red precipitate indicates the presence of 'monosaccharides'.

2. *Fehling test*: Fehling solution is a cupric tartrate alkaline solution. This test is positive to all reducing sugars.

   The Fehling solution is composed of copper sulphate, sodium potassium tartrate and potassium hydroxide.

   Carbohydrates with free aldehyde and ketone groups having an ability of reduction of copper sulphate to cuprous oxide forming a yellow or brownish red coloured precipitate.

   Test: Boil sugar solution and Fehling solution for two minutes, it gives formation of brick red precipitate which indicates the reducing sugar.
3. *Barfoed test*: This test is positive for monosaccharides. This reagent contains cupric acetate and dilute acetic acid. The monosaccharides when heated with Barfoed reagent, Cu^{2+} is reduced to Cu^{+} where later on Cu^{+} is precipitated to cuprous oxide forming red or brick red precipitate.

   The reducing disaccharides reduce Barfoed reagent very slowly as compared to monosaccharides.

   - *Significance*: This test is used to distinguish reducing monosaccharides from reducing disaccharides.
4. *Seliwanoff test*: It is the typical test for ketose type of sugar that produces a cherry-red or reddish brown colour on boiling for half minute with Seliwanoff reagent containing resorcinol in HCl. The same colour is produced on prolonged boiling of an aldose solution with Seliwanoff reagent.
5. *Iodine test*: Iodine in aqueous solution reacts with different types of carbohydrates to give different kinds of specific coloured compounds, e.g.

   Starch + I_2 ⟶ Blue violet
   Dextrin + I_2 ⟶ Pink
   Glycogen + I_2 ⟶ Brown
   Amylose + I_2 ⟶ Deep blue
6. *Molisch test*: It is the general test for identification of carbohydrates.

   - *Principle*: In this test, carbohydrate reacts with strong mineral acids like conc. H_2SO_4 to produce furfural compound. The furfural compound in second step interacts with α-naphthol to produce blue-violet colour conjugate because of alcoholic α-naphthol and strong mineral acid are not miscible with each other.

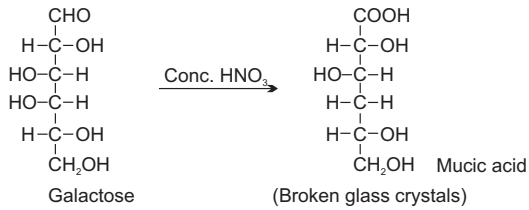
Carbohydrates + Concentrated $H_2SO_4 \rightarrow$ Furfural compound + α-naphthol (blue violet ring at the junction)

- *Observation*: The violet coloured compound forms the ring at the junction of two immiscible liquids.
- *Significance:*
  i. This test is commonly used for identification of all carbohydrates.
  ii. This test distinguishes the carbohydrates from all other organic compounds.

7. *Mucic acid test*: It is a specific test used for the detection of presence of galactose and lactose. In actual test, galactose is treated with strong oxidizing agents as concentrated HNO_3. In this reaction, both carbon 1 and 6 get oxidised and replaced by carboxyl (–COOH) group. The end product obtained is called galactosaccharic acid or mucic acid.

   This compound occurs as a broken glass and so it is very typical confirmatory test for galactose.

   Actually, mucic acid forms colourless, water insoluble crystals of broken glass type seen. Reaction can be represented as:



8. *Tollen mirror test/silver mirror test*: Reducing disaccharides commonly gives positive test for Tollen reagent.

   The sugar is heated with ammoniacal silver nitrate solution. If the sugar has a free aldehyde or ketone group, it changes to enediol which then reduces Ag^{2+} to metallic silver precipitating it in the form of a **shining mirror**.

   - *Test*: Sugar is heated with Tollen reagent, silver mirror is obtained inside the wall of vessel, indicates the presence of aldoses.

Q.16. What are anomers and epimers?

Anomers

Two isomeric forms of D-glucose, i.e. α-D(+)-glucose and β-D(+)-glucose are diastereomers differing in configuration about C-1. Such a pair of diastereomers is called anomer.

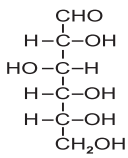
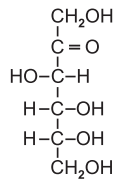
Epimers

A pair of diastereomeric aldoses that differ only in configuration about C-2 are called epimers. Glucose and galactose are epimers.

Q.17. Give the difference between reducing sugar and non-reducing sugar.

Reducing sugar	*Non-reducing sugar*
1. Free aldehyde at C-1 or a free ketone at C-2 group is present.	1. There is no free aldehyde or ketone group due to involvement in glycosidic bond formation.
2. They are hemiacetal or hemiketal forms.	2. They are in acetal or ketal form.
3. They show mutarotation.	3. They do not show mutarotation.
4. They react with phenylhydrazine and form osazone.	4. They do not form osazone.
5. With hydroxyl amine, they form oximes.	5. They do not form oximes.
6. Examples: Glucose, maltose, lactose, fructose	6. Examples: Sucrose, glycogen, insulin

Q.18. Give the difference between glucose and fructose.

Glucose	*Fructose*
1. It is the simplest member of carbohydrate containing aldehyde as a functional group.	1. It is the simplest member of carbohydrate containing ketone as a functional group.
2. Structure 	2. Structure 
3. It is also called dextrose and grape sugar as it is obtained in high concentration from grapes.	3. It is also called levulose and fruit sugar.
4. Solution of glucose is strongly dextro-rotatory.	4. Solution of fructose is strongly levo-rotatory.
5. Glucose shows specific solution of –52.5° at 25°C.	5. Fructose shows specific rotation of –92° at 25°C
6. Glucose on reduction forms sorbitol.	6. Fructose on reduction forms sorbitol and mannitol.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. **Carbohydrates** are polyhydroxy aldehydes or polyhydroxy ketones as their derivatives.
2. **Fructose** is a monosaccharide.
3. Lactose is a milk sugar containing glucose and **galactose**.
4. **Sucrose** is a cane sugar containing glucose and fructose.
5. **Glycogen** is a homopolysaccharide obtained from animal source.

6. **Heparin** is a polysaccharide used as an anticoagulant.
7. **Cerebrosides** are special carbohydrates being provided to the nervous tissue.
8. **Ribose** is useful for nucleic acid synthesis.
9. **Starch** is an important food reserve for the plant and foodstuff for men and the animals.
10. **Pentosuria** is the genetic defect in metabolism caused by a deficiency of L-xylulose dehydrogenase.
11. **Polyuria** means condition in which urine output is much higher than normal.
12. The chemical test used to detect and differentiate reducing sugar is **osazone test.**
13. Cellulose is a **homopolysaccharide**.
14. **Starch** with iodine solution gives dark blue–violet colour.
15. Sugar is detected in urine by **Benedict test and Fehling test**.
16. **Aglycone refers** to the non-carbohydrate moiety found in glycosides.
17. **Starch** is a polysaccharide composed of D-glucose units held together by alfa glycosidic bonds.

Chapter

3

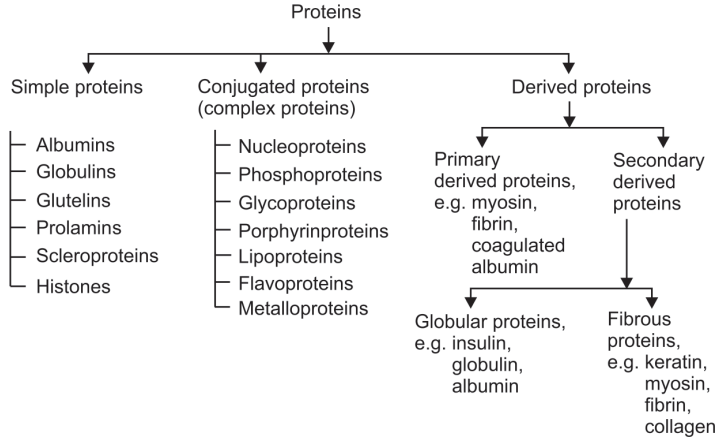
Proteins

Q.1. What are proteins? Classify proteins with suitable examples. (S.24)

Proteins

Proteins are naturally occurring polymers made up of amino acids linked together by peptide bonds (–CONH–) having high molecular weight found in all living cells.

Classification of Proteins



Explanation of Proteins

Proteins are classified as:

A. **Simple proteins:** The proteins which yield only one amino acid upon hydrolysis are known as simple proteins.
   a. *Albumins:* These are soluble in water, coagulated by heat and precipitated at high salt concentration, e.g. serum albumin, plasma albumin, egg albumin, lactalbumin, legumelin, etc.
   b. *Globulins:* These are insoluble in water, coagulated by heat and precipitated by half saturated salt solutions, e.g. plasma globulins, serum globulins, vitellin, tuberin, myosinogen.

c. *Glutelins:* These are insoluble in water, soluble in acids and bases and coagulated by heat, e.g. glutelin (wheat), oryzenin (rice).
d. *Prolamins:* These are insoluble in water but soluble in ethanol and not coagulated by heat, e.g. gliadin (wheat), zenin (maize).
e. *Protamines:* These are soluble in water and not coagulated by heat, e.g. salmine.
f. *Histones:* These are water soluble and not coagulated by heat, e.g. globin of haemoglobin and thymus histones.
g. *Scleroproteins (albuminoids):* These are water insoluble, e.g. keratin (hair, horn, nail), collagen (skin, bone tendons), elastin (ligaments).

B. **Conjugated proteins (complex proteins):** These contains simple protein molecule united with non-protein group and on hydrolysis they yield other non-proteinous substances in addition to amino acids.
The non-protein moeity is known as 'prosthetic group'.
Conjugated proteins are divided into:
a. *Nucleoprotein:* It is a combination of protein with nucleic acid, e.g. nucleoprotamines, nucleohistones.
b. *Lipoprotein:* It is a combination of proteins with lipid, e.g. lipoprotein of egg yolk, milk, lipoprotein of blood.
c. *Glycoprotein:* It is a combination of proteins with carbohydrates, e.g. mucin (saliva), ovomucoid (egg yolk).
d. *Chromoproteins (porphyroproteins):* These contain porphyrin with metal ion as their prosthetic group, e.g. haemoglobin, myoglobin, catalase, cytochrome, peroxidase.
e. *Phosphoprotein:* It contains phosphorus radical as a prosthetic group, e.g. caseinogen (milk), ovovitellin (egg yolk).
f. *Flavoprotein:* It contains riboflavin as a prosthetic group, e.g. flavoproteins of liver and kidney.
g. *Metalloproteins:* These contains metal ion as prosthetic group, e.g. siderophillin (Fe^{2+}), ceruloplasmin (Cu^{2+}), etc.

C. **Derived proteins:** These are the intermediate hydrolysis products, which are formed by the action of physical, chemical or enzymatic agents on natural proteins. These are the denatured or degraded products of simple and conjugated proteins.
a. *Primary derivatives*
   i. Proteans, e.g. fibrin from fibrinogen.
   ii. Metaproteins, e.g. acid and alkali metaproteins.
   iii. Coagulated proteins, e.g. cooked proteins, coagulated albumin.
b. *Secondary derivatives*
   i. Proteases, e.g. albumose, globumose.

ii. Peptones
iii. Peptides, e.g. glycyl-alanine, leucyl-glutamic acid.

Q.2. What do you mean by 'complete proteins' and 'incomplete proteins'? Give example.

Complete Proteins

"The proteins which contain all essential amino acids in required quantities are called complete proteins," e.g. milk proteins, egg proteins.

Incomplete Proteins

"The proteins not containing all essential amino acids are called incomplete proteins," e.g. gelatin, zein of maize.

Q.3. Give biological importance/functions of proteins. (S.24)

- Proteins are the essence of life process.
- Proteins are important for the structures of membrane, muscular tissue or connective tissues.
- Nucleoproteins have a great significance in genetics.
- Number of enzymes are proteins which catalyze number of biochemical reactions.
- Proteins are important for transport of oxygen throughout the body, e.g. haemoglobin.
- Proteins maintain the fluid balance.
- Proteins are important in regulation of metabolism by hormones such as insulin and glucagon.
- Proteins are responsible for protection against infection and other toxic substances.
- Proteins which are required to carry out mechanical work are called muscle proteins, e.g. myosin.
- Proteins which are required to give strength to the cells or tissues of the body are called structural proteins, e.g. lipoproteins, phosphoproteins, collagen.

Q.4. State the general properties of proteins.

1. *Solubility*: Some proteins are soluble in water and some are soluble in weak salt solution, acid and alkalies. Some proteins are soluble in organic solvents like acetone, chloroform. Proteins generally form colloidal solution.
2. *Precipitation*: Proteins are precipitated by salt of heavy metals, like mercury, tungsten, silver, etc.
3. *Amphoteric nature*: Proteins are made up of amino acids which are amphoteric, i.e. possess equal negative and positive charges.

4. *Coagulation*: Proteins are heat sensitive, so they can be coagulated by applying heat, where peptide bonds are broken and coagulate proteins.
5. *Colour reactions*: Almost all proteins give certain coloured reaction positive when treated with specific reagents. Hence, helpful in laboratory diagnosis.
6. *Molecular weight*: Proteins have very high molecular weight ranges between few thousands to one millions or more.
7. *Protein hydrolysis*: Proteins can be hydrolysed to obtain respective constituents as amino acids and nonprotein compounds.

Q.5. Give the coloured reactions/qualitative tests for proteins and amino acids.

1. *Xanthoproteic test*: Proteins when treated with concentrated HNO_3 produce deep yellow or orange colour, upon addition of alkali.
   - *Principle*: Aromatic amino acids like phenyl alanine, tyrosine give this coloured reaction positive. In actual reaction, particular amino acid reacts with HNO_3 to form metaproteins. Nitrocompounds actually develop deep yellow orange colour. Such colour is produced in alkaline medium because nitrocompounds undergo ionisation in alkaline medium only.
2. *Sakaguchi test* (*test for arginine*): Proteins containing amino acid (arginine), when boiled with Sakaguchi reagent (reagent containing sodium hypochlorite in α-naphthol) produce red or deep red colour.
   - *Principle*: Arginine in presence of alcoholic α-naphthol forms complex with sodium hypochlorite to produce particular red or deep red coloured conjugate.
3. *Millon's reagent test* (*test for tyrosine*): Proteins containing amino acid (tyrosine) when treated with Millon's reagent (mercuric sulphate in acidic medium with sodium nitrite) produce red colour or red coloured precipitate.
   - *Principle*: Amino acid (tyrosine) with acidified mercury sulphate forms red phenolic complex of the mercury to produce specific red colour or red coloured precipitate. For protein (gelatin), this test is positive because of absence of tyrosine in gelatin.
4. *Ninhydrin reaction/test*: Proteins containing ninhydrin compound give this reaction positive producing blue colour upon heating.
   - *Principle*: Free amino group of protein or polypeptide or amino acid reacts with ninhydrin reagent to produce specific blue colour, where heating is required.

- *Significance*:
  i. This test is used to indicate the presence of proteins, polypeptides, peptides and amino acids.
  ii. Derived proteins like proteases and peptones are also detected.
  iii. This test is of preliminary importance in laboratory detection of proteins.

5. *Nitroprusside test (test of cystine)*: Cystine or protein containing cystine produce red colour when treated with sodium nitroprusside in dilute NaOH solution.

   In alkaline condition, cystine (sulphur containing amino acid) interact with sodium nitroprusside to produce red colour.

6. *Biuret test*: It is the test given positive by all compounds containing more than one peptide linkage, i.e. given positive by proteins, proteoses, peptones and polypeptides till tripeptide. This test is also positive for substances which contain ($–CO–NH_2$) group.
   - *Principle*: In actual test, dilute $CuSO_4$ solution (1%) reacts with protein in alkaline medium to produce violet or deep violet colour. Medium in test tube is made alkaline by 40% NaOH solution. The specific colour is produced due to formation of copper complexes which indicates actually the presence of peptide linkages.
   - *Significance*: This test possess significance in laboratory detection of proteins and differentiating them from any other organic compound which does not posses peptide linkage.

7. *Hopkins-Cole reaction/test*: Protein containing amino acid tryptophan gives this test positive producing violet or purple coloured ring at the junction of two liquids.
   - *Principle*: Solution containing protein upon reaction with Hopkins-Cole reagent (glyoxylic acid) upon addition of concentrated H_2SO_4 very slowly from the sides of test tube forms two separate layers producing violet or purple colour at the junction of two liquids.

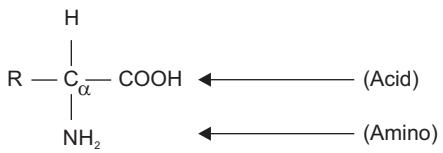
8. *Heat coagulation test*: Take the test solution of protein up to two-thirds of the test tube and heat the upper portion of the solution holding the lower part of the test tube.

   An opalescence appears which becomes deep upon addition of few drops of 2% acetic acid.

   This indicates the presence of proteins (albumin).

Q.6. What are amino acids? Classify with examples. Give biological importance of amino acids.

Amino acids are the monomers of proteins having an amino and carboxyl group attached to the same carbon atom.



General Structure

Classification of Amino Acids

i. Amino acids are classified into three groups:
   – *Neutral amino acids*: Glycine, alanine, valine, leucine, serine.
   – *Basic amino acids*: Lysine, arginine, histidine.
   – *Acidic amino acids*: Aspartic acid, glutamic acid, glycine, alanine, valine, leucine, serine.

ii. Amino acid can be classified in another fashion:
   – *Aliphatic amino acids*: Glycine, alanine.
   – *Aromatic amino acids*: Phenyl alanine, tyrosine, tryptophan.
   – *Sulphur amino acids*: Cysteine, methionine.

iii. According to dietary value:
   – *Essential amino acids*: Leucine, isoleucine, arginine.
   – *Nonessential amino acids*: Alanine, glycine, tyrosine.

Biological Role/Functions/Importance/Significance of Amino Acids

i. Amino acids are required for synthesis of various enzymes, hormones, plasma proteins and immunoglobulins.
ii. For growth and repair of body tissues.
iii. As a source of energy when body is having an adequate supply of carbohydrate or fat.
iv. Metabolic products of certain amino acids provide source for energy.
v. Glycine and glutamic acid are involved in the transmission of impulses in the nervous system.

Q.7. Define 'essential and nonessential amino acids' with examples. (W.23)

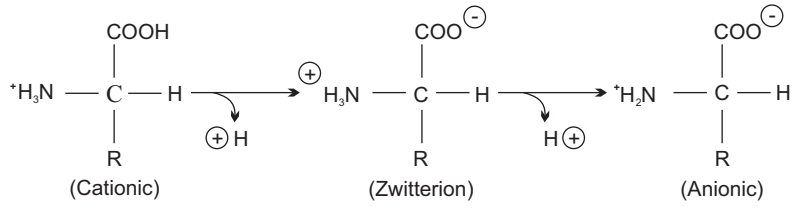
- *Essential amino acids*: The amino acids which cannot be synthesized in the body, but are badly required for normal functioning are called essential amino acids. For example, leucine, isoleucine, arginine, histidine, valine, phenylalanine.
- *Nonessential amino acids*: The amino acids which can be synthesized in the body but are not very essential for normal functioning of the body are called nonessential amino acids. For example, alanine, glycine, tyrosine, cystine, proline, glutamic acid.

Q.8. Explain physical properties of amino acids.

Properties of Amino Acids

1. *Solubility*:
   - All amino acids are soluble in water but their solubility varies to great extent.
   - Polar amino acids are highly soluble in water.
   - Nonpolar amino acids are highly soluble in organic solvents like alcohol, chloroform, ether, etc.
2. *Optical activity*: Except glycine, all amino acids are optically active due to presence of asymmetric carbon atom.
3. *Acid–base behaviour of amino acids*: Amino acids contain the acidic group carboxyl (–COOH) and the basic group amino ($–NH_2$). Hence, amino acids are amphoteric in nature. Ionisation of these groups depends upon pH of the system and nature of R-group of amino acids.
   - *Isoelectric pH*: The pH at which amino acid carries zero net charge is called isoelectric pH.

     At an isoelectric pH pure amino acid exists as dipolar ion, i.e. zwitterion. Amino acid zwitterion form possesses equal positive and negative electric charge, i.e. net charge zero. The ionisation behaviour of amino acids can be shown as follows:



Thus, amino acids are positively charged at extreme acidic pH and negatively charged at extreme alkaline pH. There exists an intermediate pH at which net charge of amino acid is zero. At such isoelectric pH, amino acids are quite insoluble in water and so they can be precipitated out. This is called isoelectric precipitation of amino acids.

Isoelectric pH can be calculated by formula, $I^{pH} = \frac{p^{K_1} + p^{K_2}}{2}$

where, I^{pH} = Isoelectric pH
p^{K1} = Negative log of dissociation constant of carboxylic group.
p^{K2} = Negative log of dissociation constant of amino group.

Q.9. Write a note on 'denaturation of proteins'.

Denaturation of Proteins

"The breakdown of secondary, tertiary and quaternary structure of native proteins results in the alterations of the physical, chemical and biological characteristics of protein by a variety of agents."

Denaturation of proteins can be done by following agents:

i. Physical agents, e.g. heat, surface action, UV light, high pressure.
ii. Chemical agents, e.g. acid, alkalies, heavy metal salt, urea.
iii. Biological agents, e.g. proteolytic enzymes.

Changes Occurred during Denaturation of Proteins

i. *Physical change*: Many proteins, especially globular type can be crystallized in native state but denatured proteins cannot be crystallized.
ii. *Chemical change*: The denatured proteins show decreased solubility.
iii. *Biological change*: Enzymatic and hormonary activity is usually destroyed by denaturation.

Significance

i. Precipitation of proteins by denaturation helps in clinical laboratory.
ii. Blood and serum samples are easily analysed by removing protein fraction.
iii. To check the loss of enzymatic activity when boiled or acidified.

Q.10. What are peptides and polypeptides? Give its biological importance.

Peptide

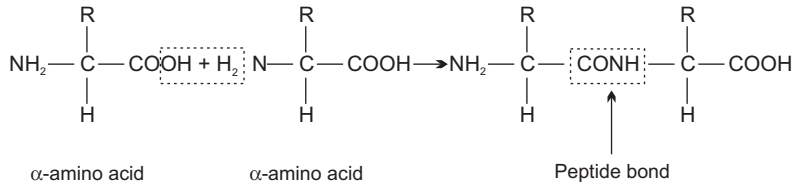
A peptide consists of two or more amino acids linked by a peptide bond (–CONH–) formed be the carboxyl group of one amino acid and amino group of another amino acid with the removal of one molecule of water.

When two amino acids combine in this way, the resultant product is dipeptide. When three amino acids combine, produce tripeptide, when four amino acids combine produce tetrapeptide and many amino acids form polypeptides.

Proteins are the polypeptides containing at least 100 or more amino acids but there is no clear dividing line in both polypeptide and proteins.

Biological Importance of Peptides and Polypeptides

i. Insulin is a peptide and plays an important role in glucose metabolism.



ii. Valinomycin and gramicidine are peptides useful as antibiotics.
iii. Bleomycin, a peptide used as anticancer agent.
iv. Bradykinin is a polypeptide used as hypotensive agent.
v. Thyrotropin-releasing hormone (TRH) is a peptide.

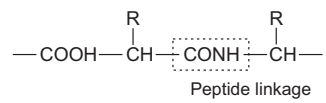
Q.11. Describe the structure of proteins. (S.23, 24, W.23)

The structure of protein can be studied as follows:

1. Primary structure
2. Secondary structure
3. Tertiary structure
4. Quaternary structure

1. Primary Structure of Protein

Primary structure of protein means simply a polypeptide chain. It includes the study of sequence of amino acids in proteins. Peptide bonds are the most common linkages involved in formation of primary structure of protein. All amino acids linked together in primary structure are in one plane. Peptide bond is formed by the amino acid linked by carboxyl group of one amino acid with amino group of another amino acid. The primary structure ultimately becomes as:



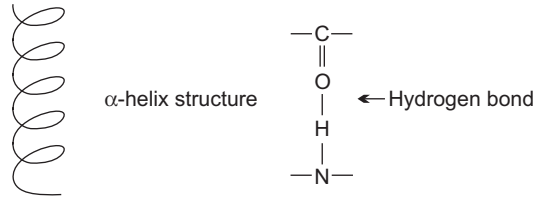
2. Secondary Structure of Proteins

Secondary structure of protein is determined by specific geometric arrangements of polypeptide chain.

There arrangements are due to hydrogen bonding between amino group and carbonyl oxygen of peptide bonds. This is called the secondary structure of proteins.

Three types of secondary structures are possible:

i. α-*helix structure*: In this case, the polypeptide chain twists on a right hand side so that hydrogen bond is formed between C=O and NH, e.g. hair protein, i.e. keratin is made-up of α-helix only.



ii. β-*pleated structure of protein*: Here, 2 polypeptide chains are present in a structure. There polypeptide chains lying side-by-side and can form hydrogen bonds between C=O and NH group of neighbouring polypeptide chain. Along, with 'H' group of neighbouring polypeptide chain. Along with 'H' bonds, disulphide linkages are also formed. Keep two polypeptide chains away at specific distance. Such structure of protein appears like pleated sheet. So, it is called β-pleated sheet.

iii. *Reverse turn structure*: The polypeptide chain may be folded back in itself to change or even reverse the direction of chain.

3. Tertiary Structure of Proteins

The peptide chain with coiled secondary structure may get further folded to form 3-D conformation giving rise to tertiary structure. It is stable final structural form, which decides and governs biological and functional properties of that particular protein. Different types of forces/bonds involved in the formation of stable tertiary structure of proteins are as follows:

i. van der Waals forces
ii. Electrostatic forces of alteration
iii. Hydrogen bonds
iv. Hydrophobic interactions
v. Disulphide bonds

4. Quaternary Structure of Proteins

Some proteins contain two or more polypeptides held together by noncovalent interaction. They are called quaternary proteins, e.g. haemoglobin, myoglobin. It has four subunits. Two alpha and two beta polypeptide chain each has a tertiary structure similar to myoglobin.



Quarternary structure of proteins

Q.12. Explain any three protein deficiency disorders.

Protein Deficiency Disorders

1. **Kwashiorkor Disease**

It is a protein deficiency disease occurring commonly in the children. It is characterized by qualitative and quantitative deficiency of proteins.

- *Causes/contributory factors of kwashiorkor*:
  i. Large family size.
  ii. Poor health of mother.
  iii Premature termination of breastfeeding.
  iv. Poor environmental condition.
  v. Delayed supplementary feeding.
  vi. Use of diluted cows milk to the infants or children.
- *Symptoms/effects*:
  i. Retarded growth

ii. Oedema
iii. Changes or alteration in pigmentation of skin and hair
iv. Changes in texture of skin
v. Enlargement of liver
vi. Hypoalbuminaemia
vii. GIT disturbances
viii. Psychic changes
ix. Hypoglycaemia
x. Stools containing much higher quantity of undigested food.

- *Other symptoms*:
  i. Macrocytic anaemia
  ii. Normocytic anaemia
  iii. Decreased BMR
  iv. Falling body temperature
  v. Fall in plasma levels of triglycerides, cholesterol and lipoprotein.
- *Treatment for kwashiorkor*:
  i. Supply of diet rich in protein.
  ii. First choice milk and egg should be given, both being rich in proteins.
  iii. Soybeans are best known vegetarian source of first class as well as second class proteins.
  iv. Food from nonvegetarian source like liver, meat, seafood.
  v. In severe condition, blood transfusion is required.
  vi. The use of preventive measures is the best way to avoid this disease.

2. **Marasmus Disease**

It is the protein deficiency disease commonly found in infants below 1 year of age.

- Causes:
  i. It is mainly caused due to deficiency of protiens and carbohydrates with some other nutritional factors.
  ii. Protein and energy deficiency disease of such type is also known as marasmic kawshiorkor.
  iii. It is commonly found in people in absence of maintaining proper diet.
  iv. Early stop breastfeeding.
- Symptoms:
  i. Retarded growth
  ii. Complete loss of body fat
  iii. Weakness

iv. Changes in texture of skin
v. Alteration in pigmentation of skin and hair
vi. GIT disturbances
vii. Oedema.

- *Treatment*:
  i. Providing diet rich in calories
  ii. Providing protein diet
  iii. Other nutritional factors are best course in prevention and cure of the marasmus.

3. **Nutritional Oedema**

This is a disease caused by prolonged and significant protein deficiency commonly found in adults.

- *Symptoms*:
  i. Loss of body weight
  ii. Reduced subcutaneous fat
  iii. Anaemia
  iv. Much higher susceptibility to the infection
  v. General lethargy
  vi. Increase in frequency of watery stools
  vii. Inability to carry-out sustained work
  viii. Delay in healing of wounds
  ix. Inability to carry out prolonged hard work
  x. Oedema
- *Treatments*:
  i. The diet consisting mainly of milk, milk products, eggs and soybean is given.
  ii. It is always better to adopt preventive action by regulating protein content of daily diet.

Q.13. Write a note on inborn errors of amino acid metabolism. Explain metabolic disorders of amino acid metabolism.

Abnormal Amino Acid Metabolism

1. Phenylketonuria
2. Alkaptonuria
3. Maple syrup urine disease
4. Hartnup disease

1. **Phenylketonuria (W.23)**

- This is a genetic disorder related to the phenylalanine metabolisms.
- Phenylalanine is a precursor for the biosynthesis of tyrosine.
- In this disorder, there is inherited deficiency of phenylalanine hydroxylase enzyme.

- This leads to accumulation of phenylalanine and it is excreted as phenylpyruvate. This condition is called phenylketonuria.
- Due to deficiency to tyrosine, mental retardation is seen in young infants.

$$\text{Phenylalanine} + O_2 \xrightarrow[\text{Hydroxylase}]{\text{Phenylalanine}} \text{Tyrosine}$$

Symptoms:

i. Retardation of mental growth in infants and children.
ii. Deficiency of neurotransmitter serotonin leading to defect in myelin sheath of myelinated nerve fibres.
iii. Disturbed synthesis of alanine.
iv. Abnormal skin and hair.
v. Excretion of various abnormal metabolites through the urine.

Treatment:

i. Early diagnosis very shortly after birth.
ii. Restriction upon intake of phenylalanine.

2. **Alkaptonuria (W.23)**

- It is an inborn metabolic disorder of phenylalanine where there is an accumulation of homogentisic acid.
- This disorder is due to deficiency of enzyme homogentisate oxidase.
- As a result, metabolism of homogentisic acid is blocked.
- Thus, homogentisic acid accumulates in blood at high levels and so also it is excreted through the urine.
- Thus, condition is seen to be present right from the birth and persists throughout the life of affected person.

$$\text{Homogentisic acid} \xrightarrow[\text{Homogentisate oxidase}]{O_2} \text{Maleyl acetoacetic acid}$$

Symptoms:

i. Accumulation of homogentisic acid in blood and its excretion through the urine.
ii. Dark black urine is excreted.
iii. Accumulation of dark (blue black) pigment in tendons, cartilages, other connective tissues, skin of face, nails, etc.
iv. Arthritis.
v. Changes in heart valves due to accumulation of homogentisic acid.

3. **Maple Syrup Urine Disease (Urine Maple Syrup)**

- It is characterised by absence of enzyme responsible for oxidative de-carboxylation of keto acids.
- Such keto acids are normally derived from branched chain amino acids like valine, lucine and isoleucine.

- It is an inborn metabolic disorder seen in the infants and resulting in blocking normal metabolism of keto acids and the amino acids.
- Final result is accumulation of keto acid derivatives of corresponding amino acid in the blood and some abnormal derivatives are excreted through urine.

Symptoms:

i. Keto acid derivatives present in blood and their excretion through the urine
ii. Vomiting
iii. Lethargy (dullness)
iv. Difficulty in speech in the infants
v. Apnoea (difficulty in breathing)
vi. Convulsions.

This disease is called maple syrup urine disease because the urine of affected person smells like maple syrup or burnt sugar.

4. *Hartnup's Disease*

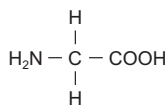
- It is inborn metabolic disorder of amino acid tryptophan.
- This disease is caused due to deficiency of enzyme 'tryptophan pyrroles' which results into accumulation of tryptophan and its derivatives indole acetic acid, indole pyruvic acid, in the blood.
- After this, there is excretion of these acids in the urine.

Symptoms:

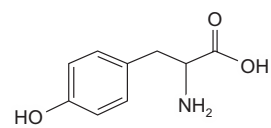
i. Pellagra like dermatitis
ii. Mental retardation
iii. Urine with large amounts of indole acetic acid and indole pyruvic acid
iv. The faeces containing large amount of tryptophan
v. Deficiency of nicotinic acid.

Q.14. Draw the structure of the following amino acids.

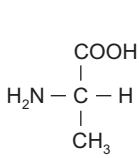
i. Glycine



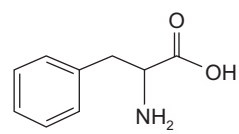
ii. Tyrosine



iii. Alanine



iv. Phenylalanine



OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. Proteins are polymers made-up of amino acids linked by **peptide bonds** (–CONH–).
2. Flavoprotein is a type of **conjugated protein**.
3. Complete proteins contain all **essential amino acids**.
4. Gelatin is an example of **incomplete protein**.
5. **Nucleoproteins** have a great significance in genetics.
6. **Haemoglobin** is a protein, important for transfer of oxygen throughout the body.
7. Specific chemical test for arginine is **Sakaguchi test**.
8. Millon's reagent test is useful for detection of **tyrosine**.
9. Sulphur containing amino acid is **cystine**.
10. **Biuret test** is useful to detect the proteins containing peptide linkages.
11. Amino acids are the **monomers** of proteins.
12. **Methionine** is a sulphur containing amino acid.
13. Phenylalanine is an example of **essential amino acid**.
14. **Proline** is an example of non-essential amino acid.
15. Except **glycine**, all amino acids are optically active.
16. The pH at which amino acid carries zero net charge is called **isoelectric pH**.
17. At an isoelectric pH, pure amino acid exists as a dipolar ion called **zwitterion**.
18. The breakdown of primary, secondary and tertiary structures of proteins is called **denaturation of proteins**.
19. **Insulin** is a peptide which plays an important role in glucose metabolism.
20. **Keratin** is a hair protein which is made-up of α-helix only.
21. **van der Waals forces/bonds** are involved in the formation of stable tertiary structures of proteins.
22. **Kwashiorkor disease** is a protein deficiency disorderoccurring commonly in children.
23. **Marasmus** is a protein deficiency disease commonly found in infants below 1 year of age.
24. **Phenylketonuria** is a genetic disorder, related to the phenylalanine metabolism.
25. Phenylalanine is a precursor for the biosynthesis of **tyrosine**.
26. Alkaptonuria is a disorder in which there is an accumulation of **homogentisic acid** in blood and is excreted in the urine.
27. **Hartnup's disease** is a metabolic disorder of amino acid tryptophan.
28. **Casein** is a complete protein containing all the essential amino acids.
29. The daily requirement of protein in an **adult is 0.8–1 g/kg** body weight/day.

Chapter

4

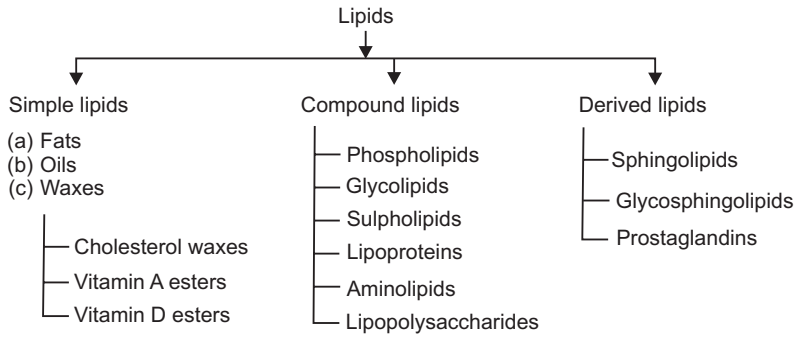
Lipids

Q.1. What are lipids? Classify with suitable examples. (S.23, W.23)

Lipids

"Lipids are heterogenous group of organic compounds related to fatty acids which are insoluble in water and soluble in organic solvents like ether, chloroform and benzene."

Classification of Lipids



Lipids are classified as follows:

A. **Simple lipids:** These are the esters of fatty acids with various alcohols.

a. *Fats and oils:* Fats are the esters of fatty acids with glycerol which are found richly in nature. Fats are solid at room temperature whereas oils are liquid.

Fats act as food reservoir, as insulator and as a padding material for protecting internal organs.

b. *Waxes:* Waxes are the esters of fatty acids with higher alcohols.

The common waxes present in human body are esters of chalesterol found in blood, e.g. carnauba wax, bees wax, lanolin, spermaceti.

B. **Compound lipids (complex lipids):** These are esters of fatty acids with alcohols containing additional groups such as phosphate, nitrogenous base, carbohydrate, protein, etc. They are further classified as:
   a. *Phospholipids:* These are the esters of fatty acids with glycerol containing phosphoric acid and a nitrogen base, e.g. lecithins, cephalins, lipositol, sphingolipids.
   b. *Glycolipids:* These lipids contain a fatty acid, carbohydrate and nitrogenous base. These are also called galactolipids. They are present in the white matter of the brain and in the myelin sheath of nerves. Glycolipids may be of two types:
      i. *Cerebrosides:* They contain galactose and spingosine and are chief constituents of myelin sheath, e.g. kerasin, cerebron, nervon, oxynervon.
      ii. *Gangliosides:* They occur in the brain and contain ceramide, i.e. sphingosine + fatty acids, glucose, galactose, N-acetyl-galactosamine and sialic acid.
   c. *Lipoproteins:* These are macromolecular complexes of lipids with proteins, e.g.
      • LDL (Low-density lipoprotein)
      • HDL (High-density lipoprotein)
      • VLDL (Very low-density lipoprotein) chylomicrons.
   d. *Aminolipids:* These contains two amino acids linked to fatty acid through an amide bond, e.g. Lipopeptides, lipid containing tyrosine.
   e. *Sulpholipids:* These are the lipids containing sulphur, e.g. sufatide, seminolipid.
   f. *Lipopolysaccharides:* These contain lipids and polysaccharides, e.g. endotoxin.

C. **Derived lipids:** Derived lipids are obtained from simple and compound lipids by hydrolysis, e.g. sphingolipids, glucosphingolipids, prostaglandins.

Q.2. Give biological functions or physiological role of lipids. (S.24)

1. Lipids, fats and oils are important constituents of daily diet of human beings.
2. Lipids act as an efficient source of energy when stored in adipose tissues.
3. Lipids serve as an insulating material in the subcutaneous tissue and certain organs.
4. Lipids provide essential fatty acids which are not synthesized by human body.
5. Lipids are the carriers of fat-soluble vitamins.

6. Lipids help to maintain functions of cells of the body, e.g. lipoproteins.
7. Lipids provide building blocks for different high molecular weight substances, e.g. cholesterol, hormones.
8. Lipids produce metabolites which are used in the interconversion of substances.
9. Fats serve as a fuel molecule.
10. In myelinated nerve fibre, axon is covered with myelin sheath which is fatty sheath.
11. Derived lipids like steroids are most important building blocks for steroid hormones, e.g. sex hormones, adrenal hormones.
12. Fats provide mechanical support and so protect vitally important organs against mechanical injuries, e.g. heart, major blood vessels, kidneys, spinal cord are supported by fats.

Q.3. What are essential fatty acids? Give examples.

Essential Fatty Acids (Unsaturated fatty acids)

"The unsaturated fatty acids which are not synthesized in the body and are required for the growth of body are called essential fatty acids."

They are supplied from diet.

Examples

i. Linoleic acid, ii. Linolenic acid, iii. Arachidonic acid.

Deficiency of Essential Fatty Acids

1. Dry and scaly skin
2. Loss of hairs
3. Poor and delayed wound healing
4. Slow growth
5. Retarded growth
6. Increased BMR.

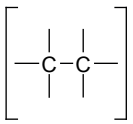
Importance/Functions of Essential Fatty Acids

1. In high concentration along with lipids constitute the structural elements of tissues.
2. They help in synthesis of prostaglandins.
3. They prolong clotting time.
4. They retard arthrosclerosis.
5. They cure skin lesions.
6. The deficiency of these acids in the diet of babies causes eczema.

Q.4. What are 'saturated and unsaturated fatty acids'? Give examples.

Saturated Fatty Acids

"The fatty acids which contain straight chain saturated hydrocarbons are called saturated fatty acids."



For example: Palmitic acid, stearic acid, caproic acid.

Unsaturated Fatty Acids (—C=C—)

"The fatty acids which have one or more double bonds in their molecules are called unsaturated fatty acids," e.g. oleic acid, linolenic acid, arachidonic acid.

Q.5. Define 'fats', 'oils' and 'waxes'.

Fats

Fats are the esters of fatty acids with glycerol and are solid at ordinary temperature (20°C).

Oils

Oils are the esters of fatty acids with glycerol and are liquid at room temperature (20°C).

Waxes

Waxes are the esters of fatty acids with higher alcohol.

Q.6. Write a note on 'rancidity of oils and fats'/'rancidification'.

Rancidification

"When fats and oils are exposed to light, air, heat, moisture for a longer time, develops disagreeable and objectionable odour. Such oil or fat is said to be rancid. This phenomenon is called rancidification."

- The bad and objectionable odour is because of liberation of volatile fatty acids like butyric acid, caproic acid, and caprylic acid.
- Oils and fats on long exposure to air turns rancid and develop disagreeable odour.
- The rancid oils or fats show acidic reactions. This is due to partial decomposition of glyceride resulting into more amount of free acid.
- Rancid oils show high acid values.
- Rancidity is of two types:
  a. *Hydrolytic rancidity*: Some oils and fats undergo hydrolysis and produce bad odour, is called hydrolytic rancidity.
  b. *Oxidative rancidity*: It is the rancidity caused due to oxidation of double bonds in fats and oils.
- Addition of some substances called antioxidants, can prevent the rancidity of fats and oils.
- Vitamin E, ascorbic acid and some derivatives of phenol are some examples of antioxidants.
- Addition of antioxidants can prolong or increase the shelf-life of food containing fats and oils.

- There are some substances called pro-oxidants which in fact promote and carry out rapidly the rancidity of fats and oils. Some examples of pro-oxidants are copper, lead, nickel, etc.

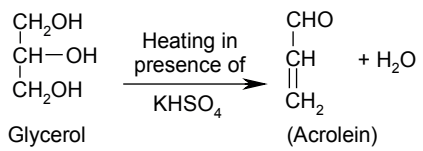
Q.7. Give the physical properties of fats and oils.

1. Fats are solid at room temperature while oils are liquid at room temperature.
2. These are insoluble in water but soluble in organic solvents like ether, benzene, chloroform, etc.
3. Fats are colourless, odourless and tasteless.
4. Fats are neutral in action and so do not show any change in litmus paper colour upon reaction.
5. Fats possess comparatively low melting point.
6. Fats and oils spread uniformly over the surface of water by monolayer formation.
   - *Chemical properties*:
     1. Hydrolysis
     2. Acrolein formation
     3. Halogenation
     4. Oxidation
     5. Rancidity
     6. Saponification
     7. Hydrogenation.

Q.8. Write a note on 'acrolein formation'.

When glycerol is heated with strong dehydrating agent as potassium bisulphate ($KHSO_4$). The product formed in called 'acrolein'. This product (acrolein) possesses characteristic strong irritating, disagreeable or bad smell. In fact, acrolein compound is identified on the basis of its particular smell only. Acrolein formation reaction occurs in both cases where glycerol is either free or glycerol in esterified form in fats and oils as triglycerides. As $KHSO_4$ is strong dehydrating agent, this reaction also form water molecule.

By any reason, if there occurs acrolein formation, for any fat or oil, then it becomes unsuitable for any use.

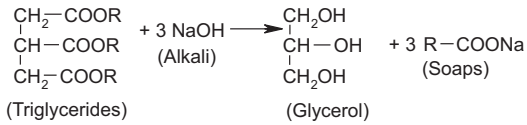


Q.9. Write a note on 'saponification'./What are soaps? How are they synthesized?/Explain alkaline hydrolysis of fat and oil?

Saponification (Alkaline Hydrolysis of Fat or Oil)

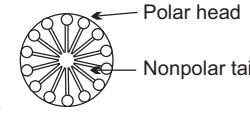
The hydrolysis of fat or oil by alkali gives the products like glycerol and alkali salts of fatty acids, i.e. soaps. This process is said to be saponification.

Generally, the sodium and potassium salts of fatty acids are called soaps.



When soap is dissolved in water it forms an emulsion to produce soaps micelle which are stable arrangements of fat droplets. For each droplet polar heads are directed outwards and nonpolar tails are directed inwards, i.e. hidden inside micelle.

The soap or the foam thus formed is not always stable. The stabilisation of soap depends upon formation of stable fat droplets or stable fat globules. Soap can be stabilized by addition of stabilizing agents such as bile salts.



Soap micelle

Q.10. Enlist various chemical constants for fats and oils/parameters used to study fats and oils (analysis of fats and oils) (IP standards for oils and fats).

1. Saponification number/sap value/soap value
2. Iodine value/number
3. Acetyl number/value
4. Acid number/value
5. Reichert-Meissl number
6. Polenske number.

Q.11. Define and give significance of the following.

1. Saponification Number (Sap Value) (Soap Value)

"It is defined as the number of milligrams of KOH or NaOH required to saponify 1 g of oil or fat."

Saponification number is determined by saponification and titration of excess of alkali with fat or oil, e.g.

	Fat or oil	*Sap value*
i.	Butter fat	210–230 milligrams
ii.	Human fat	195–200 milligrams
iii.	Olive oil	185–195 milligrams
iv.	Linseed oil	188–195 milligrams

Significance/Importance

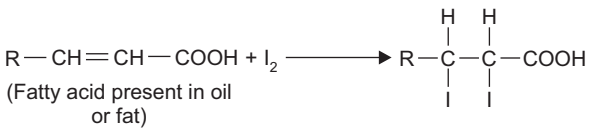
i. It tells about the content of free or bound fatty acids in a given fat or oil.
ii. It tells about the alkali required for conversion of fat into soap.
iii. It indicates the composition of oil or fat.

iv. It gives an estimate of nonfatty impurities in fat or oil.
v. A higher saponification number shows a high percentage of short chain acids in glycerides.
vi. It gives an idea about low molecular weight, if sap value is high.

2. Iodine Number (Iodine Value)

It is defined as number of grams of iodine absorbed by 100 g of fat or oil.

- The unsaturation in a fat or oil is expressed in terms of iodine value.
- In actual reaction, iodine is added to C=C of unsaturated fatty acids present in fat or oil. So unsaturation is removed, i.e. C=C. The halogenation reaction occurs as below:



Iodine Value of Some Fats/Oils

i.	Butter fat	26–28 g
ii.	Human fat	65–70 g

Significance/Importance

i. It shows degree of unsaturation in fat or oil
ii. It helps in characterizing fat and oil
iii. It helps in finding out their suitability as a soap material.

3. Acid Number (Acid Value)

It is defined as number of milligrams of KOH required to neutralize 1 g of fat or oil.

Significance

i. It gives an idea about rancidity of oil or fat.
ii. It represents amount of free fatty acids in it.
iii. It helps to judge the quality of a given fat or oil, i.e. higher the acid value more is the rancidity.

4. Acetyl Number (Acetyl Value)

It is defined as the number of milligram of KOH required for the neutralization of acetic acid obtained by saponification of 1 g of an acetylated fat or oil.

Significance

By determining acetyl number, the hydroxyl group present in fats or oils can be determined.

5. Reichert-Meissl Number

It is defined as the number of millilitres of 0.1 N KOH required to neutralise the soluble volatile fatty acids derived from 5 g of fat or oil.

Significance

i. It helps to determine the amount of volatile fatty acids present in given fat or oil.
ii. This value is used to detect adulteration in fat or oil.

6. Polenske Number

It is the number of millilitres of 0.1 N KOH required to neutralise the insoluble fatty acids from 5 g of fat or oil.

Q.12. Enlist abnormalities in lipid metabolism.

Name the disease occurred due to disorders of lipid metabolism.

1. Obesity
2. Gaucher's disease
3. Niemann-Pick disease
4. Hyperlipoproteinaemia
5. Hypolipoproteinaemia
6. Fabry's disease
7. Tay-Sachs disease.

Q.13. Explain the terms.

a. Obesity

Excessive deposition of fats in the depots with decreased mobility causes obesity. Obesity is caused due to ingestion of more food than necessary to meet the needs of the body.

Hypothyroidism, hyperinsulinism are other causes of obesity.

b. Gaucher's Disease

- This is the disease associated with abnormal lipid metabolism.
- In this term, there is an imbalance in both the synthesis and breakdown of cerebrosides.
- Thus, cerebrosides are increased in the brain, liver and spleen.

Symptoms

i. Enlargement of liver and spleen
ii. Bone erosion
iii. Mental retardation.

c. Niemann-Pick Disease

- In this disease, sphingomyelin accumulates in liver, spleen, bone marrow, lungs and lymph nodes.
- The abnormality is an imbalance of both synthesis and breakdown of the sphingomyelin.

Symptoms

i. Enlargement of liver and spleen
ii. Mental retardation
iii. Red spot on retina.

d. Tay-Sachs Disease

This disease is characterized by abnormal accumulation of glycerides in the brain. The child does not usually survive beyond 2–4 years.

Symptoms

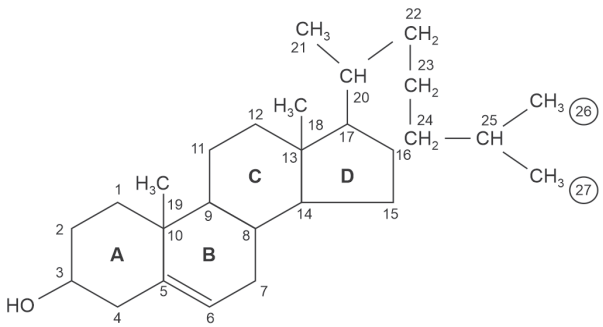
i. Retarded development
ii. Paralysis
iii. Dementia
iv. Blindness.

Q.14. Write a note on 'cholesterol'. (S.23, 24, W.23)

Cholesterol

- Cholesterol is most important monohydric or steroid alcohol.
- Cholesterol makes structural part of biomembranes.
- Cholesterol is mainly synthesized in the liver. The rate of biosynthesis depends upon the fat content of the daily diet.
- Cholesterol is abundantly found in animal tissues.
- In conjugation with phospholipids it is found in the membrane.
- Cholesterol is precursor for bile salts, sex hormones, corticosteroids and vitamin D.

Structure of Cholesterol



Functions/Importance of Cholesterol

i. It forms a structural part of all biomembranes.
ii. It acts as a precursor for biosynthesis of bile salts such as sodium glycocholate and sodium taurocholate.
iii. It plays an important role in biosynthesis of corticosteroid hormone such as glucocorticoids and mineralocorticoids. These two hormones together functions to relieve physical strain and mental stress.

iv. It is required for the biosynthesis of male and female sex hormone or prostaglandins.
v. Cholesterol is also the chief constituent of gallstones.

Abnormal Metabolism Related with Cholesterol

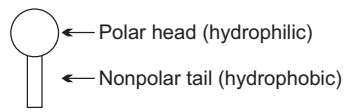
i. Hypercholesterolaemia, ii. Arteriosclerosis.

Colour Tests for Cholesterol

i. *Liebermann-Burchard reaction*: A chloroform solution of sterol when treated with acetic anhydride and sulphuric acid gives a green colour. This reaction is the basis of colorimetric estimation of blood cholesterol.
ii. *Salkowski test*: When choroform solution of the sterol is treated with an equal volume of concentrated sulphuric acid it gives red to purple colour.

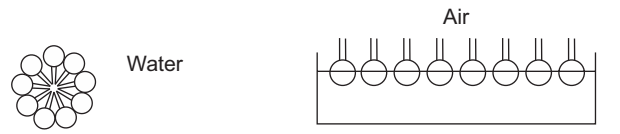
Q.15. Explain the role of lipids in biological membranes.

- The major component of biological membrane is phospholipid.
- Phospholipid has two long chains of hydrocarbon of fatty acids.



A Molecule of Phospholipid

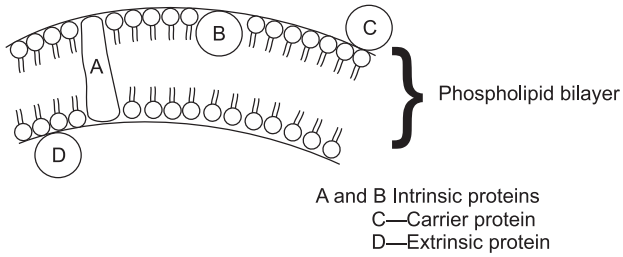
- When phospholipids are added to aqueous medium they form micelles, monolayer and bilayer, depending on the concentration of phospholipid.



(a) Micelle in water (b) Monolayer in air–water interface

- The hydrophilic and hydrophobic interaction of phospholipids forms bilayer in water. Hydrophobic tails are hidden from aqueous environment and form an internal hydrophobic phase whereas the hydrophilic heads are exposed on the surface.
- Biomembranes are made-up of phospholipids, lipoproteins, glycoproteins and proteins.

Fluid Mosaic Model of Biomembrane



Main Structural Features of Biomembrane

i. There is lipidous ocean enclosing proteins like the ice-bergs in ocean, so it is commonly called *lipoprotein membrane*.
ii. Lipids in membrane form lipid bilayer with the thickness 70–100Å.
iii. In lipid bilayer, for each lipid molecule hydrophilic or polar head is kept exposed outside. The hydrophobic or nonpolar tails for each lipid molecule are kept hidden within lipid bilayer.
iv. Proteins in the biomembrane are of three main types:
   a. Extrinsic protein
   b. Intrinsic protein
   c. Carrier protein
v. Extrinsic proteins are *loosely* attached to the lipid bilayer. So, these proteins are easily dissociable and detachable.
vi. Intrinsic proteins are *tightly* bound to lipid bilayer and so these are not easily dissociable and detachable.
vii. Extrinsic proteins are mainly the glycoproteins and their main function is to take part in structural build-up of membrane.
viii. The carrier proteins function for in-and-out transport of different substances across the membrane.

Such biomembrane is described as "fluid-mosaic model":

The lipid bilayer in the membrane gives fluidity to the membrane because of specific arrangement. Proteins in the structure of biomembranes are arranged in mosaic fashion in lipid bilayer ocean. Hence, this membrane structure model is described to be fluid-mosaic model.

Functions of Biomembranes

1. To perform the limiting boundary for cytoplasmic contents.
2. To control the flow of material and information in and out of the cell.
3. It forms selectively permeable barrier that allows in-and-out movement of some substances, selectively.
4. It possess specific sites for particular chemical substances.
5. Carrier proteins of membrane functions for active transport of required substances.

6. Irritability, i.e. response at cellular level are shown by working of biomembranes.
7. Electron-transport system made-up of flavoprotein called cyto-chromes is oxidases with biomembrane. Such ETS is required compulsory for cell respiration physiology.
8. The cilia are protoplasmic extensions and are structural part of ciliated epithelium performing specific functions in human body.

Q.16. Give differences between oils and fats.

Oils	*Fats*
1. Oils are liquid at room temperature	1. Fats are in solid form at room temperature
2. They contain large proportion of unsaturated fatty acids	2. They contain large proportion of saturated fatty acids
3. They have low melting points	3. They have high melting points
4. They have high iodine number as contain large number of unsaturated fatty acids	4. They have low iodine number as contain less number of unsaturated fatty acids
5. They have low Reichert-Meissl number	5. They have high Reichert-Meissl number
6. Stored in seeds and fruits	6. They are stored in liver and bone marrow
7. Examples: Olive oil, castor oil, soyabean oil, corn oil	7. Examples: Butter fat, beef fat, ghee

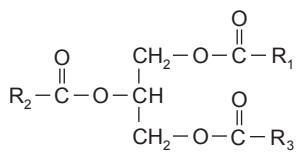
Q.17. What are triglycerides? Give the examples, structures and properties of triglycerides. (S.24)

Triglycerides (Triglycerols)

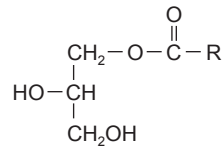
Triglycerides are the esters of glycerol with fatty acids.

- The fats and oils that widely distributed in both plants and animals are chemically triglycerides.
- Triglycerols are the most abundant group of lipids that primarily function as fuel reserves of animals.
- The fat reserves of normal human is sufficient to meet the body caloric requirement for 2–3 months.
- Examples:

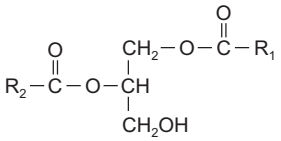
a. Triacylglycerol



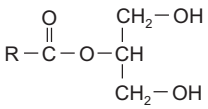
b. 1-Monoacylglycerol



c. 1,2-diacylglycerol



d. 2-Monoacylglycerol



- **Properties of triglycerides (W.23)**
  i. *Hydrolysis:* Triglycerides undergo stepwise enzymatic hydrolysis to finally liberate free fatty acids and glycerol.
  ii. *Saponification:* The hydrolysis of triglycerols by alkali to produce glycerol and soaps is known as saponification.
  Triacylglycerol + 3 NaOH → Glycerol + 3 R–COONa (soaps)
  iii. *Rancidity:* Rancidity is the term used to represent the deterioration of fats and oils resulting in an unpleasant taste. Fat containing unsaturated fatty acids are more susceptible to rancidity.

Q.18. Give differences between fats and waxes.

Fats	*Waxes*
1. The esters of fatty acids with alcohol are called fats	1. The esters of fatty acids with higher alcohol are called waxes
2. They are not secretions	2. They are the secretions
3. They act as a food reservoir	3. They act as protective in function
4. They are oxidized by atmospheric oxygen	4. They resist oxidation by atmospheric oxygen
5. Examples: Castor oil, beef fat	5. Examples: Carnauba wax, bees wax, lanoline, Spermaceti, etc.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. The **unsaturated fatty acids** which are not synthesized in the body are required for the growth of the body.
2. **Arachidonic acid** is an essential fatty acid.
3. **Waxes** are the esters of fatty acids with higher alcohol.
4. **Rancid oils** show high acid values.
5. Glycerol with potassium bisulphate produces **'acrolein'**.
6. Alkali hydrolysis of fats produces soap, this process is known as **saponification.**
7. The number in milligrams of KOH or NaOH required to saponify 1g of oil as fat is known as **sap value/soap value/saponification number**.
8. The number of grams of iodine absorbed by 100 g of fat or oil is called **iodine value/iodine number**.
9. Iodine value indicates/expresses the **unsaturation** in fat or oil.

10. The number in milligrams of KOH required to neutralize 1 g of fat or oil, is known as **acid number or acid value**.
11. **Acid value/acid number** gives an idea about rancidity of oil or fat.
12. **Acetyl number/acetyl value** determines the hydroxyl group present in fats or oils.
13. Reichert-Meissl number helps to determine the amount of **volatile fatty acids** present in a given fat or oil.
14. Excessive deposition of fats in the body with decreased mobility causes **obesity**.
15. **Cholesterol** forms a structural part of biomembranes.
16. **Cholesterol** acts as precursor for biosynthesis of bile salts such as sodium glycocholate and sodium taurocholate.
17. **Libermann-Buchard reaction** is useful for estimation of blood cholesterol.
18. The major component of biological membrane is **phospholipid**.
19. **Gallstone** is a chief source of cholesterol.
20. Atherosclerosis means **deposition of cholesterol** in the walls of arteries and destroys their normal elasticity.
21. **Triglyceride** is the basic unit of lipid.

Chapter 5

Nucleic Acids

Q.1. What are nucleic acids? Mention the functions of nucleic acids.

Nucleic Acids

Nucleic acids are the macromolecules of high molecular weight present in the living cells, especially DNA or RNA whose molecules consist of many nucleotides linked in a long chain.

- Nucleic acids are very complex, colourless, amorphous compounds made-up of carbon, hydrogen, oxygen, nitrogenous bases, i.e. purine or pyrimidine, sugar and phosphorous.
- According to the nature of sugars present, the nucleic acids are divided into two main groups:
  i. RNA (ribonucleic acid)
  ii. DNA (deoxyribonucleic acid)
- DNA is found in the nucleus and RNA is found in all subdivisions of the cells, nucleus and cytoplasm, in particles and supernatant fluid.
- Nucleic acids serve as repositories and transmitters of genetic information.

Functions of Nucleic Acids

A. Functions of DNA (S.23)

1. DNA is a chemical basis of heredity.
2. DNA is regarded as the reserve bank of genetic information.
3. DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years.
4. Every aspect of cellular function is under the control of DNA.
5. DNA is organized into genes, which is a fundamental unit of genetic information.
6. The genes control the protein synthesis through the mediation of RNA.
7. DNA in eukaryotes performs specified functions with regard to protein synthesis.

B. Functions of RNA (S.23, 24)

RNA performs several functions carried out by three different types of RNAs.

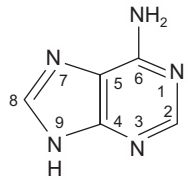
1. *Messenger RNA (mRNA):* It specifies the sequence of amino acids in the protein synthesis (translation).
2. *Ribosomal RNA (rRNA):* It is found in combination with proteins and is associated with the structure and functions of ribosomes, the factories of protein synthesis.
3. *Transfer RNA (tRNA):* It delivers the amino acids to ribosomes for protein synthesis.
4. RNA as ribonucleoprotein, participates in the post-transcriptional modification of other RNAs.
5. RNA is the genetic material carrying hereditary information in many viruses.

Q.2. Write a note on 'purine and pyrimidine' bases found in nucleic acids (nucleotides).

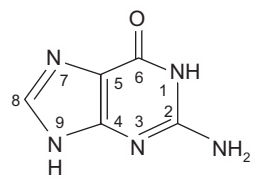
Purines and Pyrimidines

The complete acid hydrolysis of nucleic acids yields a mixture of basic substances called purines and pyrimidines, a pentose sugar and phosphoric acid.

- Purines and pyrimidines have been isolated from the hydrolysis product of nucleosides.
- Purines and pyrimidines are nitrogenous bases found in nucleotides and are aromatic heterocyclic compounds.
- Purines are numbered in the anticlockwise direction while pyrimidines are numbered in the clockwise direction.
  a. *Purines:* Adenine (A) and guanine (G) are the major purine bases found in nucleic acids.

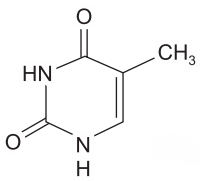


Adenine
(6-aminopurine)

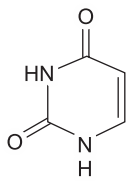


Guanine
(2-amino-6-oxypurine)

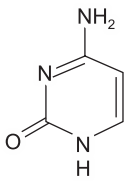
b. *Pyrimidines:* The most important pyrimidine bases found in nucleic acids are: i. Thymine (T), ii. Uracil (U), iii. Cytosine (C).



Thymine
(5-methyl-2,4-dioxy pyrimidine)

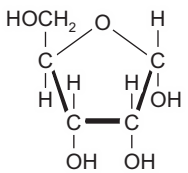


Uracil
(2,4-dioxy pyrimidine)

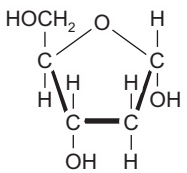


Cytosine
(2-oxy-4-amino pyrimidine)

Sugars present in nucleic acid



Ribose
(Found in RNA)



Deoxyribose
(Found in DNA)

Q.3. What are nucleosides? Explain the components/structures of nucleosides. (W.23)

Nucleosides

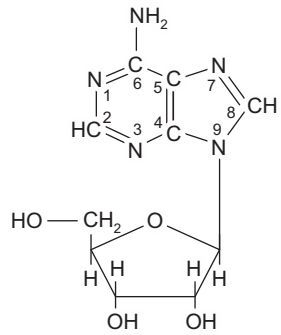
Nucleosides are the condensation products of sugar, pentose or deoxypentose and a nitrogenous, purine and pyrimidine base and are obtained by partial hydrolysis of nucleic acids.

Components of Nucleosides

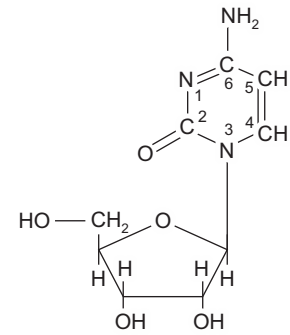
Nucleoside is generally composed of:

i. Purine and pyrimidine base,
ii. D-ribose or D-deoxyribose
iii. B-glycosidic linkage.

- Purine and pyrimidine base is linked to either D-ribose of D-2-deoxyribose through a β-N-glycoside linkage.
- This linkage in the purine nucleoside is at position 9 of the purine and in the pyrimidine nucleoside at position 3 of the pyrimidine.
- The sugars always exist as a furanose ring and the linkage to the purine or pyrimidine base is a β-glycosidic linkage.

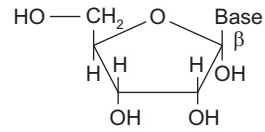


Adenosine
(adenine-β-D-ribofuranoside)
adenine-9-riboside

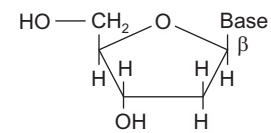


Uridine
(uracil-3-β-D-ribofuranoside)
uracil-3-riboside

- The adenine linked to ribose is called adenosine, the guanine nucleoside is called guanosine.
- The pyrimidine nucleosides are cytidine and uridine.
- When the analogous nucleosides formed with deoxyribose are called deoxyribosides, deoxyadenoside, deoxycytidine, etc.
- The general structures of ribose and deoxyribosenucleosides are:



D-ribose nucleoside



D-2-deoxyribose nucleoside

Q.4. What are nucleotides? Explain the components /structures of nucleotides. (W.23)

Nucleotides

Nucleotides are phosphoric esters of nucleosides, into which a phosphoric acid group has been attached to the sugar by esterification at a definite hydroxyl group.

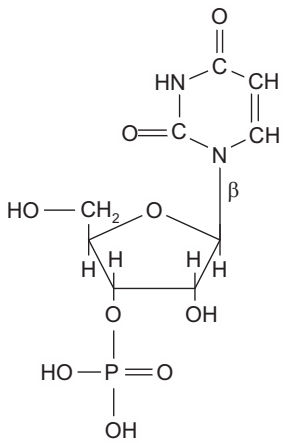
Components of Nucleotides

- Nucleotides are composed of:
  i. Nitrogenous base, ii. A pentose sugar, iii. A phosphate.
- The nucleotides consist of a base sugar and phosphate.
- The nucleotides are generally named according to the presence of purine and pyrimidine base and also as phosphate of corresponding nucleosides.

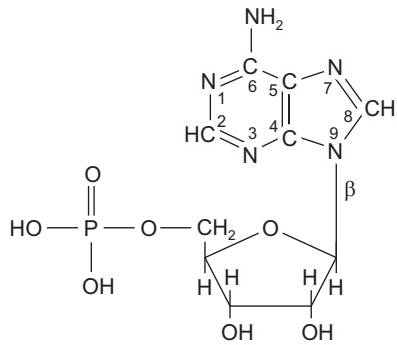
Thus,

i. Adenine nucleotide is adenylic acid of adenosine phosphate.
ii. Guanine nucleotide is guanylic acid or guanosine phosphate.
iii. Uracil nucleotide is uridylic acid or uridine phosphate.
iv. Thymine dinucleotide is thymidylic acid or thymidine phosphate.
v. Cytosine nucleotide is cytidylic acid or cytidine phosphate.

Structure of Nucleotides



Uracil nucleotide
(uridylic acid)



Adenine nucleotide
(adenylic acid)

Q.5. What is DNA? Describe structure/Watson and Crick model of DNA. (S.23, 24)

DNA

It is a deoxyribonucleic acid.

- In 1869, Miescher discovered 'nuclein' (DNA) in the cells from pus and later he separated into a protein and acid molecule.

It was known as nucleic acid after 1874.

- DNA is found in the cells of all living things.
- DNA contains all of the genetic information.
- Individual organism has unique DNA like a fingerprint.
- It contains phosphorous in the form of phosphate.
- It is a molecule that encodes the genetic instructions.
- Most of the DNA molecules are double-stranded helices.
- Each DNA molecule consists of two long biopolymers made up of simpler units called nucleotides.

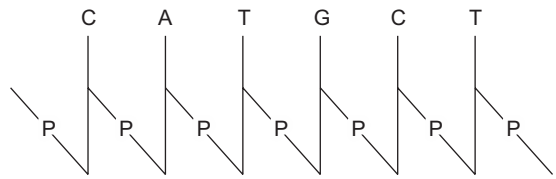
- Each nucleotide is composed of a nucleobase recorded using G, A,T, and C.
- Most DNA is located in the cell nucleus, but a small amount of DNA can also be found in the mitochondria.

Structure of DNA

- DNA is a polymer of deoxyribonucleotides.
- It is composed of
  a. Purines—adenine, guanine.
  b. Pyrimidines—thymine, cytosine.
  c. Phosphate

A. Primary Structure of DNA

DNA are high molecular weight polynucleotides made-up of chains of mononucleotides linked through 3′-5′-phosphate diester linkages,



Since only the 3′-5′–OH groups of deoxyribose in the nucleotides are available for esterification with phosphate, means nucleotides are joined by phosphate at these positions in the deoxyribose nucleic acids.

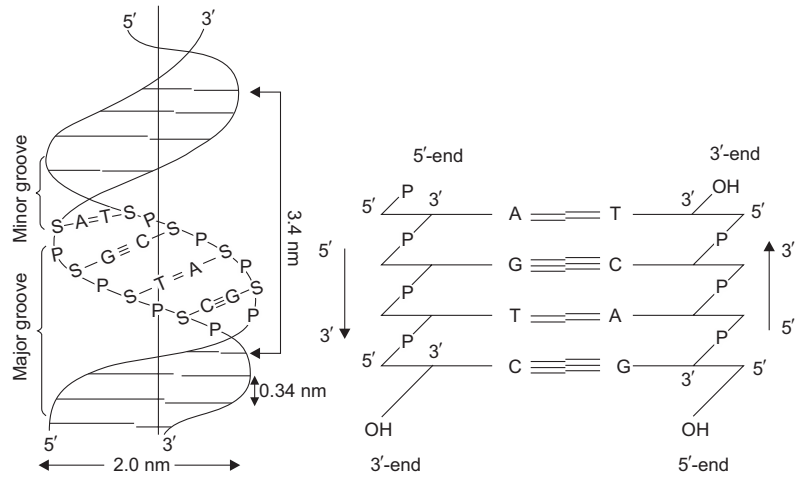
B. Secondary Structure of DNA/The Watson and Crick Model of DNA Structure

- The double helical structure of DNA was proposed by James Watson and Francis Crick in 1953.
- This structure was on the basis of X-ray analysis of DNA, is comparable to twisted ladder.

The salient features of Watson-Crick model of DNA:

1. The DNA is a right-handed double helix.
2. It consists of two polyhydroxyribonucleoside chain (strands) twisted around each other on a common axis.
3. The two strands are anti-parallel, i.e. one strand runs in the 5′-to-3′ direction, while the other in 3′-to-5′ direction. This is comparable to two parallel adjacent roads carrying traffic in opposite direction.
4. The width (diameter) of a double helix is 20 Å (2 nm).
5. Each turn of the helix is 34 Å (3.4 nm) with10 pairs of nucleotide, each pair placed at a distance of about 3.4 Å.

6. The two strands are held together by hydrogen bond formed by complementary base pairs. The A-T pair has 2 hydrogen bonds while G-C pair has 3 hydrogen bonds. The G=C is stronger by about 50% than A=T.
7. The complementary base pairing in DNA helix proves Chargaff's rule. The content of adenine is equal to that of thymine (A=T) and guanine is equal to that of cytosine (G=C).



(A) Watson-Crick model of DNA helix (B) Complementary base pairing in DNA helix

Q. 6. What is RNA? Describe the structure of RNA.

RNA

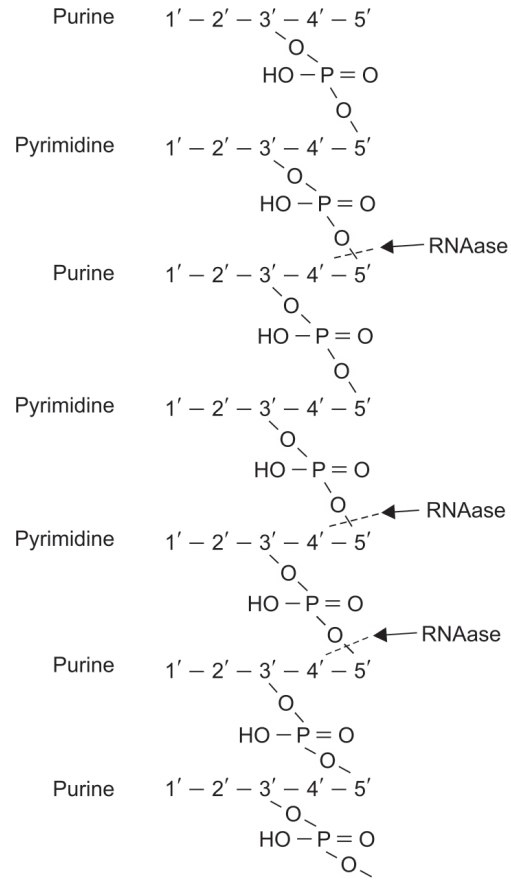
It means ribonucleic acid.

- RNA is a polymer of purine and pyrimidine ribonucleotide, linked together by 3′,5′-phosphodiester bridge.
- The sugar moeity in RNA is ribose.
- There are four types of ribose containing nucleic acid:
  1. Messanger RNA (mRNA) 5–10%
  2. Transfer RNA (tRNA) 10–20%
  3. Ribosomal RNA (rRNA) 50–80%
  4. Viral RNA

Structure of RNA

- RNA is a polymer of ribonucleotide held together by 3′,5′-phosphodiester bridges. The primary structure of RNA is shown in the following figure without branching.

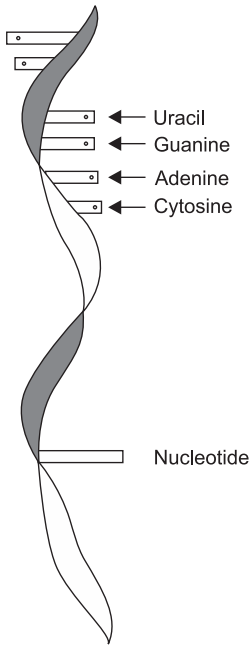
- The sugar in RNA is ribose.



Primary structure of RNA

- Purine bases in RNA are—adenine, guanine.
- Pyrimidine bases in RNA are—cytosine, uracil.
- The main polynucleotide structure of RNA may have a nucleotide chain branch.
- RNA have a chain of mononucleotide linked together through phosphate diester bond between 3′ and 5′ position of the sugar group.
- The skeleton structure of RNA may therefore be represented most simply as a polynucleotide chain with 3′-5′ linkage.

Internucleotide Phosphote Bonds of RNA



Single stranded RNA molecule

Q. 7. Give comparison/Distinguish/difference between DNA and RNA.

DNA	RNA
1. It contains bases adenine, guanine, cytosine, thymine.	1. It contains bases adenine, guanine, cytosine, uracil.
2. Deoxyribose is sugar moiety.	2. D-ribose is the sugar moiety.
3. DNAs are present in nucleus particularly in chromosomes.	3. RNA are present in cytoplasm and nucleolus.
4. They undergo mutation.	4. They do not undergo mutation.
5. They act as a carrier of genetic information from one generation of cell to the next.	5. They do not carry genetic information.
6. They contain about 1600–9000 nucleotides.	6. They contain 60–6000 nucleotides.
7. The molecules are thread-like and structures are highly complexed.	7. The molecules are unbranched and structure is less rigid.
8. They actively involve in the synthesis of protein.	8. They are also concerned with the protein synthesis.
9. They exist as double-stranded helical structure.	9. They exist as a single-stranded molecule.
10. Acid, alkali and heat may denature DNA molecule.	10. They are hydrolysed by alkalies.

Q.8. Give the biological importance /functions of nucleic acids.

Biological Importance/Functions of Nucleic Acids

1. Nucleic acids are responsible for the transmission of genetic information from one generation of cells to next and undergo mutation.
2. DNA produced mRNA helps in the placement of amino acids in the code for protein synthesis.
3. RNA functions as a template in connection with the synthesis at proteins.
4. rRNA and tRNA are also involved in the synthesis of protein.
5. Adenylic acid acts as a biochemical unit of energy exchange, in combination with two molecules of phosphates in all cells which is said to be ATP.
6. The nucleotides such as FAD, NAD, etc. act as hydrogen acceptors in biological oxidation–reduction reactions.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. RNA means **ribonucleic acid**.
2. DNA means **deoxyribonucleic acid**.
3. **DNA** is a chemical basis of heredity and purines and pyrimidines are nitrogenous bases found in nucleotides.
4. **Nucleus** is a site of chromosomes and DNA synthesis.
5. All enzymes involved in Krebs cycle are present in **mitochondria**.
6. **DNA** is organized into genes. A gene is a fundamental unit of genetic information.
7. DNA is regarded as a reserve bank of **genetic information**.
8. **Nucleic acids** serve as repositories and transmitters of genetic information.
9. **Adenine and guanine** are the major purine bases found in the nucleic acids.
10. **Thymine, uracil and cytosine** are the most important pyrimidine bases found in the nucleic acids.
11. In 1869, **Miescher** discovered nuclein (DNA) in the cells from pus.
12. DNA is a polymer of **deoxyribonuleotides**.
13. The double helix structure of DNA was proposed by **James Watson and Francis Crick** in 1953.
14. DNA is a **right-handed** double helix.
15. The complementary base pairing in DNA helix proves **Chargaff's rule**.
16. RNA is a polymer of purine and pyrimidine ribonucleotides linked together by **3′,5′-phosphodiester bridge**.
17. DNA contains about **1600–9000** nucleotides.
18. RNA exists as a **single-stranded** molecule.

Chapter 6

Enzymes

Q.1. Define enzymes. Classify enzymes into six classes with examples.

Definition

Enzymes can be *defined as soluble, colloidal, organic catalysts, protein in chemical nature, produced by living cells, which accelerate the rate of reaction and working at specific pH and temperature to convert substrate into specific product.*

- Enzymes are proteins which catalyse number of biochemical reactions.

Classification of Enzymes (Major 6 Classes of Enzymes)

1. *Oxidoreductases*: This class of enzymes is concerned with oxidation–reduction in which one compound is oxidised and other is reduced. Oxidation involves removal of H atom or addition of oxygen, e.g. dehydrogenases, oxidases.
2. *Transferase*: These are the enzymes which catalyse transfer of chemical groups such as alkyl, methyl, carboxyl, sulphate, phosphate, aldehyde, ketone, e.g. transaminase, kinase.
3. *Hydrolyses*: This class of enzymes includes hydrolytic enzymes that split different bonds such as C–N, C–O, C–C, etc. by addition of water, i.e. these enzymes catalyse hydrolytic reactions, e.g. esterases, lipases, peptidases, phosphatases, glycosidases.
4. *Lyases*: This is the 4th class of enzymes which catalyses removal of specific group from their substrate and introduce double bonds. The same enzymes can add groups to the double bonds. These enzymes catalyse the cleavage reactions which are nonhydrolytic, e.g. aldolases, decarboxylases, dehydratases, acotinoases.
5. *Isomerases*: There are the groups of enzymes which catalyse redistribution of chemical groups within a molecule to produce isomers, epimers, enantiomers, etc. They catalyse isomerization reactions, e.g. isomerases, epimerases, recemerases.

6. *Ligases*: This is the 6th class of enzymes called synthetases. They catalyse the bond formation reactions, i.e. linking together of two compounds, e.g. synthetases, carboxylases.

Q.2. Mention general properties or characteristics of enzymes.

1. All enzymes are protein in chemical nature.
2. Enzymes accelerate (increase) the rate of reaction.
3. Enzymes are always specific for their substrate.
4. They possess an active site at which interaction with substrate takes place.
5. In enzyme action mechanism, there is formation of an enzyme–substrate complex as an important intermediate in the reaction.
6. Some enzymes are regulatory in function.
7. Enzymes are thermolabile, i.e. heat sensitive as they can be denatured or inactivate by heat.
8. Enzymes are proteins with high molecular weight ranging between 10,000 to more than millions.
9. Enzymes can be precipitated by ethanol or by high concentration of inorganic salts like NH_4SO_4.
10. Enzymes are proteins in chemical nature, thus they are amphoteric, i.e. posses positive as well as negative charge due to acidic and basic functional groups.
11. Enzymes are unstable and their activity can be lowered or enzymes can be destroyed by variety of physical and chemical conditions, e.g. high temperature, wide changes in pH.

Q.3. Write in short about nomenclature of enzymes.

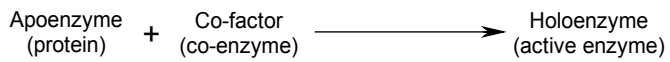
- Earlier, for the long time, enzymes were being named by adding suffix—'in', e.g. pepsin, trypsin, renin, chymotrypsin.
- Later on, because of addition, new enzymes nomenclature by above method becomes difficult, so enzymes can be named by new fashion, by adding suffix—'ase'.
    i. Suffix—'ase' is added to the substrate upon which enzyme is acting, e.g. fumarase, urease, lipase, sucrase.
    ii. Other way of naming enzyme by adding suffix—'ase' to the kind of reaction which is mediated by that enzyme, e.g. oxidase, reductase, transferase, ligase.
- As the number of enzymes were discovered, so there was need of systematic and informative nomenclature and classification of enzymes.

Thus, in 1961, the commission on enzymes, International Union of Biochemistry (IUB), proposed a new system of classification of enzymes.
  - The IUB formed Enzymes Commission (EC)
  - Thus, the names are called EC names
  - EC names comprise 4 digits:
    - First digit indicates main class
    - Second digit indicates subclass of respective main class
    - Third digit indicates main class for sub-sub-class
    - Fourth digit indicates enzyme actual.

    Example: EC 1.1.1.27 for enzyme lactate dehydrogenase (LDH).
- *Drawback*: This system is not practically usable.

Q.4. Describe in brief chemistry of enzymes.

- Some enzymes are purely protein in nature while there are certain enzymes which posses one or more nonprotein component for proper functioning of these enzymes.
- The protein part of an enzyme is called "apoenzyme" while the nonprotein part of an enzyme is called "co-factor"/"co-enzyme".
- When co-factor is firmly attached to the protein, it is called "prosthetic group".
- The active enzyme composed of apoenzyme and a co-factor is called the 'holoenzyme."



- When co-factor is not firmly (loosely) attached to the protein then it is called co-enzyme.
- There are many enzymes which requires Mg, Ca, Cu, Mn, Zn, etc. as metallic co-factor or prosthetic group.
- Some enzymes are called metalloenzymes which require compulsory presence of metallic ion for their activity.

Q.5. Discuss different factors affecting/influencing enzyme-catalysed reactions. (S.24, W.23)

i. Effect of nature and concentration of substrate
ii. Effect of nature and concentration of enzymes
iii. Effect of time
iv. Effect of temperature
v. Effect of pH
vi. Effect of UV rays
vii. Effect of inhibitors
viii. Effect of activators

i. Effect of Nature and Concentration of Substrate

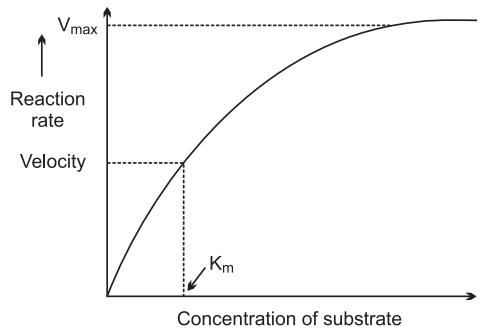
- If the concentration of substrate is increased by keeping concentration of enzyme constant, then rate of reaction is increased.
- Initially, rate of reaction is directly proportional to substrate concentration, this is because active site of enzyme occupies substrate.
- Further increase in substrate concentration can increase the catalysis rate but when all enzyme molecules are completely occupied by substrate molecule, further increase in substrate concentration *cannot increase the rate of reaction.*
- At this state, enzymes are completely saturated with substrate.
- V_{max}: The velocity at the stage where rate of reaction is maximum is called maximum velocity. The rate of enzyme catalysed reaction is:

$$V = \frac{V_{max}(S)}{K_m + (S)}$$

where, K_m = Michaelis-Menten constant, V_{max} = Maximum velocity, (S) = Substrate concentration

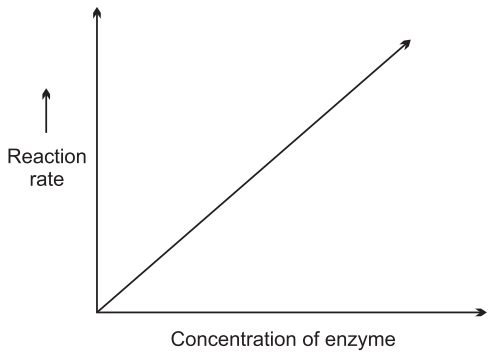
Michaelis-Menten Constant

"It is defined as the substrate concentration to which the velocity of an enzyme atalysed reaction is exactly half of V_{max}."

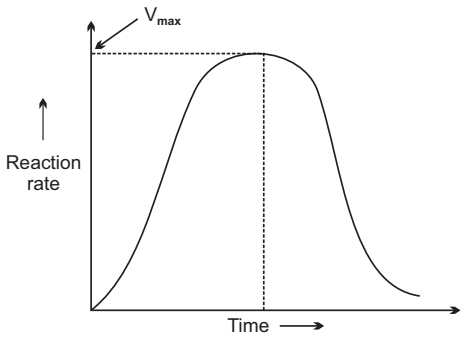


ii. Effect of Nature and Concentration of Enzymes

The enzyme activity is directly proportional to concentration of enzyme in the system, i.e. increase in concentration of enzyme increases the rate of reaction. It is assumed that, for increase in velocity to achieve V_{max} in the medium, substrate is present in highest concentration. Also to achieve V_{max}, the specific substrate, optimum pH and optimum temperature are to be provided.



iii. Effect of Time



Here, a typical bell-shaped graph is obtained when reaction velocity is *plotted against* the time.

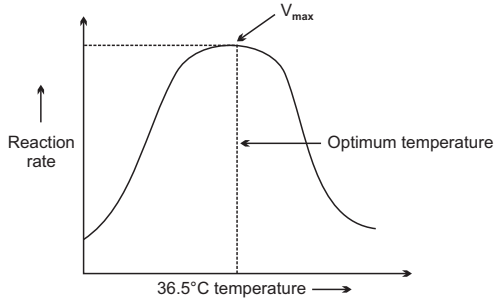
Initially, there is rapid increase in velocity till V_{max} is achieved. After that, graph slopes down sharply as substrate concentration decreases as a resultant of enzyme catalysis, as and when time proceeds further.

The bell-shaped graph is obtained upon assumption that:

a. Both enzymes and substrates are at constant and highest concentration.
b. Optimum pH and temperature are required.

iv. Effect of Temperature

- The rate of enzyme-catalysed reaction initially increases as the *temperature increases*. But this increase is obtained till optimum temperature (about 35–38ºC).
- The temperature at which *an enzyme shows maximum activity* is called *optimum temperature*.
- Further *increase in temperature decreases the velocity of enzyme* catalysis and so bell-shaped graph is obtained.

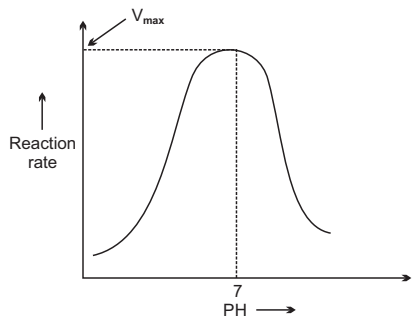


- Decrease in velocity after achieving V_{max} *at optimum temperature* is because of thermal denaturation of enzymes. This is because proteins are destroyed or denatured at high temperature.
- The *increase in temperature* above the optimum *temperature may result into inactivation of enzymes*, this is known *as thermal denaturation*.

v. Effect of pH

When a graph is plotted between velocity of enzyme catalysis and pH, a typical bell-shaped graph is obtained. pH refers to acidic or basic or neutral ranges. The most of the enzymes work with acidic, basic or neutral ranges. The most of the enzymes work with maximum rate at neutral pH (pH 7).

Initially, increase in pH from acidic to neutral side, the velocity also increases. But upon reaching optimum pH (neutral) further increase in pH velocity of enzyme catalysis decreases significantly.



The characteristic pH at which enzyme activity is maximum is called optimum pH.

For each enzyme, there is range of optimum pH, within which enzyme works with maximum velocity. This range is generally from pH 6.4 to pH 7.5. Exceptionally, there are some enzyme for which optimum pH is highly acidic or slightly acidic or alkaline are given below:

Enzyme	*Optimum pH*
1. Pepsin	2.0
2. Acid phosphatase	5.5
3. Papain	5–6
4. Amylase	6–7
5. Lipase	7.0
6. Trypsin	6–8.5
7. Alkaline phosphatase	9.2

vi. Effect of UV Rays

The UV rays affect adversely the velocity of enzyme catalysis, that is because enzymes are denatured by UV rays.

The damaging effect of UV rays is seen at highest degree at the wavelength 2650Å. It is observed that the degree of purity of enzyme decides the degree of damage of enzyme. When enzyme is with more impurities, the damaging effects of UV rays are least because impurities in enzyme absorb UV rays with damaging effect thus protecting enzyme protein.

vii. Effect of Inhibitors

Inhibitors are the agents which prevent the action of enzyme and thus decrease the rate of reaction. Such inhibition may be by:

i. Feedback inhibition
ii. Competitive inhibition.

viii. Effect of Activators

Activators are the agents which increase the activity of enzyme and velocity of enzyme catalysis. The presence of enzyme activators in certain concentration increases the enzyme activity, e.g.

i. Many enzymes require monovalent cations like K^+, Na^+ for maximum catalytic activity.
ii. Cysteine HCl increases the proteolytic activity of papain.

Q.6. Write a note on enzyme action/mechanism of enzyme action/ concept of enzyme action. (W.23)

- Enzymes are biological catalyst which act upon substrate to convert it into the end-product.
- Enzymes mainly work to accelerate the rate of reaction.
- In 1913, Michaelis and Menten established the theory of formation of an enzyme–substrate complex and its subsequent dissociation into products.
- In actual mechanism of catalysis, enzymes initially form a complex with substrate molecule called enzyme–substrate complex.

$$\text{Enzyme (E)} + \text{Substrate (S)} \longrightarrow \underset{\text{(ES complex)}}{\text{Enzyme–substrate complex}}$$

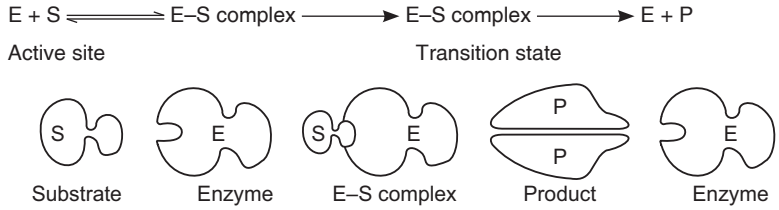
$$\text{ES} \longrightarrow \text{E} + \text{Product (P)}$$

- The binding sites on the enzyme molecules having competitive structures to the substrate molecule so that they can 'fit' into particular site on an enzyme molecule.
- The binding of a substrate with an enzyme at the active site, is explained by two theories.
  i. Lock and key hypothesis/model
  ii. Induced fit model/hypothesis.

i. Lock and Key Hypothesis (Emil Fischer)

- It is the first ever idea proposed by scientist "Emil Fischer" to explain enzyme action mechanism. It is like a lock and key.
- In this case, the shape of active site of enzyme and that of substrate is complementary to each other.
- The substrate molecule fits into the active site of an enzyme just as a key fits into a lock. Hence this type of mechanism is termed as lock and key model/hypothesis.
- In this model, the shape of the active site is rigid and complementary to the shape of the substrate complex.

- Mechanism:



Limitations/Drawbacks of Lock and Key Hypothesis

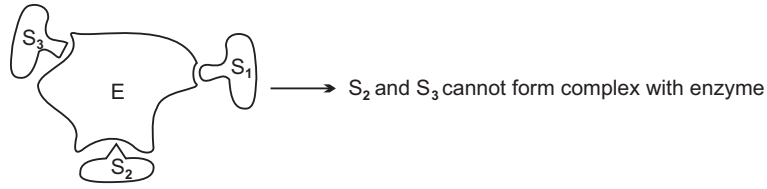
i. Rigid structure of enzyme as stated in this hypothesis is not exactly proved. In fact, enzymes being protein in nature possess structural flexibility, because of changes in coiling and recoiling of polypeptide chain in enzyme protein.

ii. For one enzyme acting upon one class of substrate, lock and key hypothesis fails, e.g. enzyme lipase acting upon lipids and fats in general, from different sources and with different chemical natures.

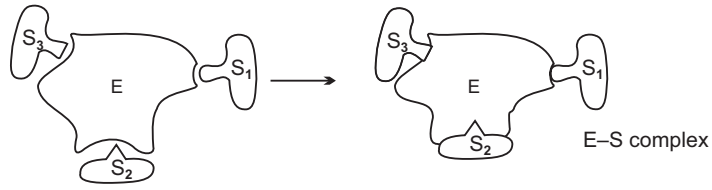
ii. Induced Fit Model/Hypothesis

- It is the hypothesis proposed by scientist Koshland, where limitations of lock and key hypothesis are removed.
- Induced fit hypothesis states that in an unoccupied enzyme molecule functional group of active site is not in its optimum position to promote catalysis, i.e. shape of active site is not complementary to the substrate.
- In this hypothesis, the active site of an enzyme is considerably flexible so as to accommodate a wide variety of susbtrate molecule.
- Thus, when substrate molecule binds to the enzyme, the shape of active site is made complementary to the substrate to certain extent.
- The hypothesis is called induced fit because the substrate molecule that induces enzyme to undergo favourable confirmation (changes).

1.



2.



Active site of enzyme is made complementary as that of shape of the substrate.

In actual mechanism, following steps are important:

a. Favourable proximity and orientation between both substrate and enzyme.
b. Covalent catalysis by covalent bond formation between substrate and enzyme at active site.
c. Several groups of enzymes (acid–base reaction) form main basis of enzyme action mechanism.

Q.7. What is enzyme inhibition? Discuss the different types of enzyme inhibition./Write a note on enzyme inhibition. (S.23)

Enzyme Inhibition

The functional groups of enzymes from their active sites and surfaces react with a variety of chemical agents and their catalytic activity is reduced. These agents are called inhibitors and the process is called enzyme inhibition.

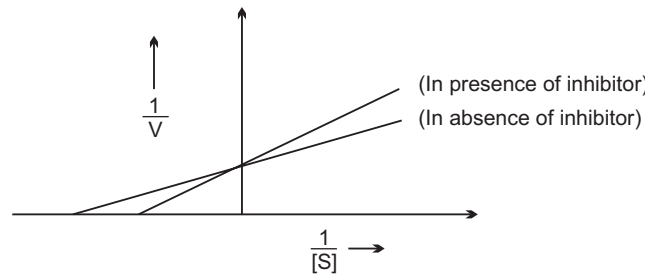
Types of Enzyme Inhibition

a. *Competitive inhibition or reversible inhibition*
   i. In this type of inhibition, the inhibitors have structural similarity with the substrate.
   ii. Due to this, the inhibitors bind at the active site of enzyme.
   iii. In this case, the inhibitors and substrate both are competing for the active site of an enzyme. Hence, it is called competitive inhibition.
   iv. If the concentration of substrate increased then the inhibition can be reversed, hence called reversible inhibition.
   v. Inhibitors bind with the enzyme to form an enzyme–inhibitor complex which does not give a product.

$$E + S \rightleftharpoons ES \longrightarrow E + P$$

$$E + I \rightleftharpoons EI \longrightarrow \text{No product}$$

   vi. Example: Malonic acid is a competitive inhibitor of enzyme succinic acid dehydrogenase because there is a structural similarity between malonic and succinic acid.
   vii. The K_m value of enzyme increases in the presence of competition inhibition and V_{max} remains constant.



viii. Other examples of competitive inhibitors:
- Allopurinol is a competitive inhibitor of xanthine oxidase.
- Ephedrine is a competitive inhibitor of mono-amino oxidase enzyme.

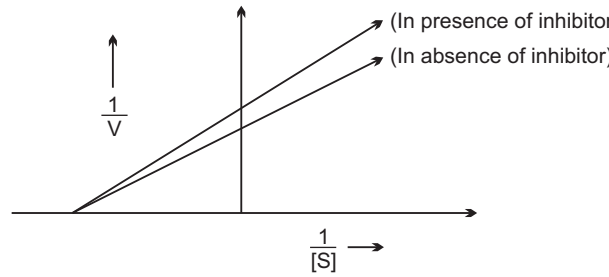
b. *Noncompetitive inhibition/irreversible inhibition*

i. In this type of inhibition, inhibitor binds with an enzyme at the surface of functional group and reduces the activity of enzyme. Thus, increase in substrate concentration does not reverse inhibition.

ii. In this case, the inhibitor can also be bound to the enzyme–substrate complex.

$$E + S \rightleftharpoons ES \longrightarrow E + P$$
$$E + I \rightleftharpoons EI \longrightarrow \text{No product}$$
$$ES + I \rightleftharpoons ESI \longrightarrow \text{No product}$$
$$EI + S \rightleftharpoons EIS \longrightarrow \text{No product}$$

iii. The K_m value of an enzyme remains constant but V_{max} decreases.



iv. Examples of noncompetitive inhibitor: Metal ions and EDTA shows noncompetitive inhibition.

Q.8. Give differences between competitive inhibition and non-competitive inhibition.

Competitive inhibition	*Noncompetitive inhibition*
i. The inhibitors have a structural similarity with the substrate.	i. No structural relationship between inhibitors and substrate.
ii. The inhibitors bind at the active site of an enzyme.	ii. The inhibitors bind with an enzyme at surface of functional group.
iii. The increase in substrate concentration decreases inhibition.	iii. The increase in susbtrate concentration does not decrease inhibition.
iv. K_m value of enzyme increases in presence of competitive inhibition.	iv. The K_m value of an enzyme remains constant.
v. V_{max} value remains constant.	v. V_{max} value decreases.
vi. This is called reversible inhibition.	vi. This is called irreversible inhibition.
vii. Examples: Ephedrine is a competitive inhibitor of MAO enzymes.	vii. Examples: Metal ions and EDTA show non-competitive inhibition.

Q.9. Define the terms with examples.

1. *Cofactor:* Some enzymes require a nonprotein group for catalytic activity which is called cofactor, e.g. the metal ions like Mg^{2+}, Mn^{2+}, Ca^{2+} are called cofactors.
2. *Coenzymes*: Coenzymes are low-molecular weight organic substances, essentially derived from vitamin B complex group and are required for catalytic reactions, e.g. pyridoxal phosphate is derived from vitamin B_6, which is a co-enzyme of transaminase.
3. *Endoenzymes/intracellular enzymes*: The enzymes which act only inside the cell and involve in synthesis of cell components, food material of the cell, are known as *endoenzymes*, e.g. synthetase, isomerases.
4. *Exoenzymes/extracellular enzymes*: The enzymes which are secured outside the cell having a digestive function are called exoenzymes, e.g. pepsin, lipase, amylase, trypsin.
5. *Constitutive enzymes*: The enzymes which are produced in the absence of substrate are called constitutive enzymes, e.g. enzymes of glycolytic series such as kinase, mutase.
6. *Induced enzymes*: The enzymes which are present in small amount but their concentration get immediately increased in the presence of substrate on which they act. Such enzymes are called induced enzymes, e.g. ethanol and barbiturates are powerful in inducing hepatic microsomal enzymes.

7. *Holoenzyme*: The active enzyme composed of apoenzyme and a cofactor is called holoenzyme.

$$\text{Apoenzyme} + \text{Cofactor} \longrightarrow \text{Holoenzyme}$$

8. *Apoenzyme*: The protein part of an enzyme is called apoenzyme.
9. *Isoenzymes: The multiple forms of the same enzyme are called isoenzymes, e.g. lactate dehydrogenase* (LDH).
10. *Proenzymes/zymogens*: The enzymes which are present in its inactive forms are called proenzymes, e.g. pepsinogen, trypsinogen.
11. *Activators* (*enzyme activators*): Some enzymes require presence of small amounts of specific inorganic ions for their activity. Such ions are called activators.

These ions may help in joining with groups on the susbtrate molecule and bringing them together with enzymes or by actual participation in transfer reaction.

i. Mg^{2+} ions required for phosphorylation reaction.
ii. Ca^{2+} ions required for coagulation.
iii. Zn^{2+} ions required for carbonic anhydrase action.
iv. Fe^{2+} and Cu^{2+} ions required for some oxidative reaction.

12. *Active site*: It is a cleft or depression upon enzyme molecule at which substrate molecule attaches to enzyme. Enzyme molecule may carry one or many active sites.
13. *Enzyme inhibitors*: The functional groups of enzymes form their active sites and surfaces reaction with a variety of chemical reagents and their catalytic activity is reduced. These agents are called enzyme inhibitors, e.g. ephedrine is an inhibitor of MAO enzymes.
14. *Allosteric enzymes: The enzymes whose catalytic activity is regulated by itself, are called allosteric enzymes*. These are also called regulatory enzymes, e.g. phosphofructokinase is an allosteric enzyme which converts fructose-6-phosphate to fructose-1,6-diphosphate.

Q.10. Write a short note on zymogens/proenzymes.

Definition

Some enzymes which are present in its inactive form are called zymogens or proenzymes.

- Proenzyme is synthesized in the inactive state.
- Subsequently proenzyme is activated and converted to the active enzyme form in the presence of some molecules or factors called activators.

- Typically, protein digesting enzymes and blood coagulation factors are synthesized in their zymogen forms.
- Examples:

1. Pepsinogen (inactive)	$\xrightarrow{\text{Gastric acidity}}$	Pepsin (active)
2. Trypsinogen (inactive)	$\xrightarrow{\text{Enterokinase}}$	Trypsin (active)
3. Chymotrypsinogen (inactive)	$\xrightarrow{\text{Trypsin}}$	Chymotrypsin (active)
4. Pro-carboxy peptidase (inactive)	$\xrightarrow{\text{Chymotrypsin}}$	Carboxy peptidase (active)
5. Prothrombin (inactive)	$\xrightarrow{Ca^{2+}}$	Thrombin (active)
6. Fibrinogen (inactive, soluble)	$\xrightarrow{\text{Thrombin}}$	Fibrin (active, insoluble)

Examples of Proenzyme Activation

- Pepsinogen is a zymogen form of protein digesting enzyme pepsin.
- This enzyme is present in gastric juice in the stomach.
- Free HCl secreted by stomach mucosa works as activator to convert inactive pepsinogen to active pepsin.
- Action of HCl results in cutting and removal of a fragment of 45 amino acids present at N-terminal of inactive pepsinogen. This changes conformation of enzyme protein molecule to convert inactive pepsinogen to active pepsin.

Significance of Zymogens

Till particular proenzyme is activated, particular enzyme cannot operate in the body, e.g. damage of gastric and intestinal mucosa can be prevented by protein digesting enzymes secreted in respective zymogen form. In another example by secreting some blood clotting factors in zymogen form clotting of circulating blood in the body is prevented. Blood clot in circulating blood (thrombus) can block blood vessels thus to prevent blood supply and further damage, some blood clotting factors are produced in zymogen forms.

Q. 11. Write a note on isoenzymes/isozymes.

Isoenzymes

The enzymes which have multiple molecular forms in the same organism and catalysing same biochemical reactions are called isoenzymes/isozymes.

The multiple forms of the same enzyme are called isoenzymes. Isoenzymes, though catalyse same reaction, they differ in degree of activity, i.e. V_{max} for different isoenzymes is different. Relative amount of different forms of isoenzymes differs in different organs and tissues.

Examples of Isoenzymes

1. LDH, i.e. lactate dehydrogenase in five different forms.
2. Alkaline phosphatase in two different forms.
3. Isocitrate dehydrogenase in three different forms.
4. Creatinine phosphokinase in three different forms.
   Creatinine phosphokinase (CPK) is an isoenzyme with three different forms as:
   a. CPK-1 BB, b. CPK-2 BM, c. CPK-3 MM.

wherein these three forms are polypeptide chain in the enzyme protein is denoted by 'B' and other polypeptide chain is denoted by 'M'.

Q.12. Write in brief about lactate dehydrogenase (LDH).

- LDH is the most important enzyme existing in almost all tissues and body fluids in the human body.
- This enzyme catalyses dehydrogenation reaction, i.e. removal of hydrogen to convert lactic acid into pyruvic acid.

$$\text{Lactate} + NAD^+ \xrightarrow{\text{Lactate dehydrogenase}} \text{Pyruvate} + NADH + H^+$$

- As a part of tissue respiration physiology in all the cell, certain amount of LDH is present.
- Following are five different isoenzyme forms of LDH with their respective subunits as:
  i. LDH_1—H_4, ii. LDH_2—H_3 M, iii. LDH_3—H_2 M_2, iv. LDH_4—HM_3, v. LDH_5—M_4.
  where two polypeptides are indicated by H and M.
- LDH is the most important glycolytic enzyme present in nearly all the cells but higher concentration is seen in:
  – Liver (LDH_5—60%)
  – Skeletal muscles (LDH_5—55%)
  – Heart (myocardium) (LDH_1—55%) (LDH_2—36%)
  – Kidney (LDH_5—45%)
  – Brain (LDH_5—40%), (LDH_1 and LDH_2 both about 20%)
- The pattern of distribution of particular type of LDH isoenzyme possesses clinical or diagnostic value.
  The disturbance and the increase in serum LDH level is seen in muscular dystrophy, kidney disease, haemolytic anaemia, megaloblastic anaemia and in different types of cancer.
- Normal value of serum LDH is 60–200 IU/L.

Q.13. What is marker enzyme?/Write a note on marker enzyme.

Marker Enzyme

Marker enzymes are that enzymes which give signals and are helpful in transportation.

- These are recognised by the specific DNA sequence.
- The soluble enzymes of citric acid cycle and β-oxidation of fatty acid found in matrix, are necessary for transporting metabolites and nucleotides across the inner membrane.
- Succinate dehydrogenase is found on the inner surface of the inner mitochondrial membrane.
- The cell organelles and relative marker enzymes are as follows:

Cell organelles	*Marker enzymes*
i. Nucleus	DNA polymerase
ii. Mitochondria	Glutamic dehydrogenase
iii. Endoplasmic reticulum	Glucose-6-phosphate
iv. Golgi apparatus	Galactosyl transferase

Functions of Marker Enzymes

i. They give signals and are helpful in transportation.
ii. They help to transport metabolites and nucleotides across the inner membrane.
iii. Marker enzymes have diagnostic value, e.g. during infection, the leakage of marker enzyme increases. Hence, such increase of certain enzymes from plasma is used for diagnosis of diseases.

Q.14. What is transaminase? Give the diagnostic applications of it.

Definition

The enzymes which are involved in transamination reaction in living organisms are called transaminases.

There are two types of transaminase found in human tissues:

i. GOT (Glutamate oxaloacetic transaminase)
ii. GPT (Glutamate pyruvic transaminase).

- The transaminase are widely distributed in nature.
- GOT is present in greatest amount in heart muscles, skeletal muscles, brain, liver, and kidney.
- Traces of these enzymes normally escape into the bloodstream.
- The normal level of SGOT and SGPT are:
  SGOT—2–30 IU/L
  SGPT—2–15 IU/L.

Diagnostic Applications of Transaminase

i. In myocardial infarction, SGOT level is increased.
ii. Damage of small portion of heart muscle by occlusion of branch of coronary arteries may increase SGOT level.
iii. In rural hepatitis, SGPT is always higher than SGOT.
iv. In cirrhosis and haemolytic jaundice SGOT is higher than SGPT.
v. Increased SGOT level in skeletal muscles indicates damage or injury to skeletal muscle and also muscular dystrophy.

Q.15. Write in brief about medicinal significance of enzymes.

Many drugs exert their actions by inhibiting certain enzyme systems. Hence, enzyme inhibition has a great significance in the treatment of diseases, these are:

i. Sulfanilamide selectively kills pathogenic organisms by inhibiting 'folic acid synthetase' enzyme.
ii. Ephedrine is a competitive inhibitor of mono-amino oxidase enzyme and prolongs the action of mono-amines and exerts an antidepressant activity.
iii. Allopurinol is a competitive inhibitor of xanthine oxidase enzyme. Hence, allopurinol is used in the treatment of gout.

Q.16. Give therapeutic and pharmaceutical importance of enzymes.

1. Therapeutic Importance of Enzymes

Enzymes are frequently used therapeutically, these are:

a. The enzyme L-asparaginase is used in treatment of cancer.
b. Galactosidase can be used for the treatment of lactose intolerance in children.
c. Fibrinolysin and deoxyribonuclease may help to remove fibrinous material from infected wounds.
d. Trypsin and streptokinase enzymes are used in the treatment of thrombosis.
e. Pepsin, lipase, amylase, peptidases are used in the treatment of chronic pancreatitis and gastrointestinal disorders.

2. Pharmaceutical Importance of Enzymes (in Manufacturing of Bulk Drugs) (S.23)

Some enzymes are used in bulk drug manufacturing.

i. Penicillin acylase is used for the production of 6-amino-penicillanic acid from penicillin-G.
ii. Papain is used as digestant for the production of protein hydrolysates.
iii. Hyaluronidase is used in orthopaedic practice.

iv. Urokinase is used in cardiac diseases.
v. Amino acylase for production of L-amino acids.
vi. Glucose isomerase is used for production of high fructose syrup.
vii. Amylase is used for production of dextrin.

Q.17. Give the diagnostic uses/significance of enzymes.

The enzymatic pattern is different for different tissues in higher animals. Hence, enzymes have a great value in the diagnosis of diseases.

Examples

i. 'Aspartate aminotransferase' and 'lactate dehydrogenase' are seen in cardiac and hepatic tissues and help in the diagnosis of 'myocardial infarction' and 'hepatitis'.
ii. 'Creatine kinase' is seen in skeletal or cardiac muscles and helps in diagnosis of skeletal or cardiac disorders.
iii. In some pathological condition, the enzyme amylase is found to be released in blood circulation, e.g. damage to gland cells and damage to secretary pathway.
iv. The increase in serum aldolase level shows some important disease like, myocardial infarction, viral hepatitis, liver cancer.
v. Human plasma contains a wide range of enzymes. During infection, the leakage of marker enzyme increases. Hence, such increase of certain enzyme from plasma is used for the diagnosis of diseases.

Q.18. Differentiate between 'lock and key mechanism' and 'induced fit mechanism'.

Lock and key mechanism	*Induced fit mechanism*
1. Active site of enzyme is rigid.	1. Active site is flexible.
2. Only one kind of substrate can fit.	2. Variety of substrates can fit.
3. Substrate cannot change the enzyme conformation.	3. Substrate induces conformational change in the enzyme.
4. This theory is proposed by Fischer in 1894.	4. This theory is proposed by Khosland in 1966.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. Enzymes are **proteins** which catalyze a number of biochemical reactions.
2. Enzymes are **amphoteric** in nature.
3. IUB means **International Union of Biochemistry**.
4. EC means **Enzymes Commission**.
5. LDH means **lactate dehydrogenase**.
6. The protein part of an enzyme is called **apoenzyme** while the non-protein part of an enzyme is called **co-factor/co-enzyme**.

7. The increase in concentration of enzyme **increases the rate of reaction**.
8. The temperature at which an enzyme shows maximum activity is called **optimum temperature**.
9. The increase in temperature above the optimum temperature may result into inactivation of enzymes, is known as **thermal denaturation**.
10. The pH at which enzyme activity is maximum is called **optimum pH**.
11. **Inhibitors** are the agents that prevent the action of enzyme and thus decrease the rate of reaction.
12. Enzymes mainly work to **accelerate** the rate of reaction.
13. In 1913, **Michaelis and Menten** established formation of an enzyme–substrate complex.
14. Lock and key model of enzyme action firstly proposed by **Emil Fischer**.
15. The active enzyme composed of apoenzyme and a cofactor is called **holoenzyme**.
16. The multiple forms of the same enzymes are called **isoenzymes**.
17. **Proenzymes/zymogens** are the enzymes which are present in its inactive form.
18. LDH is an example of **isoenzyme**.
19. **Allosteric enzymes** are also called self-regulatory enzymes.
20. CPK means **creatinine phosphokinase**.
21. The process of shifting a hydrogen atom from one carbon to another to produce enediol is referred as **tautomerization**.

Chapter 7

Vitamins

Q.1. Define vitamins. Give the classification of vitamins.

Vitamins

Vitamins are the organic compounds which are found in natural food stuffs and are essential for normal growth and metabolic functions of the body.

Classification of Vitamins

- *Fat-soluble vitamins*: Vitamin A, vitamin D, vitamin E, vitamin K.
- *Water-soluble vitamins*:
  i. Vitamin B complex group
     - Thiamine (B_1)
     - Riboflavin (B_2)
     - Niacin (B_3)
     - Pyridoxine (B_6)
     - Pantothenic acid
     - Biotin
     - Folic acid
     - Lipolic acid (PABA)
     - Cyanocobalamin.

  ii. Ascorbic acid (vitamin C).

Q.2. Explain the terms.

a. *Night blindness*: It is an inability to have vision in dim light and during dark, due to impairment in dark adaptation of eyes.
   It is caused due to deficiency of vitamin A.
   In children, additional defects like recurrent infection and diarrhoea may observe.

b. *Pellagra*: It is caused by dietary deficiency of vitamin B_3 (niacin) and protein containing essential amino acid, tryptophan.
   - *Symptoms*:
     i. Dermatitis, alopecia, oedema
     ii. A sore
     iii. Dark coloured tongue
     iv. An inability to digest and assimilate food
     v. Skin rash, itching

vi. Red skin lesions
vii. Dementia
viii. High sensitivity to sunlight

c. *Scurvy*: It is a deficiency disorder caused due to vitamin C.
   - *Symptoms*:
     i. Defective formation of collagen fibres of connective tissues
     ii. Formation of bone is also abnormal
     iii. Bleeding occurs
     iv. Pin-point haemorrhages in the skin
     v. Bleeding from gums and teeth
     vi. Slow wound healing
     vii. Slow healing of fractured bones.

d. *Egg white injury*: It is a deficiency disorder caused due to vitamin 'biotin'. Biotin has a strong affinity with avidin (egg white protein). Excess consumption of raw eggs results in deficiency of biotin called egg white injury.

   This biotin–avidin complex is not absorbed during digestion and hence produces deficiency of biotin.
   - *Symptoms*:
     i. Nausea
     ii. Anorexia
     iii. Dermatitis
     iv. Pain in muscles
     v. Fatigue.

Q.3. Write a note on beriberi.

Beriberi

It is a deficiency disorder of vitamin B_1 (thiamine). There are four types of beriberi.

a. *Dry beriberi:* It is a nutritional deficiency. The main reason behind this is consumption of polished rice and refined cereals.
   - *Symptoms*:
     i. Degeneration and demyelination
     ii. Oedema of face and legs
     iii. Pericardial pain
     iv. Palpitation
     v. Numbness in legs
     vi. Tenderness in the calf muscles.

b. *Wet beriberi:* It is characterized by oedema. Reason behind oedema is cardiac failure.
   - *Symptoms*:
     i. Rapid and notable oedema develops involving face, legs, trunk and serous cavities

ii. Breathlessness
iii. Palpitation
iv. Rise in systolic BP
v. In severe condition patient may die due to acute circulatory failure.

c. *Infantile beriberi:* It occurs in breastfed infants, usually between 2 and 5 months of age. Reason behind is mother consuming thiamine deficient diet and secreting milk with low thiamine content. It is very acute condition and can be fatal (toxic).
   - *Symptoms*:
     i. Restlessness in infants
     ii. Infant crises a lot and passes very less urine
     iii. Oedema develops
     iv. Dyspnoea
     v. Tachycardia
     vi. Infant may die within 24–48 hours
     vii. Convulsions and coma.

d. *Cerebral beriberi:* This disease is resultant of acute biochemical lesions in the brain due to thiamine deficient diet. It is further leading to abnormal metabolism in the brain:
   - *Reason behind cerebral beriberi*
     i. Alcoholism
     ii. Carcinoma in stomach
     iii. Pregnancy toxaemia
     iv. Prolonged vomiting
     v. Diarrhoea.
   - *Symptoms*:
     i. Vomiting
     ii. Psychiatric disorders like disorientation, faulty memory
     iii. Loss of pupillary reflex
     iv. Loss of extraocular movements
     v. Polyneuritis.

Q.4. Give biological role/functions and deficiency disorders of vitamin A.

Functions of Vitamin A

- Vitamin A is the structural part of retinal pigment called "rhodopsin".
- It is required compulsory to obtain proper vision mainly during dark (dim light).
- Vitamin A keeps the mucous membranes healthy.
- Vitamin A maintains integrity and normal working of epithelial tissues and glands in the body.
- Vitamin A supports normal growth of skeleton (bones and cartilages).

- Vitamin A shows anti-infective action, protecting body against diseases caused by microbes.
- Sometimes, vitamin A shows protective effect against some cancers of epithelial tissues, e.g. bronchial asthma.

Deficiency Defects of Vitamin A

i. Night blindness
ii. Conjunctival xerosis
iii. Bitot's spot
iv. Corneal xerosis
v. Keratomalacia.

Extraocumlar Manifestations

i. Follicular hyperketosis
ii. Anorexia
iii. Retarded growth
iv. Weakness towards respiratory and intestinal infections
v. Abnormal changes in the skin.

Q.5. Give biological role/functions and deficiency disorders of vitamin D.

Functions of Vitamin D

- It promotes absorption of calcium and phosphorus by mucosa of small intestine.
- It also increases renal absorption of calcium and phosphorus.
- It promotes normal growth and development of bones.
- In adult stage, it is required to maintain bones in healthy condition.
- It allows maturation of collagen and collagenous tissue.
- It stimulates and promotes overall normal growth of the body.

Deficiency Defects of Vitamin D

i. Rickets in children
ii. Osteomalacia
iii. Osteoporosis
iv. Hypocalcaemia.

Q.6. Give biological role and deficiency disorders of vitamin C. (S.23)

Functions of Vitamin C

- It keeps the gums and teeth healthy.
- It is necessary for normal tissue oxidation physiology.
- It is required for synthesis of collagen in all connective tissues.
- It reduces iron, allowing iron absorption by mucosa of small intestine.
- It provides protection against infections, so it is sometimes called anti-infective vitamin.
- It is required for separation and absorption of iron from complex sources of vegetarian food.

- It acts as a coenzyme for enzymes catalysed reactions.
- It helps in wound healing process.

Deficiency Disorders of Vitamin C

Scurvy.

Q.7. Give biological role and deficiency disorders of folic acid.

Functions of Folic Acid

- Folic acid is a coenzymes for the synthesis of purine and pyrimidines.
- Folic acid is required for synthesis of DNA and RNA.
- Folic acid is needed to promote rapid cell division to cause growth and development.
- It is required for erythropoiesis which occurs in bone marrow, i.e. process of formation of RBCs.

Deficiency Defects of Folic Acid

i. Megaloblastic anaemia, ii. Glossitis.

Q.8. Give the functions and deficiency defects of vitamin B_{12} (cyanocobalamin).

Functions of Vitamin B_{12}

- Along with folic acid, vitamin B_{12} is required for normal development and maturation of RBCs.
- It is helpful in many biochemical reactions as coenzyme.
- It plays role in synthesis of fatty acids in myelin sheath of myelinated nerve fibres.
- Vitamin B_{12} acts as a coenzyme in methyl group transfer reactions.
- Vitamin B_{12} is required for conversion of RNA into DNA.

Deficiency Disorders of Vitamin B_{12}

Pernicious anaemia.

Q.9. Give the physiological functions and deficiency of riboflavin (vitamin B_2).

Functions of Riboflavin

- It is the most important constituent of flavoprotein.
- It is required as coenzyme for tissue oxidation and cellular respiration.
- It helps to carry out proper metabolism of carbohydrates, proteins and fats.
- It protects normal growth and development.

- It is required for proper maintenance of skin, oral mucosa and for normal condition of eye.

Deficiency Symptoms of Riboflavin

i. Corneal vascularization
ii. Angular stomatitis
iii. Reddening of lips and tissues at the corner of mouth
iv. Sensation of itching
v. Burning of eyelids
vi. Dermatitis.

Q.10. Name the vitamins along with their deficiency disorders.

Vitamins	*Deficiency diseases*
Vitamin A	Night blindness, xerophthalmia
Vitamin D	Rickets, osteomalacia
Vitamin K	Impaired blood clotting
Vitamin E	Anacondas
Vitamin B_1 (thiamine)	Beriberi
Vitamin B_2 (riboflavin)	Skin lesion
Vitamin B_3 (niacin)	Pellagra
Vitamin B_6 (pyridoxine)	Dermatitis
Vitamin M (folic acid)	Megaloblastic anaemia
Vitamin B_{12} (cyanocobalamin)	Pernicious anaemia
Vitamin C (ascorbic acid)	Scurvy
Biotin	Egg white injury

Q.11. What are coenzymes? Give the coenzymes of respective vitamins.

Coenzymes: Coenzymes are organic compounds which are covalently bound to enzyme protein and are responsible for catalytic activity of several enzymes.

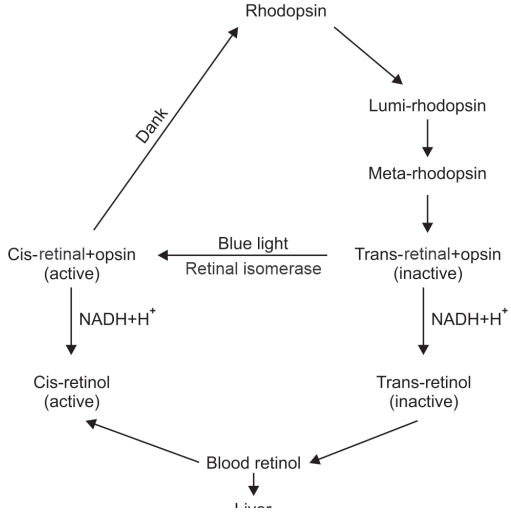
Coenzymes are generally derived from the water soluble B-complex vitamins and carry out transfer of hydrogen or any other group of substrate in an enzymatic reaction. Following is the list of coenzymes with their respective vitamins and their functions.

Vitamins	*Coenzymes*	*Functions*
Riboflavin (B_2)	FAD, FMN	Transfer of hydrogen
Niacin (B_3)	NAD^+ NADP	Transfer of hydrogen
Thiamine (B_1)	TPP	Transfer of acetaldehyde
Biotin	Biotin	Transfer in carboxylation
Pyridoxine (B_6)	Pyridoxal phosphate	Transfer of amino group
Folic acid	THF	Transfer acyl group
Pantothenic acid	CoA	Transfer acyl group

Q.12. Explain the role of vitamin A in vision cycle.

Role of Vitamin A in Vision

- The retina of the eye contains two types of receptor cells, the rod cells which are responsible for dim light vision and the cone cells, responsible for bright light vision. Cones are also responsible for colour perception. The deficiency of cone pigments makes the individual colour blind.
- In retinal pigments, the rod cells contain rhodopsin. Under the influence of light, rhodopsin is converted into lumirhodopsin which is further converted into metarhodopsin. Then metarhodopsin is hydrolysed to protein opsin of trans-retinal.
- Trans-retinal is inactive in the synthesis of rhodopsin, it must be converted to the active cis-isomer.
- In the eye, the trans-retinal is reduced to trans-retinol by the enzyme retinal reductase of NADH.
- The transretinol which is too inactive in rhodopsin synthesis is passed into bloodstream and then carried to liver.
- This trans-retinol is converted into cis-isomer (cis-retinol). In dim light active cis-retinol from the blood enters the retina where it is oxidized to cis-retinal by reverse action of retinal reductase in the presence of NAD^+.
- Finally, the cis-retinal combines with protein opsin to give back rhodopsin and thus cycle is repeated.



Role of vitamin A in vision

Q.13. Give the sources, daily requirements, deficiency disorders and role/functions of following vitamins.

Vitamins	*Sources*	*Requirement per day*	*Deficiency effects*	*Role/functions*
1. Vitamin A (S.24, W.23)	Fish, liver, butter ghee, whole milk	Adult: 750 µg Children: 250 to 600 µg	Night blindness, conjunctival xerosis, Bitot's spot, xerophthalmia	i. To maintain visual activities ii. Normal functioning of epithelial tissues and glands iii. Supports normal growth of skeleton
2. Vitamin D (W.23)	Fish, liver oil, animal fat	Adult: 25 µg Infant/children: 5.00 µg	Rickets, osteomalacia	i. Promotes normal growth and development of bone ii. Promotes absorption of clacium and phosphorus iii. Allows maturation of collagen and collagenous tissue iv. It promotes overall normal growth of the body
3. Vitamin C (S.24)	Fresh citrus fruits, green leafy vegetables, amla	Adult: 40 mg/day Infant/children: 40 mg/day	Scurvy	i. Helps to prevent skin lesions and infections like scurvy ii. Increases the resistance of the body against infection iii. Keeps the gums and teeth healthy iv. Necessary for normal tissue oxidation physiology v. Acts as a coenzyme vi. Required for absorption of iron vii. Helps in wound healing process

Contd...

Contd...

Vitamins	*Sources*	*Requirement per day*	*Deficiency effects*	*Role/functions*
4. Vitamin B_1 (thiamine)	Yeast, pulses, oil seeds, nuts, cereals	0.5 mg/100 kcal/day	Beriberi, dry beriberi, wet beriberi, infantile beriberi, cerebral beriberi	i. For the treatment of beriberi ii. Involved in synthesis of acetylcholine iii. Acts as a coenzyme
5. Vitamin B_2 (riboflavin)	Liver, meat, eggs, milk	0.6 mg/1000 kcal/day	Corneal ulcers, cataracts, photophobia	i. Acts as a coenzyme ii. Involved in matabolism of proteins, fats and carbohydrates iii. To treat riboflavinosis
6. Niacin	Liver, ground nut, whole cereals, pulses meat, fish	6.6 mg/1000 kcal/day	Pellagra	i. In treatment of pellagra ii. As antihyperlipidemic agent iii. As a vasodilator iv. Essential for normal functioning of skin, intestine, etc.
7. Vitamin B_{12} (cyanocobalamin)	Liver, kidney, meat, fish, eggs, milk, cheese	Adult: 1 μg/day Children: 0.2 to 1 μg/day	Megaloblastic anaemia, pernicious anaemia	i. Required for normal development and maturation of RBC ii. As a coenzyme iii. Required for conversion of RNA into DNA

Q.14. Give differences between 'fat-soluble vitamins' and 'water-soluble vitamins'.

Fat-soluble vitamins	*Water-soluble vitamins*
1. They are soluble in fat.	1. They are soluble in water.
2. They are absorbed along with other lipids.	2. Their absorption is simple.
3. They require carrier proteins.	3. No requirement of carrier protein.
4. They are stored in liver.	4. They are excreted in urine.
5. Deficiency manifests only when stores are depleted.	5. Deficiency manifests rapidly as there is no storage.
6. Toxicity-hypervitaminosis may occur.	6. Unlikely, since excess is excreted in the urine.
7. Single large dose may prevent deficiency.	7. Regular dietary supply is required.
8. Examples: Vit. A, D, E, K	8. Examples: B-complex, vit. C

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. **Vitamin A, D, E and K** are fat-soluble vitamins.
2. **Night blindness** is caused due to deficiency of vitamin A.
3. Deficiency of niacin (vitamin B_3) causes **pellagra**.
4. **Scurvy** is a deficiency disorder of vitamin C/ascorbic acid.
5. **Egg-white injury** is a disorder caused due to deficiency of biotin.
6. **Beriberi** is a deficiency disorder caused due to deficiency of vitamin B_1 (thiamine).
7. **Vitamin A** is the structural part of retinal pigment called 'rhodopsin'.
8. **Rickets** is a deficiency disorder of vitamin D vitamin.
9. **Vitamin C/ascorbic acid** helps to keep the gums and teeth healthy.
10. **Folic acid** is a coenzyme necessary for the synthesis of purine and pyrimidine.
11. **Folic acid** is required in the synthesis of DNA and RNA.
12. **Vitamin B_{12}** is required for conversion of RNA into DNA.
13. **Cobalt** containing vitamin is cyanocobalamine.
14. **Pernicious anemia** is a deficiency disorder of vitamin B_{12}.
15. **Riboflavin** is the most important constituent of flavoprotein.
16. **TPP** is a coenzyme of thiamine (vitamin B_1).
17. **THF** is a coenzyme of folic acid.
18. **Co-enzymes** are generally derived from the water-soluble B-complex vitamins.
19. **Vitamin E** is called an antisterility factor/tocopherol.
20. **Vitamin K** is also known as antihaemorrhagic factor.
21. **Thiamine** is often called antineuritic factor/antiberiberi substance.
22. **Nicotinic acid or niacin** is also known as P-P factor/pellagra preventive factor.
23. **Folic acid** is also known as vitamin M.
24. **Vitamin K** is required for blood coagulation.
25. **Vitamin D** is essential for calcium absorption.
26. **FAD and FMN** are the co-enzymes of riboflavin.

Chapter

8

Metabolism

Q.1. Define metabolism. Give its importance.

Metabolism

Metabolism is a process in which number of biochemical changes occurs in a body and helps in exchange of matter and energy between cell and its environment.

Importance of Metabolism

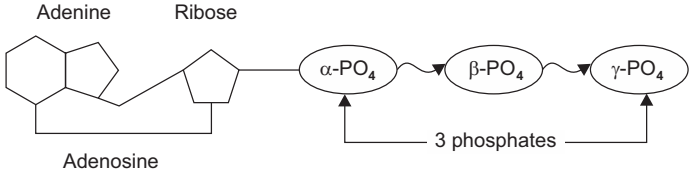
i. Chemical energy is obtained.
ii. Dietary nutrients are used for synthesis of new molecules.
iii. New molecules unite to form proteins, nucleic acids, etc.

Q.2. Define the terms.

i. *Catabolism*: It is the degradative phase of metabolism which provides metabolic fuel and building blocks for the cell.
ii. *Anabolism*: It is the process by which the absorbed food helps in the formation of new cells, new molecules and structural and functional units of cell and essential metabolites, is known as anabolism.
iii. *Abnormal metabolism*: The metabolic process where there is deficiency of enzymes, produces inborn errors of metabolism. This is called abnormal metabolism.
   - *Reasons for abnormal metabolism*

   i. Genetic defect, ii. Dietary deficiencies, iii. Diseased condition.

Q.3. What is ATP? Give its role in biological systems.

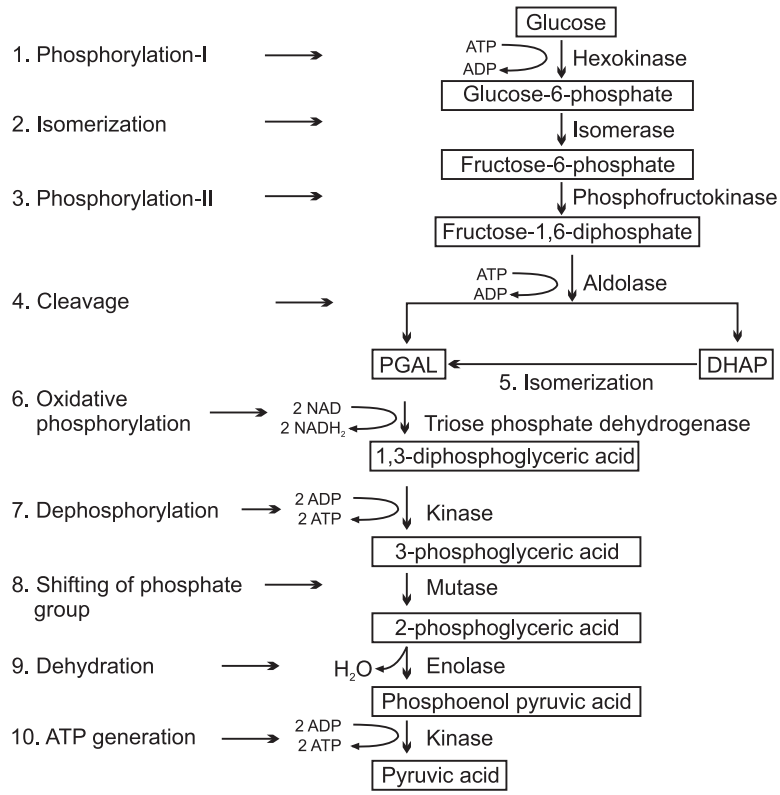


- ATP is adenosine triphosphate.
- It is a complex compound consisting of purine base-adenine, a 50 carbon sugar—the ribose, and three molecules of phosphate.
- ATP is a high energy releasing compound.

Importance of ATP

1. ATP provides energy for the synthesis of carbohydrases.
2. ATP is the main source of energy for various metabolic activities.

Q.4. Give the schematic representation of glycolysis/EMP pathway. (S.23, W.23)



Glycolysis/EMP pathway

Glycolysis

Explanation

Glycolysis is the pathway in which glucose is broken down through a series of chemical reactions leading to formation of pyruvic acid.

Reactions involved in glycolysis are as follows:

1. *Phosphorylation-I*: In this reaction, glucose is converted into glucose-6-phosphate in the presence of enzyme hexokinase. At this stage one ATP is converted into ADP.
2. *Isomerization*: In this reaction, glucose-6-phosphate is converted into fructose-6-phosphate in the presence of isomerase enzyme.
3. *Phosphorylation-II*: Fructose-6-phosphate undergoes phosphorylation with ATP and forms fructose-1,6-diphosphate in the presence of enzyme phosphofructokinase.
4. *Cleavage*: In this reaction, fructose-1,6-diphosphate splits into phosphoglyceraldehyde (PGAL) and dihydroxy acetone phosphate (DHAP) in the presence of enzyme aldolase.
5. *Isomerization*: DHAP is further undergoes isomerization to form PGAL.
6. *Oxidative phoshorylation*: PGAL is converted into 1,3-diphosphoglyceric acid in the presence of enzyme triose phosphate dehydrogenase. At this stage, 2 NAD is converted into 2 $NADH_2$.
7. *Dephosphorylation*:In this reaction, 1,3-diphosphoglyceric acid is converted into 3-phosphoglyceric acid by removal of one phosphate group.
   In this stage, 2 ADP are converted into 2 ATP.
8. *Shifting of phosphate group*: In this reaction, phosphate group from 3-phosphoglyceric acid is shifted to carbon number 2 in the presence of enzyme mutase.
9. *Dehydration*: 2-phosphoglyceric acid after dehydration produces phosphoenol pyruvic acid in the presence of enzyme enolase.
10. *Formation of pyruvic acid*: Phosphoenol pyruvic acid is converted into pyruvic acid in the presence of enzyme kinase. At this stage, 2 ATP molecules are synthesized.

Energetics of Glycolysis

Reaction	*ATP formed*
1. Oxidative phosphorylation	06
2. Dephosphorylation	02
3. Phosphoenol pyruvic acid to pyruvic acid	02
Total	10 ATP

ATP consumed in:	
1. Phosphorylation-I	01
2. Phosphorylation-II	01
Total	02 ATP

Thus, in glycolysis (10 – 2 = 08) ATPs are synthesized.

Q.5. Define the terms.

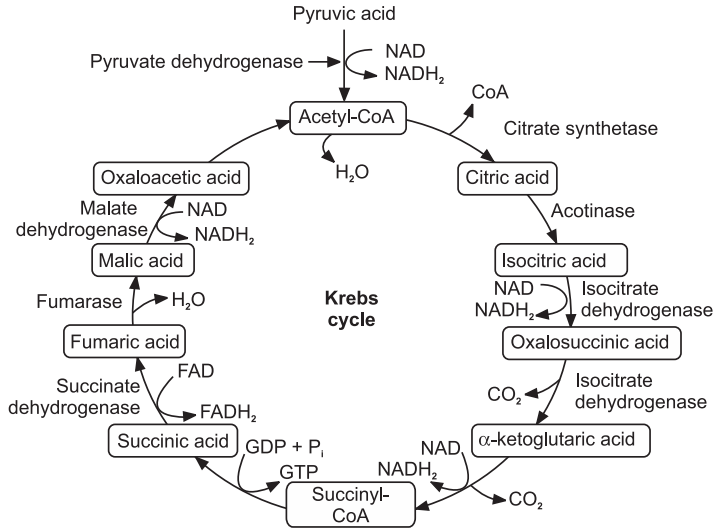
i. *Glycogenesis*: It is the process of conversion of glucose into glycogen in the liver.
ii. *Glycogenolysis*: It is the process of breakdown of glycogen into glucose in the liver.
iii. *Gluconeogenesis/neoglucogenesis*: It is the process of synthesis of glucose from noncarbohydrate sources such as amino acids, lactic acid, glycerol, etc.
iv. *Glycolysis*: It is the pathway in which glucose is broken down through a series of chemical reactions leading to formation of pyruvic acid.

Q.6. Write a note on Krebs cycle/TCA cycle/citric acid cycle. (S.23, 24, W.23)

Definition

The cycle of reactions involved in the oxidation of acetyl-CoA into CO_2 and H_2O are collectively called Krebs cycle, as it is discovered by Sir Hans Krebs.

In this cycle, different tricarboxylic acids are formed, hence called as tricarboxylic acid cycle (TCA cycle).



Reactions

1. Formation of acetyl-CoA
2. Formation of isocitric acid
3. Formation of oxalosuccinic acid
4. Formation of α-ketoglutaric acid
5. Formation of succinyl-CoA
6. Formation of succinic acid
7. Formation of fumaric acid
8. Formation of malic acid
9. Formation of oxaloacetic acid.

Krebs Cycle

1. *Formation of acetyl-CoA*: Pyruvic acid is decarboxylated to acetyl-CoA for its entry into citric acid cycle. In this stage, NAD is converted into $NADH_2$.
2. *Formation of isocitric acid*: Acetyl-CoA is converted into citric acid which further converted into isocitric acid in the presence of enzyme acotinase.
3. *Formation of oxalosuccinic acid*: Isocitric acid gets converted into oxalosuccinic acid in the presence of enzyme isocitrate dehydrogenase.
4. *Formation of α-ketoglutaric acid*: Oxalosuccinic acid is converted into α-ketoglutaric acid in the presence of isocitrate dehydrogenase.
5. *Formation of succinyl-CoA*: α-ketoglutaric acid is converted into succinyl-CoA.
6. *Formation of succinic acid*: Succinyl-CoA is converted into succinic acid.
7. *Formation of fumaric acid*: Succinic acid is converted into fumaric acid in the presence of succinate dehydrogenase.
8. *Formation of malic acid*: Fumaric acid is converted into malic acid in the presence of enzyme fumarase.
9. *Formation of oxaloacetic acid*: Malic acid is converted into oxaloacetic acid in the presence of enzyme malate dehydrogenase.This oxaloacetic acid again enters into the cycle and gets converted into acetyl-CoA.

Energetics of Citric Acid Cycle

Reactions	*ATP molecules formed*
1. Pyruvic acid → Acetyl-CoA	03
2. Isocitric acid → Oxalosuccinate	03
3. α-ketoglutaric acid → Succinyl-CoA	03
4. Succinyl-CoA → Succinic acid	01
5. Succinic acid → Fumaric acid	02
6. Malic acid → Oxaloacetic acid	03
Total	15 ATP

One molecule of glucose gives two molecules of pyruvic acid, therefore, total number of ATP formed in citric acid cycle = 15 × 2 = 30 ATP.

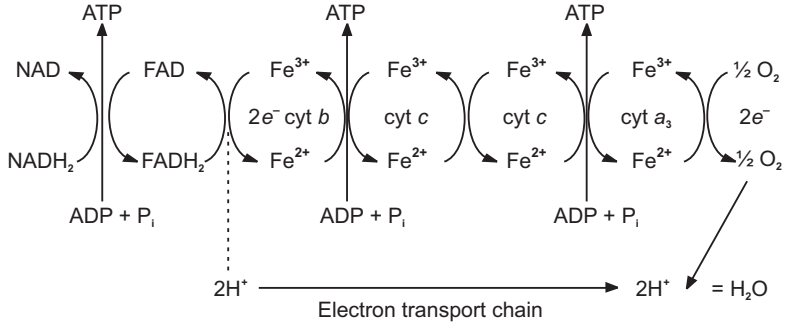
Total number of ATP formed in aerobic oxidation are:
a. From TCA cycle—30
b. From glycolysis—08

Total = 38 ATP

Q.7. Write a note on electron transport chain (ETC/ETS)./What is 'terminal oxidation'? (S.23, 24, W.23)

ETS

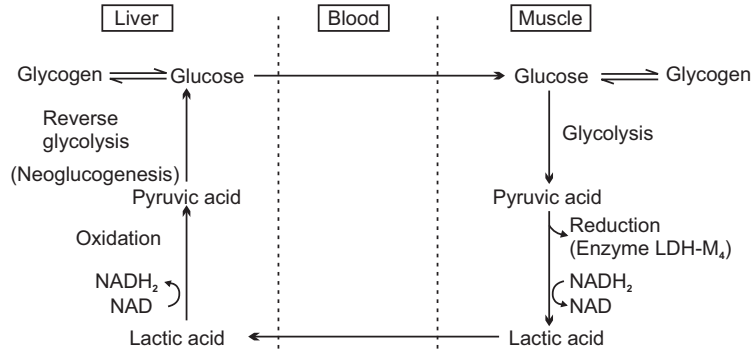
The process of oxidation of reduced coenzymes ($NADH_2$ and $FADH_2$) and different electron, carries through various enzyme systems, is called *electron transport system* or terminal oxidation. In this process, the hydrogen from ETS is transferred to molecular oxygen. This is known as terminal oxidation.



Q.8. What is Cori cycle? Explain.

Cori Cycle

The conversion of lactate to glucose takes place entirely in the liver and its re-entry into the muscle, is called Cori cycle.



- This cycle is discovered by scientistco Carl Ferdinand Cori, hence named as Cori cycle.
- It is a cyclic process by which lactic acid is converted into glucose in the liver and after that glucose appears in muscle where glucose can be converted to glycogen and stored in muscles.
- Cori cycle is designed for recycling of lactic acid.
- During vigorous muscular activity, glycogen in muscle is converted in glucose. Then glucose is converted into pyruvic acid by glycolysis.
- Muscles under such condition do not receive sufficient oxygen for normal and complete oxidation of pyruvic acid.
- Now, alternatively pyruvic acid is reduced to the lactic acid by enzyme LDH-M_4 and in presence of $NADH_2$ as hydrogen donor. So, $NADH_2$ is oxidised to NAD.
- Lactic acid if accumulates in muscles, it can result in toxicity of damaging the muscles so via circulating blood, lactic acid from muscles is taken to liver cells. In the liver cells, lactic acid is oxidised to pyruvic acid.
- Finally, pyruvic acid is converted into glucose, actually by reverse glycolysis mechanism also called *neoglucogenesis*.
- Glucose thus generated, thereafter can be converted to glycogen and stored in liver.
- Whenever necessary glycogen can be converted to glucose again by the action of hormone glucogen. Then glucose via bloodstream can be brought to muscles to repeat with same Cori cycle mechanism.

Significance of Cori Cycle

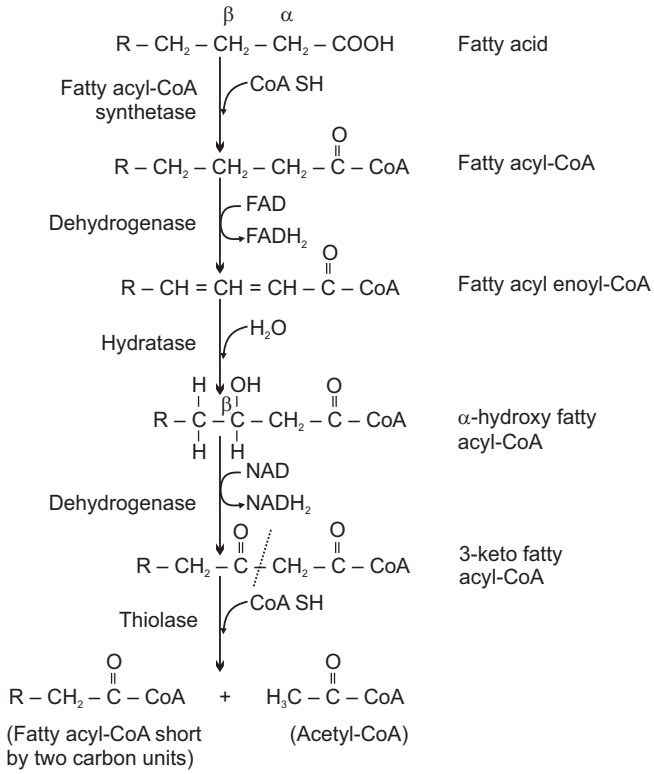
1. It allows proper cycling of lactic acid, so as to avoid toxicity of muscles due to lactic acid accumulations.
2. This mechanism allows skeletal muscles to work without any significant additional supply of oxygen to the muscles.
3. Same mechanism allows conversion of lactic acid to glucose and by proper glucose circulation, it can allow normal operation of energy metabolism in muscles.

Q.9. Write a note on β-oxidation of fatty acids. (S.23, 24)

β-oxidation of Fatty Acids

β-oxidation is a sequential removal of two carbon units as acetyl-CoA from carboxyl terminal of fatty acids by oxidation.

Reactions of β-oxidation of Fatty Acids



The steps involved in β-oxidation of fatty acids are as follows:

1. *Activation of fatty acid*: In this stage, fatty acid gets converted into an active fatty acyl-CoA in the presence of fatty acyl-CoA synthetase.
2. *Formation of unsaturated acyl-CoA*: The hydrogens from fatty acyl-CoA are taken up by FAD of the enzymes and thus unsaturated acyl-CoA is formed.
3. *Formation of β-hydroxyl acyl-CoA*: In this stage, one water molecule is added to produce β-hydroxy fatty acyl-CoA.
4. *Formation of 3-keto fatty acyl-CoA*: The hydrogens from β-hydroxyl acyl-CoA are taken up by NAD of the enzyme and thus 3-keto fatty acyl-CoA is formed.
5. *Thiolytic cleavage of 3-keto fatty acyl-CoA*: 3-keto fatty acyl-CoA undergoes thiolytic cleavage forms acetyl-CoA and active fatty acid containing two carbons less than original.

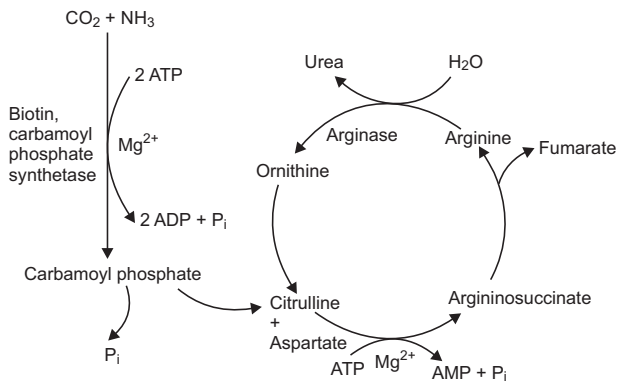
Energetics of Palmitic Acid Oxidation

Mechanism	*ATP yield*
I. **β-Oxidation (7 cycles)**	
7 $FADH_2$ [oxidized by electron transport chain (ETC), each $FADH_2$ gives 2 ATP]	14
7 NADH (oxidized by ETC, each NADH liberates 3 ATP)	21
II. **From 8 acetly-CoA**	
Oxidized by citric acid cycle, each acetyl-CoA provides 12 ATP	96
Total energy from one mole of palmitoyl-CoA	131
Energy utilized for activation (formation of palmitoyl-CoA)	–2
Net yield of oxidation of one molecule of palmitate	129

Q.10. Describe the chemical reactions involved in the formation of urea in the body./Write a note on urea cycle. (S.24)

Urea Cycle

Ammonia is combined with CO_2 and forms a urea by various reactions catalysed by the enzymes present in the liver mitochondria through urea cycle.



Reactions Involved in Urea Cycle

1. *Formation of carbamoyl phosphate*: Ammonia combines with CO_2 to form carbamoyl phosphate in the presence of biotin and 2 molecules of ATP.
2. *Formation of citrulline*: Citrulline is formed by the transfer of carbamoyl group–$CONH_2$ from carbamoyl to ornithine.
3. *Formation of argininosuccinate*: Amino group of aspartase condenses with citrulline to form argininosuccinate. This reaction is catalysed by argininosuccinate synthetase and requires a molecule of ATP.

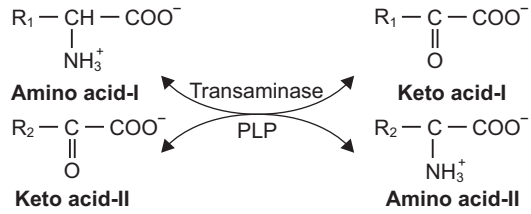
4. *Formation of arginine*: Reversible cleavage of argininosuccinate takes place to form arginine and fumarate.
5. *Formation of urea*: It is the last reaction of urea cycle which generates ornithine from arginine for its re-entry in the cycle.

Q.11. What is transamination? Give salient features of transamination./ Write a note on transamination.

Transamination

Definition: The transfer of an amino ($-NH_2$) group from an amino acid to a keto acid is known as transamination.

- The transamination process involves the interconversion of a pair of amino acids and a pair of keto acids, catalysed by a group of enzymes called transaminases (i.e. amino transferases).
- Transamination reaction is as follows:



Transamination reaction

- Salient features of transamination are:
  1. All transaminases require pyridoxal phosphate (PLP), a coenzme derived from vitamin B_6.
  2. There is no free NH_3 liberated, only the transfer of amino group occurs.
  3. Transamination is ***reversible***.
  4. It involves both catabolism (degradation) and anabolism (synthesis) of amino acids. Transamination is ultimately responsible for the synthesis of nonessential amino acids.
  5. Transamination diverts the excess amino acids towards ***energy generation***.
  6. The amino acids undergo transamination to finally concentrate nitrogen in glutamate. **Glutamate** is the only amino acid that undergoes oxidative deamination to a significant extent to liberate free NH_3 for urea synthesis.
  7. All amino acids except lysine, threonine, proline and hydroxyproline participate in transamination.

Q.12. What is deamination? Explain oxidative and non-oxidative deamination./Write a note on 'deamination of amino acids'.

Deamination

Definition: The removal of amino group from the amino acids as NH_3 (ammonia) is known as deamination.

- Deamination results in liberation of ammonia for urea synthesis.
- Deamination may be oxidative or non-oxidative.

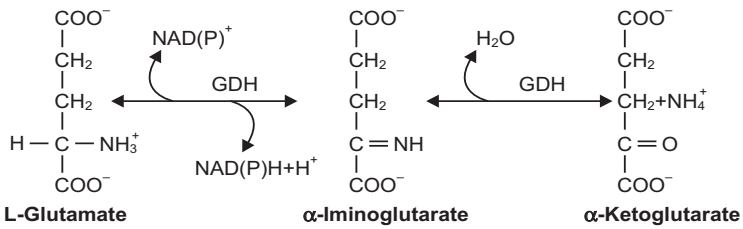
A. Oxidative Deamination

- Oxidative deamination is the liberation of free ammonia from the amino group of amino acids coupled with oxidation.
- This takes place mostly in liver and kidney.
- The purpose of oxidative deamination is to provide NH_3 for urea synthesis and α-keto acids for a variety of reactions including energy generation.

Examples

1. *Oxidative deamination by glutamate dehydrogenase (GDH):*

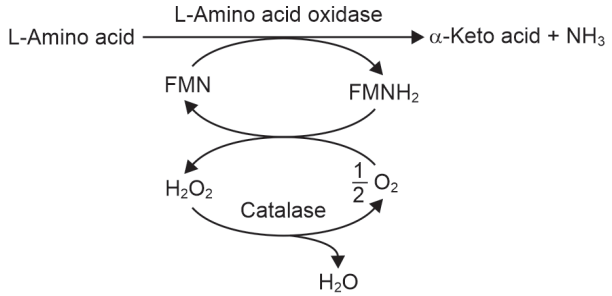
- In this reaction, glutamate rapidly undergoes oxidative deamination catalysed by glutamate dehydrogenase (GDH) to liberate ammonia.
- The conversion of glutamate to α-ketoglutarate occurs through the formation of an intermediate α-aminoglutarate.



Oxidation of glutamate by glutamate dehydrogenase (GDH)

2. *Oxidative deamination by amino acid oxidases:*

- L-amino acid oxidase and D-amino oxidase are flavoproteins, possessing FMN and FAD, respectively.
- They act on the corresponding amino acids (L or D) to produce α-keto acids and NH_3.
- In this reaction, oxygen is reduced to H_2O_2 which is later decomposed by catalase.

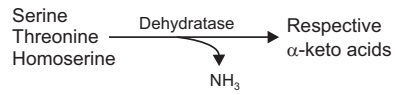


Oxidative deamination of amino acids

B. Non-oxidative Deamination

Some of the amino acids can be deaminated to liberate NH_3 without undergoing oxidation.

a. **Amino acid dehydrases:** Serine, theronine and homoserine are the hydroxy amino acids. They undergo non-oxidative deamination catalysed by PLP-dependent dehydrases (dehydratases).

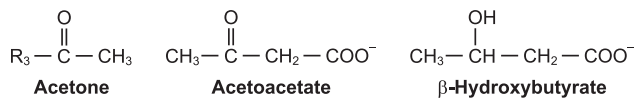


b. **Deamination of histidine:** The enzyme histidase acts on histidine to liberate NH_3 by a non-oxidative deamination process.

Q.13. What are ketone bodies? Write a note on ketogenesis. (S.24)

Ketone Bodies

- The compounds, namely acetone, acetoacetate, and β-hydroxybutyrate are known as ketone bodies.
- Ketone bodies are water-soluble and energy yielding.
- Structures of ketone bodies:



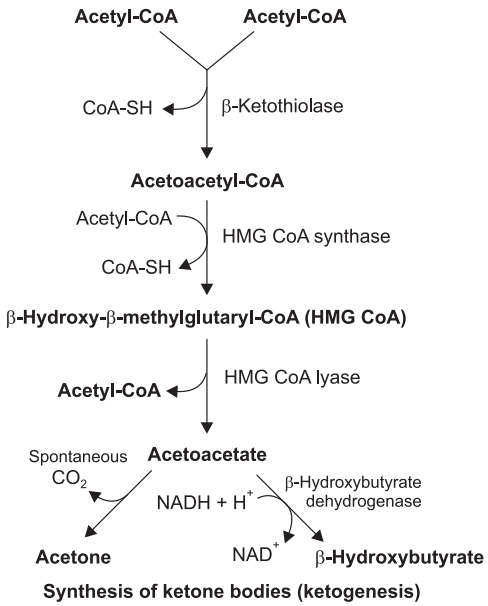
Structures of ketone bodies

Ketogenesis

The process of formation/synthesis of ketone bodies is known as ketogenesis.

- Ketogenesis occurs in the liver.
- The enzymes for ketone body synthesis are located in the mitochondrial matrix.
- Acetyl-CoA, formed by oxidation of fatty acids, pyruvate or some amino acid, is the precursor for ketone bodies.

- The reaction of ketogenesis is as follows:



Synthesis of ketone bodies (ketogenesis)

Explanation of Ketogenesis Reactions

1. Two moles of acetly-CoA condense to form acetoacetyl-CoA. This reaction is catalysed by thiolase.
2. Acetoacetyl-CoA combines with another molecule of acetyl-CoA to produce β-hydroxy-β-methyl glutaryl-CoA (HMG CoA). ***HMG CoA synthase***, catalysing this reaction, ***regulates the synthesis of ketone bodies***.
3. HMG CoA lyase cleaves HMG CoA to produce acetoacetate acetly-CoA.
4. Acetoacetate can undergo spontaneous decarboxylation to form acetone.
5. Acetoacetate can be reduced by a dehydrogenease to β-hydroxybutyrate.

The carbon skeleton of some amino acids (ketogenic) is degraded to acetoacetate or acyl-CoA and, therefore to ketone bodies, e.g. leucine, lysine, phenylalanine etc.

Significance of Ketogenesis

1. Ketogenesis is a mechanism that allows the liver to oxidise increasing quantities of fatty acids within a tightly coupled system of oxidative phosphorylation without increasing its total energy expenditure.
2. Acetoacetate and β-hydroxybutyrate are normal fuels of respiration.

3. Glucose is the major fuel for the brain and red blood cells. But, in prolonged starvation, 75% of the fuel needs of the brains are met by acetoacetate, reducing its needs for glucose.
4. Acetoacetate can be regarded as water soluble transportable form of acetyl unit.
5. Acetoacetate also has a regulatory role in lipid metabolism.

Q.14. What is ketolysis? Explain utilization of ketone bodies.

Ketolysis

Ketolysis is the opposite process to ketogenesis that aims to regain energy via oxidation of ketone bodies which takes place in the mitochondria.

Utilization of Ketone Bodies (Ketolysis)

- The ketone bodies are utilized by extrahepatic tissues as 'fuel'.
- The ketone bodies, being water-soluble, are easily transported from the liver to various tissues.
- The two ketone bodies—acetoacetate and β-hydroxybutyrate serve as an important source of energy for the peripheral tissues such as skeletal muscle, cardiac muscle, renal cortex, etc.
- The production of ketone bodies and their utilization become more significant when glucose is in short supply to the tissues, as observed in: a. Starvation, b. Diabetes millitus
- During prolonged starvation, ketone bodies are the major fuel source for the brain and other parts of the central nervous system.

Q.15. What do you mean by ketoacidosis?

Ketoacidosis

- Ketosis produces metabolic acidosis known as ketoacidosis.
- Increased utilization of fats for energy causes metabolic acidosis, due to release of ketoacids such as acetic acid, β-hydroxybutyric acid into the plasma more rapidly that can be taken up and oxidized by the tissue cells. As a result, these moderately strong acids are buffered when present in blood or other tissues and that lead to a loss of buffer cation (HCO_3^-), that progressively depletes the alkali reserve, causing ketoacidosis.
- Ketoacidosis is partly compensated by hyperventilation with reduction of PCO_2 and therefore, reduction of H_2CO_3 concentration.
- Both acetoacetate and β-hydroxybutyrate are strong acids and increase in their concentration in the blood would cause acidosis.
- Diabetic ketoacidosis is dangerous—may result in coma and even death; if not treated.

Q.16. Write a note on 'fatty liver'. (S.24, W.23)

Fatty Liver

- Fatty liver is the condition where there is an excessive accumulation of fat primarily neutral fat, triacylglycerol in the liver parenchymal cells.
- The normal concentration of lipid in the liver is around 5%.
- Liver is not a storage organ for fat.
- In pathological conditions, the fat level in the liver is increased up to 25–30% and is known as fatty liver or fatty infiltration of liver.

Causes of Fatty Liver

1. Increased synthesis of triglycerides.
2. Impairment in lipoprotein synthesis.
3. Fatty liver occurs in conditions in which there is an imbalance between hepatic triacylglycerol synthesis and the secretion of VLDL.

Classification of Fatty Liver

1. *Physiological fatty liver*: It is associated with increased levels of plasma-free fatty acids from the diet (high fat diet) or from the adipose tissue during starvation.
2. *Pathological fatty liver*: It occurs due to an impairment in the biosynthesis of plasma lipoproteins, which in turn impair the transport of triacylglycerol from liver, thus allowing triacylglycerol to accumulate in the liver.

Conditions that Cause Fatty Liver

- High fat diet
- Starvation or insulin insufficiency
- Alcoholism
- Dietary deficiency of lipotropic factors, essential fatty acids, etc.
- High cholesterol diet
- Use of certain chemicals.

Q.17. What is hypercholesterolemia? Explain.

Hypercholesterolemia

- Increase in plasma cholesterol (>250 mg/dl) concentration is known as hypercholesterolemia.
- It is also associated with atherosclerosis and coronary heart disease.
- Hypercholesterolemia is observed in many disorders like:
  a. *Diabetes mellitus*: Due to increased cholesterol synthesis since the availability of acetyl-CoA is increased.

b. *Hypothyroidism* (*myxoedema*): This may be due decrease in the HDL receptors on hepatocytes.
c. *Obstructive jaundice*: Due to an obstruction in the excretion of cholesterol through bile.
d. *Nephrotic syndrome*: Increase in plasma globulin concentration is the characteristic feature of nephrotic syndrome.

Causes of Hypercholesterolemia

- Poor diet
- Junk food, fast food
- Alcoholism
- Dialysis therapy
- Cushing's syndrome
- Anorexia nervosa

Complications due to Hypercholesterolemia

- Thrombosis
- Atherosclerosis
- Embolism
- Cardiovascular and coronary heart diseases.
- Heart attack
- Coronary thrombosis
- Fat embolism

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. **Catabolism** is the degradative phase of metabolism which provides metabolic fuel and the building blocks for the cell.
2. **ATP** is a high-energy releasing compound.
3. The process of conversion of glucose into glycogen in the liver is called **glycogenesis**.
4. **Glycogenolysis** is the process of breakdown of glycogen into glucose in the liver.
5. The process of synthesis of glucose from non-carbohydrate source is known as **gluconeogenesis/neoglucogenesis**.
6. The pathway of breakdown of glucose into pyruvic acid is known as **glycolysis**.
7. In glycolysis, total **8 ATP** molecules are synthesized.
8. Krebs cycle/citric acid cycle/TCA cycle involves **oxidation of acetyl-CoA**.
9. Total number of ATPs formed in Krebs cycle is **30**.
10. The total number of ATPs formed in aerobic oxidation of glucose is **38**.
11. **ETC** means electron transport chain and also known as terminal oxidation.
12. The conversion of lactate to glucose takes place entirely in the liver and its re-entry into the muscle is called **Cori cycle**.
13. **Cori cycle** is designed for recycling of lactic acid.
14. **β-oxidation** is a sequential removal of two carbon units as acetyl-CoA from carboxyl terminal of fatty acids by oxidation.
15. **Insulin** is a peptide which plays an important role in glucose metabolism.
16. HMP-pathway means **hexose monophosphate shunt**.

Chapter 9

Minerals

Q.1. Define and classify minerals with suitable examples.

Minerals

Minerals are the elements which are necessary for a variety of physiological functions and a number of biochemical processes.

Classification of Minerals

Macrominerals/Macroelements/Principle Elements

The minerals which are required in large quantities for the human body with respect to daily requirement, are called macronutrients, e.g. Ca, P, Na, K, Mg, Fe, Zn, etc.

Microelements/Microminerals/Trace Elements

The minerals which are required in very less quantities (trace quantities) for the human body with respect to daily requirements are called micronutrients/ trace elements, e.g. Co, Cu, I, Se, Mn, etc.

Q.2. Name the conditions after increased and decreased levels of following.

Minerals/Sub.	*Increased blood level*	*Decreased blood level*
Sodium	Hypernatraemia	Hyponatraemia
Potassium	Hyperkalaemia	Hypokalaemia
Chlorine	Hyperchloraemia	Hypochloraemia
Calcium	Hypercalcaemia	Hypocalcaemia
Sugar	Hyperglycaemia	Hypoglycaemia

Q.3. Give the functions of minerals in life process.

- For maintenance of osmotic pressure of blood (Na^+, K^+, Cl^-)
- For transport of oxygen (Fe)
- For growth and maintenance of tissues and bones (Ca^{2+})
- For working of nervous system (Ca^{2+})
- For muscle contraction (Ca^{2+})

- For maintenance of electrolyte balance (Na^+ K^+)
- For acid–base balance (Na^+)
- For blood coagulation (Ca^{2+})
- For cardiac activity (Ca^{2+})
- For maturation of sperms (Zn)
- For thyroid hormone synthesis (iodine).

Q.4. What do you mean by 'hypothyroidism' and 'hyperthyroidism'?/ Give the effect of 'hypothyroidism' and 'hyperthyroidism'.

1. *Hypothyroidism*: The decreased secretion of thyroid hormones results into condition called hypothyroidism.
   - *Effects/symptoms/characteristics of hypothyroidism*:
     i. Slow metabolic processes
     ii. Stunted growth
     iii. Mental retardation
     iv. Low body temperature
     v. Swelling of muscles of face
     vi. Enlargement of thyroid gland
     vii. Swelling of neck.
2. *Hyperthyroidism*: Excessive secretion of thyroid hormones results into hyperthyroidism.
   - *Effects/symptoms*:
     i. Increased BMR
     ii. Increased heart rate
     iii. Anxiety
     iv. Restlessness
     v. Increased blood iodine level
     vi. Increased blood pressure.

Q.5. Explain the following terms.

1. *Rickets*: It is the disorder common in children. It is caused due to initial deficiency of vitamin D_3 followed by calcium deficiency.
   - *Symptoms/characteristics/effects*:
     i. Demineralization of bones
     ii. Diffused bone pains
     iii. Weak arms and legs
     iv. Skeletal deformity
     v. Muscular weakness
     vi. Bending of bones of arms and legs.
2. *Osteoporosis*: It is a disorder common in elder persons. The main cause is reduction in total bone calcium and bones become more fragile.
   - *Symptoms*:
     i. Demineralization of bones
     ii. Porosity developed in bones
     iii. Diffused bone pains
     iv. Pains in the spine
     v. Bending of thoracic vertebrae
     vi. Vertebral compression.
3. *Osteomalacia*: It is a calcium deficiency disorder found in adult. It may be due to less intake of calcium or calcium loss in renal failure.
   - *Symptoms*:
     i. Softening of bones
     ii. Abnormal development of bones

iii. Diffused bone pains
iv. Inability of a person to perform sustained work.

4. *Tetany*: Tetany is a disease that occurs due to decreased ionized fraction of serum calcium.
   - *Causes*:
     i. An increase in pH of blood
     ii. Poor absorption of calcium from the intestine
     iii. Decreased dietary intake of calcium
     iv. Increased renal excretion of calcium
     v. Increased retention of phosphorus.
   - *Symptoms*:
     i. Muscles loose tonicity
     ii. Affects face, hands and feet.
5. *Anemia*: It means an abnormal decrease in haemoglobin or RBCs.
   - *Causes*:
     i. Excessive blood loss
     ii. Abnormal menstruation
     iii. Internal ulcer and bleeding
     iv. Bleeding from piles
     v. Intestinal damage
     vi. Failure of function of bone marrow.
   - *Symptoms*:
     i. Decreased Hb content
     ii. Low RBC count
     iii. Abnormal structure of RBCs (microcytic)
     iv. Loss of appetite
     v. Breathlessness and restlessness
     vi. Pale skin.
6. *Goitre/goiter*: It is caused by deficiency of iodine in the blood. Iodine is required for the formation of thyroxine and triiodothyronine.
   - *Symptoms*:
     i. Enlargement of thyroid gland
     ii. Low BMR
     iii. Low pulse rate and heart rate
     iv. Hypotension (low BP)
     v. Metabolic disturbances
     vi. Low body temperature.
   - *Treatment*:
     i. Regular use of iodised salt
     ii. Iodine is added to drinking water.

7. *Hypokalaemia*: It is an abnormal condition indicating decreased level of potassium in the blood plasma.
   - *Causes*:
     i. Prolonged diarrhoea and vomiting
     ii. Overactivity of adrenal cortex
     iii. Prolonged use of diuretics
     iv. Heart failure treatment with digitalis
     v. Diabetic coma treatment with insulin.
   - *Symptoms*:
     i. Muscular weakness
     ii. Irritability
     iii. Paralysis
     iv. Tachycardia (increased in heart rate)
     v. Dilation of heart
     vi. Changes in ECG.
8. *Hyperkalaemia*: It is an abnormal condition indicating increased level of potassium in blood plasma.
   - *Causes*:
     i. Renal failure
     ii. Severe dehydration
     iii. Excess use of potassium salts by IV
     iv. Shock.
   - *Symptoms*:
     i. Cardiac and CNS depression
     ii. Bradycardia
     iii. Peripheral vascular collapse
     iv. Mental confusion
     v. Weakness of respiratory muscles.
9. *Hyponatraemia*: It is an abnormal condition indicating decreased level of Na^+ in blood plasma.
   - *Causes*:
     i. Fluid loss from the body
     ii. Kidney failure
     iii. Renal diseases
     iv. Severe burns
     v. Excessive vomiting and diarrhoea
     vi. Prolonged diabetes with polyuria
     vii. Addison's disease.

Q.6. Give the biochemical role (functions) and deficiency disorders of following minerals.

Minerals	*Sources*	*Dietary requirements*	*Functions/biochemical roles*	*Deficiency disorders*
1. Calcium (S.23, W.23)	Milk and milk products, beans, leafy vegetables, fish, cabbage, egg yolk	Adult: 400–500 mg/day Infant and children: 500–600 mg/day	i. For formation, maintenance and growth of bones ii. For formation of tooth iii. For blood clotting iv. For absorption of vitamin B_{12} v. For contraction of muscle vi. For activation of enzymes vii. For excitability of nerve fibres	• Rickets • Osteoporosis • Hypocalcaemia • Osteomalacia • Tetany
2. Iron	Liver, meat, poultry, fish, cereals, green leafy, vegetables, nuts, jaggery, dry fruits, pulses, cereals, milk, wheat	Adult: 2–6 g/day	i. For formation of Hb/RBCs ii. For DNA synthesis iii. For formation of myoglobin iv. As an electron carrier v. For transport of gases	• Iron deficiency anaemia • Hemochromatosis
3. Iodine	Sea fish, cod liver oil, sea weeds, milk, meat, cereals, vegetables	Adult: 50 g/day	i. For biosynthesis of thyroid ii. For growth and development	• Goitre/goiter • Hypothyroidism • Cretinism
4. Copper	Liver, kidney, meat, egg yolk, cereals, nuts, green leafy vegetables	Adult: 2–3 mg/day	i. In haemoglobin synthesis ii. For melanin formation iii. In bone formation iv. In several enzyme systems v. In maintenance of integrity of myelin sheath	• Homeostasis • Hypochromic • Microcytic anaemia
5. Phosphorus	Milk, cereals, leafy vegetables, meat, eggs	Adult: 0.8 g/day Infants/children: 0.2–0.3 g/day	i. For formation and development of bones and teeth ii. For formation of phospho-lipids, nucleic acids	• Hypophosphataemia • Rickets

Contd.

Contd.

Minerals	*Sources*	*Dietary requirements*	*Functions/biochemical roles*	*Deficiency disorders*
			iii. It forms co-enzymes like NADP, ADP, AMP, ATP iv. It is required in the absorption of glucose by phosphorylation	• Osteomalacia
6. Sodium (S.24)	Fish, meat, nuts, eggs, milk, leafy vegetables, table salt	Adult: 10–15 g/day	i. For maintenance of osmotic pressure ii. For retaining water in the body activity iii. For neuromuscular junction iv. For excitability of nerves v. For acid–base balance vi. For maintenance of viscosity of blood vii. To maintain electrolyte balance	• Hyponatraemia
7. Potassium	Banana, orange, pineapple, potato, beans, chicken, liver, coconut water	Adult: 3–4 g/day	i. For acid–base balance ii. For cardiac function iii. As a co-factor iv. For neuromuscular junction activity v. To neutralize effect of Ca^{2+} vi. To maintain osmotic pressure	• Hypokalaemia
8. Chlorine (S.24)	Common salt as cooking medium, whole grains, leafy vegetables, eggs and milk	Adult: 5–10 g/day	i. For acid–base balance ii. For secretion of HCl in stomach iii. For maintenance of osmotic pressure iv. For synthesis of CSF	• Hypochloraemia

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. **Iron** is useful for the transport of oxygen in the body.
2. Increased level of sodium in the blood is called **hypernatraemia**.
3. **Calcium** is necessary for blood coagulation.
4. Decreased level of potassium in the blood is known as **hypokalaemia**.
5. Decreased level of sodium in the blood is known as **hyponatraemia**.
6. Increased level of **potassium** in the blood is known as hyperkalaemia.
7. Increased blood sugar level is described as **hyperglycaemia**.
8. Decreased blood sugar level is described as **hypoglycaemia**.
9. Rickets is a deficiency disorder of **calcium**.
10. Deficiency of iodine causes **goitre**.
11. **Iodine** is necessary for synthesis of thyroid hormones.
12. Copper is useful for synthesis of **melanin**.
13. Deficiency of chlorine in the body produces **hypochloraemia**.
14. Decreased secretion of thyroid hormones is called **hypothyroidism**.
15. Increased secretion of thyroid hormones is called **hyperthyroidism/thyrotoxicosis**.
16. **Osteoporosis** is a disorder in which bones become more fragile.
17. Tetany is a disorder caused due to deficiency of **serum calcium**.
18. **Anemia** means decrease in haemoglobin of RBCs in the blood.
19. **Iodine** is required for the formation of thyroxine and triiodothyronine (T_4, T_3).
20. Excessive loss of water from the body causes **dehydration**.
21. **ADH** maintains water balance in the body.
22. The **minerals** constitute about 80% of all inorganic materials in the body.
23. **Goitre** is a disease caused by deficiency of iodine characterized by enlargement of thyroid gland.

Chapter
10

Water and Electrolytes

Q.1. Write in brief about distribution of water in body compartment.

Water

- Water is the solvent of life.
- Water is the major body constituent.
- An adult human contains about 60% water.
- A 70 kg normal man contains about 42 litres of water.
- Water is distributed in intracellular and extracellular compartments, respectively known as intracellular fluid (ICF) and extracellular fluid (ECF).
- ECF is further divided into interstitial fluid and plasma.

Distribution of water in an adult man weighing 70 kg		
Compartment	*% Body weight*	*Volume (litres)*
1. Total body water	60	42
2. Intracellular fluid (ICF)	40	28
3. Extracellular fluid (ECF)	20	14
a. Interstitial fluid	15	10.5
b. Plasma	05	3.5

Q.2. State/mention/give the properties of water.

Properties of Water

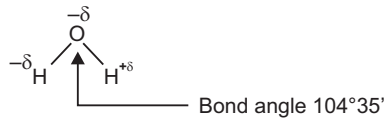
i. Water can dissociate in the hydronium and hydroxy ions.

$$H_2O \rightarrow H^+ + OH^-$$

ii. Water is capable of interacting with many inorganic or organic molecules such as proteins, sugar, etc.

iii. Water helps to maintain characteristic structure and specific biological properties of proteins, nucleic acids and ATP.

iv. Specific heat of water is much high, hence it can work as a best medium for absorption of heat.
v. Water has very high dielectric constant.
vi. Water is a polar molecule, due to which it is very good solvent.



Q.3. Give the functions of water in the body/biological role of water in the body. (S.24)

Functions of Water in the Body/Biological Role of Water

i. Water can act as the best transportation medium in the body.
ii. Water acts as the best solvent for different organic and inorganic substances.
iii. Water dissociates into H^+ and OH^- and acts as a hydrogen donor for various metabolic reactions.
iv. Water is highly inert and simplest in chemical nature. Hence, it can participate in variety of biochemical reactions.
v. Water helps to maintain constant body temperature.
vi. Water is a polar molecule, it can take part in different biochemical reactions.
vii. Water dissociates into hydrogen ion (H^+), which maintains the pH of the body and is essential for activity of enzymes in biological system.
viii. Water interacts with various substances and provides specific properties to the cell.
ix. Dehydration and rehydration are specific reactions related with water as a part of various metabolic pathways.
x. Water can interact with many substances like protiens, fats, carbohydrates and keeps them in biological functional form.

Q.4. Explain water balance in our body. Give the mechanism of balancing body water content. Describe regulation of water content in human body.

Water is the most common and abundant compound of all living systems. An equilibrium is maintained between intake and loss of water from the body. The regulation of water balance is influenced by certain hormones such as ADH, aldosterone, etc.

The specific ways of intake and output of water with correspondings are showing below (figures in normal healthy adult).

Water input		*Water output*	
1. Oral drinks	1200 ml	1. Urination	1400 ml
2. Solid food	1000 ml	2. Sweating	600 ml
3. Oxidation of food stuff	300 ml	3. Expiration	300 ml
		4. Defecation	200 ml
Total input	2500 ml	Total output	2500 ml

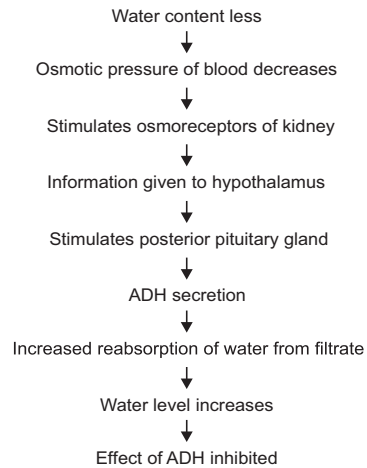
Mechanism of Balancing Body Water Content

Thirst Mechanism

The decrease in water content of the body leads to dehydration. This stimulates the sensory nerve in mouth and tongue and shows sensation of feeling of thirst. Thus, individual drinks water. Thus, water content of the body is balanced with respect to inputs and outputs.

Urine Output Mechanism/ADH Mechanism

This is the another mechanism to balance body water content. When water content in the body is less, then blood gets concentrated. This decreases osmotic pressure of blood. So, osmoreceptors of kidneys are stimulated and this information is given to the brain (hypothalamus) by sensory nerves. The posterior lobe of pituitary gland stimulates and releases ADH (anti-diuretic hormone). This hormone increases reabsorption of water from urinary filtrate and water content in body is balanced.



Water balance mechanism

Q.5. Explain distribution of electrolytes in body compartments./ Describe electrolyte composition of the body fluids.

Electrolyte Composition of the Body Fluids

- Electrolytes are well distributed in the body fluids in order to maintain the osmotic equilibrium and water balance.
- The total concentration of cations and anions in each body compartment (ECF or ICF) is equal to electrical neutrality.
- Electrolytes are positively and negatively charged ions which are present in solution of all body fluids.
- The concentration of electrolytes is expressed as milliequivalent per litre (mEq/L).
- Na^+ and K^+ are the principle extracellular cations.
- The difference in the concentration of these cations is essential for the cell survival which is maintained by Na^+–K^+ pump.
- The body water balance is closely linked to the balance of dissolved electrolytes, the most important of which are Na^+ and K^+.

Distribution of Electrolytes in Body Compartments

Electrolyte content of ECF and ICF		
Ions	*Extracellular fluid (mEq/L)*	*Intracellular fluid (mEq/L)*
Cations		
Na^+	142	10
K^+	5	150
Ca^{2+}	5	2
Mg^{2+}	3	40
Total	155	202
Anions		
Cl^-	103	2
HCO_3^-	27	10
HPO_4^-	2	140
SO^{2-}	1	5
Organic acids	6	5
Protein	16	40
Total	155	202

Q.6. Write a note on 'dehydration' (abnormal metabolism of water). (S.23, 24, W.23)

Dehydration

Dehydration is defined as more loss of water from the human body, than the normal output with respect to the input of water.

- ***Causes/reasons of Dehydration***

i. Severe diarrhoea and vomiting due to viral or bacterial infections produce increased water loss causing dehydration.
ii. Due to severe diarrhoea.
iii. Excess loss of water through expired air may results in certain loss of water causing dehydration.
iv. The person following desert travel suffers from dehydration.
v. Mental patients refusing to drink water can cause dehydration.
vi. The disturbance in exchange of electrolytes during elimination may lead to dehydration.
vii. In diabetic patients because of body physiology there is an excess of urination, may lead to dehydration.
viii. In unconscious condition or difficulty in swallowing condition, there is a decreased intake of water causing dehydration.
ix. Unavailability of water for shipwrecked persons cause dehydration.
x. Loss of water from serious burned cases causes dehydration.

- ***Symptoms/characteristics/effects of Dehydration***

i. Dry, hot skin and dry tongue.
ii. Very little secretion of tears and saliva.
iii. Loss of weight due to reduction in tissue water.
iv. Disturbances in acid–base balance.
v. Rise in body temperature during reduction in circulating fluid.
vi. Dryness, wrinkling and loosening of skin.
vii. Rise in the nonprotein content of plasma.
viii. Decrease in urine output comparatively.
ix. Increased pulse rate and reduced cardiac output.
x. Much increase in packed cell volume.

- ***Treatment of Dehydration***

i. By giving plenty of water as oral drinks.
ii. IV administration of fluids.
iii. Dextrose saline as energy.
iv. Keep the victim in a cool environment.

Q.7. What is ORT? Write a note on oral rehydration therapy (ORT/ORS). (S.24, W.23)

ORT/ORS

- These are orally administered electrolyte solutions used to supply water and electrolytes needed to the patients.

- A large number of formulations of oral rehydration preparations are available in the market.
- These preparations contain glucose, sodium chloride, potassium chloride, sodium bicarbonate. These may contain flavouring agents.
- These are dry powdered preparations and are mixed with water and taken orally.
- ORS are made available at free of cost by Government of India.
- It is available at PHCs, generally at free of cost.
- ORS available in market are electrol powder and paediatric powder.
- ORS contains

NaCl	3.5 g
KCl	1.5 g
Sodium citrate	2.9 g
Glucose	20 g

- This mixture is added in 1 litre of water and then taken by oral route.
- It is the first aid remedy in condition of dysentery, diarrhoea, prolonged fever, vomiting, etc.

Q.8. Give a brief account of 'electrolyte combination therapy'.

Electrolyte Combination Therapy

Electrolytes are combined together in a definite quantity for the specific purpose, which is called electrolyte combination therapy.

- When patient is unable to take normal diet before or after surgery the elctrolyte combination therapy is used. For this purpose, infusion containing dextrose and NaCl is used.
- As per need of the patient, combinations of electrolytes are prepared and given to the patients.
- After surgery, nutrients and electrolytes are used for physiological acid–base balance.
- In dysentery, diarrhoea, prolonged fever, vomiting, the loss of electrolytes is observed which is supplied by electrolyte solutions.
- Various electrolyte combinations available in the market are divided into two groups:
  i. Fluid maintenance group
  ii. Electrolyte replacement group

i. Fluid Maintenance Group

- All the fluid maintenance of electrolyte infusions contain at least 5% dextrose, which helps to reduce starvation.

- It is given after surgery or to the patients who do not take food orally.
- These solutions of electrolytes are administered intravenously which provide the normal requirement of water and electrolytes.
- The electrolytes used in combination with dextrose are Na^+, K^+, Ca^{2+}, Cl^-, Mg^{2+}, phosphate.

ii. Electrolytes Replacement Group/Replacement Therapy

- This electrolyte replacement therapy is required when there is an excessive loss of water and electrolytes in diarrhoea, vomiting, sweating, prolonged fever, etc.
- Electrolyte replacement group contains infusions which are used as replacement fluids. These are of two types:
  i. A solution for rapid initial replacement.
  ii. A solution for subsequent replacement.
- Initially, for rapid replacement, the Na^+ ions are more and K^+ ions are less and reverse in next.
- Formula for electrolyte combination therapy
  i. General use:

Sodium chloride	1 g	for 1 litre of solution
Potassium chloride	1.5 g	
Sodium bicarbonate	1.5 g	
Anhydrous glucose	30.4 g	
Glucose	40 g	

  ii. WHO and UNICEF recommended formula

NaCl	3.5 g	for 1 litre of solution
KCl	1.5 g	
$NaHCO_3$	2.5 g	
Anhydrous glucose	20 g	
Glucose	22 g	

- Electrolyte replacement therapy includes:
  i. Infusions
  ii. Powders for oral solutions
- Electrolyte infusions available are:
  i. Sodium lactate injection IP, BP.
  ii. Compound sodium chloride injection IP (Ringer's solution).
  iii. Compound sodium lactate injection IP (Ringer's lactate solution).

Q.9. Define electrolytes. Give types of electrolytes.

Electrolytes

The substances whose aqueous solutions conduct electricity are known as electrolytes.

Types of Electrolytes

- Major intracellular ions, e.g. K^+, Mg^{2+}, HPO_4^{2-}, $H_2PO_4^-$.
- Major extracellular ions, e.g. Na^+, Ca^{2+}, Cl^-, bicarbonate.

Q.10. What is intracellular fluid (ICF) and extracellular fluid (ECF)?

Intracellular Fluid (ICF)

It means fluid present inside the cell, e.g. cytoplasm.

Extracellular Fluid (ECF)/Interstitial Fluid

It means fluid present between the cells, e.g. tissue fluid.

Plasma (Vascular Fluid)

It means the fluid present within the blood vascular system.

- *Anionic electrolytes*, e.g. HCO_3^-, Cl^-, SO^{2-}, HPO_4^-.
- *Cationic electrolytes*, e.g. K^+, Ca^{2+}, Na^+, Mg^{2+}.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. An adult human contains about **60%** of water.
2. ICF means **intracellular fluid**.
3. ECF means **extracellular fluid**.
4. Water has a **dielectric** constant.
5. ADH means **antidiuretic hormone**.
6. The concentration of electrolyte is expressed as **milliequivalent per litre (mEq/L)**.
7. Water is a **polar** molecule due to which it is a very good solvent.
8. Regulation of water balance is influenced by the hormones such as **ADH, aldosterone**.
9. **Na^+ and K^+** the principle cations.
10. Loss of water from the body is called **dehydration**.
11. ORT means **oral rehydration therapy**.
12. ORS means **oral rehydration salt**.
13. WHO means **World Health Organization**.
14. UNICEF means **United Nations International Children's Fund**.
15. Compound sodium chloride injection IP is known as **Ringer's solution.**
16. The fluid present inside the cell is known as **intracellular fluid (ICF)**.
17. The fluid present between the cells is known as **extracellular fluid (ECF)**.

Chapter
11

Introduction to Biotechnology

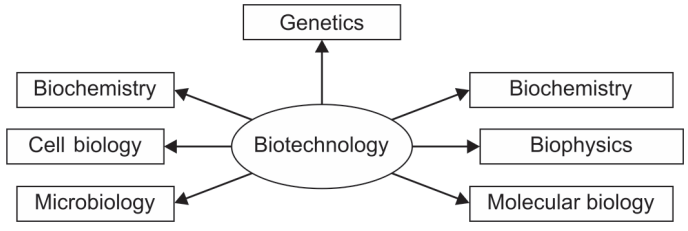
Q.1. Define biotechnology. Mention various basic biological disciplines involved in the origin of biotechnology. (S.23, 24)

Biotechnology

According to OECD (Organization for Economic Cooperation and Development, 1981), "biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services to the human welfare."

- Biotechnology is the product of interaction between the biological science and technology.
- The term biotechnology was first used by Karl Ereky in 1919 to describe a process for large scale production of pigs.
- Biotechnology is the application of biological organisms, systems, processes to manufacturing and service industry.

Various basic biological disciplines involved in the origin of biotechnology are:



Q.2. Enlist various branches of biotechnology.

Branches of Biotechnology

1. *Agriculture biotechnology:* It is involved in the production of newer variety of high yielding, pest and disease resistant and cost effective agricultural plants based on biotechnology concepts.

2. *Medical biotechnology:* In this field, the diagnostic aids like AIDS detection kits, glucose measuring kits, etc. are developed using biotechnology techniques. The production of artificial organs like liver and kidney are new fields in biotechnology.
3. *Engineering biotechnology:* It involves utilization of biotech base enzyme sensors for chemical process monitoring, etc.
4. *Biomedical engineering*: It involves preparation of some artificial organs as an option or replacement alternative for the vital organs lost due to accident, etc.
5. *Textile and paper biotechnology:* The concept of biotechnology is used in polymer engineering and production of special fibres, i.e textile biotechnology.
6. *Environmental biotechnology:* It involves the techniques of bio-technology for the destruction of wastes from industrial, urban areas and also purification of waste water.
7. *Mining and metal biotechnology:* It involves the use of micro-organisms which are capable of affecting the degradation and purification of metals and minerals.
8. *Leather biotechnology:* Leather industry is based on the tanning of skin by various enzyme systems.
9. *Pharmaceutical biotechnology:* It is a major branch of biotechnology, involved in the production of the therapeutically active products like antibiotics, vaccines, etc.
10. *Some other branches of biotechnology are:* Protein engineering, bio-informatics, immunology, plant biotechnology, marine biotechnology, nano biotechnology.

Q.3. Give the objectives/goals/scope/aim of biotechnology. Mention different techniques of biotechnology.

Objectives/Goals/Scope/Aim of Biotechnology

1. To understand more about the processes of inheritance and gene expression.
2. To provide better understanding and treatment of various diseases particularly genetic disorders.
3. To generate economic benefits, including improved plants and animals for agriculture and efficient production of valuable biological molecules.

4. To develop modern diagnostic test kits useful to identify various diseases and disorders.
5. Biotechnological techniques are useful to control pollution and production of biofuels helps to maintain good ecosystem.

Different Biotechnology Techniques

1. DNA isolation
2. DNA amplification
3. DNA cloning (recombinant DNA technology)
4. Restriction enzyme digestion
5. Gel electrophoresis
6. DNA sequencing

Q.4. Give the applications/uses of biotechnology.

Applications of Biotechnology

Biotechnology has wide applications in various fields and processes as follows:

1. Development of virus-resistant crop plants and livestock.
2. Development of diagnostic kits for detecting genetic diseases and acquired diseases.
3. Development of therapies that use genes to cure diseases.
4. Development of recombinant vaccines to prevent diseases.
5. Biotechnology also aids the environment in various ways.
6. Techniques of biotechnology are used in cell and molecular biology, microbiology, genetics, biochemistry, etc.
7. Biotechnology has helped to improve food quality, quantity and processing.
8. Modern biotechnology is based on two main techniques i.e. genetic engineering and chemical engineering.
9. Biotechnology helps in tissue culture, pharmacogenomics and gene therapy.
10. Microbial biotechnology helps in development of biofertilizers, biopesticides, IPM, microbial genomics.
11. Biotechnology is of great significance in horticulture, enzyme industry, and textile industry.
12. Biotechnology is useful in animal breeding.

13. Biotechnology techniques are used in detergent manufacturing industry.
14. Biotechnology is of great importance in health care system.
15. Biotechnology is useful in enzyme industry and leather industry.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. The term biotechnology was first used by **Karl Ereky** in 1919 to describe a process for large scale production of pigs.
2. OECD means **Organization for Economic Corporation and Development**.
3. Biotechnology is the product of interaction between the **biological science and technology**.
4. **Gel electrophoresis** is a technique of biotechnology.
5. The DNA fragments have sticky ends due to **unpaired bases**.
6. The human genome project was launched in the year **1990**.
7. Excision and incision of a gene is called **genetic engineering**.
8. Retrovirus is used as a **vector** for cloning into higher organisms.
9. **The European Federation of Biotechnology (EFB)** gave the definition of biotechnology.
10. **Vaccine** is the product of biotechnology.

Chapter
12

Organ Function Tests

INTRODUCTION

Each organ of the body has to perform its biochemical function to keep the body, as a whole, in a healthy state. Any abnormality in the tissue caused by exogenous or endogenous factors will seriously impair the organ function, which ultimately influences the health of an individual. So, biochemical investigations in the laboratory are essential to measure the functioning of liver, kidney, stomach, etc.

Q.1. Explain various functions of kidney./Mention the role of kidney.

Kidneys are the vital organs of the body performing following major functions:

1. *Maintenance of homeostasis*: Kidneys are largely responsible for the regulation of water, electrolyte and acid–base balance in the body.
2. *Excretion of metabolic waste products*: The end products of protein and nucleic acid metabolism are eliminated from the body by kidneys. These includes urea, creatinine, creatine, uric acid, sulphate, and phosphate.
3. *Retention of substances vital to body*: Kidneys reabsorb and retain several substances of biochemical importance in the body, e.g. glucose, amino acids.
4. *Hormonal functions*: Kidneys also function as endocrine organs by producing hormones, e.g. erythropoietin, calcitriol.
5. Kidneys help in formation of urine.
6. Kidneys maintain blood pressure.
7. Kidneys remove excess of foreign substances such as drugs, pigments, etc. from the body.
8. Kidneys help to maintain water balance of the body.

Q.2. Mention various tests to assess the kidney/renal functions.

The kidney function tests are divided into four groups:

1. Glomerular Function Tests

a. Clearance test
b. Creatinine clearance test
c. Urea clearance test

2. Tubular Function Tests

a. Urine concentration test (dilution test)
b. Urine acidification test

3. Analysis of Blood/Serum

a. Estimation of blood urea
b. Estimation of serum creatinine
c. Estimation of protein and electrolytes

4. Urine Examination

a. Urine examination for volume of urine
b. pH
c. Specific gravity
d. Osmolality
e. For presence of abnormal constituents such as proteins, blood, ketone bodies, glucose.

Q.3. Explain following tests to assess the function of kidney along with their clinical significance. (S.23, 24, W.23)

a. Clearance Test

Clearance test is used to access the rate of glomerular filtration (GFR) and renal blood flow.

Definition

The renal clearance of a substance is defined as the volume of plasma from which the substance is completely cleared by the kidneys per minute. This depends on:

i. Plasma concentration of the substance and its excretion rate.
ii. GFR (normal—120 ml/minute)
iii. Renal plasma flow

Clearance (C) is expressed as ml/minute

Clearance can be calculated by using formula,

$$C = \frac{U \times V}{P}$$

where U = Concentration of the substance in urine
V = volume of urine in ml excreted per minute
P = Concentration of the substance in plasma

- The clearance of a given substance is determined by its mode of excretion.
- The maximum rate at which the plasma can be cleared of any substance is equal to the GFR.
- Inulin is intravenously administered to measure GFR.
- The two compounds, namely urea and creatinine are commonly employed for this purpose.
- Creatinine clearance (~145 ml/min) is marginally higher than the GFR, as it is cleared by the tubules.
- On the other hand, urea clearance (~75 ml/min) is less than the GFR, since it is partially reabsorbed by the tubules.

b. Creatinine Clearance Test

- Creatinine is an excretary product derived from creatine phosphote (largely present in muscle).
- Creatinine is filtered by the glomeruli and only marginally secreted by the tubules.
- The value of creatinine clearance is close to GFR, hence its measurement is a sensitive and good approach to access the renal glomerular function.
- *Definition of the "creatinine clearance"*: Creatinine clearance may be defined as the volume (ml) of plasma that would be completely cleared of creatinine per minute.
- In the traditional method, creatinine content of a 24-hour urine collection and the plasma concentration in this period are estimated.
- The creatinine clearance (C) can be calculated as follows:

$$C = \frac{U \times V}{P}$$

where U = Urine concentration of creatinine
V = Urine output in ml/min (24-hour urine volume divided by 24 × 60)
P = Plasma concentration of creatinine

- *Reference values*: The normal range of creatinine clearance is around 120–145 ml/min. These values are slightly lower in women.
- *Clinical significance/Diagnostic importance:*
  1. A decrease in creatinine clearance value (<75% normal) serves as sensitive indicator of a decreased GFR, due to renal damage.
  2. This test is useful for an early detection of impairment in kidney function.

c. Urea Clearance Test

- Urea is the end-product of protein metabolism.
- After filtration by glomeruli, urea is partially reabsorbed by the renal tubules. Hence, urea clearance is less than the GER. Therefore, urea clearance is not as sensitive as creatinine clearance for assessing renal function.
- *Definition of 'Urea clearance'*: Urea clearance is defined as the volume (ml) of plasma that would be completely cleared of urea per minute.
- Urea clearance is calculated by the formula:

$$C_m = \frac{U \times V}{P}$$

where, C_m = maximum urea clearance
U = Urea concentration in urine (mg/ml)
V = Urine excreted per minute in ml
P = Urea concentration in plasma (mg/ml)

The normal value of urea clearance is around 75 ml/min.

- *Standards of urea clearance:* It is observed that urea clearance drastically changes when the volume of urine is less than 2 ml/min. This is known as 'standard urea clearance (C_s)' and the normal value is around 54 ml/min.
- Standard urea clearance is calculated by modified formula:

$$C_s = U \times V/ P$$

- *Clinical significance/diagnostic importance:* A urea clearance value below 75% of the normal is an indicator of renal damage.

Q.4. Explain various functions of liver. (S.24, W.23)

Functions of Liver

1. *Metabolic functions:* Liver actively participates in carbohydrate, lipid, protein, mineral and vitamin metabolism.

2. *Excretory functions:* Bile pigments, bile salts and cholesterol are excreted in the bile into intestine.
3. *Protective function:* Kuffer cells of liver perform phagocytosis to eliminate foreign substances.
4. *Detoxification:* Liver performs the function of detoxification. Ammonia is detoxified to urea. Liver is responsible for the metabolism a xenobiotics (detoxification).
5. *Haematological functions:* Liver participates in the formation of blood synthesis of plasma proteins and destruction of erythrocytes.
6. *Storage functions:* Glycogen, vitamin A, D and B_{12} and trace elements mainly iron are stored in the liver.
7. *Secretion of bile:* The bile is a secretion of liver which is necessary for digestion and absorption of fats.
8. Liver helps in production of heat which helps in maintaining body temperature.
9. Liver helps in formation of urea which is then carried to the kidney and thrown out in the form of urine.

Q.5. Give the objective of liver function test. What are various liver dysfunctions/disorders? Enlist various tests used to access liver functions. (S.24, W.23)

Objective/Uses of Liver Function Tests (LFTs)

1. To detect the presence of liver disease.
2. To distinguish among different types of liver disorders.
3. To know the extent of liver damage.
4. To follow the response to the treatment.

Various Liver Dysfunctions/Disorders

- Cirrhosis of liver
- Fatty liver
- Cancer of liver
- Genetic disorders of liver
- Hepatocellular diseases (viral hepatitis, ALD)
- Jaundice
- Hemochromatosis (iron storage)
- Wilson's disease.

Various Tests Used to Access the Function of Liver

1. Test for bilirubin
2. Test for SGPT (ALT), SGOT (AST)

3. Test for alkaline phosphatase (ALP)
4. Test for serum GGT
5. Test for serum albumin

Q.6. Explain various tests to access the liver functions (LFTs).

1. Test for Bilirubin

Bilirubin is the excretory end-product of heme degradation. It is conjugated in liver to form bilirubin diglucuronide and excreted in bile.

A. Serum Bilirubin

- The normal concentration of serum bilirubin is in the range of 0.2–1.00 mg/dl.
- Out of this, the conjugated bilirubin is about 0.2–0.4 mg/dl while the unconjugated bilirubin is 0.2–0.6 mg/dl.

I. Van den Bergh Reaction

- This is a specific reaction to identify the increase in serum bilirubin (above the reference level).
- Normal serum gives a negative van den Bergh reaction.
  a. *Direct and indirect reactions:* Bilirubin as such is insoluble in water while the conjugated bilirubin is soluble.
     - Van den Bergh reagent reacts with conjugated bilirubin and gives a purple colour immediately within 30 seconds.
     - This is known as a direct positive van den Bergh reaction.
     - Addition of methanol dissolves the unconjugated bilirubin which then gives the Van den Bergh reaction within 30 minutes and this is referred to as indirect positive.
     - If the serum contains both conjugated and unconjugated bilirubin in high concentration, the purple colour is produced, immediately, (direct positive) which is further intensified by the addition of alcohol (indirect positive).
     - This type of reaction is known as biphasic.

II. van den Bergh Reaction and Jaundice

This reaction is highly useful in understanding the nature of jaundice.

- This is due to the fact that the type of jaundice characterised by increased serum concentration of unconjugated bilirubin (haemolytic), conjugated bilirubin (obstructive) or both of them (hepatic).
- Therefore, the response of van den Bergh reaction differentiate the jaundice as follows:
  – *Indirect positive:* Haemolytic jaundice

- *Direct positive:* Obstructive jaundice
- *Biphasic:* Hepatic jaundice

B. Bilirubin in Urine

- The conjugated bilirubin, being water soluble is excreted in urine but unconjugated bilirubin is not excreted in urine.
- Bilirubin in urine can be detected by Fouchet's test or Gmelin's test.

a. Fouchet's Test

- *Principle:* Bilirubin is precipitated by barium chloride. This bilirubin is oxidised to green biliverdin by Fouchet's reagent.
- *Test (Fouchet's test)*:
  i. Acidify 10 ml of urine with a few drops of dilute acetic acid and add 5 ml of 10% solution.
  ii. If there is no much precipitate, add 2 drops of saturated solution of magnesium sulphate, mix and allow to stand for few minutes.
  iii. Filter and unfold the filter paper.
  iv. Add one drop of Fouchet's reagent to precipitate.
  v. The development of green colouration indicates the presence of bile pigments.

b. Modified Gmelin's Test

To 10 ml of urine, add 2–3 drops of dil. HCl. Filter it through filter paper, allow to dry and put a drop of conc. HNO_3 at the apex of paper. Different coloration can be seen in the order of—green, blue, violet, red and yellowish red, showing the presence of bile pigments.

2. Test for Serum Enzymes

- Liver cells contain several enzymes which may be released into the circulation in liver damage.
- The measurement of some enzymes in serum is used to access the liver function.

a. Transaminases of Aminotransferases

The activities of the following two enzymes are widely used to access the liver function.

i. Serum glutamate pyruvate transaminase (SGPT), recently called alanine transaminase (ALT).
ii. Serum glutamate oxaloacetate transaminase (SGOT), recently called aspartate transaminase (AST).
- Serum ALT and AST are increased in liver'damage.
- The alanine transaminase is more sensitive and reliable for the assessment of LFT.

b. Alkaline Phosphatases (ALP)

- Alkaline phosphatase (ALP) is mainly derived from bone and liver.
- The rise in serum ALP (normal 3–13 KA units/dl). Usually, associated with elevated serum bilirubin which indicates the condition of obstructive jaundice.
- ALP is also elevated in cirrhosis of liver and hepatic tumors.

c. γ -Glutamyl Transpeptidase

- Measurement of γ-glutamyl transpeptidase (GGT) activity provides a sensitive index to asses liver abnormality.
- Serum GGT is highly elevated (normal 10–15 units/litre) in biliary obstruction and alcoholism.

d. Serum Albumin

- Albumin is solely synthesized in liver.
- It has half-life of about 20–25 days, therefore it is a good marker to access chronic liver damage.
- Low serum albumin is commonly observed in patients with severe liver damage.
- Functional impairment in liver is frequently associated with increased synthesis of globulins.
- Cirrhosis of liver causes a reversal of albumin/globulin ratio (A/G ratio).

Q.7. What do you mean by lipid profile/lipid panel? Explain lipid profile tests and mention their clinical significance. (W.23)

Lipid Profile/Lipid Panel

Lipid profile/lipid panel is a panel of blood tests that acts as a initial screening tool for abnormalities in lipid, such as cholesterol and triglycerides.

A complete cholesterol tests is also known as lipid profile or lipid panel.

A typical lipid profile includes following four tests:

1. High density lipoprotein cholesterol (HDL cholesterol), i.e. 'good cholesterol'.
2. Low density lipoprotein cholesterol (LDL cholesterol), i.e. 'bad cholesterol'.
3. Total cholesterol
4. Triglycerides
5. LDL/HDL ratio
6. Very low density lipoprotein cholesterol (VLDL cholesterol)

Lipid Profile

Type	*Normal range*	*Border line*	*High risk*
Cholesterol	<200 mg/dl	200–239 mg/dl	240 mg/dl
Triglycerides	<150 mg/dl	150–199 mg/dl	200–499 mg/dl
HDL cholesterol	60 mg/dl	35–45 mg/dl	<35 mg/dl
LDL cholesterol	60–130 mg/dl	130–139 mg /dl	160–189 mg/dl
Cholesterol/HDL ratio	4.0	5.0	6.0

Clinical Significance of Lipid Profile (S.23)

Lipid profile is useful for:

1. Screening of suspected heart diseases like coronary artery disease, stroke, etc.
2. To evaluate CVS disorders by analysing cholesterol level in the blood.
3. To prevent the damage of blood vessels and arteries.
4. To avoid the rise of disorders like heart attack, arteriosclerosis, hyperthyroidism, multiple myeloma, hypercholesterolaemia.
5. Low levels of triglycerides may produce hypobetalipoproteinemia and high levels may produce metabolic syndromes.
6. Increased level of HDL is observed in exercise and moderate consumption of alcohol while decreased level of HDL is observed in obesity, tension, hepatocellular diseases and cigarette smoking.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. **Clearance test** is used to access the rate of glomerular filtration (GFR) and renal flow.
2. Normal GFR is **120 ml/minute**.
3. GFR means **glomerular filtration rate**.
4. Clearance test is expressed as **ml/minute**.
5. **Inulin** is intravenously administered to measure GFR.
6. The clearance of a given substance is determined by its **mode of excretion**.
7. Urea is the end-product of **protein metabolism**.
8. **Urea clearance** is defined as the volume of plasma that would be completely cleared of urea per minute.
9. A urea clearance value **below 75%** of the normal is an indicator of renal damage.

10. LFTs mean **liver function tests**.
11. Bilirubin is the excretory product of **heme degradation**.
12. The normal concentration of serum bilirubin is **0.2–1 mg/dl**.
13. **van den Bergh reagent reaction** is used to identify the increase in serum bilirubin level.
14. **Modified Glemin's test** is used for detection of bile pigments.
15. Fauchet's test is used for the detection of **bilirubin in the urine**.
16. ALP means **alkaline phosphatase**.
17. ALT means **alanine transaminase**.
18. AST means **aspartate transaminase**.
19. SGPT means **serum glutamate pyruvate transaminase**.
20. SGOT means **serum glutamate oxaloacetate transaminase**.
21. GGT means **γ-glutamyl transpeptidase**.
22. HDL cholesterol means **high density lipoprotein cholesterol**.
23. LDL cholesterol means **low density lipoprotein cholesterol**.
24. VLDL cholesterol means **very low density lipoprotein cholesterol**.
25. HDL cholesterol is **'good cholesterol'** and LDL cholesterol is **'bad cholesterol'**.

Chapter
13

Pathology of Blood and Urine

Q.1. Define the terms 'pathology' and 'abnormal urine'.

Pathology

It is the branch of science which deals with the study of diseases and also deals with causes, effects, mechanisms and nature of diseases.

Abnormal Urine/Pathological Urine

The urine which contains abnormal constituents such as sugars, ketone bodies, bile, pus, etc. is known as abnormal urine or pathological urine.

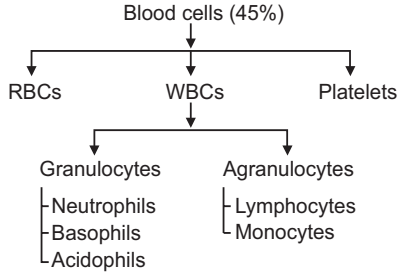
Q.2. What is blood? Give composition and functions of blood.

Blood

Blood is a fluid connective tissue circulated throughout the body containing blood cells and plasma.

Composition of Blood

Blood is composed of 45% of blood cells and 55% of plasma.



Plasma (55%)

1. *Water*—91–92%
2. *Solids* — 8–9%

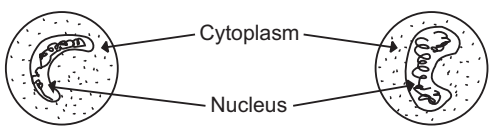
a. *Inorganic constituents*: Sodium, potassium, calcium.
b. *Organic constituents*:
   i. Proteins, e.g. albumin, globulin, prothrombin, fibrinogen.
   ii. Non-protein, nitrogenous substances, e.g. urea, uric acid, creatinine.
   iii. Nutrients, e.g. glucose, amino acids, vitamins, glycerol.
   iv. Hormone and enzymes.
   v. Gaseous: O_2, CO_2, nitrogen.
   vi. Antibodies and antitoxins.
   vii. Fats, e.g. neutral fats, phospholipids.
   viii. Colouring matter, e.g. bilirubin.
   ix. Other substances: Internal secretion.

Functions of Blood

1. Blood helps to transport the gases from lungs to the tissues and CO_2 from tissues to the lungs.
2. Blood helps to transport of absorbed digested materials to the tissues of the body.
3. Blood acts as a vehicle through which many substances are transported to their places of activity.
4. Blood helps to drain out waste materials present in the body.
5. Blood acts as a great defensive mechanism.
6. Blood helps to regulate body temperature.
7. Blood maintains acid–base balance.
8. Blood has coagulation property which prevents loss of blood from the body.
9. Blood helps to transport hormones.
10. It regulates the blood pressure.

Q.3. What are lymphocytes? Name two types of lymphocytes. Mention their role in the body.

Lymphocytes are granular leukocytes, i.e. WBCs. The normal count of lymphocyte is 25–30% of total WBCs. Lymphocytes are made in lymph nodes and in the lymphatic tissue which are present in spleen, liver and bone marrow. There are two types of lymphocytes.



a. Small lymphocytes (T-cells), b. Large lymphocytes (B-cells).

The large lymphocytes are considered to the younger forms of small lymphocytes. They are found to contain abundant cytoplasm which stains, pale-blue and non-granular. The nucleus is very large, single, generally spherical and stains blue. The small lymphocytes range from 7–10 μ in size and large up to 20 μ.

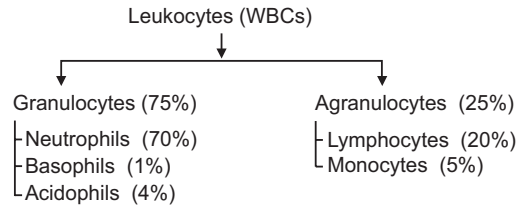
Functions

i. They are responsible for formation of antibodies.
ii. They manufacture β- and γ-serum globulins.
iii. They play important role in defensive mechanism.
iv. They help in repairment of inflamed tissues.
v. The small lymphocytes have very long life span and play an important role in immunity.

Q.4. What are leukocytes? Give different types of leukocytes. (S.23)

The leukocytes are colourless cells containing, irregular shaped large nucleus and are named white blood cells.

The normal count of leukocytes is 6000–10,000/mm^3 of blood. On the basis of granules, leukocytes are classified into two groups.



A. Granulocytes

They constitute about 75%. These cells contain granules in the cytoplasm hence called granulocytes.

1. *Neutrophils*: The granules of these cells are stained by neutral dye. The nucleus is multi-lobed.
   - *Functions:* They ingest the microbes and destroy them by phagocytosis.
2. *Basophils*: The granules of these cells are stained by basic dye. The nucleus is usually oval or slightly kidney-shaped.
   - *Functions:* They are responsible for destruction of products of antigen–antibody reactions.

3. *Eosinophils*: The granules of these cells are stained by red acidic dye called eosinophil. The nucleus is bilobed.
   - *Function:* Phagocytosis.

B. Agranulocytes

These are mononuclear cells and they do not show presence of granules in their cytoplasm.

1. *Monocytes*: These are large cells with large nucleus. The nucleus is convoluted kidney-shaped.
   - *Function*: They give phagocytic action.
2. *Lymphocytes*: These are produced in the lymph glands hence called lymphocytes.
   i *Small lymphocytes*: The thin rim is present around the nucleus and is stained by basic stains.
   ii. *Large lymphocytes*: The nucleus is oval, rounded or kidney-shaped and is stained by basic stains.
   - *Functions*: They are responsible for the development of immunity against foreign substances such as microorganisms.

Q.5. What are erythrocytes? Explain (RBCs).

These are small, circular, disc-shaped cells suspended in blood plasma. All the cells in group appear red in colour and thus the blood becomes red coloured. They are very minute with diameter of 7.2 μ.

Normal values of RBCs:

i. In adult—5 million/mm^3 of blood
ii. In male—5–5.5 million/mm^3 of blood
iii. In female—4.5–5 million/mm^3 of blood.

RBCs are produced in the red bone marrow. The process of formation of RBCs in the blood is called erythropoiesis.

The RBCs contain a substance known as haemoglobin and is enclosed in the stroma of RBCs.

Haemoglobin is a complex protein of high molecular weight. It consists of a protein material called globin and nonprotein material called 'haem'. The haem contains iron which gives red colour to the haemoglobin.

The lifespan of RBC is 120 days.

Functions of RBCs/Erythrocytes

1. It transports the gases such as O_2 and CO_2 in the form of oxyhaemoglobin and carboxyhaemoglobin.

2. It maintains acid–base balance by buffering action of haemoglobin.
3. RBCs help to maintain viscosity of blood.
4. RBCs maintain iron balance of the body.
5. Various pigments are derived from haemoglobin after disintegration of RBCs, e.g. bilirubin and biliverdin.

Q.6. What are platelets? Give their importance.

- Platelet is also known as thrombocyte.
- These are minute spherical structures present in the blood.
- They are produced by large cell, i.e. megakaryotes present in the bone marrow.
- They are disc-shaped, non-nucleated bodies about 2–4 m in diameter.
- The average life span of platelets is about 5–10 days and are destroyed in the spleen.
- The normal count of platelet is 3–4 lac/mm^3 of blood.
- The platelet contain thrombokinase or thromboplastin which is liberated when platelet comes in contact with rough surface and it plays an important role in clotting of blood.

Functions of Platelets

1. The platelets contain thromboplastin which plays an important role in blood clotting.
2. The platelet agglutination helps in the control of bleeding as they seal the small leakings of injured blood vessels or capillaries.
3. The platelets act as protective measure for endothelial lining of blood vessels.
4. The platelets release histamine and 5-hydroxy-tryptamine to induce vasoconstriction.

Q.7. Explain the terms.

a. *Purpura*: It is the abnormal condition of blood in which platelet count is below normal:
   - *Symptoms:*
     i. Red patches beneath the skin.
     ii. Bleeding in the skin and mucous membrane.
     iii. The appearance of lesions.
     iv. The colour of lesion is first red and the fading to a brownish yellow.
     v. The clotting time remains normal but bleeding time is prolonged.

b. *Thrombocytopenia*: A decrease in the platelet count below 70,000/mm^3 of blood produces increased tendency to capillary bleeding. This condition is called thrombocytopenia.

Q 8. Give the composition of normal urine (physiological urine).

Composition of Urine

Water	96%	
Urea	2%	
Uric acid	Chlorides	2%
Creatinine	Phosphates	
Ammonia	Sulphates	
Sodium	Oxalates	
Potassium	Glucose	
Hippuric acid	Oxalic acid	

Characteristic of Urine

1. Urine is amber in colour
2. Specific gravity is 1.020–1.030
3. Acidic in nature
4. Healthy adult passes 1000–1500 ml of urine per day.

Q.9. What are the abnormal constituents of urine? Give their significance in disease or pathological conditions. (S.23, 24, W.23)

The following are abnormal constituents of urine.

Abnormal constituents	*Significance disease*
1. Proteins	Proteinuria
2. Sugar	Glycosuria
3. Ketone bodies	Ketonuria
4. Bile pigments and salts	Jaundice
5. Blood	Haematuria
6. Pus	Pyuria

1. *Protein:* The presence of proteins in the urine is called proteinuria. The presence of albumin and globulin in urine is called albuminuria and globulinuria.

   The proteinuria results in following pathological conditions:

   i. Nephritis
   ii. Nephrotic syndrome

iii. Renal tuberculosis
iv. Bacterial infections in kidney
v. Mercury poisoning
vi. Proteinuria is observed in severe exercise, high protein meal, pregnancy, etc.

2. *Sugars*: The presence of sugar in urine is described as glycosuria. This is associated with the increased blood sugar levels exceeding the threshold level. The glycosuria occurs in the following pathological conditions:
   i. Diabetes mellitus
   ii. Renal glycosuria.
3. *Ketone bodies* (*acetone bodies*): Under certain conditions of the body, carbohydrates utilization is not up to the required quantity, the increased quantity of fats are broken down for the production of energy.

   This results in the formation of ketone bodies which appear in the blood called **ketonemia** and the excretion of the ketone bodies in the urine is called **ketonuria**.

   Thus ketosis is a process in which ketonemia and ketonuria occur. The *acetone, acetoacetic acid,* and β-hydroxy butyric acid are collectively described as ketone bodies.

   Ketonuria is found in the following pathological conditions:
   i. Carbohydrate starvation.
   ii. Pregnancy
   iii. In anaesthesia.
4. *Bile pigments and salts*: Sodium glycolate and sodium taurocholate are bile salts while bilirubin and biliverdin are bile pigments.

   The presence of bile pigments and bile salts produces greenish yellow, greenish brown colour to the urine.

   In defective liver function and when the bile passage is obstructive then bile appears in the urine.

   Bile pigments appear in all types of jaundice.
   i. Haemolytic jaundice
   ii. Obstructive jaundice
   iii. Toxic jaundice.

   Jaundice: Jaundice is a medical condition with yellowing of the skin or whites of the eyes, arising from excess of the pigment bilirubin and typically caused by obstruction of the bile duct, by liver disease or by excessive breakdown of red blood cells.

5. *Blood*: When blood appears in urine, the condition is called haematuria. In haemoglobinuria, the only haemoglobin pigment is found in urine.
   - *Pathological conditions*:
     i. Haematuria occurs due to kidney lesions.
     ii. Haemoglobinuria occurs in enteric fever, malaria, haemolytic poisoning.
     iii. Snake venom causes haemolysis which results in presence of haemoglobin in urine.
6. *Pus*: Presence of pus in the urine is termed as pyuria.
   Pyuria is caused due to inflammation of the urinary bladder, urethra and pelvis of kidney.

Q.10. Write a note on 'megaloblastic anaemia'. (S.24)

It is also known as macrocytic anaemia.

It occurs due to stopped development of erythrocyte at megaloblastic stage. It is because of deficiency of vitamin B_{12} and folic acid.

It characterised by large red cells than normal.

The life span of these cells is also reduced.

The average red cell size is greater than normal, hence it is termed as macrocytic anemia.

The deficiency of vitamin B_{12} is the result of absence of 'intrinsic factor' from the gastric secretion.

- *Main characters of this anaemia are:*
  i. Much large RBCs than normal
  ii. Presence of large and pale nucleus in RBC
  iii. Immature RBCs appear in blood circulation due to decrease in physiology.
- *Symptoms:*
  i. RBCs of different size, shape and colour.
  ii. RBCs with large and pale nucleus.
  iii. Polychromatic pigment granules in RBCs.
  iv. General nervousness.
  v. Sensations such as numbness and tingling.
  vi. Occurrence of pins and needles in the fingers and toes.
  vii. Very reduced RBC count.
  viii. Decreased O_2 carrying capacity.

- *Treatment*:
  i. Increased dietary intake of vitamin B_{12} or vitamin B_{12} tablets as therapeutic treatment.
  ii. Intramuscular injection of vitamin B_{12}.

Q.11. Write a note on 'sickle cell anaemia'. (S.24)



Sickle Normal RBCs

Sickle cell anaemia is also called sickle cell disease. In this anaemia, there is abnormal formation of RBCs and they are having a sickle shape.

The main reason of this anaemia is the bone marrow which produces abnormal type of haemoglobin. It is a haemoglobin of 'S' type instead of normal haemoglobin 'A'. The difference between two is a small change in structure of molecule.

Haemoglobin 'S' is peculiar sensitive to a lowered oxygen supply.

The red cells with this type of haemoglobin form sickle or cresent shapes when subjected to lowered oxygen concentration. The sickle cells do not pass through the small blood capillaries readily and hence may block the blood supply to vital organs. Patient with sickle cell disease show a marked susceptibility to infections.

- *Characteristic/symptoms of sickle cell anaemia*:
  i. Sickle-shaped RBCs (observed under microscope).
  ii. Sudden, severe abdominal pains followed by excretion of dark urine.
  iii. Blockage of blood capillaries may block the blood supply to vital organs.
  iv. Decreased blood supply and decreased O_2 supply to body organs.
  v. General tissue damage due to local necrosis.
- *Treatments*:
  i. The sickle cell patient should avoid situations where a lowered concentration of oxygen may be present.
  ii. Reaching high altitudes and air polluted areas should be avoided.
  iii. Patient should obtain prompt medical care in case of cold pneumonia.

Q.12. Write a note on 'microcytic anaemia'. (S.24)

- This is also called iron deficiency anaemia because the deficiency of iron causes the bone marrow to produce small red blood cells.
- RBCs are pale and less in number.
- Such anaemia is common in women than in men and it is found common in Indian women.
- The main cause of this anaemia is iron deficiency followed by bone marrow depression.
- The iron deficiency may be due to:
  i. Dietary deficiency of iron
  ii. Hookworm infestation
  iii. Lack of HCl in stomach, where HCl is required for normal absorption of iron.
- *Symptoms*:
  i. Abnormally small sized RBCs containing very low haemoglobin
  ii. RBCs of very pale colour
  iii. Shortness of breath with exercise
  iv. Faintness
  v. Headache
  vi. Total RBC count is very low
  vii. Pale colour of skin and nails.
- *Treatments*:
  i. Iron therapy through proper diet
  ii. Actually, proper cause of iron deficiency is found out and patient is treated accordingly
  iii. Antiworm drugs should be used to kill the hookworms.

Q.13. Write a note on 'haemolytic anaemia'. (S.24)

It is the condition of abnormal destruction of RBCs in blood called haemolysis. Such destruction may occur in bloodstream.

- *Causes/Reasons:*
  i. Poisoning by various substances like lead, mercury, arsenic, etc.
  ii. Toxins produced by bacteria called *Streptococcus haemolyticus*.
  iii. Infection by malarial parasite as *Plasmodium* species.
  iv. RBC destruction due to cancer or malignancy.
  v. Mismatching of blood groups due to incompatible blood transfusion.

- *Symptoms*:
  i. Decreased RBC count
  ii. Decreased haemoglobin content
  iii. Low O_2 carrying capacity
  iv. Breathlessness
  v. Restlessness
  vi. Very pale skin.
- *Treatments*:
  i. Proper blood transfusion to compensate RBC loss is main treatment
  ii. Antidote in case of poisoning
  iii. Antimalarial drug treatment in case of malaria
  iv. Avoiding blood group mismatching during transfusion
  v. Preventive measures for streptococcal infection.

Q.14. Write a note on 'haemorrhagic anaemia'.

Haemorrhage means blood loss due to any reason, so can result in condition called haemorrhagic anaemia.

- *Causes/Reasons*
  i. Peptic ulcer of severe bleeding to blood vomits.
  ii. Intestinal ulcers of severe degree leading to blood loss through stools.
  iii. Dysmenorrhoea is abnormally heavy bleeding during menstruation in women.
  iv. Heavy bleeding wounds in case of accident victim.
  v. Blood vomits as in case of blood cancer, etc.
- *Symptoms*:
  i. Low blood volume
  ii. Low RBC count
  iii. Reduced haemoglobin content of blood
  iv. Pale skin and nails
  v. General fatigue
  vi. Faintness.
- *Treatments*:
  i. Stop the bleeding immediately.
  ii. Earliest blood transfusion to compensate blood loss is another treatment.

iii. Treating the patient specifically by finding actual cause of bleeding.
iv. Symptomatic treatment can be conducted.

Q.15. Explain the terms. (S.23, W.23)

1. *Anaemia*: Anaemia means reduction in amount of oxygen-carrying capacity of blood, i.e. haemoglobin. Deficiency of RBCs causes anaemia.
   - *Causes/reasons of anaemia*:
     i. Due to excessive blood loss, i.e. severe haemorrhage.
     ii. Failure of function of red bone marrow so that no blood cells are formed.
     iii. Due to increased destruction of RBCs by haemolysis.
     iv. Defective formation of RBCs includes abnormal reduction of RBCs in the blood.
     v. Dietary deficiency of iron may cause decrease in % of RBC causing anaemia.
   - *Type of anaemia*:
     i. Megaloblastic anaemia
     ii. Sickle cell anaemia
     iii. Pernicious anaemia
     iv. Haemolytic anaemia
     v. Haemorrhagic anaemia
     vi. Iron deficiency anaemia
     vii. Hypochromic anaemia
     viii. Hypoplastic anaemia
     ix. Nutritional anaemia.
   - *Treatments of anaemia*:
     i. Increase dietary intake of vitamin B_{12}
     ii. Use of haematinics
     iii. Iron therapy through proper diet
     iv. To prevent blood loss due to any reason
     v. Blood transfusion to compensate blood loss or RBCs.
2. *Polycythaemia*: An abnormal increase in RBCs in the blood is called polycythaemia.

Due to increase in erythrocyte, the viscosity of blood increases and rate of blood flow becomes slow and increases the risk of intravascular clotting (thrombosis). This also increases BP.

- *Types of polycythaemia*
  i. *Primary polycythaemia*: In this case, along with increased number of red cells, the bone marrow is markedly hyperplastic. Thus, skin and mucous membrane of the mouth are red. The conjunctiva is also red.
  ii. *Secondary polycythaemia*: In this case, there is a large increase in red cells in the condition of insufficient oxygenation.

3. *Leukaemia* (*increase in WBCs*): It is a malignant disease of bone marrow that results in uncontrolled increase in production of leukocytes in blood. Immature forms of WBCs make their appearance in the circulating blood in leukaemia condition. It is also called cancer of blood.
   - *Causes of leukaemia*:
     i. Ionising radiations produced by X-ray or radioactive isotopes are known to cause malignant changes in the precursors of WBCs. The genetic material of the cells is changed. Some cells die while others reproduce at abnormally rapid rate.
     ii. Some chemicals used in general or work environments are known to change the genetic make-up of WBC precursor in the bone marrow.
4. *Leucopenia* (*decrease in WBCs*): This is the condition in which there is a decrease in WBC count below 4000/mm^3 of blood. Commonly this disease is caused due to fall in the count of neutrophil cells.
5. *Leucocytosis*: It is the abnormal condition in which there is an increased number of WBCs in the blood above normal range. It is observed in some respiratory diseases like allergic bronchitis.
6. *Granulocytosis*: This is the pathological condition indicated by presence of increased number of granulocytes in blood.
7. *Agranulocytosis*: It is the condition of complete absence of granulocytes from blood or bone marrow.

   Different reasons can lead to such condition, e.g. suppression of the function of bone marrow.

   Agranulocytosis can often resulting in high fever, weakness, and ulceration of the mucous membrane.

8. *Haemophilia* (*bleeding disease*): This is a hereditary disease which runs in families. In this condition, the bleeding occurs continuously by even a small skin cut or puncture.

   A person suffering from haemophilia can lead to death while even small injury or small cut, as the blood lacks the ability to clot. A person suffering from this disease is known as haemophilic person.

   In this hereditary disorder, the female is carrier while effect is pronounced in male.
9. *Eosinophilia*: It is an abnormal condition indicated by increase in number of eosinophils in blood, e.g. eosinophils increase in the conditions like malaria, dengue and in case of treatment of antibiotics.
10. *Erythrocytopenia*: It is the pathological condition of decreased number of RBCs in peripheral blood vessels.
11. *Erythrocytosis*: It is the condition indicated by presence of increased RBC count much above normal and it is associated with increase in total blood volume.

Q.16. What are ketone bodies/acetone bodies? How are ketone bodies detected in urine?

- Acetone, acetoacetic acid and β-hydroxy butyric acid are collectively described as ketone bodies.
- Only 3–15 mg of ketone bodies are excreted in urine normally.
- The increased amount of ketone bodies is excreted in urine in starvation, diabetes mellitus, pregnancy and ether anaesthesia.
- Ketone bodies in urine are detected by the following tests.

1. *Rothera's test*:
   - *Principle*: Acetoacetic acid forms a complex with sodium nitroprusside in alkaline solution developing a purple colour.
   - *Test*:
     i. Saturate 5 ml of urine with solid ammonium sulphate by shaking it vigorously.
     ii. Then add 2 drops of freshly prepared 5% solution of sodium nitroprusside and 1 ml of ammonium hydroxide.
     iii. Allow to stand for a while.
     iv. A permanganate or purple colour develops just above the layer of ammonium sulphate indicates the presence of acetone bodies.

2. *Gerharelt tests*:
   - *Principle*: Acetoacetic acid gives a red colour with $FeCl_3$.
   - *Test*:
     i. Add 5% ferric chloride solution drop by drop to about 5 ml urine till no more precipitate of ferric chloride is formed.
     ii. Filter and to the filtrate add some more ferric chloride solution.
     iii. The development of red colour indicates the presence of acetoacetic acid.

Q.17. How albumin (protein) is detected in urine?

Abnormal albumin in urine is detected by:

1. *Sulphosalicylic acid test*: Albumin is denatured by sulphosalicylic acid causing coagulation.
   - *Test*: Add a few drops of sulphosalicylic acid to 2 ml of clear urine. A turbidity indicates presence of albumin.
2. *Heller's nitric acid ring rest*: Nitric acid causes the precipitation of proteins.
   - *Test:*
     i. To 3 ml of nitric acid in a narrow tube add 3 ml of urine in such a way that the two liquids do not mix.
     ii. The presence of white ring at the function of two fluids indicates the presence of albumin.

Q.18. How bile salts and bile pigments are detected in urine?

1. *Bile salts*: Sodium glycocholate and sodium taurocholate are the bile salts, found in urine in defective liver function and is the characteristic of the jaundice.

   Hay's test for bile pigments: Bile salts reduce the surface tension present in the urine for which the sulphur powder sinks.
   - *Test*:
     i. Fill half of a test tube with urine and another test tube with water.
     ii. Sprinkle gently same sulphur powder on the surface of two liquids.
     iii. The sulphur powder spontaneously sinks in the test tube containing urine which indicates presence of bile salts.
     iv. But in other test tube containing water, sulphur powder does not sink.
2. *Bile pigments*: Bilirubin and biliverdin are the bile pigments. Bile pigments are detected by Fouchet's test.

Fouchet's test

- *Principle*: Bilirubin is precipitated by barium chloride. This bilirubin is oxidised to green biliverdin by Fouchet's reagent.
- *Test*
  i. Acidify 10 ml of urine with a few drops of dilute acetic acid and add 5 ml of 10% solution.
  ii. If there is no much precipitate, add 2 drops of saturated solution of magnesium sulphate, mix and allow to stand for few minutes.
  iii. Filter and unfold the filter paper.
  iv. Add one drop of Fouchet's reagent to precipitate.
  v. The development of green colouration indicates the presence of bile pigments.

Q.19. How sugar is detected in urine?

Sugar is detected in urine by: a. Benedict's test, b. Fehling's test

a. Benedict's Test

i. Add 0.5 ml of urine to about 5 ml of Benedict qualitative reagent.
ii. Boil it for 2 minutes by holding the test tube firmly with a test tube holder.
iii. A light green, yellow and brick red precipitate indicates the presence of reducing sugar in urine.
iv. The various coloured precipitates depend on the concentration of reducing sugar in urine which gives rough estimation of concentration, as follows:

Light green precipitate	0.1–0.5% of sugar
Green precipitate	0.1–1% of sugar
Yellow precipitate	1–2% of sugar
Brick red precipitate	>2% of sugar

b. Fehling's Test

Boil sugar solution and Fehling's solution for 2 minutes, gives formation of brick red precipitate which indicates the reducing sugar.

Q.20. Discuss bile salts and bile pigments. In which disease these appear in urine?

- *Bile salts*: Sodium glycocholate and sodium taurocholate are bile salts which act as emulsifying agent and emulsify fats. They activate pancreatic lipase and cholesterol esterase.
- *Bile pigments*: Bilirubin and biliverdin are the bile pigments formed from the breakdown of haemoglobin. Bile pigments are excreted in bile.
- In obstructive jaundice, bile salts and bile pigments appear in urine.

OBJECTIVE QUESTIONS WITH ANSWERS IN BOLD LETTERS

1. The normal count of WBCs/leukocytes is **6000–10000/mm^3** of blood.
2. RBCs are produced in the red bone marrow by the process known as **erythropoiesis**.
3. The total life of RBCs is **120 days**.
4. The average lifespan of a platelet is about **5–10 days**.
5. The normal count of platelets is **3–4 lac/mm^3** of blood.
6. **Haematuria** is a condition where blood appears in the urine.
7. When pus cells appear in the urine, condition is called **pyuria**.
8. In jaundice condition, **bile salts of bile pigments** appear in the urine.
9. The acetone, acetoacetic acid and β-hydroxy butyric acid are collectively described as **ketone bodies**.
10. **Megaloblastic anaemia** is also known as macrocytic anaemia.
11. The main reason of sickle cell anaemia is that the bone marrow produces **abnormal type of haemoglobin**.
12. The **microcytic anaemia** is also called iron deficiency anaemia.
13. **Haemorrhage** means excessive loss of blood from the body.
14. An abnormal increase in number of RBCs in the blood called **polycythaemia**.
15. **Leukaemia** is a malignant disease of bone marrow where there is an uncontrolled increase of WBCs/leukocytes in the blood.
16. The decrease in WBC count below/4000/mm^3 of blood is known as **leucopenia**.
17. **Haemophilia** is a hereditary disease, also known as bleeding disease.
18. Only **3–15 mg** of ketone bodies are excreted in the urine, normally.
19. Rothera's test and Gerhardt's test are used for detection of **ketone bodies in the urine**.
20. **Fouchet's test** is used for the detection of bile pigments.
21. **Bilirubin and biliverdine** are bile pigments.
22. **Sodium glycocholate and sodium taurocholate** are the bile salts.
23. **Purpura** is a disease caused by the decrease in the normal platelet count.
24. The pH of urine is **6–7.5**.

Board Examination Papers

Summer Examination 2023 (Question Paper)

Second Year Diploma in Pharmacy

Subject: Biochemistry and Clinical Pathology (20223)

Time: 3 Hours **Max Marks: 80**

Q.1 Attempt any SIX of the following. **30 Marks**

a. Discuss TCA cycle along with its energetics.
b. What are carbohydrates? Classify them with suitable examples.
c. What is enzyme inhibition? Explain competitive and non-competitive inhibition.
d. What is the Embden-Meyerhof pathway? Discuss various stages of the pathway.
e. Explain primary and secondary structure of protein.
f. Explain routinely performed tests to assess the functions of the kidney.
g. Discuss in brief about B-oxidation of fatty acids.

Q. 2 Attempt any TEN of the following. **30 Marks**

a. Write biological role, deficiency condition and symptoms of vitamin C.
b. Explain the process of ETC.
c. What are abnormalities of red cells? Explain.
d. What are lipids? Classify them with suitable examples.
e. Discuss the functions, deficiency and recommended dietary requirement of calcium.
f. Explain structure and functions of DNA.
g. Define dehydration. Explain causes, symptoms and treatment of dehydration.
h. Draw the structure of cholesterol and give functions of it.
i. Enlist different abnormal constituents of urine.
j. Discuss in detail about lipolysis.
k. What is the clinical significance of lipid profile?

Q. 3 Attempt ALL questions the following. **20 Marks**

a. Draw the structure of glucose
b. Write any two functions of RNA.
c. Name any two sulphur containing amino acids.
d. Give two pharmaceutical applications of enzymes.
e. Write any two functions of lymphocytes.
f. The chemical name of vitamin D is_____
g. Define biotechnology.
h. Coenzyme form of vitamin riboflavin is_____
i. Name the site for protein synthesis in the cell.
j. Write deficiency diseases of vitamin thiamine.
k. The extracellular fluid comprises_____
   (i) Tissues/cells (ii) Plasma
   (iii) Plasma and interstitial fluid (iv) Intertitital
l. Synthesis of cholesterol and steroid is the function of_____
   (i) Nucleus (ii) Golgi complex
   (iii) Endoplasmic reticulum (iv) Peroxisomes
m. The nitrogen base found in RNA but not in DNA is_____
n. The protein part of holoenzyme is known as_____
   (i) Active site (ii) Allosteric site
   (iii) Co-enzyme (iv) Apoenzyme
o. Where does oxidative phosphorylation take place?
p. Body water is regulated by the hormone_____
   (i) ADH (ii) ACTH
   (iii) FSH (iv) Epinephrine
q. Biotechnology has made contribution in which areas_____
   (i) Medicine (ii) Industrial
   (iii) Environmental (iv) All of these
r. Give significance to the SGPT test.
s. Write full form of ECF and ICF.
t. Rothera's test is for detection of_____ in the urine.

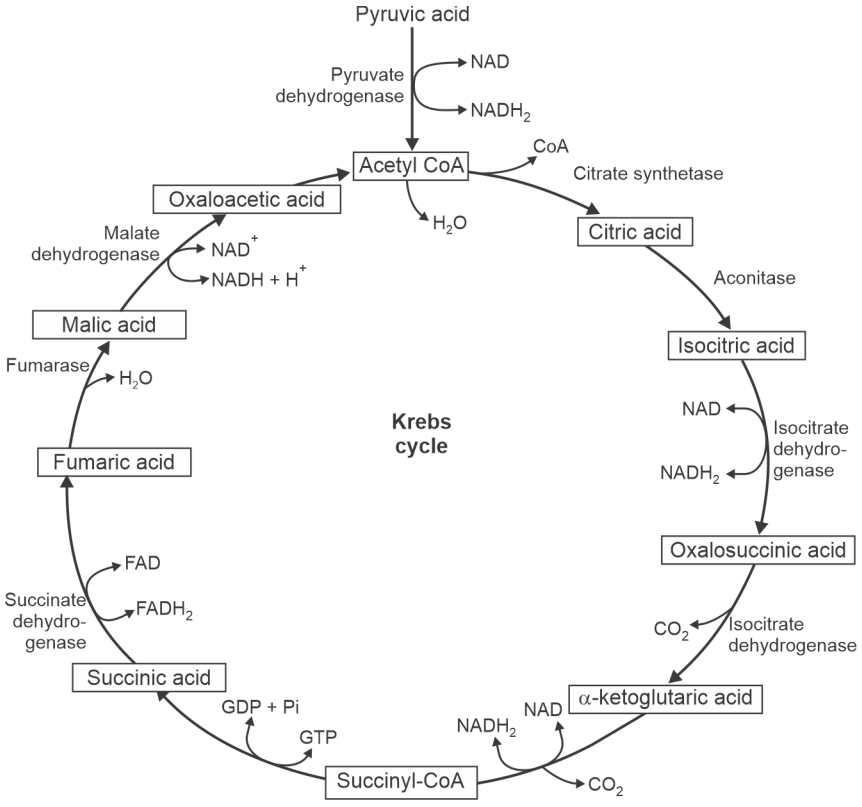
Summer Examination 2023 (Specimen Answer Paper)
Second Year Diploma in Pharmacy
Subject: Biochemistry and Clinical Pathology (20223)

Time: 3 Hours **Max Marks: 80**

Q.1 Attempt any SIX of the following: **30 Marks**

a. Discuss TCA cycle along with its energetics.

Ans: TCA cycle:



Tricarboxylic acid Cycle (TCA Cycle) / Krebs' Cycle:

It is a central pathway for release of energy from acetyl CoA which is produced from glycolysis, catabolism of fatty acids or amino acids.

1. Condensation of acetyl CoA obtained from pyruvic acid/pyruvate with oxaloacetate to form citric acid in presence of citrate synthase.
2. Conversion of citric acid/citrate to cis aconitate in presence of aconitase and Fe^{2+}.Cis aconitic acid/aconitate accepts water to give isocitric acid/isocitrate in presence of aconitase and Fe^{2+}.
3. Isocitric acid/isocitrate undergoes oxidation in presence of isocitrate dehydrogenase and NAD^{+} to give Oxalosuccinic acid/ oxalosuccinate.
4. Decarboxylation of oxalosuccinic acid/oxalosuccinate to alpha ketoglutaric acid/alpha ketoglutarate in presence of isocitric acid dehydrogenase, Mg/ Mn.
5. Oxidative decarboxylation of alpha ketoglutaric acid/alpha ketoglutarate to succinyl CoA in presence of alpha ketoglutarate dehydrogenase, CoA-SH, NAD^{+}, Mg.
6. Succinyl CoA gets converted to succinic acid/succinate in presence of succinate thiokinase/succinyl CoA synthetase, GDP, Mg.
7. Succinic acid/succinate undergoes dehydrogenation in presence of succcinate dehydrogenase, FAD^{+} to form fumaric acid/fumarate.
8. Fumaric acid/fumarate takes up water molecule in presence of fumarase to form maleic acid/malate.
9. Maleic acid/mal2. Conversion of citric acid/citrate to cis aconitate in presence of aconitase and Fe^{2+}. Cis aconitic acid/aconitate accepts water to give isocitric acid/isocitrate in presence of aconitase and Fe^{2+}.
10. Isocitric acid/isocitrate undergoes oxidation in presence of isocitrate dehydrogenase and NAD^{+} to give oxalosuccinic acid/oxalosuccinate.
11. Decarboxylation of oxalosuccinic acid/oxalosuccinate to alpha ketoglutaric acid/alpha ketoglutarate in presence of isocitric acid dehydrogenase, Mg/Mn.
12. Oxidative decarboxylation of alpha ketoglutaric acid/alpha ketoglutarate to succinyl CoA in presence of alpha ketoglutarate dehydrogenase, CoA-SH, NAD^{+}, Mg.
13. Succinyl CoA gets converted to succinic acid/succinate in presence of succinate thiokinase/succinyl CoA synthetase, GDP, Mg.

14. Succinic acid/succinate undergoes dehydrogenation in presence of succcinate dehydrogenase, FAD^+ to form fumaric acid/fumarate.
15. Fumaric acid/fumarate takes up water molecule in presence of fumarase to form maleic acid/malate.
16. Maleic acid/malate undergoes oxidation in presence of malate dehydrogenase, NAD^+ to form oxaloacetic acid/oxaloacetate.
17. Cycle gets repeated again by the entrance of another molecule of Acetyl CoA.

Energetics of TCA cycle:

Reactions	*No. of ATP formed*
Isocitrate to oxalosuccinate	3
Alpha ketoglutarate to succinyl Co-A	3
Succinyl Co-A to succinate	1
Succinate to fumarate	2
Malate to oxaloacetate	3
Total	12 ATP

b. What are carbohydrates? Classify them with suitable examples.

Ans: **Carbohydrate:** Carbohydrates may be defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis. Carbohydrates are essential biomolecules consisting of carbon, hydrogen and oxygen and are known as hydrates of carbon. Chemically, they are polyhydroxy alcohols with aldehyde or ketone as functional groups. Carbohydrates are broadly classified into:

A. Sugars and

B. Non-sugars

Sugar type of carbohydrates are further classified as mentioned below:

I. Monosaccharides are the simplest group of carbohydrates and are often referred to as simple sugars.

- They have general formula CnH_2nOn and they cannot be further hydrolysed.
- They are further classified as:
  - A. On basis of functional groups:
    - (i) **Aldoses:** when the functional group of monosaccharides is an aldehyde they are known as aldoses, e.g. glyceraldehyde, glucose.
    - (ii) **Ketoses:** when the functional group of monosaccharides is a ketone they are known as ketoses, e.g. fructose

B. On basis of number of carbon atoms:
- **Trioses:** Three carbon atoms, e.g. glyceraldehyde
- **Tetroses:** Four carbon atoms, e.g. erythrose, erythrulose.
- **Pentoses:** Five carbon atoms, e.g. ribose, ribulose.
- **Hexoses:** Six carbon atoms, e.g. glucose, fructose, galactose, mannose, etc.
- **Heptoses:** Seven carbon atoms, e.g. sedoheptose, sedoheptulose.

II. Oligosaccharides contain two to ten monosaccharide molecules.

Based on the number of monosaccharide units present, the oligosaccharides are further subdivided into:

(i) **Disaccharide:** Class of oligosaccharide consisting of two monosaccharide units.

For example, ***Sucrose*** (glucose + fructose), ***lactose*** (galactose + glucose), ***maltose*** (glucose + glucose).

(ii) **Trisaccharide:** class of oligosaccharide consisting of three monosaccharide units.

For example, ***Raffinose*** (three galactose sugar units), ***maltotriose*** (three glucose sugar units).

III. Non-sugars (Polysaccharides) are the polymers of monosaccharide units with higher molecular weight held together by glycosidic bonds.

Polysaccharides are of two types:

(i) **Homopolysaccharide:** These on hydrolysis yield only a single type of monosaccharide unit, e.g. starch, cellulose, glycogen, etc.

(ii) **Heteropolysaccharide:** These on hydrolysis yield a mixture of few monosaccharides or their derivatives unit, e.g. hyaluronic acid, heparin, chondroitin sulphate, etc.

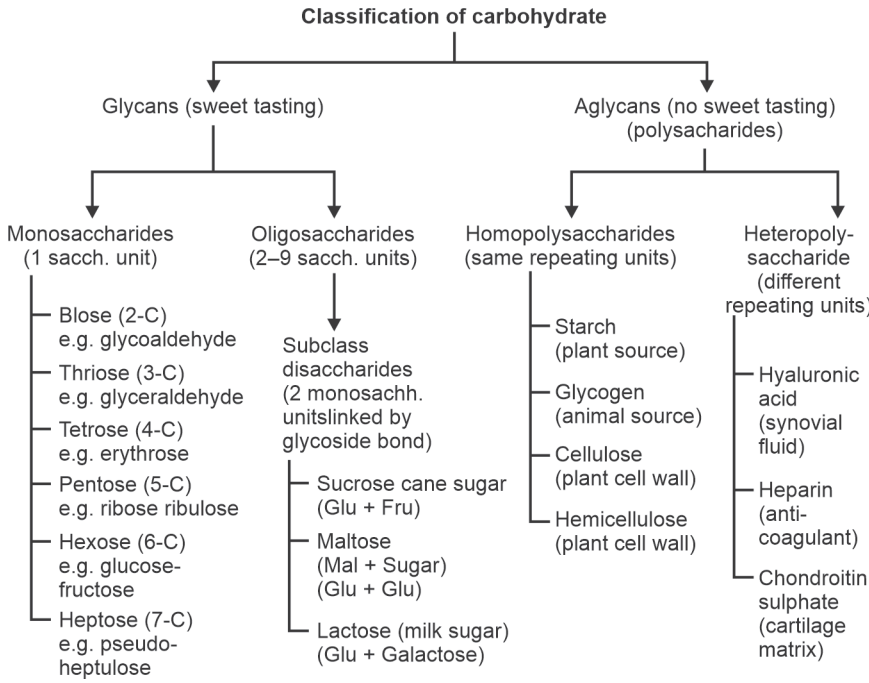
Or

Schematic classification of carbohydrates can be considered (See next page top)

c. What is enzyme inhibition? Explain competitive and non-competitive inhibition.

Ans: Enzyme Inhibition:

Enzyme inhibition is defined as a process wherein a substance binds with the enzyme and brings about a decrease in catalytic activity of that enzyme. The inhibitor binds non-covalently with the enzyme and the enzyme inhibition can be reversed if the inhibitor is removed.



There are 3 broad categories of enzyme inhibition:

- Reversible inhibition (Competitive and non-competitive)
- Irreversible inhibition
- Allosteric inhibition

The reversible inhibition is further subdivided into;

I. Competitive inhibition

II. Non-competitive inhibition

Competitive Inhibition:

- The inhibitor (I) which closely resembles the real substrate (S) is regarded as a substrate analogue.
- The inhibitor competes with substrate and binds at the active site of the enzyme but does not undergo any catalysis.
- As long as the competitive inhibitor holds the active site, the enzyme is not available for the substrate to bind.
- During the reaction, ES and EI complexes are formed as shown on next page (top). The relative concentration of the substrate and inhibitor and their respective affinity with the enzyme determines the degree of competitive inhibition.
- The inhibition could be overcome by a high substrate concentration.

Enzyme	*Substrate*	*Inhibitor*	*Significance*
Monoamine oxidase	Catecholamines	Ephedrine, amphetamine	Elevates catecholamine level
Dihydrofolate reductase	Dihydrofolic acid	Methotrexate	Treatment of cancers
Acetylcholine esterase	Acetylcholine	Succinylcholine	Muscle relaxant in surgery
HMG CoA reductase	HMG CoA	lovastatin	Inhibit cholesterol synthesis

Non-competitive Inhibition

- The inhibitor binds at a site other than the active site on the enzyme surface. This binding impairs the enzyme function.
- The inhibitor has no structural resemblance with the substrate.
- However, there usually exists a strong affinity for the inhibitor to bind at the second site.
- In fact, the inhibitor does not interfere with the enzyme-substrate binding.
- But the catalysis is prevented, possibly due to a distortion in the enzyme conformation.
- The inhibitor generally binds with the enzyme as well as the ES complex.
- The overall relation in non-competitive inhibition is represented below:

Drug	*Enzyme inhibited*	*Significance*
Disulfiram	Alcohol dehydrogenase	Treats chronic alcoholism
Isocarboxazid	Monoamine oxidase	Treats depression
Digoxin	Na^+/K^+ ATPase	Cardiotonic

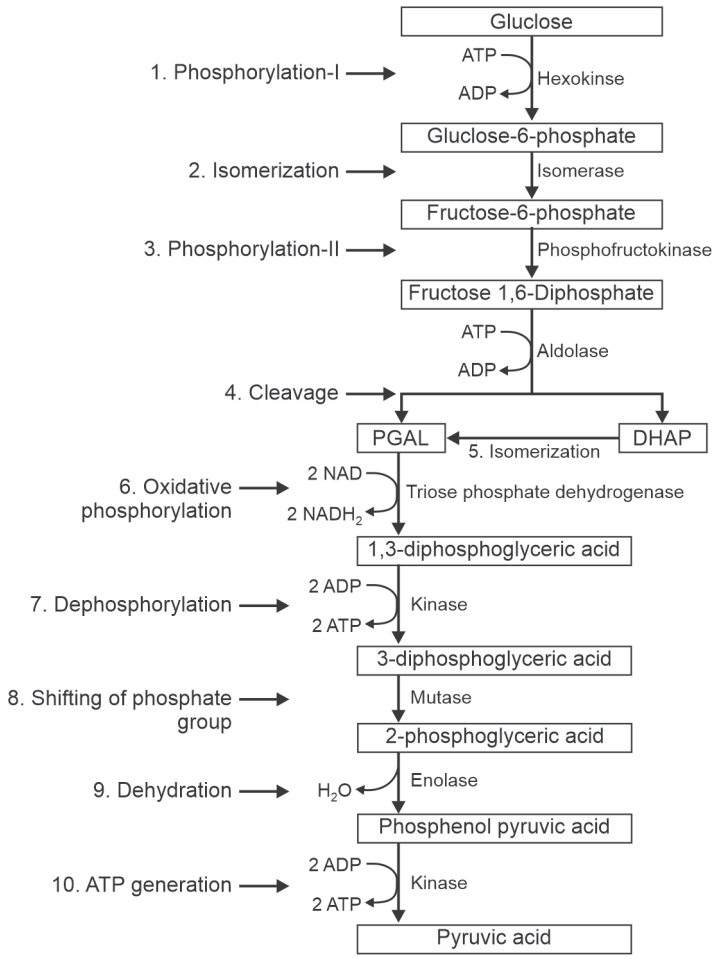
d. What is the Embden-Meyerhof pathway? Discuss various stages of the pathway.

Ans: **Glycolysis** or **Embden-Meyerhof pathway** is the sequence of reactions converting glucose (or glycogen) to pyruvate or lactate, with the production of ATP. It takes place in all cells of the body.

The various stages of the pathway are:

1. Phosphorylation of glucose to glucose 6-phosphate in presence of enzyme hexokinase and ATP and Mg.
2. Isomerisation of glucose 6-phosphate to fructose 6-phosphate in presence of phosphohexose isomerase.
3. Phosphorylation of fructose 6-phosphate to fructose 1,6-diphosphate in presence of phosphofructokinase, ATP and Mg.

4. Cleavage of fructose 1,6-diphosphate to dihydroxyacetone phosphate and glyceraldehydes 3-phosphate in presence of aldolase. These 2 products are interconvertible in presence of triose phosphate isomerase.
5. Glyceraldehyde 3-phosphate further undergoes oxidation to 1,3-diphosphoglycerate in presence of glyceraldehyde 3- phosphate dehydrogenase and NAD+.
6. Transformation of 1,3-diphosphoglycerate to 3-phosphoglycerate in presence of phosphoglycerate kinase, Mg and ADP.
7. 3-phosphoglycerate changes to 2-phosphoglycerate in presence of phosphoglycerate mutase.
8. Loss of water molecule from 2-phosphoglycerate results in the formation of phosphoenol pyruvic acid in presence of enolase.
9. Loss of phosphate from phosphoenol pyruvic acid results in formation of enol pyruvic acid in presence of pyruvate kinase, Mg and ADP.
10. Enol pyruvic acid gets converted to keto form of pyruvic acid in presence of pyruvate kinase.
11. Keto pyruvic acid under aerobic conditions enters the TCA cycle in mitochondria.
    Pyruvic acid forms the main end product of glycolysis in those tissues which are supplied with sufficient oxygen.
12. But in tissues where oxygen is not supplied, lactic acid is formed as an end product of glycolysis by reduction in presence of lactate dehydrogenase and NADH.



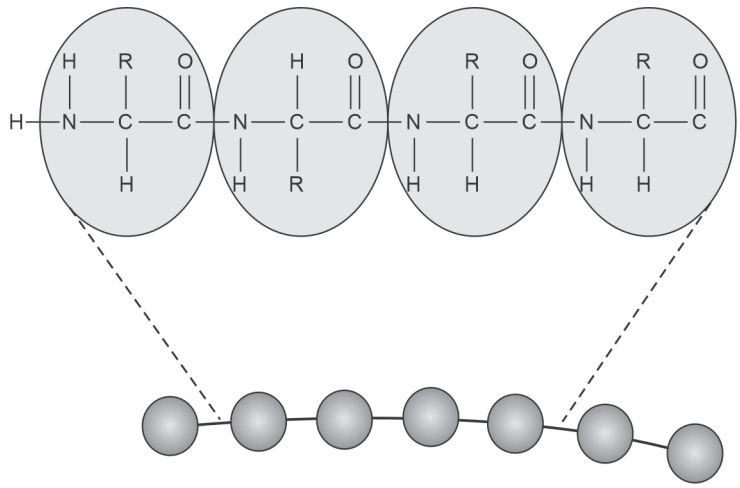
Glycolysis/EMP pathway

e. Explain primary and secondary structure of protein.

Ans: Primary structure of proteins:

- The primary structure of protein is referred mainly to the number, nature and the sequence of amino acids along the polypeptide chains.
- This sequence determines the further levels of organization of the protein molecule.
- The linear sequence of amino acid residue in a polypeptide chain is called the Primary structure of protein.
- While representing the primary structure,
  a. The N-terminal amino acid, i.e. the amino acid with either free amino group, is always on the left end of the polypeptide chain and

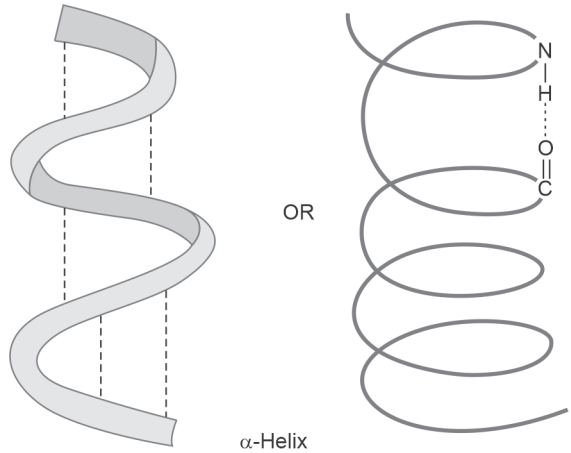
b. The C-terminal amino acid, i.e. amino acid with free –COOH group, at the right end of the chain.



Secondary structure of proteins:

(i) **α- helix (α- helical)**

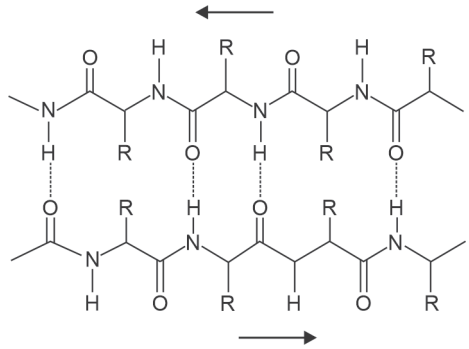
- The α helical is the most common spiral structure of protein.
- It has a rigid arrangement of polypeptide chains.
  The α - helical structure depends on the intramolecular hydrogen bonding between **NH** and **C=O** group of peptide bonds.
- In the α - helix the polypeptide is folded in such a way that the C=O of each amino acid residue is hydrogen bonded to the NH of 4th amino acid residue along the chain.



(ii) **β-pleated sheet:** It is another form of secondary structure, this result from hydrogen bonding between two peptide chains. It may occur in two types:

a. Parallel pleated sheet:
   - In this type of structure the polypeptide chain is side by side and in the same direction so that N-terminal residues are on the same end.
   - This pleated sheet conformation is stabilized by hydrogen bonding, here bonds are formed between the NH group of a peptide in one chain and C=O group of a neighboring chain.

b. Anti-parallel pleated sheet:
   - In this type of structure the polypeptide chain lies in opposite directions so that the N-terminal end of one and the C-terminal of the other, face each other.
   - In this structure the polypeptide chains are held together by hydrogen bonds, so as to give a sheet like structure and hence are called as β – pleated sheet conformation.



f. Explain routinely performed tests to assess the functions of the kidney.

Ans: The kidney function tests may be divided into four groups.

1. **Glomerular function tests:**
   All the clearance tests (inulin, creatinine, and urea) are included in this group.
2. **Tubular function tests:**
   Urine concentration or dilution test, urine acidification test.
3. **Analysis of blood/serum:**
   Estimation of blood urea, serum creatinine, protein and electrolyte are often useful to assess renal function.

4. **Urine examination:**
   Simple routine examination of urine for volume, pH, specific gravity, osmolality and presence of certain abnormal constituents (proteins, blood, ketone bodies, glucose, etc.) also helps to assess kidney functioning.
5. **The clearance tests**
   The clearance tests, measuring the glomerular filtration rate (GFR) are the most useful in assessing the renal function.
   Clearance, in general, is defined as the volume of plasma that would be completely cleared of a substance per minute.
6. **Creatinine clearance test:**
   Creatinine is an excretory product derived from creatine phosphate (largely present in muscle).
   Creatinine clearance may be defined as the volume (ml) of plasma that would be completely cleared of creatinine per minute.
   Creatinine concentration in urine and plasma should be expressed in the units as mg/dl or mmol/l.
   Reference values: The normal range of creatinine clearance is around **120–145 ml/min**.
   These values are slightly lower in women.
   Diagnostic importance:
   A decrease in creatinine clearance value (<75% normal) serves as a sensitive indicator of a decreased GFR, due to renal damage.
   This test is useful for an early detection of impairment in kidney function, often before the clinical manifestations are seen.
7. **Urea clearance test:**
   - Urea is the end product of protein metabolism.
   - After being filtered by the glomeruli, it is partially reabsorbed by the renal tubules.
   - Hence, urea clearance is less than the GFR and, further, it is influenced by the protein content of the diet.
   - For these reasons, urea clearance is not as sensitive as creatinine clearance for assessing renal function.

A. Diagnostic importance:
- A urea clearance value below 75% of the normal is viewed seriously, since it is an indicator of renal damage.
- Blood urea level as such is found to increase only when the clearance falls below 50% normal.

B. Urine concentration test:
- This is a test to assess the renal tubular function.

- It is a simple test and involves the accurate measurement of specific gravity which depends on the concentration of solutes in urine.
- A specific gravity of 1.020 in the early morning urine sample is considered to be normal.
- Several measures are employed to concentrate urine and measure the specific gravity.
- These include overnight water deprivation and administration of antidiuretic hormone.
- If the specific gravity of urine is above 1.020 for at least one of the samples collected, the tubular function is considered to be normal.

C. Analysis of blood or serum:

- Estimation of serum creatinine and blood urea are often used to assess the overall kidney function, although these tests are less sensitive than the clearance tests.
- Serum creatinine is a better indicator than urea in this regard.

D. Urine examination:

- The routine urine examination is a guiding factor for renal function.
- The volume of urine excreted, its pH, specific gravity, osmolality, the concentration of abnormal constituents (such as proteins, ketone bodies, glucose and blood) may help to have some preliminary knowledge of kidney function.

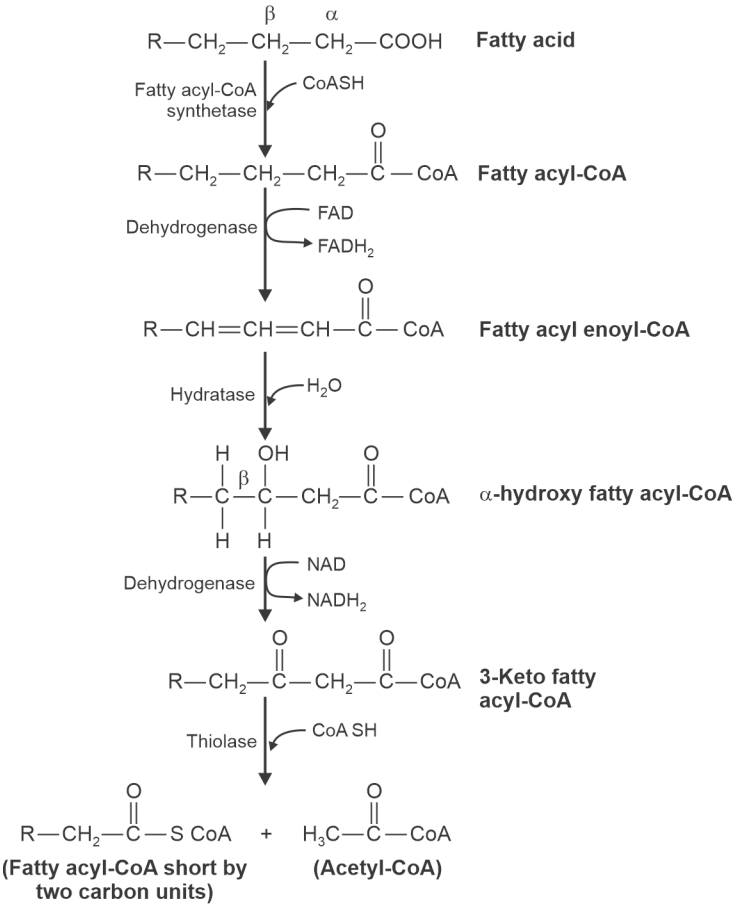
g. Discuss in brief about β-oxidation of fatty acids.

Ans: β-oxidation of fatty acids

- Beta oxidation is the main pathway used to liberate energy by oxidation of fatty acid.
- It takes place in the beta carbon of fatty acid with removal of 2 carbons at a time from the carboxyl end of the molecule.
- The process repeats itself until the fatty acid with an even number of carbon is completely converted to acetate molecules.
- Fatty acids containing even and odd number of carbon atoms as well as unsaturated fatty acids are oxidised by beta oxidation.
- It takes place in 5 steps in the mitochondria of the liver.

1. ***Activation of fatty acid:***
   - Long chain fatty acid gets activated to fatty acyl CoA in presence of CoASH, thiokinase and ATP
2. ***Desaturation:***
   - Fatty acyl CoA undergoes dehydrogenation in presence of acyl CoA dehydrogenase and FAD to give alpha, beta unsaturated fatty acyl CoA

3. ***Hydration:***
   - Addition of water molecule across the double bond results into formation of beta hydroxy acyl CoA in presence of enoyl CoA hydratase
4. ***Oxidation:***
   - Hydroxyl group of beta hydroxy acyl CoA gets oxidised to keto group forming beta ketoacyl CoA in presence of beta hydroxy acyl CoA dehydrogenase and NAD^+
5. ***Thiolytic cleavage:***
   - Thiolytic cleavage of acyl CoA takes place in presence of Beta keto acyl CoA Thiolase and CoASH.
   - Acyl CoA thus formed contains 2 Carbons less than original acyl CoA which undergoes further oxidation by Beta-oxidation. Acetyl CoA is also formed which enters the TCA cycle.



Q.2. Attempt any TEN of the following: 30 Marks

a. Write biological role, deficiency condition and symptoms of vitamin C.

Ans: Biological role of Vitamin C

1. It is involved in the oxidation-reduction reactions of the cells, since it undergoes reversible oxidation.
2. It is involved in the conversion of folic acid to folinic acid.
3. It is also involved in the hydroxylation of steroids in the adrenal cortex.
4. It is required in the metabolism of tyrosine, phenylalanine and tryptophan.
5. It is required for the absorption of iron and incorporation of plasma iron in ferritin.
6. It is involved in the formation of nor-epinephrine.
7. It requires in the normal regulation of the colloidal conditions of fibrils and collagen of connective tissues, osteoid tissues, dentine etc.
8. It is required for the hydroxylation of proline and hydroxyproline.

Deficiency condition of Vitamin C: Scurvy.

Symptoms of Vitamin C deficiency:

1. Weakness, fatigue, restlessness, shortness of breath, anemia and susceptibility to infection.
2. Pain in the bones, joints, muscles of the extremities, swelling of long bones.
3. Loosening of the teeth, gums become swollen, blue red, spongy, bleeding from gums.
4. Poor healing of wounds, internal haemorrhage, etc.

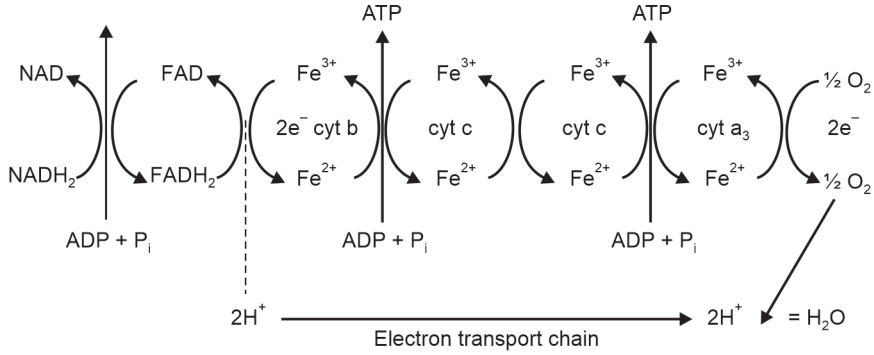
b. Explain the process of ETC.

Ans: The respiration chain or electron transport chain (ETC):

1. During biological oxidation of substances, like carbohydrates, fatty acids and amino acids, most of the energy is evolved which is trapped in the form of ATP.
   Thus, ETC principally takes place in biological oxidation and oxidative phosphorylation.
2. The sequence of enzymes and carriers responsible for the transport of reducing equivalents from substrate to molecular oxygen is described as the respiratory chain.
3. It takes place in mitochondria and the energy formed is also stored there itself in the form of ATP.
4. The mitochondria contain a series of catalysts which are concerned with transport of reducing equivalents, i.e. hydrogen and electrons and with their final reaction with oxygen to form water.

5. In the respiratory chain the electrons flow from more electronegative components to more electropositive oxygen. Thus, the redox potential of a component of a chain gives the information regarding position in the chain.
6. The respiratory chain in the mitochondria starts from the NAD-linked dehydrogenase system on one side through flavoproteins and cytochromes to molecular oxygen on the other side. The reducing equivalents are either as H^+ or covalent hydrogen.
7. One additional carrier is present in between flavoproteins and cytochrome b which is called cytochrome-b is said to be 'ubiquinone' or 'Co-Q. Among the various cytochromes, Cytochrome b has the lowest redox potential.
8. The cytochromes are arranged in order of increasing redox potential. The terminal cytochrome a3 is responsible for the final combination of reducing equivalent with molecular oxygen to form water.
9. At the electronegative end of the chain, dehydrogenase enzymes catalyze the transfer of electrons from the substrate to NAD of the chain. The reduced NAD is oxidized by the metallo flavoprotein enzyme - NADH dehydrogenase, with FMN as 'prosthetic group'.

The major components of respiratory chain are arranged in order of increasing redox potential as shown below:



c. What are abnormalities of red cells? Explain.

Ans: Abnormalities of red cells

1. Anaemia: Pernicious anaemia, sickle cell anaemia, megaloblastic anemia, iron-deficiency anemia, aplastic anemia, haemorrhagic anaemia, hemolytic anemia.
2. Polycythemia.

1. **Anaemia:** Anaemia is a condition in which the oxygen-carrying capacity of blood is reduced. Anaemia is characterized by decreased number of RBCs or decreased concentration of haemoglobin. Loss of haemoglobin or RBCs or both causes anemia. The symptoms are fatigue intolerance to cold, breathlessness, loss of appetite, pale skin.

   Types of anaemia:

   i. **Pernicious anaemia:** Inability of the stomach to produce intrinsic factor which is required for absorption of vitamin B_{12} in the small intestine leads to insufficient hemopoiesis and this condition is called pernicious anaemia.

   ii. **Sickle cell anaemia:** It is also called sickle cell disease or haemoglobinopathic haemolytic anaemia. In this disease, the bone marrow produces an abnormal type of haemoglobin, i.e. "S" type and forms sickle or crescent shaped cells (i.e. C shaped) when subjected to lowered oxygen concentrations. The sickle cells do not pass through the small blood capillaries readily and may block the blood supply to vital organs. Patients with sickle cell disease show a marked susceptibility to infections.

   iii. **Megaloblastic anaemia:** It is caused due to inadequate intake of vitamin B_{12} or folic acid. The red bone marrow produces large, abnormal red blood cells called megaloblasts. It may be caused due to some drugs which are used in the treatment of cancer.

   iv. **Iron-deficiency anemia:** It is caused by inadequate absorption of iron, excessive loss of iron, increased iron requirement, or insufficient intake of iron. Women are at higher risk for this type of anaemia due to menstrual blood loss and increased iron demand during pregnancy.

   v. **Aplastic anaemia:** Destruction of red bone marrow results in a condition called aplastic anaemia. It can be caused due to gamma radiation, toxins and some medications that inhibit enzymes required for haemopoiesis.

   vi. **Haemorrhagic anaemia:** Bleeding due to large wounds, stomach ulcers or heavy menstruation leads to excessive loss of RBCs. This condition is called haemorrhagic anaemia.

   vii. **Hemolytic anaemia:** In hemolytic anaemia, RBC plasma membranes rupture prematurely and the haemoglobin in RBCS is released in plasma which may damage glomeruli in kidneys.

2. **Polycythemia:**

   When concentration of red blood cells increases abnormally, usually with corresponding increase in haemoglobin level, the condition is called polycythemia. Polycythemia can be classified into two classes' relative and absolute polycythemia.

d. What are lipids? Classify them with suitable examples.

Ans: **Lipids:** Lipids are a heterogeneous group of compounds which are esters of fatty acids relatively insoluble in water but freely soluble in organic solvents like ether, chloroform, alcohol.

Classification of lipids:

Lipids are classified as follows:

1. Simple lipids:
   (i) Fats and oils
   (ii) Waxes

2. Compound lipids:
   (i) Phospholipids, e.g., lecithins, cephalins, plasmalogens, etc.
   (ii) Glycolipids, e.g. cerebrosides, gangliosides.
   (iii) Other compound lipids, e.g. lipoproteins, sulpholipids, amino-lipids, etc.

3. Derived lipids, e.g. fatty acids, glycerols, sterols, sex hormones, prostaglandins, sphingolipids, etc.

e. Discuss the functions, deficiency and recommended dietary requirement of calcium.

Ans: **Functions of calcium:**

1. Calcium and phosphorus are essential for formation and development of bones and teeth.
2. Ionized calcium is required in the blood coagulation process.
3. It regulates the excitability of nerve fibres and nerve centres.
4. Responsible for transmission of nerve impulse.
5. It is essential for muscular contraction.
6. It regulates permeability of membranes.
7. It is required for activation of several enzymes like succinate dehydrogenase, ATPase, and certain proteolytic enzymes.

Deficiency diseases of calcium: Hypoparathyroidism, tetany, rickets, osteoporosis, renal rickets, etc.

Recommended Daily Requirements of Calcium:

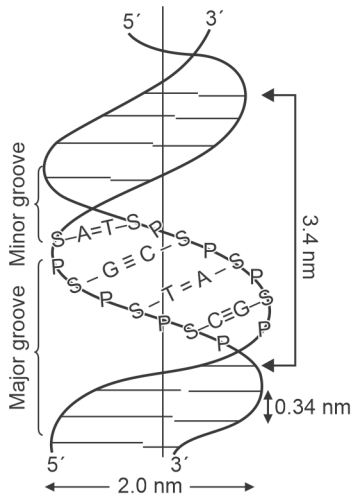
1. Adult males and females: 800 mg per day.
2. Women during pregnancy and lactation: 1.2 g per day.
3. Children 1–18 years: 0.8–1.2 g per day. Infants under 1 year: 360–540 mg per day.

f. Explain structure and functions of DNA.

Ans: **Structure of DNA (Watson and Crick Model):**

- DNA is a double-stranded molecule.
- It is made of two helical chains or strands that are spirally coiled around a common axis to form a right-handed double helix like a twisted ladder.
- Each strand has two ends; 5' end with a phosphate group and 3' end with a hydroxyl group. The DNA strands run in opposite directions which means the 5' end of one chain and 3' end of another chain are on the same side, so they are anti-parallel to each other.
- The diameter of DNA is uniform and is around 2 nm.
- The distance between each turn or the length of each spiral turn is 3.6 nm (earlier 3.4 nm).
- The distance between base pairs or two successive rings is 0.34 nm.
- There are 10.5 nucleotides per turn or in one complete spiral turn or one complete rotation of 360 degrees (earlier 10 nucleotides).
- The alternating deoxyribose sugar and phosphate groups are located on the outside of the double helix. So, it makes the backbone of the helix.

  The spiral arrangement of chains creates major and minor grooves between the two chains or strands. The major groove is large, whereas the minor groove is small.
- Each DNA strand consists of a long sequence of four bases that include adenine (A), cytosine (C), guanosine (G) and thymine (T). The bases on one strand are bonded or paired with the complementary bases on the opposite strand.
- The alternating deoxyribose sugar and phosphate groups are located on the outside of the double helix. So, it makes the backbone of the helix.
- The pyrimidine (thymine and cytosine) and purine (adenine and guanine) bases are located inside the double helix.
- A specific purine base is bonded or made pair with a specific pyrimidine base through hydrogen bonds. For example, adenine (A) pairs with thymine (T) and guanine (G) pairs with cytosine (C).
- Adenine and thymine are joined through two hydrogen bonds (A=T), whereas, guanine and cytosine are joined through three hydrogen bonds (G≡C).
- The double helix structure is stabilized by hydrogen bonds that are formed between purine and pyrimidine bases.



Watson-Crick model of DNA helix

Functions of DNA:

1. **Genetic information:** DNA is the genetic material. It carries all hereditary information, coded in the arrangement of its nitrogen bases.
2. **Replication:** DNA has a unique property of replication through which genetic information is transferred to one cell to its daughters and from one generation to the next.
3. **Chromosomes:** DNA occurs inside chromosomes, essential for equitable distribution of DNA during cell division.
4. **Recombination:** During meiosis, crossing over gives rise to new combinations of genes called recombinations.
5. **Mutations:** Changes in sequence of nitrogen bases due to addition, deletion or wrong replication give rise to mutations which are responsible for variations and formation of new species.
6. **Transcription:** DNA gives rise to RNAs through the process of transcription.
7. **Cellular metabolism:** Cellular metabolism in a cell is controlled through the help of specific RNAs, synthesis of specific proteins, enzymes and hormones.
8. **Differentiation**: Due to differential functioning of some specific regions of DNA or genes, different parts of organisms get differentiated in shape, size and functions.
9. **Development:** DNA controls development of an organism through working of an internal genetic clock with or without the help of extrinsic information.

g. Define dehydration. Explain causes, symptoms and treatment of dehydration.

Ans: **Dehydration:** It is a condition characterized by water depletion in the body. It may be due to loss of water alone or due to deprivation of water and electrolytes.

Causes of dehydration:

1. Non-availability of water in certain areas.
2. Difficulty in swallowing, unconsciousness and impairment of the sensation of thirst.
3. Diabetes insipidus and diabetes mellitus conditions.
4. Chronic nephritis due to inability of tubule to concentrate urine.
5. Severe diarrhoea and vomitting.
6. Excessive sweating and loss of fluids from skin in burns.
7. Excessive loss of water through respiration on prolonged exposure to sun.

Symptoms of dehydration:

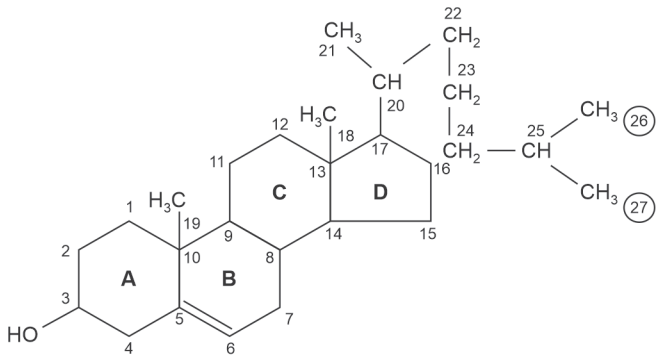
1. Feeling thirsty, dark yellow and strong smelling pee.
2. Feeling dizzy or lightheaded.
3. Feeling tired.
4. A dry mouth, lips and eyes.
5. Peeling little, and fewer than 4 times a day.
6. Increased pulse rate.

Treatment of dehydration:

1. Intake of plenty of water. If a person cannot take orally water, be given intravenously in an isotonic solution (5% glucose).
2. If dehydration is due to loss of electrolytes, then electrolytes can be given orally or intravenously. **ORS (oral rehydration solution/ salts)** is a type of fluid replacement used to prevent or treat dehydration especially that is due to diarrhoea.
3. The oral rehydration therapy involves drinking water with modest amounts of sugar and salt added. Mild-to-moderate dehydration in children is best treated with ORT.
4. Persons taking ORT should eat within 6 hours and return to their full diet within 24–48 hours.

h. Draw the structure of cholesterol and give functions of it.

Ans: **Structure of cholesterol:**



Functions of cholesterol:

1. It is a structural component of cell membrane, e.g. red blood cells and in myelinated nerve cells.
2. It is an essential ingredient in the structure of lipoprotein.
3. It plays an essential role in secretion of several other vital enzymes and hormones including aldosterone, cortisol, estrogen, cortisone, progesterone, testosterone etc.
4. It plays an important role in the synthesis of vitamin-D_3 which I responsible for proper bone calcification.
5. It acts as a precursor to fat-soluble vitamins A, D, E, K.
6. It regulates membrane fluidity over the range of physiological temperatures.
7. It is also helpful in the healing process after a surgery.
8. It helps in maintenance of our body temperature and protects our internal organs.
9. In pharmaceutical industries, cholesterol is used in the manufacture of steroid hormones and vitamin D.
10. It is a poor conductor of heat and electricity and serves as an insulator. In the brain, where it is present abundantly, it acts as an insulator against nerve impulses which are electric in nature.
11. Cholesterol, when oxidized under suitable conditions, undergoes rapid oxidation to form a ketone called cholestenone.
12. The hydroxyl group of cholesterol readily forms ester with fatty acids like stearic acid.

i. Enlist different abnormal constituents of urine.

Ans: Abnormal constituents of urine:

1. Proteins (albumin, glycoproteins, globulins)
2. Blood (RBCs, haemoglobin, myoglobin)
3. Glucose and other sugars (e.g, galactose, lactose, fructose, pentose, maltose, etc.)

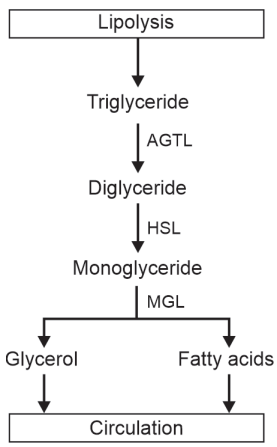
4. Ketone bodies (e.g. acetone, acetoacetate, beta hydroxybutyric acid)
5. Bile pigment (bilirubin and urobilinogen)
6. Bile salts.
7. WBCs/pus cells
8. Cast (granular, hyaline, cellular and epithelial cast)
9. Bacterial microbes in urine
10. Yeast cells/parasites
11. Crystals (amorphous urates, uric acid crystals, amorphous phosphates, amorphous carbonates, calcium oxalate, etc.)
12. Porphyrins
13. Proteose.

j. Discuss in detail about lipolysis.

Ans: Lipolysis:

1. Chemically lipids are esters of glycerol and fatty acids. During metabolism, lipids are broken down with the process called lipolysis.
2. Triglycerides stored in adipose tissue are degraded when there is stress or in energy deficient conditions like starvation or diabetes. It happens through the process of breakdown of lipids called lipolysis.
3. Hormone sensitive lipase present in adipose tissue converts triglycerides to di- or mono triglycerides and fatty acids. Additional di- or monoglyceride lipase converts mono- or diglyceride to free fatty acids and glycerol.
4. The free fatty acids are released into circulation. They reach other tissues after combining with plasma albumin. Most of them are used for energy production in peripheral tissues. Liver converts them into ketone bodies. The glycerol is released into circulation; Glucose is formed from glycerol in the liver.

Process of lipolysis is shown below:



k. What is the clinical significance of lipid profile?

Ans: Clinical Significance of Lipid Profiles:

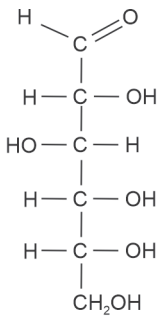
Primary prevention recommendations for adults aged between 40 and 75 years old with an LDL level of 70–189 mg/dL.

1. High levels of low-density lipoprotein-cholesterol (LDL-C) and low levels of high-density lipoprotein cholesterol (HDL-C) are risk factors for atherosclerosis, heart attack, stroke and coronary heart disease.
2. Large clinical trials have shown that lowering LDL-C levels significantly reduces cardiovascular events and mortality rate.
3. Increased plasma lipoproteins is known as hyperlipoproteinemia and decreased plasma lipoproteins is known as hypolipoproteinemia.
4. Excess triglycerides can increase the likelihood of heart attack, stroke and obesity.
5. The cholesterol/HDL ratio is used to help to calculate a person's risk of heart attack or stroke.
6. Excessive total cholesterol causes health problems like heart diseases.

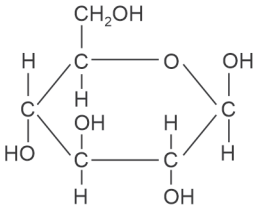
Q.3. Attempt ALL questions of the following. 20 Marks

a. Draw the structure of glucose.

Ans: Glucose



OR



b. Write any two functions of RNA.

Ans:

- The primary function of RNA is to create proteins via translation.
- RNA carries genetic information that is translated by ribosomes into various proteins necessary for cellular processes.
- mRNA, rRNA, and tRNA are the three main types of RNA involved in protein synthesis.
- mRNA is a direct carrier of genetic information from the nucleus to the cytoplasm.
- Usually molecule of mRNA contains information required for the formation of one protein molecule.
- t-RNA is the carrier of amino acid to the site of protein synthesis.
- r-RNAs are required for the formation of ribosomes.

c. Name any two sulphur containing amino acids.

Ans: Methionine and cysteine

d. Give two pharmaceutical applications of enzymes.

Ans:

- Rennin is used for cheese preparation
- Glucose isomerase is used for production of syrup
- Alpha amylase is used in food industry to convert starch to glucose
- Penicillin acylase is used for production of 6- aminopenicillanic acid
- Papain, pepsin and trypsin are used in preparation of digestants.
- The action of certain drugs depend upon the enzyme inhibition.
- Antimetabolites have been prepared on the basis of competitive inhibition.
- Sulphanilamide because of its similarity with PABA competes with it and inhibits enzyme folic acid synthase and selectively kills pathogenic organisms.
- Xanthine oxidase enzyme is involved in conversion of xanthine and hypoxanthine to uric acid. Allopurinol acts as a competitive inhibitor of xanthine and reduces its conversion to uric acid. So it is useful in treatment of gout.

e. Write any two functions of lymphocytes.

Ans:

- The main function of lymphocytes is that they serve as part of the immune system.
- They produce specific antibodies.
- This helps in providing protection against infectious diseases.
- The T- lymphocytes help in cell-mediated response while the humoral immunity is provided by B-lymphocytes.

f. The chemical name of vitamin D is_____.

Ans: Calciferol

g. Define biotechnology.

Ans: Biotechnology is defined as utilization of organisms or its organelles or biological processes to make products or to solve problems for the welfare of mankind.

h. Coenzyme form of vitamin riboflavin is_____.

Ans: Flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD).

i. Name the site for protein synthesis in the cell.

Ans: Ribosomes.

j. Write deficiency diseases of vitamin thiamine.

Ans: Beriberi

k. The extracellular fluid comprises_____.

(i) Tissues/cells (ii) Plasma
(iii) Plasma and interstitial fluid (iv) Intertitital

Ans: (iii) Plasma and interstitial fluid

l. Synthesis of cholesterol and steroid is the function of_____

(i) Nucleus (ii) Golgi complex
(iii) Endoplasmic reticulum (iv) Peroxisomes

Ans: (iii) Endoplasmic reticulum

m. The nitrogen base found in RNA but not in DNA is_____

Ans: Uracil

n. The protein part of holoenzyme is known as_____

(i) Active site (ii) Allosteric site
(iii) Co-enzyme (iv) Apoenzyme

Ans: (iv) Apoenzyme

o. Where does oxidative phosphorylation take place?

Ans: Mitochondria

p. Body water is regulated by the hormone_____

(i) ADH (ii) ACTH (iii) FSH (iv) Epinephrine

Ans: (i) ADH

q. Biotechnology has made contribution in which areas_____

(i) Medicine (ii) Industrial (iii) Environmental (iv) All of these

Ans: (iv) All of these

r. Give significance to the SGPT test.

Ans: The test is primarily used to diagnose liver disease, to monitor the course of treatment for hepatitis, cirrhosis, and the effect of drug therapy.

s. Write full form of ECF and ICF.

Ans: **ECF**- Extracellular fluid
ICF- Intracellular fluid

t. Rothera's test is for detection of _____ in the urine.

Ans: Ketone bodies.

Winter Examination 2023 (Question Paper)
Second Year Diploma in Pharmacy
Subject: Biochemistry and Clinical Pathology (20223)

Time: 3 Hours **Max Marks: 80**

Q.1. Answer any SIX of the following: **30 Marks**

a. Explain the various structural levels of proteins.
b. Discuss the pathway for the conversion of glucose to pyruvate.
c. Explain the mechanism of action of enzymes with various theories.
d. Explain Krebs cycle.
e. What is dehydration? What are the causes of dehydration? Write a note on ORS.
f. Enlist various functions of the liver. What are the routinely performed tests for assessing the functions of the liver?
g. Define lipids. Write about the structure and functions of cholesterol in the body. Enlist any two properties of triglycerides.

Q.2. Answer any TEN of the following: **30 Marks**

a. Draw structure of any three reducing monosaccharides.
b. Define carbohydrates. Classify them.
c. What are nucleosides and nucleotides?
d. Enlist factors affecting enzyme action.
e. Explain ETC chain.
f. Write the functions of calcium and its deficiency diseases.
g. Which pathological conditions are observed due to abnormal constituents in urine?
h. Discuss glycogenesis.
i. What is lymphocytosis, lymphocytopoenia and phenylketonuria?
j. Write the functions of any three fat-soluble vitamins.
k. Discuss diseases related to abnormal carbohydrate metabolism.

Q.3. Answer ALL questions of the following. **20 Marks**

a. Define anemia.
b. Which of the following is a sulphur containing amino acid?
(i) Alanine (ii) Glycine (iii) Methoinine (iv) Valine

c. Enlist any two routinely performed kidney function tests.
d. Name any two lipid profile tests.
e. What are the coenzymes of riboflavin and nicotinic acid?
f. Which of the following diseases is caused by the deficiency of niacin?
(i) Scruvy (ii) Rickets (iii) Pellagra (iv) Pernicious anemia
g. Explain fatty liver.
h. Alkaptonuria is a disease related to_____.
i. Define essential amino acids.
j. When glucose reacts with bromine water it forms_____.
(i) Glutaric acid (ii) Glyceraldehyde
(iii) Saccharic acid (iv) Gluconic acid
k. Name any two diseases due to malnutrition of proteins.
l. Which of the following is essential fatty acids has three double bonds?
(i) Linolenic acid (ii) Arachidonic acid
(iii) Linolenic acid (iv) Clupanodonic acid
m. Stearic acid has _____carbon atoms.
n. Name of vitamin A is_____.
o. Hypercholesterolemia is caused due to_____.
p. Write full form of SGOT and SGPT.
q. Jaundice is a symptom of disease. True or False.
r. What is the significance of BUN?
s. Chloride and bicarbonate ions occur predominantly in_____.
t. Identify the purine base of nucleic acids in the following:
(i) Cytosine (ii) Thymine (iii) Uracil (iv) Adenine

Winter Examination 2023 (Specimen Answer Paper)
Second Year Diploma in Pharmacy
Subject: Biochemistry and Clinical Pathology (20223)

Time: 3 Hours **Max Marks: 80**

Q.1. Answer any SIX of the following: **30 Marks**

a. Explain the various structural levels of proteins.

Ans: The various structural levels of proteins are-

Primary structure: Linear sequence of amino acids forming the back-bone of proteins (polypeptides).

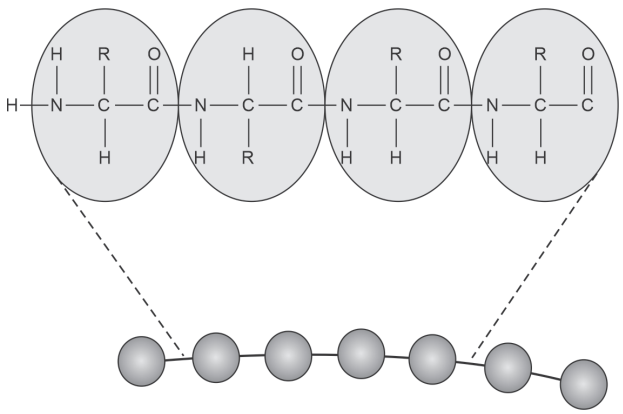
Secondary structure: Spatial arrangement of proteins by twisting of polypeptide chains.

Tertiary structure: 3-dimensional structures.

Quaternary structure: Some proteins are composed of 2 or more polypeptide chains called subunits. The spatial arrangement of these subunits is a quaternary structure.

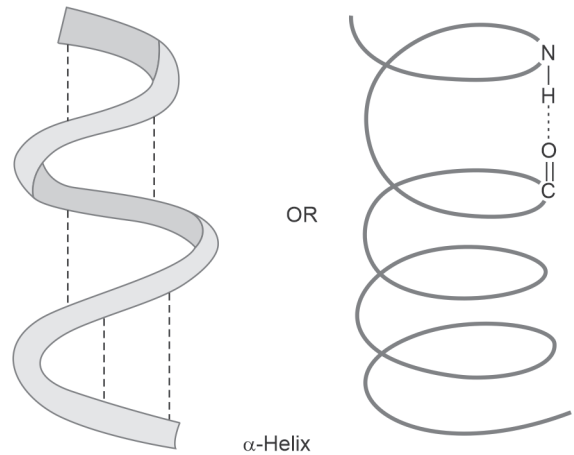
Primary structure:

- It is a straight chain structure.
  The 'N' terminal amino acid, i.e. amino acid with free amino group is always on the left end of the polypeptide chain and the 'C' terminal amino acid, i.e. amino acid with free –COOH group is at the right end of the chain.



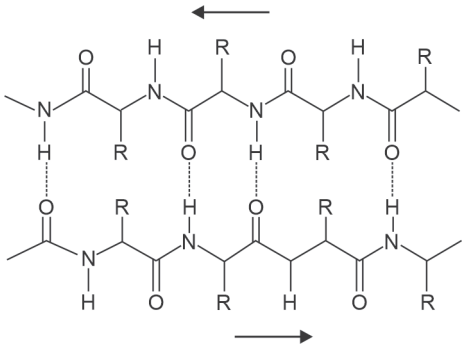
Secondary structure:

- Disulphide bridges and hydrogen bonds are formed.
- As a result the primary chain acquires a characteristic folding or twisting.
- In secondary structure different types of arrangements are seen:
- Alpha helix and Beta pleated sheet (parallel or anti-parallel) alpha helix:
- The peptide chain forms regular helical coils.
- In this form there are 3.6 amino acid residues per complete turn.
- The structure is stabilized by intra-molecular hydrogen bonding in such a way that the –NH group of one amino acid comes into close proximity to the –CO group of the fourth amino acid residue in the peptide chain.
- Although hydrogen bonds are fairly weak, a large number of bonds involved maintain a stable structure.
- All peptide bonds except first and last, participate in hydrogen bonding.



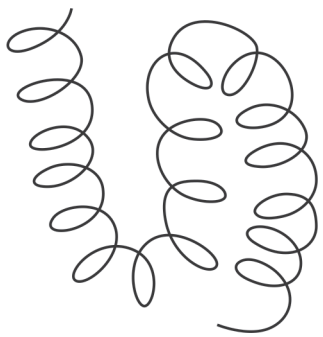
Beta-pleated sheet:

- It is another form of secondary structure. This results from hydrogen bonding between two peptide chains.
- The chains may be parallel or anti-parallel.
- In a parallel beta pleated sheet 'N' atoms point in the same direction while in anti-parallel sheet alternate chains are oriented in the same direction.



Tertiary structure:

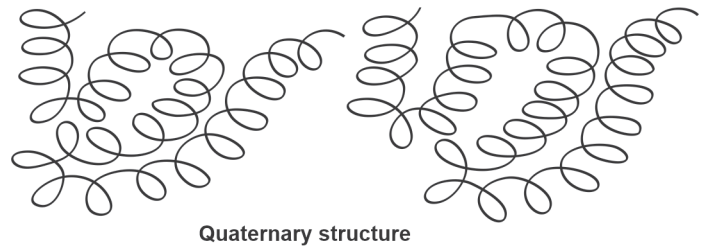
- Polypeptide chains may undergo coiling and folding to produce tertiary structure. The secondary structure will take on 3-dimensional shape in which there is folding, looping and binding of the chains in such a way as to expose most polar groups to the surface and most non-polar groups to the interior.
- The shape may be ellipsoid or a globe or any irregular shape. The shape is determined by forces like hydrogen bonds, disulphide bridges, hydrophobic and electrostatic bonds.



Tertiary structure

Quaternary structure:

- There is association of two or more polypeptide chains.
- Association is due to hydrophobic interactions, hydrogen bonds and electrostatic bonds.
- Protein like hemoglobin exhibits quaternary structure.
- If protein consists of identical units it is said to have homogenous quaternary structure otherwise heterogeneous quaternary structure.



Quaternary structure

b. Discuss the pathway for the conversion of glucose to pyruvate.

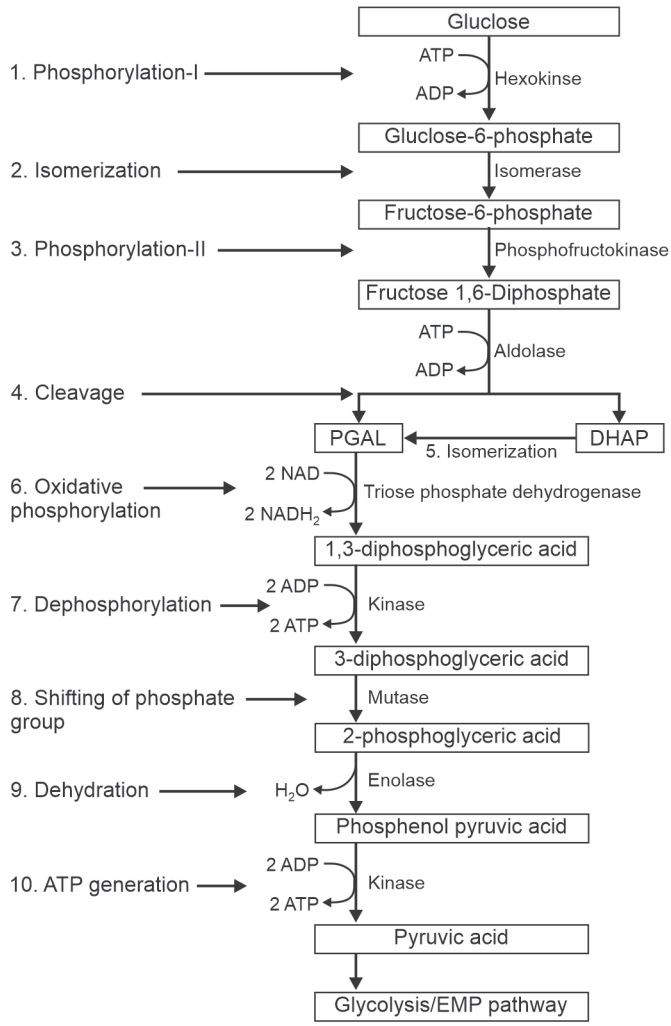
Ans: Glycolysis (Embden-Meyerhof Pathway) (E.M. Pathway)

- Glycolysis is defined as the sequence of reactions converting glucose (or glycogen) to pyruvate or lactate, with the production of ATP.
- It takes place in all cells of the body.
- The enzymes of this pathway are present in the cytosomal fraction of the cell.
- It occurs in absence of oxygen (anaerobic) or in the presence of oxygen (aerobic). Lactate is the end product under anaerobic condition. In aerobic condition, pyruvate is formed which is then oxidized to CO_2 and H_2O.

Various steps of the pathway are:

1. Phosphorylation of glucose to glucose 6-phosphate in presence of enzyme hexokinase and ATP and Mg.
2. Isomerisation of Glucose 6-phosphate to fructose 6-phosphate in presence of phosphohexose isomerase.
3. Phosphorylation of fructose 6-phosphate to fructose 1, 6-diphosphate in presence of phosphofructokinase, ATP and Mg.
4. Cleavage of fructose 1, 6-diphosphate to dihydroxyacetone phosphate and glyceraldehyde 3- phosphate in presence of aldolase. These 2 products are interconvertible in presence of triose phosphate isomerase.
5. Glyceraldehyde 3-phosphate further undergoes oxidation to 1, 3-diphosphoglycerate in presence of glyceraldehyde 3- phosphate dehydrogenase and NAD+.
6. Transformation of 1, 3-diphosphoglycerate to 3-phosphoglycerate in presence of phosphoglycerate kinase, Mg and ADP.
7. 3-phosphoglycerate changes to 2-phosphoglycerate in presence of phosphoglycerate mutase.
8. Loss of water molecules from 2-phosphoglycerate results in the formation of phosphoenol pyruvic acid in presence of enolase.

9. Loss of phosphate from phosphoenol pyruvic acid results in formation of enol pyruvic acid in presence of pyruvate kinase, Mg and ADP.
10. Enol pyruvic acid gets converted to keto form of pyruvic acid in presence of pyruvate kinase.
11. Keto pyruvic acid under aerobic conditions enters the TCA cycle in mitochondria. Pyruvic acid forms the main end product of glycolysis in those tissues which are supplied with sufficient oxygen.



Net reaction for glycolysis is:

Glucose + NAD^+ + 2 ADP + 2 Pi → 2 pyruvate + 2 ATP + 2 NADH + 2 H_2O

c. Explain the mechanism of action of enzymes with various theories.

Ans: Mechanism of action of enzymes

- Catalysis is the prime function of enzymes.
- The nature of catalysis taking place in the biological system is similar to that of non-biological catalysis.
- The enzyme lowers the energy barrier of reactants, thereby making the reaction go faster.
- The enzymes reduce the activation energy of the reactants in such a way that all the biological reactions occur at body temperature (<40°C).
- The prior requirement for enzyme catalysts is that the substrate[S] must combine with the enzyme[E] at the active site to form enzyme substrate complex [ES] which ultimately results in the product formation[P].

$$[E] + [S] \rightarrow [ES] \rightarrow [E] + [P]$$

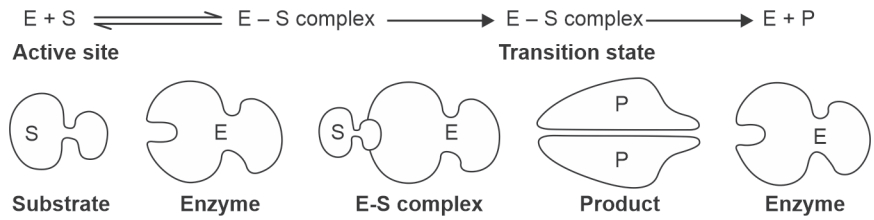
Some theories have been postulated to explain the mechanism of enzymes.

Lock and Key Model (Fischer's Template Theory)

- Shape of the active site and that of the substrate is complementary to each other.
- Based on its fitting it is called the Lock and Key model.
- According to this model, the structure of the enzyme is rigid.
- The substrate fits to the binding site (active site) just as a key fits into the proper lock.
- Thus the active site of an enzyme is a rigid and pre-shaped template where only a specific substrate can bind.

Lock and Key Model

• Mechanism

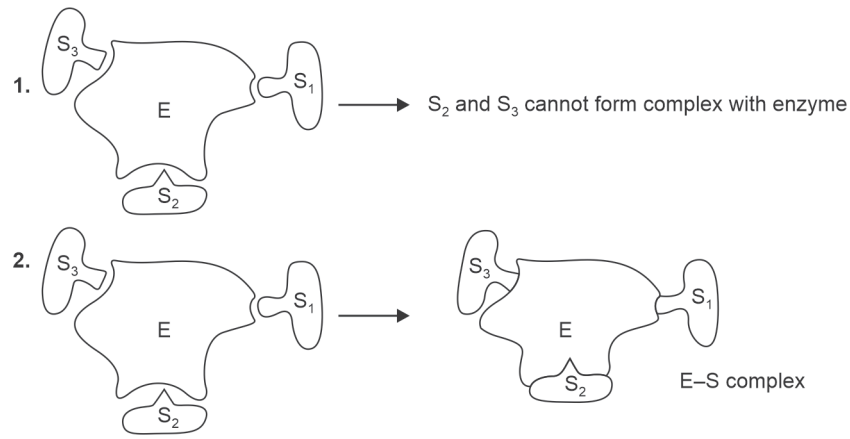


Induced Fit Theory or Koshland's Model

- Active site of enzymes is considerably flexible to accommodate a wide variety of substrate molecules.

- Shape of the active site is made complementary to the substrate to a certain extent.
- The interaction of the substrate with the enzyme induces a fit or a conformational change in the enzyme, resulting in the formation of a strong substrate binding site.

Induced Fit Model



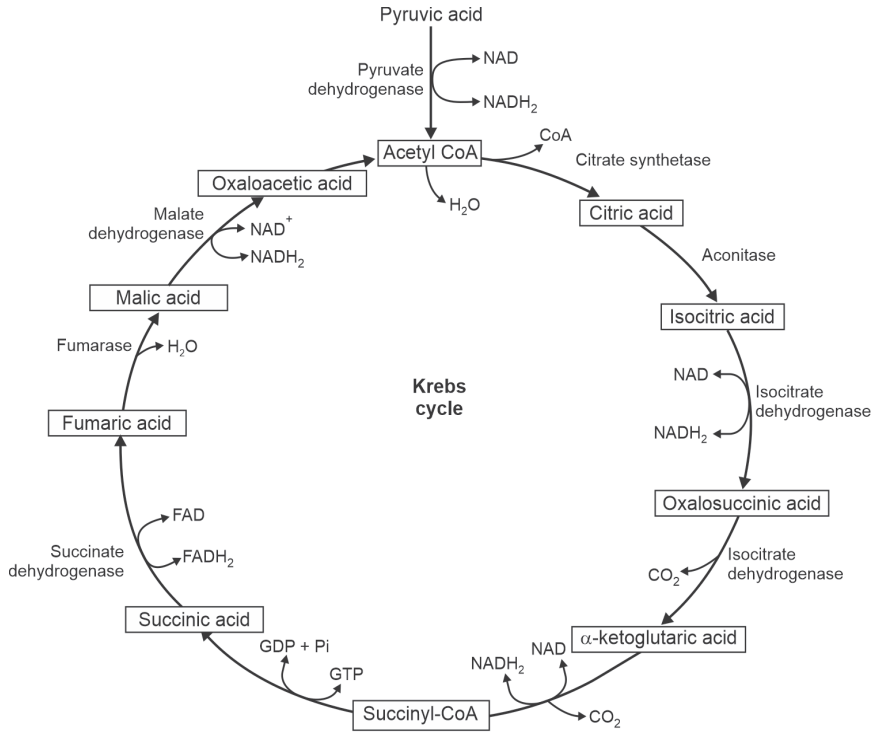
d. Explain Krebs' cycle.

Ans: Tricarboxylic acid cycle (TCA Cycle)/Krebs' cycle:

It is a central pathway for release of energy from acetyl CoA which is produced from glycolysis, catabolism of fatty acids or amino acids.

1. Condensation of acetyl CoA obtained from pyruvic acid/pyruvate with oxaloacetate to form citric acid in presence of citrate synthase.
2. Conversion of citric acid/citrate to cis aconitate in presence of aconitase and Fe^{2+}.Cis aconitic acid/aconitate accepts water to give isocitric acid/isocitrate in presence of aconitase and Fe^{2+}.
3. Isocitric acid/isocitrate undergoes oxidation in presence of isocitrate dehydrogenase and NAD^+ to give Oxalosuccinic acid/oxalosuccinate.
4. Decarboxylation of oxalosuccinic acid/oxalosuccinate to alpha ketoglutaric acid/alpha ketoglutarate in presence of isocitric acid dehydrogenase, Mg/ Mn.
5. Oxidative decarboxylation of alpha ketoglutaric acid/alpha ketoglutarate to succinyl CoA in presence of alpha ketoglutarate dehydrogenase, CoA-SH, NAD^+, Mg.

6. Succinyl CoA gets converted to succinic acid/succinate in presence of succinaten thiokinase/succinyl CoA synthetase, GDP, Mg.
7. Succinic acid/succinate undergoes dehydrogenation in presence of succinate dehydrogenase, FAD^+ to form fumaric acid/fumarate.
8. Fumaric acid/fumarate takes up water molecules in presence of fumarase to form maleic acid/malate.
9. Maleic acid/malate undergoes oxidation in presence of malate dehydrogenase, NAD^+ to form oxaloacetic acid/oxaloacetate.
10. Cycle gets repeated again by the entrance of another molecule of Acetyl CoA.



Krebs' cycle/ TCA cycle

e. What is dehydration? What are the causes of dehydration? Write a note on ORS.

Ans: **Dehydration:** It is a condition characterized by water depletion in the body. It may be due to loss of water alone or due to deprivation of water and electrolytes.

Dehydration is generally classified into two types:

1. Due to loss of water alone.
2. Due to deprivation of water and electrolytes.

Causes of dehydration:

1. Non-availability of water in certain areas.
2. Difficulty in swallowing, unconsciousness and impairment of the sensation of thirst.
3. Diabetes insipidus and diabetes mellitus conditions.
4. Chronic nephritis due to inability of tubule to concentrate urine.
5. Severe diarrhoea and vomitting.
6. Excessive sweating and loss of fluids from skin in burns.
7. Excessive loss of water through respiration on prolonged exposure to sun.

Oral Rehydration Salts (ORS)

- Oral rehydration therapy (ORS) is a type of fluid replacement used to prevent and treat dehydration, especially due to diarrhea.
- It involves drinking water with modest amounts of sugar and salts, specifically sodium and potassium.
- Use of oral rehydration Salts has been estimated to decrease the risk of death from diarrhea by up to 93%.
- Mild to moderate dehydration in children seen in an emergency department is best treated with ORS
- Oral rehydration Salts therapy may also be used as a treatment for the symptoms of dehydration and rehydration in burns in resource-limited settings.
- A number of other formulations are also available including versions that can be made at home.
- The recommended formulation includes sodium chloride, sodium citrate, potassium chloride, and glucose.
- Glucose may be replaced by sucrose and sodium citrate may be replaced by sodium bicarbonate, if not available.
- It works as glucose increases the uptake of sodium and thus water by the intestines.
- Sodium and potassium are needed to replace the body losses of these essential ions during diarrhea and vomiting.

f. Enlist various functions of the liver. What are the routinely performed tests for assessing the functions of the liver?

Ans: Functions of liver

1. **Metabolic functions**
   - Liver actively participates in carbohydrate, lipid, protein, mineral and vitamin metabolisms.

- Excretory functions: Bile pigments, bile salts and cholesterol are excreted in the bile into the intestine.

2. **Protective functions and detoxification**
   - Kupffer cells of the liver perform phagocytosis to eliminate foreign compounds. Ammonia is detoxified to urea.
   - Liver is responsible for the metabolism of xenobiotics (detoxification).
3. **Haematological functions**
   Liver participates in the formation of blood (particularly in the embryo), synthesis of plasma proteins (including blood clotting factors) and destruction of erythrocytes.
4. **Storage functions**
   Glycogen, Vitamins A, D, B_{12} and trace element iron are stored in the liver.

Tests to assess liver function

- LFT helps to detect the abnormalities and the extent of liver damage.
- Tests based on excretory functions—measurement of bile pigments, bile salts, bromosulfophthalein.
- Tests based on serum enzymes derived from liver determination of transaminases, alkaline phosphatase, 5'-nucleotidase, γ-glutamyl transpeptidase.
- Tests based on metabolic capacity—galactose tolerance, antipyrine clearance.
- Tests based on synthetic functions—prothrombin time, serum albumin
- Tests based on detoxification—Hippuric acid synthesis.

1. Bilirubin

Bilirubin in Urine

- The conjugated bilirubin, being water soluble, is excreted in urine.
- The bilirubin in urine can be detected by Fouchet's test or Gmelin's test.
- Bilirubin in urine tests measures the levels of bilirubin in your urine. Normally, urine does not have any bilirubin. If there is bilirubin in your urine, it may be an early sign of a liver condition. A positive (+) result of bilirubin in urine (bilirubinuria) is indicative of a liver problem or a bile obstruction.

2. Tests based on serum enzymes from liver

- Liver cells contain several enzymes which may be released into the circulation in liver damage.
- Measurement of selected enzymes in serum is often used to assess liver function.

a. Transaminases or aminotransferases

- The activities of 2 enzymes-serum glutamate pyruvate transaminase (SGPT; recently known as alanine transaminase—ALT) and serum glutamate oxaloacetate transaminase (SGOT; recently known as aspartate transaminase—AST)—are widely used to assess the liver function.
- The activity of these enzymes is low in normal serum (SGPT-5-40 IU/litre; SGOT-5-45 IU/Iitre).

b. Alkaline phosphatase

- Alkaline phosphatase (ALP) is mainly derived from bone and liver.
- A rise in serum ALP (normal 3-13 KA units/dl KING ARMSTRONG), usually associated with elevated serum bilirubin is an indicator of biliary obstruction(obstructive jaundice).
- ALP is also elevated in liver cirrhosis and hepatic tumours.
- Measurement of other serum enzymes like γ-glutamyl transpeptidase (ggt), 5'-nucleotidase, isocitrate dehydrogenase and isoenzymes of lactate dehydrogenase are also useful in LFT.

3. LFT based on serum proteins (albumin)

- Albumin is only synthesized by the liver.
- It is a good marker to assess chronic liver damage.
- Low serum albumin is commonly observed in patients with severe liver damage.
- It must however, be noted that the serum albumin concentration is also decreased due to malnutrition.

4. LFT based on serum proteins (globulin)

- Increased synthesis of Globulins indicates impairment of liver.
- Cirrhosis of the liver is indicated by the reversal of albumin/globulin (A/G) ratio.

5. Galactose tolerance test

- Galactose is a monosaccharide, almost exclusively metabolized by the liver.
- The liver function can be assessed by measuring the utilization of galactose.
- This is referred to as the galactose tolerance test. In normal individuals, the half-life of galactose is about 10–15 minutes.
- This is markedly elevated in infective hepatitis and cirrhosis.

6. Prothrombin time

- The liver synthesizes all the blood clotting factors.
- A decrease in the concentration of plasma clotting factors is found in the impairment of liver function.

- This can be checked by measuring prothrombin time which is prolonged in patients with liver damage compared to normal.
- The half-lives of clotting factors are relatively short (5–72 hrs.), therefore, changes in prothrombin time occur quickly.
- Hence, this test is useful to assess acute as well as chronic liver damage.

7. Hippuric acid synthesis

- The liver is the major site for the metabolism of xenobiotics (detoxification).
- Measurement of hippuric acid synthesis is an ideal test for assessing the detoxification function of the liver.

Choice of liver functions tests:

The choice of biochemical test to measure liver functions mostly depends on the purpose of the investigation.

A combination of laboratory investigations is employed in LFT.

These include serum bilirubin (conjugated and unconjugated), SGPT, SGOT, alkaline phosphatase and proteins (albumin and globulins).

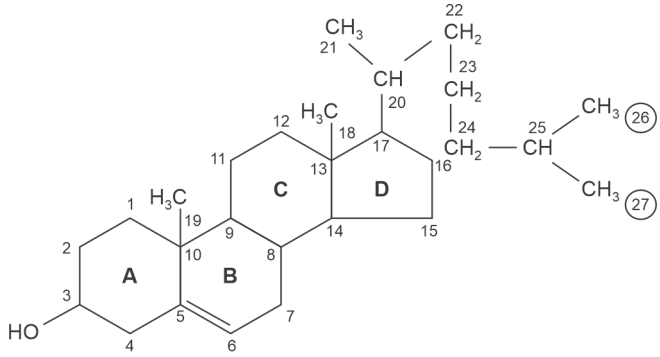
g. Define Lipids. Write about the structure and functions of cholesterol in the body. Enlist any two properties of triglycerides.

Ans: Lipids: Lipids are a heterogeneous group of compounds which are esters of fatty acids relatively insoluble in water but freely soluble in organic solvents like ether, chloroform, alcohol, etc.

Or

Lipids: These are organic compounds containing hydrogen, carbon, and oxygen atoms, which form the framework for the structure and function of living cells.

Structure of cholesterol:



Functions of cholesterol:

1. It is a structural component of cell membrane e.g. of red blood cells and in myelinated nerve cells.
2. It is an essential ingredient in the structure of lipoprotein.
3. It plays an essential role in secretion of several other vital enzymes and hormones including aldosterone, cortisol, estrogen, cortisone, progesterone, testosterone, etc.
4. It plays an important role in the synthesis of vitamin-D_3 which is responsible for proper bone calcification.
5. It acts as a precursor to fat-soluble vitamins A, D, E, K.
6. It regulates membrane fluidity over the range of physiological temperatures.
7. It is also helpful in the healing process after a surgery. It helps in maintenance of our body temperature and protects our internal organs.
8. In pharmaceutical industries, cholesterol is used in the manufacture of steroid hormones and vitamin D.
9. It is a poor conductor of heat and electricity and serves as an insulator. In the brain, where it is present abundantly, it acts as an insulator against nerve impulses which are electric in nature.
10. Cholesterol, when oxidized under suitable conditions, undergoes rapid oxidation to form a ketone called cholestenone.
11. The hydroxyl group of cholesterol readily forms ester with fatty acids like stearic acid.

PROPERTIES OF TRIGLYCERIDES

Physical Properties

- They are non-polar, hydrophobic in nature.
- They are insoluble in water and soluble in organic solvents.
- The specific gravity is less than water. Therefore fats and oil float on water.
- They serve as solvent for other fats, e.g. fat-soluble vitamins A, D, E and K.
- The saturated fatty acids have higher melting points than unsaturated fatty acids of corresponding length.

Chemical Properties

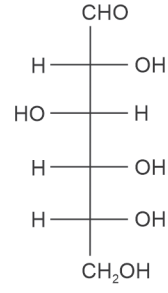
- Hydrolysis: Triacylglycerols undergo stepwise enzymatic hydrolysis to finally liberate free fatty acids and glycerol. This process of hydrolysis catalyzed by lipases is important for digestion of fat in the gastrointestinal tract and fat mobilization from the adipose tissues.

- Saponification: The hydrolysis of triacylglycerols by alkali to produce glycerol and soaps is known as saponification.

  Triacylglycerol + 3NaOH → Glycerol + 3 R-COONa(soaps)
- Rancidity: Rancidity is the term used to represent the deterioration of fats and oils resulting in an unpleasant taste. Fats containing unsaturated fatty acids are more susceptible to rancidity. Rancidification is the process of complete or incomplete autoxidation or hydrolysis of fats and oils when exposed to air, light, moisture, or bacterial action, producing short-chain aldehydes, ketones and free fatty acids. When these processes occur in food, undesirable odors and flavors can result. Rancid oils and fats are unsuitable for human consumption.
- Lipid peroxidation in vivo: In the living cells, lipids undergoes oxidation to produce peroxides and free radicals which can damage the tissue. The free radicals are believed to cause inflammatory diseases, aging, cancer, atherosclerosis, etc. It is fortunate that the cells possess antioxidants such as vitamin E, urate and superoxide dismutase to prevent in vivo lipid peroxidation.

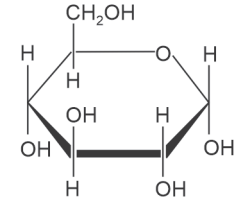
Q.2. Answer any TEN of the following: 30 Marks

a. Draw structure of any three reducing monosaccharides.

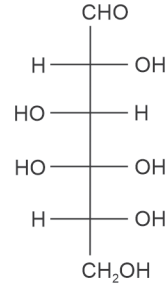


Glucose

OR

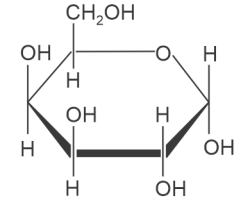


Glucose

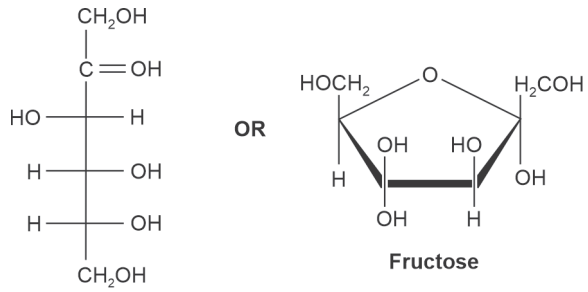


Galactose

OR



Galactose



b. Define Carbohydrates. Classify them.

Ans: Carbohydrates may be defined as polyhydroxy aldehydes or ketones or compounds, which produce them on hydrolysis.

Two major classes of Carbohydrates are **Sugars and non-sugars**.

Sugar type of carbohydrates are classified into two groups based on the number of sugar units-

I. Monosaccharides are the simplest group of carbohydrates and are often referred to as simple sugars.They have general formula CnH2nOn and they cannot be further hydrolysed. They are further classified as-

A. On basis of functional groups:

(i) **Aldoses:** When the functional group of monosaccharides is an aldehyde they are known as aldoses e.g. glyceraldehyde, glucose.

(ii) **Ketoses:** When the functional group of monosaccharides is a ketone they are known as ketoses, e.g. dihydroxyacetone, fructose.

B. On basis of number of carbon atoms:

(i) **Trioses:** Three carbon atoms, e.g. glyceraldehyde, dihydroxy-acetone.

(ii) **Tetroses:** Four carbon atoms, e.g. erythrose, erythrulose.

(iii) **Pentoses:** Five carbon atoms, e.g. ribose, ribulose.

(iv) **Hexoses:** Six carbon atoms, e.g. glucose, fructose, galactose, mannose, etc.

(v) **Heptoses:** Seven carbon atoms e.g. Sedoheptose, sedoheptulose.

II. Oligosaccharides contain two to ten monosaccharide molecules. Based on the number of monosaccharide units present, the oligosaccharides are further subdivided into:

(i) **Disaccharide:** Class of oligosaccharide consisting of two mono-saccharide units

e.g. *Sucrose* (glucose + fructose), *lactose* (galactose + glucose), *maltose* (glucose + glucose).

(ii) **Trisaccharide:** Class of oligosaccharide consisting of three monosaccharide units.
e.g. *Raffinose* (three galactose sugar units), *maltotriose* (three glucose sugar units).

III. **Non-sugars (polysaccharides)** are the polymers of monosaccharide units with higher molecular weight held together by glycosidic bonds.
Polysaccharides are of two types:

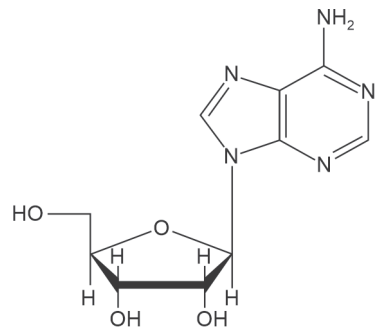
(i) **Homopolysaccharide**—these on hydrolysis yield only a single type of monosaccharide unit, e.g. starch, cellulose, glycogen, etc

(ii) **Heteropolysaccharide—**these on hydrolysis yield a mixture of few monosaccharides or their derivatives unit, e.g. hyaluronic acid, heparin, chondroitin sulphate, etc.

c. What are nucleosides and nucleotides?

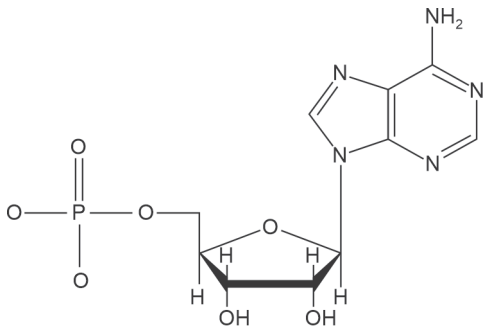
Ans:

- Upon complete hydrolysis of nucleic acid yields, a mixture of basic substances called 'purines' and 'pyrimidines', a pentose or deoxypentose sugar component and phosphoric acid.
- Upon partial hydrolysis of nucleic acids, nucleotides and nucleosides can be isolated.
- **Nucleoside** is a compound formed by union of nitrogenous bases along with pentose sugar.
- If pentose sugar is ribose it is ribonucleoside, e.g. adenosine.



Nucleotide is a compound formed by union of nitrogenous base along with pentose sugar and phosphate.

- If pentose sugar is ribose then it is ribonucleotide, e.g. **AMP (adenosine-5'monophosphate)**



d. Enlist factors affecting enzyme action.

Ans: Following are the factors affecting the Enzyme action;

1. Concentration of enzyme
2. Concentration of substrate
3. Temperature
4. pH
5. Product concentration
6. Activators (coenzymes and cofactors)
7. Time
8. Light and radiation
9. Oxidizing agents
10. Enzyme inhibitors
11. Anti-enzymes

e. Explain ETC chain.

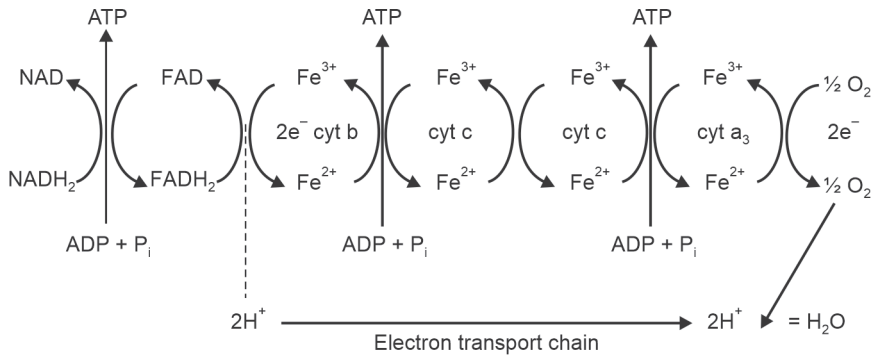
Ans: The respiration chain or electron transport chain (ETC):

1. During biological oxidation of substances, like carbohydrates, fatty acids and amino acids, most of the energy is evolved which is trapped in the form of ATP. Thus, ETC principally takes place in biological oxidation and oxidative phosphorylation.
2. The sequence of enzymes and carriers responsible for the transport of reducing equivalents from substrate to molecular oxygen is described as the respiratory chain.
3. It takes place in mitochondria and the energy formed is also stored there itself in the form of ATP.
4. The mitochondria contain a series of catalysts which are concerned with transport of reducing equivalents, i.e. hydrogen and electrons and with their final reaction with oxygen to form water.
5. In the respiratory chain the electrons flow from more electronegative components to more electropositive oxygen. Thus, the redox

potential of a component of a chain gives the information regarding position in the chain.

6. The respiratory chain in the mitochondria starts from the NAD-linked dehydrogenase system on one side through flavoproteins and cytochromes to molecular oxygen on the other side. The reducing equivalents are either as H+ or covalent hydrogen.
7. One additional carrier is present in between flavoproteins and cytochrome b which is called cytochrome-b is said to be 'ubiquinone' or 'Co-Q'. Among the various cytochromes, Cytochrome b has the lowest redox potential.
8. The cytochromes are arranged in order of increasing redox potential. The terminal cytochrome a3 is responsible for the final combination of reducing equivalent with molecular oxygen to form water.
9. At the electronegative end of the chain, dehydrogenase enzymes catalyze the transfer of electrons from the substrate to NAD of the chain. The reduced NAD is oxidized by the metalloflavoprotein enzyme - NADH dehydrogenase, with FMN as 'prosthetic group'.

Multiprotein complexes in electron transport chain can be shown as follow:



f. Write the functions of calcium and its deficiency diseases.

Ans: Functions of calcium:

1. Development of bones and teeth
2. Muscle contraction
3. Blood coagulation
4. Nerve transmission
5. Membrane integrity and permeability
6. Activation of enzymes
7. Calmodulin mediated action

8. Calcium as an intracellular messenger
9. Release of hormones
10. Secretory process
11. Contact inhibition
12. Action on heart

Following diseases observed due to deficiency of calcium:

1. Hypocalcemia (tetany)
2. Rickets
3. Osteoporosis
4. Osteopenia

g. Which pathological conditions are observed due to abnormal constituents in urine?

Abnormal constituents	*Significance*
Sugar/Glucose	Glycosuria, diabetes mellitus
Ketone Bodies	Ketonuria-diabetes mellitus pregnancy, carbohydrate starvation
Protein/Albumin	Proteinuria-pregnancy, severe exercise, high protein meal, nephritis
Bile pigments	Jaundice/hepatitis
Blood	Haematuria-acute inflammation of urinary organs, TB, cancer, haematolytic jaundice, etc.
Pus	Pyuria-inflammation of urinary bladder, urethra, kidney

h. Discuss glycogenesis.

Ans: Glycolysis

- It is the process of conversion of glucose into glycogen in the liver.
- It takes place in the cytosol, requires ATP and UTP, besides glucose.

Importance of glycogenesis:

- Excess of glucose is utilised to form glycogen, which is stored in the liver and muscles reserved for muscular activities.
- Helps to maintain blood glucose level.
- In case of carbohydrate starvation stored glycogen is converted to glucose to give energy.

The process of glycogenesis is as follows:

1. **Synthesis of UDP-glucose:**
   - Hexokinase and glucokinase convert glucose into glucose-6-phosphate.
   - Glucose-6-phosphate conversion to glucose-1-phosphate is catalyzed by phosphoglucomutase.
   - Uridine diphosphate glucose (UDPG) is synthesized from glucose-1-phosphate and UTP by UDP-glucose pyrophosphate.

2. **Requirement of primer to initiate glycogenesis:**
   - A small fragment of pre-existing glycogen must act as a primer.
   - In absence of primer, a protein 'glycogenin' can accept the glucose from UDPG.
   - The enzyme glycogen initiator synthase transfers the glucose to glycogenin.
   - Later, glycogenin itself takes up glucose molecules to form a fragment to accept the rest of the glucose molecules.
3. **Glycogen synthesis by glycogen synthase:**
   - Glycogen synthase is responsible for the formation of 1,4-glycosidic linkage.
4. **Formation of branches in glycogen:**
   - Glycogen synthase catalyses synthesis of linear unbranched molecules with 1,4-α-glycosidic linkage.
   - Formation of branching is brought about by a branching enzyme called glucosyl 4-6 transferase.

Overall reaction:

(Glucose)n + Glucose + 2ATP → (Glucose)n+1 + 2ADP + Pi

i. What is lymphocytosis, lymphocytopoenia and phenylketonuria?

Ans:

1. **Lymphocytosis:**
   - Increase in the number of lymphocytes count above the normal range in blood.
   - It is observed in viral infections like hepatitis A, pneumonia in newborn babies as well as in pregnancy.
2. **Lymphocytopenia (Lymphopenia)**
   - Decrease in number of lymphocytes below the normal value.
   - It is observed in CHF, tuberculosis and in temporary conditions of administration of adrenocorticosteroid hormones.
3. **Phenylketonuria (PKU):**
   - It is the most common disorder in amino acid metabolism. The incidence of PKU is 1 in 10000 births. It is due to the deficiency of hepatic enzyme, phenylalanine hydroxylase.
   - Phenylketonuria primarily causes the accumulation of phenyl-alanine in the tissues and blood, and results in increased excretion in urine.
   - Mental retardation, failure to walk or talk, failure of growth, seizures and tremors are observed.

Treatment of PKU:

- The maintenance of plasma phenylalanine concentration within the normal range is done by selecting foods with the low phenylalanine content and or feeding synthetic amino acid preparation, low in phenylalanine.

j. Write the functions of any three fat soluble vitamins.

Vitamin A functions:

1. Vitamin A plays important role in vision
2. Vitamin A helps in maintaining the integrity of epithelial tissue, such as epithelial layers of skin, respiratory mucosa, oesophagus, and genitourinary tract.
3. It is also involved in the preservation of structural integrity and the normal permeability of the cell membrane.
4. It helps in the normal formation of bones and teeth.
5. It acts as a growth promoting factor in children.
6. Cholesterol synthesis requires vitamin A.
7. Carotenoids (most important beta-carotene) function as antioxidants and reduce the risk of cancers initiated by free radicals and strong oxidants.
8. Vitamin A is considered essential for the maintenance of a proper immune system.
9. Retinol is necessary for normal reproduction.

Vitamin D functions

1. Vitamin D is responsible for increasing the availability and retention of calcium and phosphorus and their utilization for proper mineralization of the skeleton.
2. The major function of vitamin D is to stimulate transcription of mRNA for calcium transport.
3. It increases the excretion of phosphate by kidney and decreases concentration of serum phosphate.
4. It decreases the pH in the lower intestinal tract which helps in increasing the absorption of calcium and phosphorus.
5. It is required for the development of bones and normal growth of the body.
6. It stimulates calcification of bones in both the adults and growing children.
7. It increases the citrate level of blood, bone, kidney and heart tissues and also excretion of citric acid.
8. It stimulates the activity of phytase which catalyses the hydrolysis of phytic acid in the intestine.

Vitamin E functions

1. It acts as a powerful 'antioxidant', where it stabilizes polyunsaturated fatty acids and certain fats, vit. A, and sulphur containing acids, by molecular oxygen in the formation of peroxides.
2. The antioxidant property of vitamin E protects the lung tissue from damage by oxidants in the air.
3. It plays a part in stabilization of cellular membranes.
4. It protects enzymes in muscle, nerves or gonads from destruction.
5. It prevents hepatic necrosis, produced by the lack of sulphur containing amino acids in dietary proteins.
6. It prevents the development of cerebral disorders.
7. It is believed to be involved in heme synthesis.

Vitamin K functions

1. It catalyses the synthesis of 'prothrombin' by the liver.
2. It reduces prothrombin time.
3. It regulates the synthesis of clotting factors viz. factor VII, IX, and factor X.
4. It is involved in the oxidative phosphorylation in animal tissues.
5. It maintains the normal level of blood clotting factors—II, VII, IX and X.
6. It is used therapeutically to prevent poisoning by dicoumarol-type drugs.

k. Discuss diseases related to abnormal carbohydrate metabolism.

Ans: Following diseases are observed in abnormal carbohydrate metabolism:

1. **Diabetes mellitus:**
   - When the body is unable to utilize the glucose then there is an appearance of excessive sugar in the blood, as well as in the urine, called 'glycosuria' and the disease is termed as 'diabetes mellitus'.
   - The blood sugar level is regulated by the pancreatic protein hormone, insulin, which is secreted by the β-cells of islets of Langerhans of pancreas.
   - If the insulin is unable to utilize the sugar, the sugar level may be increased in the blood and excreted in the urine.

Symptoms of diabetes mellitus

(i) Hyperglycemia
(ii) Glycosuria
(iii) Increased fat and protein metabolism
(iv) Ketosis

(v) Hypercholesterolemia
(vi) Atherosclerosis
(vii) Polyuria (increased urine volume)
(viii) Polydipsia (increased thirst)
(ix) Polyphagia (excessive ingestion of food)
(x) Coma and death.

Treatment

Diabetes mellitus can be treated by administering insulin subcutaneously or by giving oral antidiabetic agents. The patient may be advised to take a protein diet, but not the carbohydrate diet.

2. Glycosuria

Appearance of usually high amounts of sugar in the urine is called 'glycosuria'. Depending upon the causes, glycosuria has been classified into various groups as:

- Alimentary glycosuria:
  This term is used to denote glycosuria which sets up after the consumption of excessive amounts of sweet things like glucose, cane sugar, sweets or even starch via diet.
- Diabetic glycosuria:
  It is a pathological condition in which carbohydrate metabolism gets impaired which results in the appearance of sugar in the urine.
- Renal glycosuria (renal diabetes):
  This occurs due to some defect in the renal tubular transport mechanism of glucose.
- Adrenaline glycosuria:
  It is also known as 'emotional' or 'psychic glycosuria'. It occurs generally due to hypersecretion of adrenaline hormone from adrenal cortex.

3. Glycogen storage diseases

These diseases are referred to as the diseases caused by the accumulation of polysaccharide-glycogen. These are:

- **von Gierke's disease:** It is due to hepatic glycogen storage.
- **Pompe's disease:** It is due to storage of normal glycogen in almost every organ of the body, including the heart.
- **Limit dextinosis, Forbe's or Cori's disease:** It is due to increased deposition of glycogen with very outer branches in the liver and other tissues.
- **Amylopectonosis or Anderson's disease:** It is due to deficiency of branching enzymes, which results in accumulation of glycogen.

4. Galactosemia:

- Due to deficiency of the enzyme galactose-1-phosphate uridyl transferase (G1PUT) and galactokinase, galactose cannot be converted into glucose, which leads to a condition called galactosemia.
- It is characterized by increased galactose levels in circulation and urine.
- Accumulated galactose is converted into galactitol, which is responsible for the development of cataract.
- The clinical symptoms include jaundice, hepatosplenomegaly, mental retardation etc.

5. Fructose intolerance:

- One of the very normal hexose sugars of fruits (i.e. fructose) gets normally metabolized to give energy and CO_2.
- Defective metabolism of fructose develops in high concentration of this sugar in blood, known as fructose intolerance.

Q.3. Answer ALL of the following: 20 Marks

a. Define anemia.

Ans: Anemia is one type of red blood cell disorder where there is decrease in oxygen carrying capacity of blood due to deficiency of haemoglobin or due to decrease in RBCs count than normal or due to deficiency of iron.

b. Which of the following is a sulphur containing amino acid?

(i) Alanine (ii) Glycine (iii) Methoinine (iv) Valine

Ans: (iii) Methionine.

c. Enlist any two routinely performed kidney function tests.

Ans: Routinely performed kidney function tests are as follows:

1. Complete urine analysis
2. Plasma urea and creatinine
3. Plasma electrolytes
4. Glomerular filtration rate
5. Clearance tests: Urea clearance test, inulin clearance test, creatinine clearancetest, etc.
6. Glomerular permeability, proteinuria
7. Reabsorption studies: Blood urea nitrogen
8. Secretion
9. Concentration and dilution tests
10. Renal acidification, etc.

d. Name any two lipid profile tests.

Ans: The lipid profile tests are as follows:

1. Total cholesterol (TC)

2. High density lipoprotein cholesterol (HDL-C)
3. Low density lipoprotein cholesterol (LDL-C)
4. Triglycerides (TGs)
5. Very low density lipoprotein cholesterol (VLDL-C).

e. What are the coenzymes of riboflavin and nicotinic acid?

Ans: **Coenzyme of riboflavin:** Flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD).

Coenzyme of nicotinic acid: Nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP).

f. Which of the following diseases is caused by the deficiency of Niacin?

(i) Scruvy (ii) Rickets (iii) Pellagra (iv) Pernicious anemia

Ans: (iii) Pellagra.

g. Explain fatty liver.

Ans: **Fatty liver:** It is the condition when excessive fat is deposited in the liver and results in deposition of toxic materials in the liver, this condition also known as hepatic steatosis. In this condition, weight of the liver increases about 10% than that of normal weight and causes inflammation, poor appetite, weight loss, abdominal pain, fatigue, weakness, fibrosis and cirrhosis of liver.

h. Alkaptonuria is a disease related to _____.

Ans: Abnormal metabolism of amino acids.

i. Define essential amino acids.

Ans: Essential amino acids are those which cannot be synthesized by the body and hence it is essential to supply/consume from diet.

j. When glucose reacts with bromine water it forms:

(i) Glutaric acid (ii) Glyceraldehyde
(iii) Saccharic acid (iv) Gluconic acid

Ans: (iv) Gluconic acid.

k. Name any two diseases due to malnutrition of proteins.

Ans: Kwashiorkor, nutritional oedema, marasmus etc.

l. Which of the following essential fatty acids has three double bonds?

(i) Linolenic acid (ii) Arachdonic acid
(iii) Linolenic acid (iv) Clupanodonic acid

Ans: (i) Linolenic acid.

m. Stearic acid has _____ carbon atoms.

Ans: 18

n. Name of vitamin A is_____.

Ans: Retinol (Vit.A_1), dehydroretinol (Vit. A_2).

o. Hypercholesterolemia is caused due to_____.

Ans: Increased level of cholesterol (>200 mg/dl) in blood than normal.

p. Write full form of SGOT and SGPT.

Ans: SGOT: Serum glutamic oxalo-acetic transaminase.
SGPT: Serum glutamic pyruvic transaminase.

q. Jaundice is a symptom of disease. True or False.

Ans: True.

r. What is the significance of BUN?

Ans: BUN i.e. Blood urea nitrogen, it shows how well the kidneys are functioning.

s. Chloride and bicarbonate ions occur predominantly in_____.

Ans: Extracellular fluid.

t. Identify the purine base of nucleic acids in the following-
(i) Cytosine (ii) Thymine (iii) Uracil (iv) Adenine

Ans: (iv) Adenine.

Summer Examination 2024 (Question Paper)
Second Year Diploma in Pharmacy
Subject: Biochemistry and Clinical Pathology (20223)

Time: 3 Hours **Max Marks: 80**

Q.1. Attempt any SIX of the following. **30 Marks**

a. Define carbohydrate and write classification with examples.
b. What are proteins? Briefly explain their biological role. Explain secondary structure of proteins.
c. Discuss different factors affecting enzyme activity.
d. What is Krebs cycle? Mention steps in Krebs cycle.
e. Explain biological oxidation with ETC and oxidative phosphorylation.
f. Discuss urea cycle and decarboxylation.
g. Discuss the functions of liver. Explain liver function test.

Q.2. Attempt any TEN of the following. **30 Marks**

a. Draw the structure and enlist any two functions of cholesterol in the body.
b. Explain the following:
   (i) Triglycerides (ii) Fatty liver (iii) Emulsification test
c. Explain the structure of DNA.
d. Describe vitamin A. Its chemical nature and deficiency diseases.
e. Give an account of metabolism of fats with reference of B-oxidation.
f. What are ketone bodies? Discuss formation of ketone bodies,
g. Give the functions of following:
   (i) Sodium (ii) Chloride (iii) Cobalt
h. What is dehydration? Discuss its causes and ORT.
i. Write in detail about renal function test.
j. Discuss about abnormal constituents of urine and their significance.
k. Write about abnormal RBCs and related diseases.

Q.3. Attempt ALL of the following. **20 Marks**

a. Which one is the largest organelle in the cytoplasm?
   (i) Lysosomes (ii) Mitochondria
   (iii) Golgi apparatus (iv) Endoplasmic reticulum

b. The cellular organelles called suicidal bags are_____
   (i) Lysosome (ii) Ribosome (iii) Nucleolus (iv) Golgi complex
c. Draw the structure of glucose.
d. Name one optically inactive amino acid.
e. Name any two sulfur containing amino acids.
f. Define vitamins.
g. Write any two functions of RNA.
h. What is holoenzyme?
i. Enlist any two functions of lipids.
j. Write any two functions of vitamin C.
k. The deficiency of vitamin B, causes_____
   (i) Xeropthalmia (ii) Beriberi (iii) Pellegra (iv) Scurvy
l. Name the coenzymes of vitamin B, and vitamin B_2.
m. What is glycogenolysis?
n. Body water is regulated by the hormone_____
   (i) ADH (ii) ACTH (iii) FSH (iv) Epinephrine
o. Enlist any two functions of water.
p. Explain the terms ECF and ICE.
q. The term biotechnology was coined in 1919 by_____
   (i) Karl Ereky (ii) Alexander flemming
   (iii) James Waston (iv) Francis Cricks
r. Define “biotechnology”.
s. ALT is also known as_____
   (i) Alanine amino transferase (ii) Amino leucine transferase
   (iii) Aspartate amino transferase (iv) None of these
t. What is Rothera's test?

Summer Examination 2024 (Specimen Answer Paper)
Second Year Diploma in Pharmacy
Subject: Biochemistry and Clinical Pathology (20223)

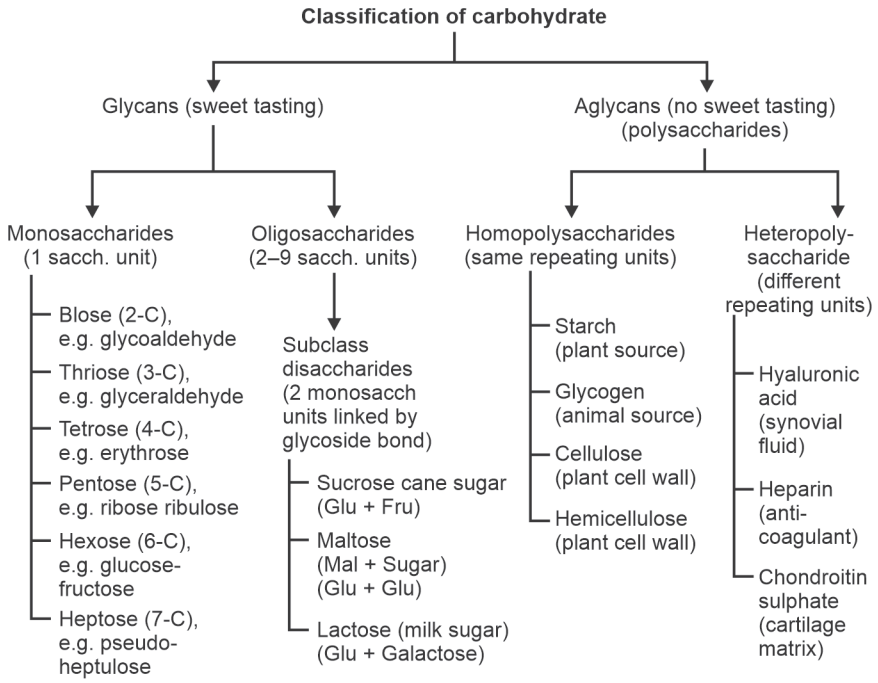
Time: 3 Hours **Max Marks: 80**

Q.1. Attempt any SIX of the following. **30 Marks**

a. Define carbohydrate and write classification with examples.

Ans: Carbohydrates may be defined as optically active polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis. Carbohydrates are also known as saccharide molecules.

They have general formula $Cn[H_2O]n$.



A. Monosaccharide

1. It is the simplest group of carbohydrates.
2. It is also called as a simple sugar.

3. It cannot be further hydrolyzed.
4. This compound possesses free aldehyde or ketone group.

B. Disaccharide

Maltose is generally composed of two molecules of glucose:

1. Maltose is reducing sugar.
2. Natural source of maltose.

C. Oligosaccharide

It consists of more than 2 molecules up to 10 molecules of sugar. Oligosaccharide compound that in two to ten molecules of the same or different monosaccharide. The monosaccharide units are joined by glycosides linkage.

D. Polysaccharide

It consists of ten or more than molecules of sugar, e.g. starch, glycogen.

1. Polysaccharides are major unit of biomolecule.
2. It is also called as glycans.

Classification of polysaccharide

a. Homopolysaccharide
e.g. starch, glycogen

b. Hetropolysaccharide
e.g. heparin

a. Homopolysaccharide

The monomeric unit are arrange in the long term chain either branched or unbranched, e.g. starch, glycogen.

Chemical Nature of Starch

1. Starch is the storage from of carbohydrate present in the plant, root, tubers, fruits, stem and cereals.
2. Our daily diet rice, wheat and vegetables where majorly consists of good source of starch. Polysaccharide homopolysaccharide, e.g. starch, glycogen

b. Hetropolysaccharide, e.g. heparin.

b. What are proteins? Briefly explain their biological role. Explain secondary structure of proteins.

Ans: Proteins are naturally occurring polymers made up of amino acids linked together by peptide bonds (–CONH) having high molecular weight found in all living cells.

Biological Role of Protein

1. Protein is important for the structure of membrane muscular tissue or connective tissue.
2. Nucleoprotein have a great significance in genetic.

3. Protein maintains the fluid balance.
4. No. of enzymes are protein which catalyzed the no of biochemical reactions.
5. Protein is important for transport of oxygen through the body, e.g. Hemoglobin.
6. Protein is responsible for protection against infection.
7. Protein is important to in regulation of metabolism by hormones, e.g. insulin.

Secondary Structure

1. The secondary structure of a protein is determined by the specific polypeptide geometric arrangement of polypeptide chain.
2. It is an arrangement of hydrogen bonding.
3. There are two groups' amino group and carbonyl oxygen of peptide bond. It is called a secondary structure.

Alpha Helical Structure

1. Pauling and carrying structure has proposed the alpha helical structure.
2. In α-helical structure R-group are directed out word from the center of helix.
3. Alpha helical structure established by hydrogen bond.
4. Alpha helical structure from spontaneously due to low energy.
5. Right handed helix is most stable that left handed helix. e.g. Keratin.

Beta-plated Sheet Structure

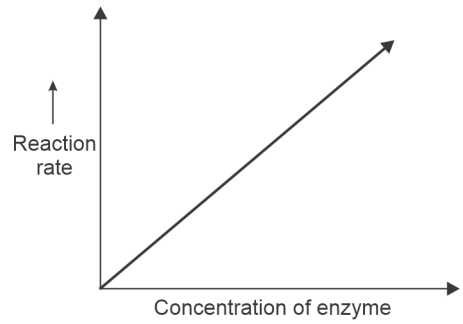
1. Pauling and Corey haveproposed the beta plated sheet.
2. Two polypeptide chain are present in structure.
3. There polypeptide chain lying side by side.
4. Hydrogen bond between C=O and NH neighbouring polypeptide chain.
5. Such structure of protein appears like plated sheet is called as beta plated sheet.

c. Discuss different factors affecting enzyme activity.

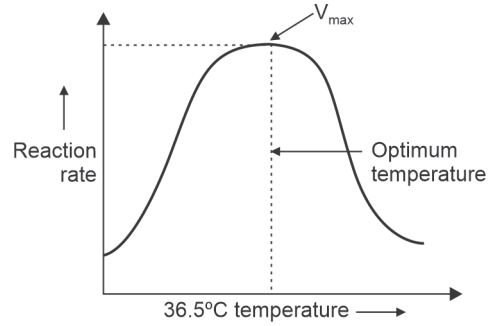
Ans: Enzyme activity can be affected by several factors, including:

Concentration of enzyme

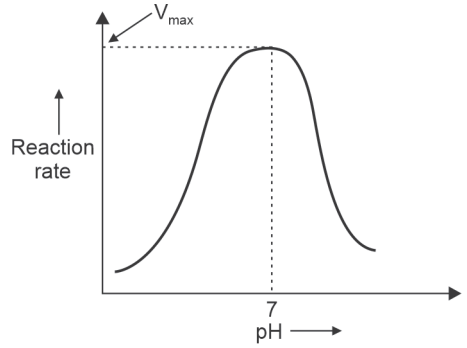
If a concentration of enzyme increase. The velocity of the reaction also increases. The concentration of enzyme is proportional to the velocity of enzyme. This property is mainly used in serum enzyme determination for disease diagnosis.



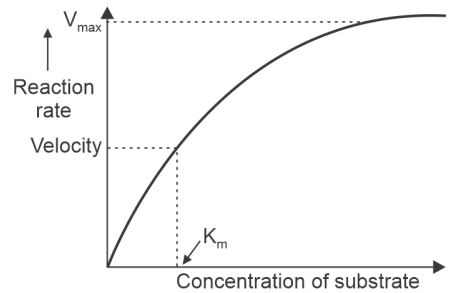
Temperature: Enzymes have optimal temperatures at which they function best. An increase in temperature can increase enzyme activity, but excessive heat can denature the enzyme, rendering it inactive.



pH: Enzymes have optimal pH levels at which they function best A change in pH can affect the shape of the enzyme, making it unable to bind to its substrate, and therefore less active.



Substrate concentration: As the concentration of substrate increases, the rate of enzyme-catalyzed reactionsalso increases, up to a point. Beyond that point, the enzymes become saturated andthe reaction rate levels off.



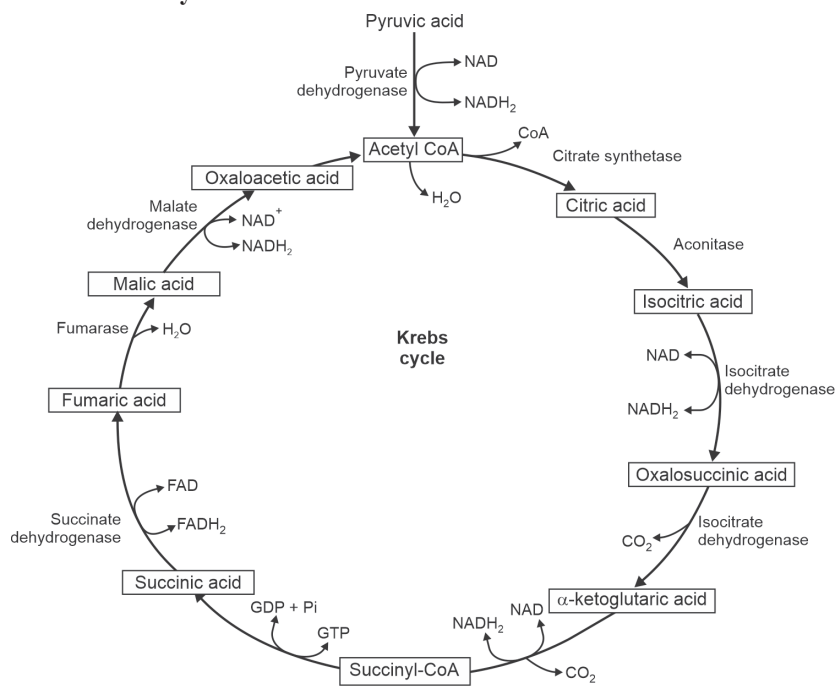
Enzyme concentration: Increasing the amount of enzyme present will increase the rate of the reaction, up to a point. Beyond that point, the reaction rate levels off.

Inhibitors: Compounds that bind to enzymes and prevent them from functioningproperly are called inhibitors. They can be competitive or non-competitive, and can be reversible or irreversible.

Co-factors: Many enzymes require small, non-protein molecules, called co-factors to function. Cofactors can be metal ions or organic molecules, and if they are not present, the enzyme will not function.

d. What is Krebs cycle? Mention steps in Krebs cycle.

Ans: Krebs cycle:



Kreb cycle

Formation of acetyl CoA: Pyruvic acid is decarboxylated to acetyl CoA for its entry into citric acid cycle. In this stage NAD is converted into $NADH_2$.

Formation of isocitric acid: Acetyl CoA is converted into citric acid which further converted into isocitric acid in the presence of enzyme acotinase.

Formation of oxalosuccinic acid: Isocitric acid gets converted into oxalosuccinic acid in the presence of enzyme isocitrate dehydrogenase.

Formation of α-ketoglutaric acid: Oxalosuccinic acid is converted into α-ketoglutaric acid in the presence of isocitrate dehydrogenase.

Formation of succinyl CoA: Alpha-ketoglutaric acid is converted into succinyl CoA.

Formation of succinic acid: Succinyl CoA is converted into succinic acid.

Formation of fumaric acid: Succinic acid is converted into fumaric acid in the presence of succinate dehydrogenase.

Formation of malic acid: Fumaric acid is converted into malic acid in the presence of enzyme fumarase.

Formation of oxalo acetic acid: Malic acid is converted into oxaloacetic acid in the presence of enzyme maleate dehydrogenase.

1. Glycogen is the storage form of glucose in animals, as is starch in plants.
2. It is stored mostly in liver (6–8%) and muscle (1–2%).
3. Due to more muscle mass, the quantity of glycogen in muscle (250 g) is about three times higher than that in the liver (75 g).
4. Glycogen is stored as granules in the cytosol.
5. Most of the enzymes of glycogen synthesis and breakdown are present.
6. The prime function of liver glycogen is to maintain the blood glucose levels.

e. Explain biological oxidation with ETC and oxidative phosphorylation.

Ans: I. Biological Oxidation

Prior to the understanding the biological oxidation we need to know that someimportant concept and terminologies.

Bioenergetics

Bioenergetics or biochemical thermodynamics deals with the study of energy changes (transfer and utilization) in biochemical reactions. The reactions arebroadly classified as exergonic (energy releasing) and endergonic (energy consuming). Bioenergetics is concerned with the

initial and final states of energycomponent of the reactants and not the mechanism of chemical reactions.

Free energy

The energy actually available to do work (utilizable) is known as free energy. Changes in the free energy (ΔG) are valuable in predicting the feasibility of chemical reactions. If free energy change (ΔG) is represented by a negative sign, there is a loss of free energy. The reaction is said to be exergonic, and proceeds spontaneously. On the other hand, a positive ΔG indicates that energy must be supplied to the reactants. The reaction cannot proceed spontaneously and is endergonic in character.

Enthalpy (ΔH) is a measure of the change in heat content of the reactants, compared to products.

Entropy (ΔS) represents a change in the randomness or disorder of reactants and products. Entropy attains a maximum as the reaction approaches equilibrium.

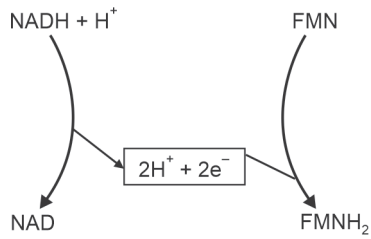
The relation between the changes of free energy (ΔG), enthalpy (ΔH) andentropy (ΔS) are expressed as.

$$\Delta G = \Delta H - T\Delta S$$

Biological oxidation

Oxidation is defined as the loss of electrons and reduction as the gain of electrons. This may be illustrated by the interconversion of ferrous ion (Fe^{2+}) to ferric ion (Fe^{3+}).The electron lost in the oxidation is accepted by an acceptor which is said to be reduced. Thus, the oxidation-reduction is a tightly coupled process.

The general principle of oxidation-reduction is applicable to biological systems also. The oxidation of NADH to NAD^+ coupled with the reduction of FMN to $FMNH_2$ is illustrated.



In the above illustration, there are two redox pairs NADH/NAD^+ and FMN/$FMNH_2$.The redox pairs differ in their tendency to lose or gain electrons.

Redox potential

The oxidation-reduction potential or, simply, redox potential, is a quantitative measure of the tendency of a redox pair to lose or gain electrons. The redox pairs are assigned specific standard redox potential (E0 volts) at pH 7.0 and 25°C.The more negative redox potential represents a greater tendency (of reductant) to lose electrons. On the other hand, a more positive redox potential indicates a greater tendency (of oxidant) to accept electrons. The electrons flow from a redox pair with more negative E0 to another redox pair with more positive E0.

The redox potential (E0) is directly related to the change in the free energy ($\Delta G°$).

Electron transport chain

The energy-rich carbohydrates (particularly glucose), fatty acids and amino acids undergo a series of metabolic reactions and, finally, get oxidized to CO_2 and H_2O.

The reducing equivalents from various metabolic intermediates are transferred to coenzymes NAD^+ and FAD to produce, respectively, NADH and $FADH_2$.

The latter two reduced coenzymes pass through the electron transport chain (ETC) or respiratory chain and, finally, reduce oxygen to water. The passage of electrons through the ETC is associated with the loss of free energy. A part of this free energy is utilized to generate ATP from ADP and Pi.

Mitochondrial organisation

1. The mitochondria are the centres for metabolic oxidative reactions togenerate reduced coenzymes (NADH and $FADH_2$) which, in turn, are utilized in ETC to liberate energy in the form of ATP. For this reason, mitochondrion is appropriately regarded as the power house of the cell.
2. The mitochondrion consists of five distinct parts. These are the outer membrane, the inner membrane, the intermembrane space, the cristae and the matrix.
3. The inner mitochondrial membrane can be disrupted into five distinct respiratory or enzymecomplexes, denoted as complex I, II, III, IV and V.
4. The complexes I–IV are carriers of electrons while complex V is responsible for ATP synthesis.
5. Besides these enzyme complexes, there are certain mobile electron carriers in the respiratory chain. These include NADH, coenzyme Q, cytochrome C and oxygen.

6. The enzyme complexes (I–IV) and the mobile carriers are collectively involved in the transport of electrons which, ultimately, combine with oxygen to produce water. The largest proportion of the oxygen supplied to the body is utilized by the mitochondria for the operation of electron transport chain.

II. Oxidative Phosphorylation

The transport of electrons through the ETC is linked with the release of free energy. The process of synthesizing ATP from ADP and Pi coupled with the electron transport chain is known as oxidative phosphorylation. The complex V of the inner mitochondrial membrane is the site of oxidative phosphorylation.

P:O ratio

1. The P:O ratio refers to the number of inorganic phosphate molecules utilized for ATP generation for every atom of oxygen consumed. Morethat it can be eliminated from the body. Without this enzyme, bilirubin builds up in the blood and can lead to jaundice.
2. The mitochondrial oxidation of NADH with a classical P:O ratio of 3. Further, a P:O ratio of 2 has been assigned to the oxidation of $FADH_2$.

Sites of oxidative phosphorylation in ETC

There are three sites in the ETC that are exergonic to result in the synthesis of 3ATP molecules:

1. Oxidation of $FMNH_2$ by coenzyme Q.
2. Oxidation of cytochrome b by cytochrome c_1.
3. Cytochrome oxidase reaction.

Mechanism of oxidative phosphorylation

Important hypothesis regarding the phosphorylation.

Chemical coupling hypothesis: This hypothesis was put forth by Edward Slater (1953). According to chemical coupling hypothesis, during the course of electron transfer in respiratory chain, a series of phosphorylated high-energy intermediates are first produced which are utilized for the synthesis of ATP. These reactions are believed to be analogous to the substrate level phosphorylation that occurs in glycolysis or citric acid cycle. However, this hypothesis lacks experimental evidence, since all attempts, so far, to isolate any one of the high-energy intermediates have not been successful.

Chemiosmotic hypothesis: This mechanism, originally proposed by Peter Mitchell (1961), is now widely accepted. It explains how

the transport of electrons through the respiratory chain is effectively utilized to produce ATP from ADP + Pi. The concept of chemiosmotic hypothesis based on the positive and negative charges gradient (Proton gradient) and enzymatic induction.

Proton gradient: The inner mitochondrial membrane, as such, is impermeable to protons (H^+) and hydroxyl ions (OH^-). The transport of electrons through ETC is coupled with the translocation of protons (H+) across the inner mitochondrial membrane (coupling membrane) from the matrix to the inter-membrane space.

The pumping of protons results in an electrochemical or proton gradient. This is due to the accumulation of more H^+ ions (low pH) on the outer side of the inner mitochondrial membrane than the inner side. The proton gradient developed due to the electron flow in the respiratory chain is sufficient to result in the synthesis of ATP from ADP and Pi.

Enzyme system for ATP synthesis: ATP synthase, present in the complex V, utilizes the proton gradient for the synthesis of ATP. This enzyme is also known as ATPase since it can hydrolyse ATP to ADP and Pi. ATP synthase is a complex enzyme and consists of two functional subunits, namely F1 and F0. Its structure is comparable with 'lollipops'. The protons that accumulate on the inter-membranespace re-enter the mitochondrial matrix leading to the synthesis of ATP.

f. Discuss urea cycle and decarboxylation.

Ans: Urea cycle

Ammonia is constantly being liberated in the metabolism of amino acids (mostly) and other nitrogenous compounds. At the physiological pH, ammonia exists as ammonium (NH^{4+}) ion. Ammonium ions are very important to maintain acid base balance of the body.

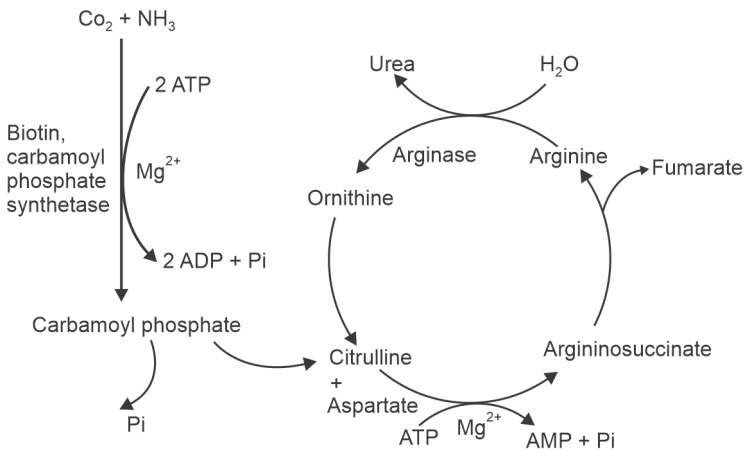
The production of NH_3: It occurs from the amino acids (transamination and deamination), biogenic amines, amino group of purines and pyrimidines and by the action of intestinal bacteria (urease) on urea.

Outline of Urea Cycle

Steps of urea cycle

Synthesis of carbamoyl phosphate: Carbamoyl phosphate synthase I (CPS I) of mitochondria catalyzes the condensation of NH_4+ ions with CO_2 to form carbamoyl phosphate. This step consumes two ATP and is irreversible, and rate-limiting.

Formation of citrulline: Citrulline is synthesized from carbamoyl phosphate and ornithine by ornithine transcarboxylase. Ornithine is



Urea cycle

regenerated and used in the urea cycle. Ornithine and citrulline are basic amino acids. Citrulline produced in this reaction is transported to the cytosol by a transporter system.

Synthesis of arginosuccinate: Arginosuccinate synthase condenses citrulline with aspartate to produce arginosuccinate. The second amino.A group of urea is incorporated in this reaction. This step requires ATP which is cleaved to AMP and pyrophosphate (PPi). The latter is immediately broken down to inorganic phosphate (Pi).

Cleavage of arginosuccinate: Arginosuccinate cleaves arginosuccinate to give arginine and fumarate. Arginine is the immediate precursor for urea. Fumarate liberated here provides a connecting link with the TCA cycle, gluconeogenesis, etc.

Formation of urea: Arginase is the fifth and final enzyme that cleaves arginine to yield urea and ornithine. Ornithine, so regenerated, enters mitochondria for its reuse in the urea cycle. Arginase is activated by CO^{2+} and MN^{2+} Ornithine and lysine compete with arginine (competitive inhibition). Arginase is mostly found in the liver, while the rest of the enzymes (four) of the urea cycle are also present in other tissues.

g. Discuss the functions of liver. Explain liver function test.

Ans: Functions of Liver

Liver serves as a central organ for body's metabolism. The major functions of liver are:

1. Metabolic functions: Liver actively participates in carbohydrate, lipid, protein, mineral and vitamin metabolisms.

2. Excretory functions: Liver is responsible for bile pigments; Bile salts and cholesterol are excreted in the bile into intestine.
3. Protective functions and detoxification: Kupffer cells of liver perform phagocytosis to eliminate foreign compounds. Ammonia is detoxified to urea. Liver is responsible for the metabolism of xenobiotic (detoxification).
4. Processing of haemoglobin foe use of its iron content (the liver stores iron).
5. Resisting infections by making immune factors and removing bacteria from the blood stream.

Liver Function Tests

Tests based on excretory function:

1. Measurement of bile pigments, bile salts, bromosulphthalein.
2. Tests based on serum enzymes derived from liver.
3. Determination of transaminases, alkaline phosphatase, 5'-nucleotidase, γ-glutamyltranspeptidase.
4. Tests based on metabolic capacity, galactose tolerance, antipyrine clearance.
5. Tests based on synthetic functions, prothrombin time, serum albumin.
6. Tests based on detoxification hippuric acid synthesis.
7. Test based on serum enzyme derived from liver transaminases.

The activities of two enzymes-namely serum glutamate pyruvate transaminase (SGPT):

1. Serum glutamate oxaloacetate transaminase (SGOT) is widely used to assess the liver.
2. SGPT: is a cytoplasmic enzyme with SGPT is found in both cytoplasm and mitochondria.
3. Serum SGPT and SGOT are increased in liver damage. The normal SGPT and SGOT ratio is around 0.8.
4. This ratio is increased (>2) in myocardial infarction, alcoholic hepatitis band cirrhosis.
5. SGPT and SGOT ratio is decreased (i.e. ALT higher) in acute, hepatocellular damage and cholestasis.

Alkaline Phosphatase

1. Alkaline phosphatase (ALP) is mainly derived from bone and liver.
2. Normal value in ALP–3–13 KA LD units/dl).
3. ALP is also elevated in cirrhosis of liver and hepatic tumours.

γ-Glutamyltranspeptidase

1. This is microsomal enzyme widely a distributed in body tissues, including liver.

2. Measurement of y-glutamyltranspeptidase (GGT) activity provides a sensitive index to asses liver abnormality.
3. Normal value: 5–40 IU/1.

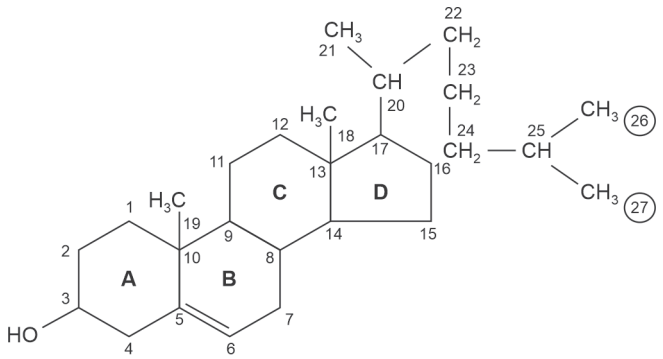
Nucleotides

1. Normal value: 2–15 U/1) is elevated in hepatobiliary disease.
2. The advantage with 5-nucleotidase is that it is not altered in bone disease

Q.2. Attempt any TEN of the following: 30marks

a. Draw the structure and enlist any two functions of cholesterol in the body.

Ans: Cholesterol:



Structure of cholesterol

Function of Cholesterol

1. Cholesterol is an essential component of cell membrane.
2. It is a need to maintain permeability and fluidity.

b. Explain the following:

Ans: (i) Triglycerides

1. High levels of total cholesterol, LDL cholesterol, triglycerides and low levels of HDL indicate high risk of atherosclerosis and heart diseases like heart attack, or stroke.
2. Low levels of total cholesterol, LDL cholesterol, triglycerides and high HDL cholesterol levels Indicates low risk.

(ii) Fatty liver

Fatty liver

1. The normal concentration of lipid (mostly as phospholipid) in liver is around 5%.
2. Liver is not a storage organ for fat, unlike adipose tissue.

3. However, in especially the certain conditions, lipids triacylglycerols accumulate in excessively in liver, resulting in fatty liver.
4. In fatty liver, droplets of triacylglycerols are found in the entire cytoplasmof hepatic cells.
5. This causes impairment in metabolic functions of liver.
6. Fatty liver may occur due to two main causes.
7. Increased synthesis of triacylglycerols.
8. Impairment in lipoprotein synthesis.

(iii) Emulsification test

1. Emulsification test use to detect of presence of lipid.
2. It is process that stabilized the water and oil emulsion by using the emulsifying agent.

Method

Take a 2 test tubes and label with A and B.

↓

Add oil to each of the test tube.

↓

Shake the test tube and allow standing for 2 min.

↓

Observe the test tube.

↓

Appearance of tiny drop let in the suspension of lipid.

Positive Result

It gives stable emulsion of lipid and water.

Negative Result

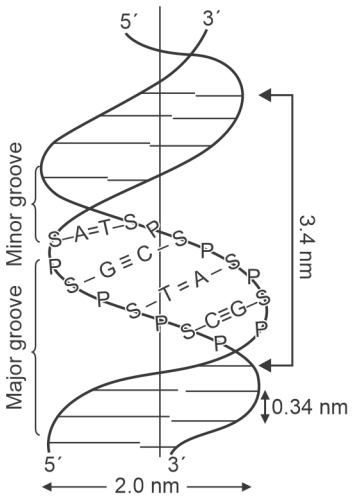
Oil in water emulsion Neill from at the ion.

c. Explain the structure of DNA.

Ans: Structure of DNA

DNA as an acidic substance present in the nucleus was first identified by Frederic Moister in 1869. He named it as nuclear. Due to technical limitations in isolating such a long, polymer intact the elucidation of structure of DNA remained elusive for a long period of time.

It was only in 1953 that James Watson and Francis Crick proposed the very simple but famous double helix model for the structure of DNA. The main opposition was base pairing between the two strands of polynucleotide chains.



Watson-Crick model of DNA helix

The salient features of double helix structure of DNA:

1. It is made up of two polynucleotide chains.
2. The two chains have anti-parallel polarity if one has polarities and the second chain must have polarity.
3. The base into strands is paired through hydrogen bond forming base pairs. Adenine forms to hydrogen bonds with thymine from opposite strands and vice versa.
4. Similarly, guanine forms three H bonds with cytosine. As a result, purine comes opposite to pyrimidine.
5. Because of this approximate a uniform distance between the two strengths of the helix occurs.

d. Describe vitamin A. Give its chemical nature and deficiency diseases.

Ans: Vitamin A

Dietary Sources

Plant source: Vegetable fruits papaya, sweet potato, tomato, carrot, leafy green vegetables.

Animal source: Fish, egg, butter, milk, meat, liver oil.

Chemical Nature

1. Retinol, retinal, and retinoic acid are termed as vitamins.
2. The side chain has so two isoprenoids unit's four double bonds and onehydroxyl group.
3. Retinol present in animal tissue.
4. Beta carotene which is pro-vitamin A present in plants.

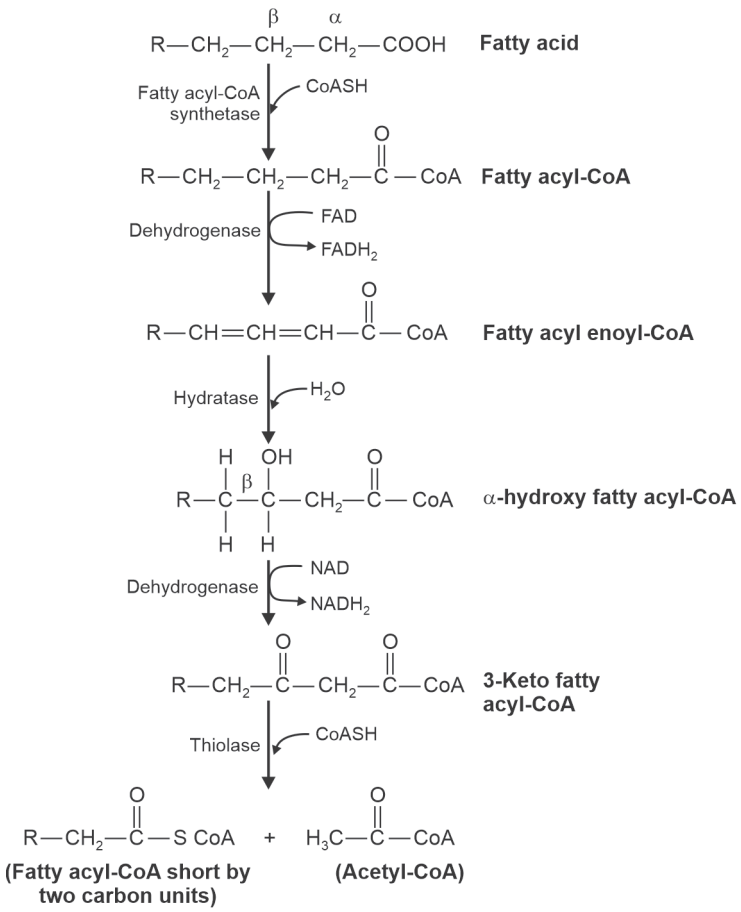
Vitamin A Deficiency Disease

1. Xerophthalmia
2. Follicular conjunctivitis keratomalacia.
3. Blindspot
4. Night blindness.

e. Give an account of metabolism of fats with reference of β-oxidation.

Ans: β-Oxidation of Fatty Acid

1. Oxidation of fatty acid in beta carbon atom is called as a beta oxidation of fatty acid.
2. Fatty acids are oxidised by a, b, γ oxidation.
3. Among the three, β-oxidation is the most important pathway.



4. β-Oxidation means, oxidation takes place in the β-carbon of the fatty acid.
5. Each cycle results in the removal of 2 carbon atoms in the form of acetyl CoA from the carboxyl end of the fatty acid.
6. So, in each cycle, the fatty acid is made shorter by two carbon atoms.
7. Enzymes of fatty acid oxidation are present in the mitochondria of liver.

f. What are ketone bodies? Discuss formation of ketone bodies,

Ans: Ketone Bodies

Acetone, acetoacetic acid, β-hydroxyl butyric acid is collectively described as ketone bodies.

1. Fatty acids undergo beta oxidation in the liver mitochondria to generate a high amount of energy and form three energy compounds.
2. These ketone bodies are water-soluble and do not require lipoproteins for transportation across the membrane.
3. Ketone bodies are lipid molecules having a carbonyl group attached to two -R Groups.

The three ketone bodies formed are:

(i) Acetoacetate
(ii) D-3-hydroxybutyrate
(iii) Acetone

g. Give the functions of following:

Ans: (i) Sodium

- For maintenance of osmotic pressure
- For maintenance of viscosity of blood
- For maintenance of electrolyte balance
- For acid base balance
- For retaining water in body
- For neuromuscular junction activity
- For excitation of nerves

(ii) Chloride

- For acid base balance.
- For secretion of HCL in stomach.
- For maintenance of osmotic pressure.
- For synthesis of CSF (Cerebrospinal Fluid).

(iii) Cobalt

- Cobalt is only important as a constituent of vitamin B_{12} needed for the formation of normal RBC.
- It is highly available in all types of food. Total body content of cobalt is 1.1 mg.
- It is present in liver, kidney and bones. Main function is to serve the formation of RBC.

h. What is dehydration? Discuss its causes and ORT.

Ans: Dehydration

Dehydration is defined as more loss of water from human body than the normal output with respect to the input of water.

Effect of Dehydration

- Loss of weight due to the reduction in tissue water.
- Disturbance in acid base balance.
- Rise in non-protein Nitrogen of blood.

Causes

- Primary rehydration:
  i. Simple deprivation of water from desert travel.
  ii. Mental patient refusing to drink water can cause dehydration.
  iii. It occurs more quickly in fever.
  iv. Excessive water loss due to vomiting and diarrhea.
- Secondary rehydration:
  i. The concentration of electrolytes of the body fluids maintain theconstant through the elimination of water.
  ii. There is slowing of circulation of kidney function.
  iii. Dehydration due to injection of hypertonic solution.
  iv. When highly concentrated salt or sugar solutions injected in the body of osmotic pressure of blood with increased.

Oral Rehydration (ORT)

- It is a simple chief highly effective treatment of dehydration.
- Cause by diarrhea and gastritis.
- Simply consist of NA, K, Cl, water and other basic nutrient.
- Patient is suggested ORS are regular intervals of 30 min.

Uses

- ORS is recommended to maintain the level of electrolytes.
- Use in the treatment of short vowel syndrome infection diarrhoea, pediatric viral illness.

Composition of ORS:

Contents	*Amount*	*Ions*	*Concentration*
Glucose	13.5 g	Citrate	10 mM
KCl	1.5 g	K^+	20 mM
NaCl	2.6 g	Na^+	75 mM
Trisodium citrate	2.9 g	Cl^-	65 mM
Water	1 litre	Glucose	75 mM
Total osmolarity = 245 mOsm/L			

i. Write in detail about renal function test.

Ans: Renal Function Tests:

1. **The clearance tests**

   The clearance tests, measuring the glomerular filtration rate (GFR) are the most useful inassessing the renal function.

   Clearance, in general, is defined as the volume of plasma that would be completelycleared of a substance per minute.

2. **Creatinine Clearance test:**

   Creatinine is an excretory product derived from creatine phosphate (largely present in muscle).

   Creatinine clearance may be defined as the volume (ml) of plasma that would becompletely cleared of creatinine per minute.

   Creatinine concentration in urine and plasma should be expressed in the units as mg/dl or mmol/l.

   Reference values: The normal range of creatinine clearance is around 120–145 ml/min.

   These values are slightly lower in women.

   Diagnostic importance:

   A decrease in creatinine clearance value (<75% normal) serves as a sensitive indicator of a decreased GFR, due to renal damage.

   This test is useful for an early detection of impairment in kidney function, often beforethe clinical manifestations are seen.

3. **Urea Clearance test:**

   - Urea is the end product of protein metabolism.
   - After being filtered by the glomeruli, it is partially reabsorbed by the renal tubules.
   - Hence, urea clearance is less than the GFR and, further, it is influenced by the protein content of the diet.
   - For these reasons, urea clearance is not as sensitive as creatinine clearance for assessing renal function.

   Diagnostic importance:

   - A urea clearance value below 75% of the normal is viewed seriously, since it is an indicator of renal damage.
   - Blood urea level as such is found to increase only when the clearance falls below 50% normal.

j. Discuss about abnormal constituents of urine and their significance.

Ans: Abnormal Constituents of Urine and their Significance

i. Proteins

ii. Glucose

iii. Ketone bodies
iv. Bile salts and bile pigments
v. Blood
vi. Pus

Protein: The appearance of proteins in the urine is called 'proteinuria, if albumin appears it is referred as albuminuria.

Causes: Severe exercise, high protein diet. Pregnancy, kidney diseases, lower urinary tract damage, fasting, etc.

Glucose: The appearance of glucose (sugar) in urine is called as glycosuria and the disease condition is called diabetes mellitus.

Ketone bodies: The presence of ketone bodies, such as acetone, and hydroxybutyric acid and aceto-acetic acid in the urine is called as ketonuria' and the pathological condition is called 'ketosis'.

Causes: Excessive fat metabolism, usually seen in diabetes, during starvation, pregnancy, etc.

Bile salts and bile pigments: It may appear in the urine in conditions like obstructive hemolytic jaundice or hepatic jaundice.

Blood: The appearance of blood in the urine is called hematuria. The blood may appear in the urine, due to tuberculosis, cancer, renal stones or acute inflammation of kidney.

Pus: Pyuria refers to having white blood cells or pus cells in the urine. A urinary tract infection (UTI) is the most common cause of pyuria.

k. Write about abnormal RBCs and related diseases.

Ans: Abnormalities of Erythrocytes (RBCs) and related diseases:

Anaemia:

The deficiency of RBC in the blood or the percentage of hemoglobin decreases than the normal, the condition is called anaemia. The anaemia may be due to excessive blood loss or increased destruction of RBC or defective formation of RBC.

Types of Anaemia

Hemolytic anaemia: In this type, the cells are small, spherical and can be easily broken down. Sickle cell anemia: In this type, the cells have sickle shape.

Aplastic anaemia: It is an anaemic condition in which the bone marrow fails to form the RBC.

Pernicious anaemia: It is a type of anaemia, in which the essentialfactors which are responsible for the formation of RBC are absent, so the RBC count reduced.

Hypochromic or microcytic anaemia: It is due to the deficiency of iron. The hemoglobin content of the red cell is diminished. The size and volume of the red cells are below average.

Polycythemia

Polycythemia also known as polyglobulia) is a disease state in which the hematocrit (the volume percentage of red blood cells in the blood) and/or hemoglobin concentration are elevated in peripheral blood. It can be due to an increase in the number of red blood cells ("absolute polycythemia") or to a decrease in the volume of plasma ("relative polycythemia").

Q.3. Answer ALL questions of the following. 20 Marks

a. Which one is the largest organelle in the cytoplasm?

(i) Lysosomes (ii) Mitochondria
(iii) Golgi apparatus (iv) Endoplasmic reticulum

Ans: (ii) Mitochondria

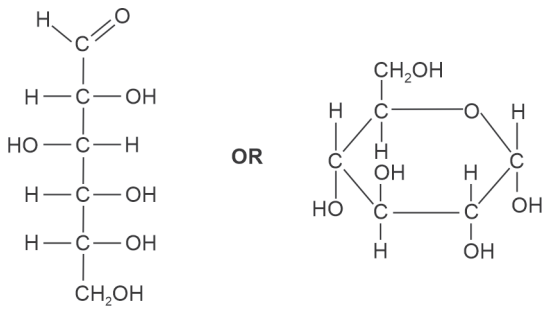
b. The cellular organelles called suicidal bags are_____

(i) Lysosome (ii) Ribosome
(iii) Nucleolus (iv) Golgi complex

Ans: (i) Lysosome

c. Draw the structure of glucose.

Ans:



d. Name one optically inactive amino acid.

Ans: Glycine

e. Name any two sulfur containing amino acids.

Ans: Methionine, cysteine

f. Define vitamins.

Ans: Vitamins may be regarded as organic compounds required in the diet in small amounts to perform specific biological functions for normal maintenance of optimum growth and health of the organism.

g. Write any two functions of RNA.

Ans: Function of RNA

- The primary function of RNA is to create proteins via translation. mRNA, rRNA, and tRNA are the three main types of RNA involved in protein synthesis.

- They are also involved in the transfer and expression of genetic information.
- They act as primers for DNA formation.
- Some RNAs act as enzyme as well as coenzyme

h. What is holoenzyme?

Ans: Apoenzymes in combination with its prosthetic group constitutes Holoenzymes. OR The functional unit of the enzyme is known as holoenzyme which is often made up of apoenzyme (the protein part) and a coenzyme (non-protein part) holoenzyme apoenzyme + coenzyme

i. Enlist any two functions of lipids.

Ans: Energy storage: Triacylglycerols, stored in adipose tissue, are a major form of energy storage.

- Acting as structural components of cell membranes: The glycero-phospholipids are the main structural component of biological membranes
- Dietary fats help to dissolve fat soluble vitamins: (A, D, E and K)
- Lipids provide excellent insulation as fat is bad conductor of heat.
- Fats provide padding to protect internal organs
- Lipoproteins and glycolipids are essential for cellular integrity.
- Lipids play diverse and important roles in nutrition and health.
- Humans have a requirement for certain essential fatty acids, such as linoleic acid, linolenic acid. These are provided by lipids.

j. Write any two functions of Vitamin C.

Ans: Vitamin C plays important role in:

- Collagen formation
- Bone formation
- Iron and haemoglobin metabolism
- Tryptophan, Tyrosine, Folic acid metabolism
- Synthesis of immunoglobulins (antibodies)
- Synthesis of peptide hormone and corticosteroid hormones
- Reduces risk of cataract formation
- As an antioxidant reduces risk of cancer, coronary heart disease.

k. The deficiency of Vitamin B_1 causes-

(i) Xeropthalemia (ii) Beriberi
(iii) Pellagra (iv) Scurvy

Ans: Beriberi

l. Name the coenzymes of vitamin B_6 and vitamin B_2.

Ans: Vitamin B_6 - Pyridoxal phosphate; Vitamin B_2—Flavin adenine dinucleotide (FAD)

m. What is glycogenolysis?

Ans: It involves breakdown of glycogen in the tissue to glucose in liver and kidneys or to glucose 6-phosphate in muscles.

n. Body water is regulated by the hormone-

(i) ADH (ii) ACTH
(iii) FSH (iv) Epinephrine

Ans: (i) ADH

o. Enlist any two functions of water.

Ans: Water provides the aqueous medium to the organism which is essential for the various biochemical reactions to occur. Water directly participates as a reactant in several metabolic reactions. It serves as a vehicle for transport of solutes. Water is closely associated with the regulation of body temperature.

p. Explain the terms ECF and ICF.

Ans: (i) Intracellular fluid (ICF) is the cytosol within the cell.

(ii) Extracellular fluid (ECF) surrounds the cells and is divided into the interstitial fluid and intravascular fluid (i.e., plasma, lymph, and cerebral spinal fluid)

q. The term biotechnology was coined in 1919 by ----------

(i) Karl Ereky (ii) Alexander Flaming
(iii) James Watson (iv) Francis Cricks

Ans: (i) Karl Ereky

r. Define "Biotechnology".

Ans: It is defined as the application of biological organisms, systems, or processes by various industries to learning about the science of life and the improvement of the value of materials and organisms such as pharmaceuticals, crops, and livestock.

s. ALT is also known as___.

(i) Alanine amino transferase
(ii) Amino leucine transferase
(iii) Aspartate amino transferase
(iv) None of these

Ans: (i) Alanine amino transferase

t. What is Rothera's test?

Ans: It is a method of testing urine for the presence of acetone or acetoacetic acid (ketone bodies), a sign of diabetes mellitus.

Winter Examination 2024 (Question Paper)
Second Year Diploma in Pharmacy
Subject: Biochemistry and Clinical Pathology (20223)

Time: 3 Hours **Max Marks: 80**

Q.1. Attempt any SIX of the following. **30 Marks**

a. Define and classify carbohydrates with example. Draw the structure of Glucose and galactose.
b. Discuss in brief the steps involved in glycolysis and give its energetic.
c. Define the term 'enzyme'. Enlist the factors affecting enzyme activity. Explain effect of substrate concentration and temperature on rate of enzyme catalysed reaction
d. Define proteins. Enlist different types of structure of proteins. Describe secondary structure of proteins.
e. Explain beta-oxidation of unsaturated fatty acid with energetic of palmitic acid.
f. Describe lipid profile tests with its clinical significance.
g. What is biological oxidation? Explain electron transport chain in details.

Q.2. Attempt any TEN of the following: **30 Marks**

a. Give types and functions of lipoproteins.
b. Give the schematic representation of overall view of TCA cycle.
c. Explain Watson and Crick model of DNA.
d. State the causes of:
   (i) Phenyl ketonuria (ii) Alkaptonuria (iii) Ketoacidosis.
e. Define dehydration. Give causes and treatment of dehydration.
f. Explain different liver function tests.
g. What are minerals? Give its classification and functions.
h. Name normal and abnormal constituents of urine. Write significance of abnormal constituents in disease
i. What are fatty acids? Classify it based on chemical structure and nutritional requirements with example.
j. Define and classify vitamins. Give deficiency diseases of vitamin D.
k. Define anaemia. Explain megaloblastic and sickel cell anaemia.

Q.3. Attempt ALL questions. **20 Marks**

a. Full form of DNA is_____

b. Define biochemistry.

c. True or false : The prokaryote cell has a nucleus.

d. _____is sulfur containing essential amino acid.

e. Lock and key model of enzyme action is proposed by_____.

(i) Emil Fischer (ii) Koshland

(iii) Crick (iv) Watson

f. Match the following:

1	Vitamin D	a	Beriberi
2	Vitamin C	b	Pernicious anemia
3	Vitamin B_{12}	c	Scurvy
4	Vitamin B_1	d	Rickets

g. Co-enzyme form of vitamin B_6 is_____

(i) Pyridoxal phosphate

(ii) Tetrahydrofolate

(iii) Thiamine pyrophosphate

(iv) Nicotinamide adenine dinucleotide

h. Define endoenzymes.

i. Define osmolarity.

j. Draw a structure of lactose.

k. Name the two hormones responsible for the regulation of electrolyte balance.

l. Give coenzyme of riboflavin.

m. ORS stands for_____

n. Define biotechnology.

o. If one NADH molecule completely oxidized by electron transport chain reaction in mitochondria, then it generates_____

(i) 2 ATP (ii) 3 GTP (iii) 4 ATP (iv) 3 ATP

p. Normal range of creatinine in urine is_____

q. Two amino acids are joined together by_____ bond.

(i) Glycosidal (ii) Peptide (iii) Covalent (iv) Pi

r. Which of the following nitrogenous base is not the component of RNA?

(i) Adenine (ii) Guanine (iii) Cytosine (iv) Thymine

s. Normal range of leucocytes in adult is_____.

t. Term biotechnology was coined in_____.

(i) 1954 (ii) 1919 (iii) 1857 (iv) 1820

Winter Examination 2024 (Specimen Answer Paper)
Second Year Diploma in Pharmacy
Subject: Biochemistry and Clinical Pathology (20223)

Time: 3 Hours **Max Marks: 80**

Q.1. Attempt any SIX of the following. **30 Marks**

[*Refer Specimen Answer Papers of Summer 2023, Winter 2023, Summer 2024 Examinations and Answers from this book for the Question 1 (a), (b), (c), (d), (e), (f), (g)]

Q.2. Attempt any TEN of the following: **30 Marks**

[*Refer Specimen Answers Paper of Summer 2023, Winter 2023, Summer 2024 Examinations and Answers from this book for the Question 2 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k)]

Q.3. Attempt ALL questions. **20 Marks**

a. Full form of DNA is_____.

Ans. Deoxyribonucleic acid.

b. Define Biochemistry.

Ans: The study dealing with the chemistry of living organisms in its different phases of activity is called biochemistry

c. True or false: The prokaryote cell has a nucleus.

Ans: False

d. _____is sulfur containing essential amino acid.

Ans: Methionine

e. Lock and key model of enzyme action is proposed by_____

(i) Emil Fischer (ii) Koshland (iii) Crick (iv) Watson

Ans: (i) Emil Fischer

f. Match the following

Ans:

1. Vitamin D	d. Rickets
2. Vitamin C	c. Scurvy
3. Vitamin B_{12}	b. Pernicious anemia
4. Vitamin B_1	a. Beriberi

g. Co-enzyme form of vitamin B6 is_____

(i) Pyridoxal phosphate (ii) Tetrahydrofolate

(iii) Thiamine pyrophosphate (iv) Nicotinamide adenine dinucleotide

Ans: (i) Pyridoxal phosphate

h. Define endoenzymes.

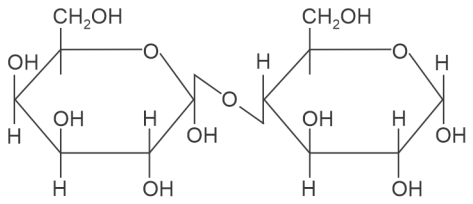
Ans: The enzymes which act only inside the cell are known as Endoenzymes/ Intracellular enzymes.

i. Define osmolarity

Ans: The term osmolarity refers to the number of particles of solute per liter of solution.

j. Draw a structure of lactose.

Ans:



k. Name the two hormones responsible for the regulation of electrolyte.

Ans: Aldosterone and anti-diuretic hormone

l. Give coenzyme of riboflavin.

Ans: Flavin adenine dinucleotide (FAD), Flavin mononucleotide (FMN)

m. ORS stands for _____.

Ans. Oral rehydration salt.

n. Define biotechnology.

Ans: Biotechnology is defined as the application of biological organisms, systems, or processes by various industries to learning about the science of life and the improvement of the value of materials and organisms such as pharmaceuticals, crops, and livestock.

o. If one NADH molecule completely oxidized by electron transport chain reaction in mitochondria, then it generates.

(i) 2 ATP (ii) 3 GTP (iii) 4 ATP (iv) 3 ATP

Ans: (iv) 3 ATP

p. Normal range of creatinine in urine is_____.

Ans: 500–2000 mg/day (4,420–17,680 mmol/day).

q. Two amino acids are joined together by _____ bond.

(i) Glycosidal (ii) Peptide (iii) Covalent (iv) Pi

Ans: (ii) Peptide

r. Which of the following nitrogenous base is not the component of RNA?

(i) Adenine (ii) Guanine (iii) Cytosine (iv) Thymine

Ans: (iv) Thymine

s. Normal range of leucocytes in adult.

Ans. 4,500–11,000 white blood cells per microliter of blood (4.5–11.0 × 109/L).

t. Term biotechnology was coined in _____.

(i) 1954 (ii) 1919 (iii) 1857 (iv) 1820

Ans: (ii) 1919

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