DAY TEN

Biomolecules and Enzymes

Learning & Revision for the Day

- Metabolites
- Biomolecules
- Carbohydrates
- Proteins
- Lipids
- Nucleic Acids
- Enzymes

Chemicals or molecules present in the living organisms are essential for the maintenance of their physiological processes. These are known as **biomolecules**. These include large molecules like proteins, nucleic acids, polysaccharides, lipids and small molecules like metabolites.

Mineral Elements and Their Functions in the Body

Element	Percentage	Function
Oxygen	65%	Cellular respiration and component of water.
Carbon	18%	Backbone of organic molecules.
Hydrogen	9.5%	Electron carrier, component of water and most organic molecules.
Nitrogen	3.3%	Component of protein and nucleic acid.
Calcium	1.5%	Component of bone, teeth, trigger for muscle contraction and enzyme activator.
Phosphorus	1.0%	Backbone of nucleic acid and energy transfer.
Potassium	0.4%	Important in nerve function and stomatal movement.
Sulphur	0.3%	Component of most proteins.
Chlorine	0.2%	Principal negative ion in the cells.
Sodium	0.2%	Principal positive ion bathing cell and important in nerve function.
Magnesium	0.1%	Component of many energy transferring enzyme and chlorophyll.
Iron	Trace	Critical component of haemoglobin and important in chlorophyll synthesis.

Metabolites

These are those biomolecules which are either utilised in metabolic functions or synthesised by the cellular machinery. These are of two types

1. The **primary metabolites** in an animal tissue are sugars, amino acids, fatty acids, fats and oils, nucleosides and nucleotides.
2. In plants, fungal and microbial cells, there are thousands of compounds other than primary metabolites, e.g. alkaloides, flavonoides, rubber, essential oils, antibiotics,

coloured pigments, scents, gums, spices. These are called **secondary metabolites.**

Some Secondary Metabolites

Group	Metabolite
Pigments	Carotenoids, anthocyanins, etc.
Alkaloids	Morphine, codeine, etc.
Terpenoides	Monoterpenes, diterpenes, etc.
Essential oils	Lemon grasss oil, etc.
Toxins	Abrin and ricin.
Lectins	Concanavalin A.
Drugs	Vinblastin, curcumin, etc.
Polymeric substances	Rubber, gums and cellulose.

- Secondary metabolites are **organic compounds** that are not directly involved in the normal growth and development or reproduction of an organism.
- These are often restricted to a narrow set of species within a phylogenetic group.
- Secondary metabolites often play an important role in **plant defence** against herbivory and other interspecies defences.

Biomolecules

These chemical compounds found in living organisms are of two types

(i) **Microbiomolecules** The molecules, which have molecular weights less than one thousand dalton are usually referred to as micromolecules or simply biomolecules.

(ii) **Macrobiomolecules** The molecules which are found in the acid insoluble fraction are called biomacromolecules.

The chemical composition of living tissue from abundance point of view is given below

Average Composition of Cells

Component	Percentage of the Total Cellular Mass
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

Carbohydrates

They are the basic component of food and principal source of energy, which are composed of carbon (C), hydrogen (H) and oxygen (O) in the approximate ratio of 1 : 2 : 1.

Types of Carbohydrates

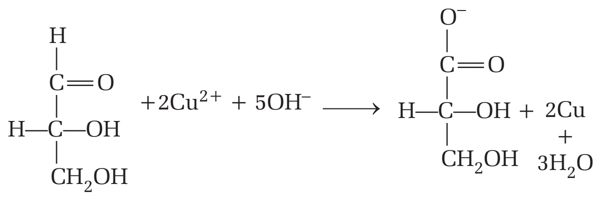
The carbohydrates can be divided into three major groups on the basis of hydrolysis products as follows

Types of Carbohydrates

CHO Type	Compound	Sub-unit	Occurrence in Living Thing
Monosaccharide	Glucose	—	Widespread
	Fructose	—	Sweet fruits
	Galactose	—	Milk
Oligosaccharide	Maltose	2 × Glucose	Germinating seeds
	Sucrose	Glucose + Fructose	Sugarcane
	Lactose	Glucose + Galactose	Milk
	Raffinose	Glucose + Fructose + Galactose	Plants
Polysaccharide	Starch	Glucose	Plants (storage)
	Glycogen	Glucose	Animals (storage)
	Cellulose	Glucose	Plant cell walls
	Chitin	Glucosamine	Arthropod exoskeletons

(i) Monosaccharides

- These are the simplest group of carbohydrate and cannot be hydrolysed further to give simpler units of polyhydroxyaldehyde or ketone.
- They are referred as simple sugars. They are sweet in tast, colourless solids having solubility in water, but sparingly soluble in alcohol and insoluble in ether.
- These have atleast one asymmetric carbon atom, hence they exist in different isomeric forms.
- The term 'reducing' reflects the fact that some sugars have carbonyl groups (C$=$O), which can be oxidised to carboxylic acids (— COOH), reducing other chemicals in the process.
- A standard test for a reducing sugar is **Benedict's solution**, a blue solution that contains copper sulphate. If a reducing sugar is present, the Cu (I) ions result in an orange precipitate.
- Glucose, fructose, galactose, maltose and lactose are all reducing sugars but sucrose is a non-reducing sugar. However, after sucrose is boiled with dilute acid to hydrolyse it into its monosaccharides, it produces a positive result.

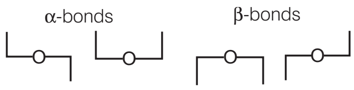


D-Glyceraldehyde is a three carbon, aldotriose (aldose sugar + triose sugar). It is also the smallest carbohydrate.

- D-Ribose is an important sugar used in genetic material. This sugar is not used as an energy source but is a part of the backbone of RNA.
- When OH group of C-2 position is removed (H in place of OH) from ribose, the sugar becomes deoxyribose, which is used in the backbone of DNA.
- Pentose sugar ribose is found in every animal cell. It is the main constituent of ATP, ADP, riboflavin and RNA.

(ii) Oligosaccharides

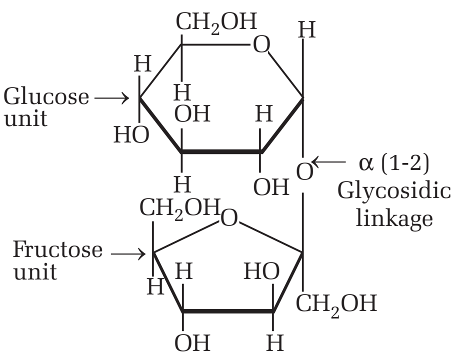
- These are the group of compounds, which on hydrolysis produce two or more molecules of same or different monosaccharide unit held together by a glycosidic bond.
- They are crystalline, water soluble and sweet to taste. They can be disaccharide, trisaccharide, tetrasaccharide and so on.
- The carbon that carries the aldehyde or the ketone can react with any hydroxyl group on a second sugar molecule to form a bond called **glycosidic bond**.
- Based on the position of the C – 1 OH, glycosidic bonds may be
  (a) α- **glycosidic bond** linkage between a C – 1 α OH and a C – 4 OH.
  (b) β – **glycosidic bond** linkage between a C-1 β OH and a C-4OH.



- C-4 end can be either up or down depending on the orientation of the monosaccharide.
- Cellobiose consists of two molecules of β-D glucose.
- It is similar to maltose except in the presence of β (1 – 4) linkage in cellobiose instead of α(1-4) in maltose.
- Due to the presence of β (1-4) linkage, cellobiose is undigestible.

Examples of oligosaccharides are as follows

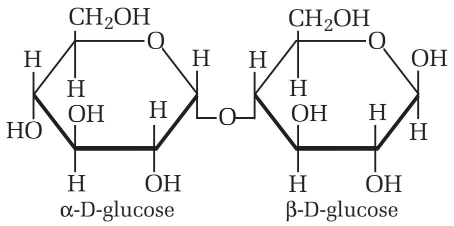
(a) **Sucrose or Table sugar** It is found in sugarcane and sugarbeet up to 20 % by mass.



Sucrose

(b) **Maltose or Malt sugar** It is not common in nature except in germinating starchy seeds.

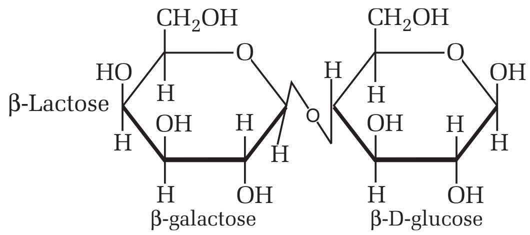
It is referred to as β–maltose because the unreacted C-1 on β-D glucose is in the β position.



Maltose, α (1-4) linkage

- Maltose is produced commercially from starch by a starch hydrolysing enzyme diastase.

(c) **Lactose or Milk sugar** It is a dimer of β-D galactose and either the α or β-D glucose.



Lactose, β-(1-4) linkage, β-disaccharide

- Lactose does not occur in nature except as a product of the mammary gland. Compared to milk of cow, buffalo and goat, lactose quantity is highest in the human milk.

(iii) Polysaccharides

- These are long chains of sugars. They are threads containing different monosaccharide units as building blocks.
- For example, cellulose is a polymeric polysaccharide consisting of only one type of monosaccharide, i.e. glucose.
- The major polysaccharides of interest in nutrition are glycogen, found in certain animal tissues and starch and cellulose, both of plant origin.
- All these polysaccharides consist of only glucose units.
- They may be either **homopolysaccharides** (i.e. containing a single type of monomers, e.g. starch, glycogen, cellulose, chitin) or **heteropolysaccharides** (i.e. containing two or more different units), e.g. hemicellulose, pectic substances, some gums, etc.

Some of the complex carbohydrates present in nature are as follows

1. **Glucans** are polymers of glucose monomers, e.g. starch, glycogen, cellulose, chitin.
2. **Galactans** are polymers of galactose monomers, e.g. agar-agar, pectin, galacton from snails.

3. **Mannans** are polymers of mannose monomers, e.g. yeast mannan.
4. **Xylans** are polymers of xylose monomers, e.g. hemicellulose xylan.
5. **Fructans** are polymers of fructose monomers, e.g. inulin.
6. **Agar-agar** is a galactan consisting of both D-and-L-galactose. It is used as a mircrobial culture medium.
7. **Pectin** contains arabinose, galactose and galacturonic acid. Pectins are abundant in fruits such as orange, lemon, etc.
8. **Pectic acid** is a homopolymer of the methyl ester of D-galacturonic acid.
9. **Glycogen** (animal starch) is commonly found in fungi and animals. It is water soluble, which gives a red colour with iodine. A starving man first consumes reserve glycogen.
10. Human cannot digest **cellulose**. It is digested by termites and sheeps by harbouring bacteria and protozoans that synthesise the necessary enzyme cellulase.
11. **Inulin** (Dahlia starch) is a polymer of fructose units linked by β-1, 2 glycosidic linkages.
12. **Hyaluronic acid** found in skin, vitreous humor of the eye, umbilical cord as a coating around the ovum and in certain bacteria as mucopolysaccharides.
13. **Chondriotin sulphates**, predominant in cornea, cartilage, tendons, skin, heart valves and saliva are also mucopolysaccharides.
14. **Callose** is a polymer of glucose. It occurs in the sieve tubes of phloem (in plants) and is formed often as a response to wounds.
15. **Hemicellulose** is a polymer of pentoses and sugar acids. It occurs in the plant cell wall and functions as cell wall matrix.
16. **Lignin** is composed of glucose. It is found in dead cells like sclerenchyma of plant cell walls.
17. **Chitin** is also a polymer of glucose, which functions as exoskeleton of arthropods.
18. **Murein** is polysaccharides cross linked with amino acids. It occurs in the connective tissue matrix and outer coat of mammalian eggs.
19. **Heparin** is related to chondroitin and is found in connective tissue cells. It functions as an anticoagulant.
20. **Gums and mucilages** are polymers of sugars and sugar acids. These are found in the bark of trees and mucilages of flowers. They help in retaining water during the dry season.

Functions of Various Carbohydrates

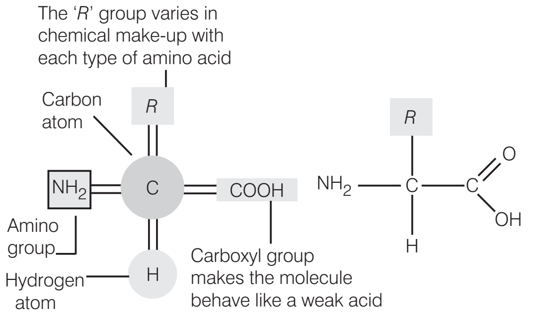
- Glucose is the most important sugar in our diet, which is used as immediate source of energy. It is also called **dextrose**.
- It is stored as **glycogen** in liver and muscles. Level in blood can be as high as 0.1 %.
- **D-fructose** (levulose) is a ketohexose and sweetest of all sugars.
- **Erythrose** is raw material for synthesis of anthocyanin and lignin.
- **Galactose** in milk is a component of milk sugar lactose.
- **Galactosides** are compounds of galactose. They occur in brain and nervous tissue. Galactose is a constituent of agar-agar.

Proteins

The term 'protein' was coined by **Berzelius** (1837) and **Mulder** (1838). Though approximately 300 amino acids occur in nature but only 20 make the composition of proteins. Proteins are polymers of amino acids.

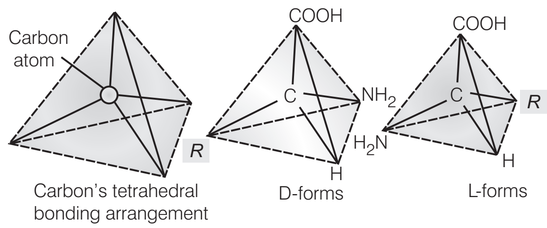
Structure of Amino Acid

- All amino acids have a common structure. The only difference between the different amino acids lies with *R*-groups in general formula. The *R*-group have quite diverse chemical properties.



General structure of an amino acid

- All amino acids (except glycine) show optical isomerism. This can result in two different arrangements as shown in the diagram.



- Gamma Amino Butyric Acid (GABA), histamine, serotonin, ornithine, citruline and β-alanine are the amino acids, which are not found in proteins.
- Glycine is the simplest amino acid with lowest molecular weight and absence of asymmetrical carbon atom. It is involved in the formation of haeme.
- Tryptophan is the most complex amino acid containing indole ring.
- Methionine and cysteine are sulphur containing **amino acids**.

- In proline and hydroxyproline, instead of NH_2 (amino) group, NH (imino) group is present. These amino acids are called **imino acids**.
- Proteins contain L-(Levorotatory) isomers of amino acids. D-(Dextrorotatory) isomers of amino acids are found only in bacterial cell walls.
- Isoleucine is an amino acid with two asymmetrical carbon atoms. Tyrosine gives rise to dopamine, melanin, thyroxine, adrenaline and nor-adrenaline.
- Lysine and arginine are basic amino acids, which contain more than one amino groups. Glutamic acid and aspartic acid are acidic amino acids, which contain more than one acidic groups.
- Tryptophan amino acid forms the vitamin nicotinamide and a plant hormone Indole Acetic Acid (IAA). Amino acids that cannot be synthesised in the body are called **essential amino acids**, while those which can be synthesised in the body and need not be supplied through diet are called **non-essential amino acids**.
- For human beings, eight amino acids are essential. Infants require arginine and histidine in addition.

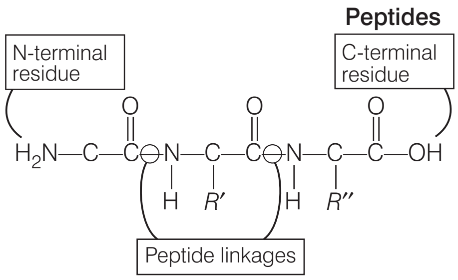
Essential and Non-Essential Amino Acids

Essential	Non-Essential
*Arginine	Glycine
*Histidine	Alanine
Isoleucine	Serine
Leucine	Aspartic acid
Methionine	Asparagine
Phenylalanine	Cysteine
Threonine	Glutamic acid
Tryptophan	Glutamine
Lysine	Proline
Valine	Tyrosine

**Arginine and histidine are considered semi-indispensable amino acids. These two are not essential in the adult organisms.*

Peptide Bond

Proteins are the linear sequence of amino acids linked together by **peptide bonds**. This bond is chemically a covalent bond formed between the α-amino group of one amino acid and the α-carboxylic group of another.



Formation of peptide bond

Depending on the number of peptide bonds present in a protein molecule, it may be a

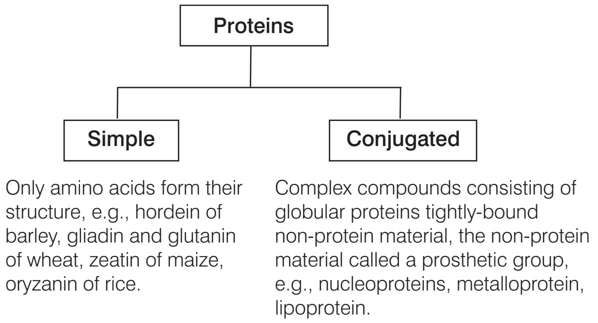
(i) **Dipeptide** When two amino acids are joined together *via* a peptide bond, a dipeptide is formed.

(ii) **Oligopeptide** It is a long, unbranched chain of 2-25 amino acids residues, which are linked by peptide bonds.

(iii) **Polypeptide** It is a long chain of many amino acids (>25 amino acid residues) linked end to end by peptide bond.

Classification of Proteins

Proteins are classified on the basis of increasing complexity in their structure. These can be of following types



Some Conjugated Proteins, their Prosthetic Groups and Location

Name	Prosthetic Group	Location
Phosphoprotein	Phosphoric acid	Casein of milk, vitelline of egg yolk.
Glycoprotein	Carbohydrate	Membrane structure, mucin (component of saliva).
Nucleoprotein	Nucleic acid	Component of viruses, chromosomes, ribosome structure.
Chromoprotein	Pigment	Haemoglobin -haeme (iron-containing pigment), phytochrome (plant pigment), cytochrome (respiratory pigment).
Lipoprotein	Lipid	Membrane structure, lipid transported in blood as lipoprotein.
Flavoprotein	FAD (Flavine Adenine Dinucleotide)	Important in electron transport chain in respiration.
Metal proteins	Metal	Nitrate reductase, the enzyme in plants, which converts nitrate into nitrite.

Types of Proteins Based on Structure

Type	Nature	Function
Fibrous	Secondary structure is most important (little or no tertiary structure), insoluble in water, physically tough, long parallel polypeptide chains cross-linked at intervals forming long fibres or sheets.	Perform structural function in cell and organisms, e.g. collagen (tendons, bone and connective tissue), myosin (in muscle), silk (spider's webs), keratin (hair, horn, nails and feathers).
Globular	Tertiary structure is most important. Polypeptide chains tightly folded to form spherical-shape. Easily soluble.	Form enzymes, antibodies and some hormones, e.g. insulin.
Intermediate	Fibrous but soluble.	Fibrinogen-forms insoluble fibrin when blood clots.

Structural	Collagen	Component of connective tissue, bone, tendons and cartilage.
	Keratin	Skin, feathers, nails, hair and horn.
	Elastin	Elastic connective tissue (ligaments).
	Viral coat proteins	'Wraps up' nucleic acid of virus.

Types of Proteins Based on their Functions

Type	Example	Occurrence/ Function
Enzymes	Trypsin	Catalyses hydrolysis of protein.
	Ribulose bisphosphate carboxylase	Catalyses carboxylation (addition of CO_2) of ribulose bisphosphate in photosynthesis.
	Glutamine synthetase	Catalyses synthesis of the amino acid glutamine from glutamic acid + ammonia.
Hormones	Insulin	Helps to regulate glucose metabolism.
	Glucagon	Stimulates growth and activity of the adrenal cortex.
	ACTH	Stimulates secretion of glucocorticoids.
Respiratory pigment	Haemoglobin	Transports O_2 in vertebrate blood.
	Myoglobin	Stores O_2 in muscles.
Transport	Serum albumin	Transport of fatty acids and lipids in blood.

Type	Example	Occurrence/ Function
Protective	Antibodies	Form complexes with foreign proteins.
	Fibrinogen	Forms fibrin in blood clotting.
	Thrombin	Involved in blood clotting mechanism.
Contractile	Myosin	Moving filaments in myofibrils of muscle.
	Actin	Stationary filaments in myofibrils of muscle.
Storage	Ovalbumin	Egg white protein.
	Casein	Milk protein.
Toxins	Snake venom	Enzymes
	Diphtheria toxin	Toxin made by diphtheria bacteria.

Structural Organisation in Proteins

There are following types of structural organisation in proteins.

1. **Primary structure** It consists of the linear sequence of amino acid residues in a polypeptide chain.
   - The enzyme ribonuclease and the protein myoglobin function only in their primary structure.
   - Primary structure determines the higher levels of organisation in protein and its biological functions.
2. **Secondary structure** It is regular folding patterns of continuous portions of the polypeptide chains, e.g. α-helix and β-pleated sheets. Secondary structures are stabilised by hydrogen bonds**.** Most globular proteins contain region of α-helices together with β-sheet.

   (i) **α-Helix** chains are coiled spirally in right-handed manner. At places, the helix is less regular forming random coils. The helix is stabilised by H–bond between oxygen [or carboxylic group (— CO)] of one amino acid residue and > NH group of next fourth amino acid residue. This secondary structure is found in several proteins like keratin, myosin, topomyosin, fibrin.

   (ii) In **β–Pleated sheets**, two or more α chains are joined by intermolecular bond, hydrogen bond. They can be of following types
   - **β– parallel sheets** Adjacent strand of polypeptide runs in the same direction, e.g. β–keratin.
   - **β–antiparallel sheets** Adjacent strand of polypeptide runs in the opposite direction, e.g. fibroin of silk.

3. **Tertiary structure** Three dimensional structure formed by the folding of the secondary structure into a complex shape.
   - The interactions involved in folding include weak ionic bonds, hydrogen bonds, hydrophobic interactions and strong disulphide bonds between neighbouring cysteine amino acids.
   - Enzymes are functional with a tertiary structure only.
4, **Quarternary structure** Proteins consist of two or more polypeptide chains. **Haemoglobin,** a globular protein composed of four polypeptide chains (i.e. two β-chains + two α-chains) each having a haeme group at the centre of chain.

Some Important Points Related to Proteins

- Proteins constitute about 10 to 12% of the cell contents.
- Proteins are made up of carbon (51%), oxygen (25%), nitrogen (16%), hydrogen (7%), sulphur (0.4%) and sometimes phosphorus is also present in traces.
- **Insulin** (human) has 53 amino acids arranged in two polypeptide chains of 22 and 31 amino acids.
  Human serum albumin has 582 amino acids in its polypeptide chain.
- Proteins show enormous diversity because of different proportions and sequence of amino acids.
- The number and variety of proteins vary from species to species and within a species from cell to cell.
- A bacterium *Escherichia coli* may have about 3000 types of proteins.
- A human liver cell may have millions of proteins. However, all these proteins are synthesised from the same 20 amino acids.
- Proteins and amino acids are **amphoteric** in nature. It means they can react with both acids and bases.
- Proteins are oxidised by putrefaction process and produce bad smell.
- **Denaturation** refers to the loss of three-dimensional structure of a protein.
- Strong acids and alkalis, heavy metals, heat, UV radiations and detergents can denature a protein.
- **Collagen** is the most abundant protein in animal world and Ribulose Biphosphate Carboxylase Oxygenase (RuBisCO) is the most abundant protein in the whole of the biosphere.
- P-proteins are involved in the transport of organic compounds through phloem.
- Snake venom, ricin of castor and bacterial toxins are proteinaceous in nature.
- Protamines are basic proteins associated with DNA of chromosomes, these are rich in lysine and arginine.
- Monellin, a protein is the sweetest chemical obtained from an African berry.

Lipids

- The term 'lipid' was first used by **Bloor** (1943).
- Lipids are water insoluble and consist of C, H and O but the ratio of H and O is more than 2 : 1.
- Lipids are less dense than water and therefore they float on it.

Classification of Lipids

On the basis of their chemical structure, the lipids are classified into following classes:

Simple Lipids (True Lipids)

Simple lipid like triglycerides, fats, wax, suberin and cutin are formed from fatty acids and alcohol. A brief account of triglycerides and waxes are

- **Triglycerides** (Neutral fats) Neutral fats such as butter and vegetables oils are mostly triglycerides. Each has three fatty acids linked to a glycerol (glycerine or trihydroxy propane).
  In fats when all three fatty acids are similar they are called pure fats and when these fatty acids are dissimilar they termed as mixed fat.
- **Waxes** These are long chain fatty acid linked to long chain of alcohol or carbon ring. All waxes have firm consistency and repel water.
  In plants, they cover the surface of leaf and other aerial surfaces to avoid excess transpiration. In animals, cutaneous glands secretes wax (lanolin) for forming a protective water insoluble coating on animal fur.

Compound Lipids (Conjugated Lipids)

Complex or compound lipids contain an additional group in addition with alcohol and fatty acids. These are

- **Glycolipids** These contains sphingosine (alcohol) with a fatty acid and monosaccharide sugar, i.e. cerebrosides, terpenes and gangliosides.
- **Phospholipids** (Common membrane lipid) These are triglyceride lipids with one fatty acid replaced by phosphoric acid which is often linked to additional nitrogenous group like choline, ethanolamine, etc.
- **Lipoproteins** These are the complex of lipids and proteins and are present in blood, milk and egg yolk.
  On the basis of compactness, these can be divided into:
  - **LDL** Low Density Lipoprotein also called as bad cholesterol.
  - **HDL** High Density Lipoprotein which removes bad cholesterol.

Derived Lipids

These are derivative of lipid (steroid) or its chemicals (prostaglandins).

- **Steroids** The group of complex lipids that possess a rigid backbone of four fused-together carbon rings. Sterols are the components of every eukaryotic cell membrane, e.g. cholesterol.
- **Palmitic acid** ($C_{16}H_{32}O_2$) saturated fatty acid, found in coconut, etc.
- **Arachidonic acid** ($C_{20}H_{32}O_2$) An unsaturated fatty acid found in ground nut, etc.

Complex Lipids

The complex lipids may be of following types

(i) Chylomicrons which transport triglycerides from intestine to other tissues except kidneys.

(ii) Very Low Density Lipoproteins (VLDL) which bind triglycerides in liver and carry them to fat tissue.

(iii) Low Density Lipoproteins (LDL) which carrry cholesterol to peripheral tissues.

(iv) High Density Lipoproteins (HDL) which bind to plasma cholesterol and transport it to liver.

Fatty Acids

- Most of the fatty acids found in nature have an even number of carbon atoms (usually 14 to 24).
- The general formula of a saturated fatty acid is $CH_3(CH_2)_nCOOH$.
- Fatty acids may be classified into following two types

  (i) **Saturated fatty acids** have single bonds only, they are solid at room temperature, and their melting point is high. These are straight chain compounds, found more commonly in animal tissues, e.g. palmitic acid.

  (ii) **Unsaturated fatty acids** have one or more double bonds, they are liquid at room temperature and have a low melting point. These compounds show more bending in their chains and are more common in plant tissues, e.g. oleic acid.

Empirical Formulae of Saturated Fatty Acids

Common Name	Empirical Formula	Symbol	Number of Double Bond
Capric acid	$C_{10}H_{20}O_2$	10 : 0	0
Lauric acid	$C_{12}H_{24}O_2$	12 : 0	0
Myristic acid	$C_{14}H_{28}O_2$	14 : 0	0
Palmitic acid	$C_{16}H_{32}O_2$	16 : 0	0
Stearic acid	$C_{18}H_{36}O_2$	18 : 0	0
Arachidic acid	$C_{20}H_{40}O_2$	20 : 0	0

Empirical Formulae of Unsaturated Fatty Acids

Common Name	Empirical Formula	Symbol	Number of Double Bond
Palmitoleic acid	$C_{16}H_{30}O_2$	16 : 1	1
Oleic acid	$C_{18}H_{34}O_2$	18 : 1	1
Linoleic acid	$C_{18}H_{32}O_2$	18 : 2	2
Linolenic acid	$C_{18}H_{30}O_2$	18 : 3	3
Arachidonic acid	$C_{20}H_{32}O_2$	20 : 4	4

- If a fatty acid has more than one double bonds (2 in linoleic acid, 3 in linolenic acid and 4 in arachidonic acid), it is said to be **polyunsaturated**.
- Unsaturated fatty acids are slightly more abundant in nature than saturated fatty acids, especially in higher plants.
- Oils are rich in unsaturated fatty acids and have low melting point. In **hydrogenation**, the unsaturated fatty acids become saturated and oil becomes solid fat.
- Fat is a molecule used by most animals for long term energy storage.
- Rich source of polyunsaturated fatty acids in the diet is vegetable oils.
- Sunflower oil is rich in linoleic acid and minimum fatty acid content is in coconut oil. Mustard oil is one of the most unsaturated.

Essential Fatty Acids

- These serve as a precursor for synthesis of prostaglandins.
- These acids are some polyunsaturated fatty acids, which cannot be synthesised in the animal body and must be supply with food to avoid their deficiency.
- Linoleic, linolenic and arachidonic acids are essential fatty acids for man.
- Maximum number of double bonds present in essential fatty acids is four.
- Phospholipids are main constituents of plasma membrane because they contain both polar and non-polar portions.
- They may be divided into following types

  (i) **Sphingophospholipids** These are a complex family of compounds, i.e., phosphoric acid with amine alcohol 4–sphingamine (or sphingosine) instead of glycerol in addition to fatty acids and chlorine.

  (ii) **Glycolipids** These contain sphingosine (alcohol) with a fatty acid and a monosaccharide sugar (usually galactose, glucose, etc.), e.g. cerebrosides and gangliosides.

- **Cerebroside** They are the glycolipid with galactose as the main sugar (sometimes glucose may be found). They are abundant in myelin sheath of nerves and white matter of brain.

- **Gangliosides** They are made up of sphingosine or dihydrosphingosine, fatty acid, glucose, galactose, N–acetyl galactosamine and sialic acid.
- They are involved in the ion transport and form receptor for viral particles and toxin, e.g., cholera toxin.
- Lecithin is a phospholipid. It is an excellent emulsifying agent, which is produced commercially from soyabean (*Glycine max*) seeds.
- Steroids are derivatives of a four membered ring known as **phenanthrene**.
- A diet rich in saturated fats in one of several factors that may contribute to the human cardiovascular disease known as **atherosclerosis.**
- A layer of fat beneath the skin insulates the body. This subcutaneous layer is especially thick in whales, seal and most other marine mammals.
- Cholesterol is insoluble in water and chemically unreactive. It is synthesised from acetyl Co-A or acetate in liver.
- Phytosterol is a steroid found in plants.
- Cholesterol content is minimum in vegetable oils.
- Diosgenin is a steroid obtained from the plant called ***Dioscorea***. It is used for manufacturing antifertility pills**.**
- Animal hormones such as androgens, oestrogens, progesterons, glucocorticoids, mineralocorticoids, etc, are steroids, which are derived from cholesterol.
- Bile salts are derivatives of cholesterol, which are synthesised in liver. They help in emulsification of fat in small intestine.
- Saponins are glycoside having steroids (e.g. sapogenin) which form foam when their watery solution is shaken.
- They are widely distributed in plants (e.g. *Saponaria*, *Quillaja*). They can dissolve RBCs even in high dilution.
- Prostaglandins are derivatives of arachidonic acid and other C_{20} fatty acids, which have several functions like vasodilation, vasoconstriction, bronchoconstriction, acid production in stomach, cell communication and hormone modulation.
- In most fungi, ergosterol replaces cholesterol in the cell membranes. Ergosterol inhibitors are antifungal compounds.

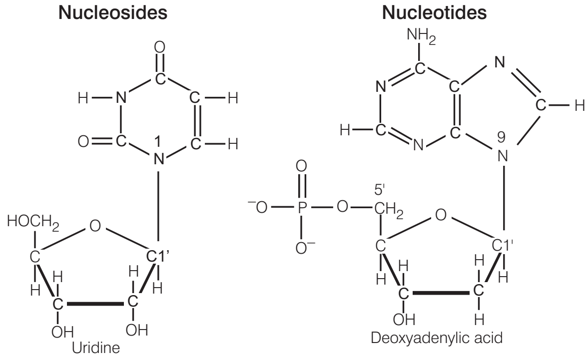
Functions of Lipids

- Waxes and oils are secreted on surfaces to provide waterproofing in plants and animals.
- Fats absorb shocks, organs that are prone to bumps and shocks (e.g. kidneys) are cushioned with a relatively thick layer of fat.
- Lipids are a source of metabolic water. During respiration, stored lipids are metabolised for energy, producing water and carbon dioxide.
- Lipid constructed from five carbon compound isoprene are called **terpenes.**
- Isoprene and its derivatives are joined in various combination to produce substances such as vitamin-A and carotenoids.
- Carotenoids are isoprenoid hydrocarbon, a plant pigment containing 40 carbon atoms.
- Natural rubber is a polyterpenes.

Nucleic Acids

- They are polymers of nucleotides and hence known as polynucleotides. A molecule of a nucleotide is composed of three smaller molecules, i.e. phosphate (P), sugar (S) and a nitrogen base (N).
- The phosphate group is represented by phosphoric acid (H_3PO_4). The sugar molecule in the nucleotide is a 5-carbon pentose sugar.
- It is represented by either ribose sugar ($C_5H_{10}O_5$) or deoxyribose sugar ($C_5H_{10}O_4$). Both the sugars have a furanose ring structure**.**
- The two types of nitrogen bases present are
  - **Purines,** which have a double ring structure.
  - **Pyrimidines,** which have a single ring structure.
- Purines are of two types, adenine (A) and guanine (G).
- Pyrimidines are of three types, cytosine (C), thymine (T) and uracil (U).
- The nitrogen base molecule is attached to the sugar molecule by a **glycosidic bond**.
- A combination of nitrogen base with sugar is called **nucleoside**.
- Nucleosides involving ribose sugars are called **ribonucleosides**.
- Similarly, **nucleosides** involving deoxyribose sugars are called **deoxyribonucleosides**.
- Nucleotides formed by ribonucleosides are called ribonucleotides.
- They form the monomers of Ribose Nucleic Acid (RNA).
- Nucleotides formed by deoxyribonucleosides are called **deoxyribonucleotides**.

They form the monomers of Deoxyribose Nucleic Acid (DNA).



Ribonucleosides	Ribonucleotides	Deoxyribonucleosides	Deoxyribonucleotides
Adenosine	Adenylic acid	Deoxyadenosine	Deoxyadenylic acid
Cytidine	Cytidylic acid	Deoxycytidine	Deoxycytidylic acid
Guanosine	Guanylic acid	Deoxyguanosine	Deoxyguanylic acid
Uridine	Uridylic acid	Deoxythymidine	Deoxythymidylic acid

Nucleosides and nucleotides of RNA and DNA

DNA

- It is the genetic material in all living organisms except viruses, where genetic material may be either DNA or RNA.
- A small amount of DNA is also found in the cytoplasm (in cell organelles like mitochondria and plastids, known as extra-nuclear DNA).
- Uracil nucleotides are absent in DNA.
- The DNA molecule is composed of two polynucleotide chains.
- This structure is well-explained by the double helix model proposed by **Watson** and **Crick** in 1953.
- The two polynucleotide chains are coiled around each other like a spiral staircase (double helix).
- The cross-rungs (steps) are formed by the nitrogen bases, while phosphates and sugars form the uprights.
- The two-polynucleotide chains run in opposite directions (antiparallel).
- One chain runs in the 3′–5′ direction, while the other chain is in 5′–3′ direction.
- The average distance between the two chains (B–DNA) is 20 Å.
- One full turn of the helix, called gyre, measures 34 Å in length. The distance between two successive sugar molecules is 3.4 Å. Thus, each gyre accommodates 10 nucleotides.
- The nitrogen bases of the two opposite chains exhibit highly specific base pairing.
- A purine in one chain always pairs with a pyrimidine in the opposite chain.

Comparison of Major Forms of DNA

Character	A-DNA	B-DNA	C-DNA	D-DNA	Z-DNA
Base pair per turn of the helix	11	10	9.33	8	12
Tilt of base pairs (y)	20.2°	6.3°	–7.8°	–16.7°	7°
Axial rise (h)	2.56 Å	3.37 Å	3.32 Å	3.03 Å	3.7 Å
Helical diameter (Å)	23 Å	19 Å	19 Å	–	18 Å
Handedness of the double helical structure	Right-handed	Right-handed	Right-handed	Right-handed	Left-handed

- Among purines, adenine (A) pairs only with the pyrimidine thymine (T) and *vice-versa*. Similarly, guanine (G) pairs only with cytosine (C) and *vice-versa*.
- There are two weak hydrogen bonds between A and T or T and A and three weak hydrogen bonds between G and C or C and G.
- The total amount of purines is equal to the total amount of pyrimidines (A + G) = (C + T). The two polynucleotide chains of DNA molecule are not identical to each other but complementary to each other. The fact that the total amount of purines will be equal to the total amount of pyrimidines, was first enunciated by **Chargaff** (1950).
- The DNA strand, which serves as a template for RNA synthesis is known as template strand, minus (–) strand or sense strand. Its complementary strand is named non-template strand, plus (+) strand or antisense strand.

Functions of DNA

- It is the genetic material in all prokaryotes and eukaryotes.
- It is capable of replication through which it can be faithfully passed on to successive generations.
- It is involved in the synthesis of RNA.
- It provides the code for protein biosynthesis.
- It is involved in mutations and genetic recombinations, which bring about variations.

RNA

- It occurs mostly in the cytoplasm in the eukaryotic cells.
- A small amount occurs in the nucleus of the cell, as a constituent of nucleolus.
- RNA is a single polynucleotide chain composed of nucleotides of adenine, guanine, cytosine and uracil. Thymine nucleotides are absent.
- There are three types of RNA, i.e. ribosomal RNA (*r*RNA), messenger RNA (*m*RNA) and transfer RNA (*t*RNA).

Comparison of Different Types of RNA

Character	Ribosomal RNA (*r*RNA)	Messenger RNA (*m*RNA)	Transfer RNA (*t*RNA)
Description	A type of molecule that combines with certain proteins to form the ribosome (the structural work bench, on which a polypeptide chain is assembled).	The 'blueprint' (a linear sequence of specific nucleotides) that is delivered to the ribosome for translation into a polypeptide chain.	An adaptor molecule. It can pick up one type of amino acid and pair with an *m*RNA 'code word' (a specific sequence of three bases calling for that amino acid).
Percentage of total RNA of cell	~80%	3-5%	10-20%
Sedimentation coeficient	28S, 18S, 5.8S, 5S, 23S, 16S, S	8S	3.8S
Number of nucleotides	5 S RNA : 120 nucleotides. 16.18S RNA : 1,600–2,500 nucleotides 23-28 S RNA : 3,200 to 5,000 nucleotides	*E. coli* : 900-1,500 nucleotides	73-93 nucleotides
Molecular weight	23 S RNA : 1.1×10^6 30 S RNA : 0.55×10^6	5,00,000	25,000-30,000
Unusual bases	Small amount of methylated bases (*E. coli* : 1 per 100-150 nucleotides).	Small amount of unusual bases.	High content of unusual bases (*E. coli* : 1 per 30-40 nucleotides).
Site of synthesis	Derived from nucleolar DNA.	Synthesised in nucleus on DNA template.	Synthesised in nucleus on DNA template.
Beginning of synthesis	Synthesis begins at gastrulation and increases as development proceeds.	Some *m*RNA is found in the ovum. New *m*RNA is synthesised during early cleavage.	*t*RNA synthesis occurs at the end of adaptor for attaching amino acids to cleavage stages.
Base of relationship to DNA	No obvious base relationship to DNA. *r*RNA is formed from only small section of DNA.	*m*RNA shows bases relationship to DNA. It is formed from all sections of DNA.	Same as in *r*RNA.
Function	Helps in protein synthesis during translation.	Conveys genetic information from ribosomes, where it takes part in protein synthesis.	Adaptor for attaching amino acids to *m*RNA template.

Enzymes

- The term 'Enzyme' was coined by **Kuhne** (1878). There are approximately 3000 enzymes present in a cell.
- The molecular weight of enzymes ranges from 10,000 to more than 1,00,000 daltons.
- Enzyme zymase was discovered by **Buchner**, he was awarded Nobel Prize in 1907 for his studies based on yeast extract.
- Approximately, all enzymes are proteins (ribozymes are exception). Being proteins, they are coded by DNA.
- Enzymes are biocatalysts having prominent active sites. These are very efficient, i.e. a very small amount of catalyst brings about the change of a large amount of substrate.
- They are highly specific, i.e. an enzyme will generally catalyse only a single reaction.
- Metabolic reactions are catalysed reaction. There is no uncatalysed, metabolic conversion in living systems.
- The constant making and breaking of biomolecules in a living cell through chemical reactions is called **metabolism.** Each of the metabolic reactions results in transformation of biomolecules.
- The flow of metabolites through the metabolic pathway has a definite rate and direction. This metabolic flow is called the dynamic state of body constituents.
- Enzymes are also used for therapeutic means to treat diseases, e.g. streptokinase is used in cleaning blood clots inside blood vessels.
- Peroxidase is the smallest enzyme.
- Diastase is the earliest known enzyme.
- Catalase is a non-porphyrin, antiageing enzyme.

Cofactors

- Enzymes are composed of one or several polypeptide chains. The cofactors are bound to the enzyme to make the enzyme catalytically active. Three kinds of cofactors may be identified as prosthetic groups, coenzymes and metal ions.

- A complete enzyme is called a **holoenzyme** it consists of an apoenzyme and a prosthetic group.
- Enzymes are thermolabile, amphoteric, colloidal and substrate specific.
- If working inside the cell, in which they are produced, they are called **endoenzymes**.
- Enzymes secreted outside the cell and act on external medium are called **exoenzymes.**
- Most human enzymes function best within a relatively narrow temperature range between 35 and 40°C (close to body temperature).
- Below this temperature range, the bonds that determine enzyme shape are not flexible enough to permit the induced-fit change sometimes necessary for catalysis.
- Above this temperature range, the bonds are too weak to hold the enzyme's peptide chains in the proper position.
- Bacteria that live in hot springs have enzymes with stronger bonding between their peptide chains and therefore, can function at temperatures of 70°C or higher.
- The temperature coefficient (0-10) of enzyme is 2-3 within optimum range, that is rate of reaction increases from 2-3 times for 10°C increment.

The Categories of Cofactors

Cofactor Type	Property	Example
Prosthetic groups	These are always organic in nature. Tightly bound to the apoenzyme.	Haeme is the prosthetic group and is part of active site of catalase enzyme, which hydrolyses H_2O_2 $2H_2O_2 \longrightarrow 2H_2O + O_2$
Coenzymes	Always organic in nature. Associated with apoenzyme only during the course of catalysis. Generally derived from the vitamins. Act as carriers of chemical groups or atoms or electrons.	FAD (from Riboflavin-B_2) for Succinate DHase. NAD (from Niacin-B_5) for Malate DHase. TPP (from Thiamine-B_1) for Decarboxylases.
Metal ions	Always inorganic in nature. Form a functional part of active site of enzyme. Form coordination bonds with the side chains at the active sites.	Fe cytochrome oxidase, catalase, peroxidase Mg hexokinase, glucose 6-phosphatase, pyruvate kinase Cu cytochrome oxidase Zn carbonic dehydrogenase, alcohol dehydrogenase Mo nitrogenase, Ni urease

Action of Some Selected Enzymes

Enzyme	Reaction Catalysed	pH Optimum
Pepsin (stomach)	Digestion of protein	2.0
Acid phosphatase (prostate)	Removal of phosphate group	5.5
Salivary amylase (saliva)	Digestion of starch	6.8
Lipase (pancreatic juice)	Digestion of fat	7.0
Alkaline phosphatase (bone)	Removal of phosphate group	9.0
Trypsin (pancreatic juice)	Digestion of protein	9.5
Monoamine oxidase (nerve endings)	Removal of amine group from norepinephrine	9.8

Naming and Classification of Enzyme

- Enzymes are named by adding a suffix-ase to the root word of the substrate, on which that enzymes acts, e.g. lipase (fat hydrolysing enzyme), sucrase (breaking down sucrose).
- Sometimes the enzymes are named on the basis of the reaction that they catalyse, e.g. polymerase (aids in polymerisation), dehydrogenase (removal of H-atoms).
- Some enzymes have been named on the basis of source from which they were first identified, e.g. papain from papaya.
- The names of some enzymes ends with an 'in' indicating that they are basically proteins, e.g., pepsin, trypsin, etc.
- **Thomas Cech** and **Sydney Altmann** were awarded Nobel Prize for the discovery of enzymatic activity of ribonuclease (ribozyme). They are non-proteinaceous enzymes.
- Mainly enzymes are classified into six classes.

Classification of Enzymes

Group of Enzyme	Reaction Catalysed	Example
Oxidoreductases	Transfer of hydrogen and oxygen atoms or electrons from one substrate to another	Dehydrogenases oxidases
Transferases	Transfer of a specific group (a phosphate or methyl, etc) from one substrate to another	Transaminase kinases
Hydrolases	Hydrolysis of a substrate	Esterases digestive enzymes
Isomerases	Change of the molecular form of the substrate	Phosphohexo isomerase, fumarase
Lyases	Non-hydrolytic removal of a group or addition of a group to a substrate	Decarboxylases aldolases
Ligases (synthetases)	Joining of two molecules by the formation of new bonds	Citric acid synthetases

Mechanism of Enzyme Action

- Enzymes possess active sites, where the reaction takes place. These have specific shapes. Enzymes remain unaltered up to the end of chemical reactions therefore, it can be used again and again.

- Enzyme works by lowering the **activation energy** (energy required to start a reaction).
- An enzyme combines with its substrate (S) to form a short lived Enzyme Substrate (ES) complex, which breaks up into products and enzyme.
- Only a small portion (4-12 amimo acids) of the large enzyme molecule comes in direct contact with the substrate, this portion is called **active site.**
- **Fisher** (1980) suggested the **lock and key hypothesis** (template theory) for enzyme action on the basis of **specificity**.
- According to this theory, the enzyme has a particular shape (lock) into which particular substrate (key) fits.
- **Koshland** (1959) proposed **induced fit hypothesis**. This states that combination of a substrate with enzyme induces changes in the enzyme structure, which enables the enzyme to perform its catalytic function effectively.
- On increasing the subsrate concentration, the catalytic activity of given concentration of an enzyme will increase to approach maximum rate V_{max}.
- The substrate concentration at which the chemical reaction attains half its maximum velocity is called **Michaelis Menten constant** (K_m)**.**
- EC number is called **Enzymes Commission number**. It gives a code number to an enzyme, which is in 4 digits.
- First digit of EC number denotes class, second digit denotes sub-class, third digit denotes sub-sub-class and the fourth-one denotes enzyme number in sub-sub-class**.**
- Specificity of an enzyme is due to apoenzyme position. Apoenzyme is a protein composed of α amino acid units.
- Tertiary structure of enzymatic protein is folded in such a way as to create a region called **active site** that has correct molecular dimension and topology to accommodate and bind with a specific substance.
- Enzymes useful in hydrolysing fats and lipids are known as **esterases.**

Diagnostic Value of Some Enzymes

Enzymes	Diseases Associated with Abnormal Plasma Enzymes Concentrations
Alkaline phosphatase	Obstructive jaundice, Paget's disease (osteitis deformans) and carcinoma of bone.
Acid phosphatase	Benign hypertrophy of prostate and cancer of prostate.
Amylase	Pancreatitis and perforated peptic ulcer.
Aldolase	Muscular dystrophy.
Creatine kinase (or creatine phosphokinase-CPK)	Muscular dystrophy and myocardial infarction.
Lactate dehydrogenase (LDH)	Myocardial infarction, liver disease, renal disease and pernicious anaemia.
Transaminase	Myocardial infarction, hepatitis and muscular dystrophy.

- There are some enzymes, which have slightly different molecular structure but exert similar catalytic action. Such enzymes are called **isoenzymes** or **isozymes**. More than 100 isozymes have been identified.
- The enzyme Lactic Dehydrogenase (LDH) in human skeletal muscle has five isozymes.

Factors Affecting Enzyme Activity

The activity of an enzyme can be affected by a change in the conditions which can alter the tertiary structure of the protein.

- **Substrate concentration** Enzyme activity increase with increase in concentration of the substrate to a maximum and then it levels off.
- **Enzyme concentration** In general the rate of reaction will increase with increasing enzyme concentration, due to availability of more active sites for reaction.
- **Temperature and pH** In most of the enzymatic reactions, rise of 10°C in the temperature doubles the rate of reaction between 5-40°C.
  Enzymes are **denatured** (secondary and above level of structures degraded) at higher temperature due to their proteinaceous nature and rate of reaction drops.
- **Redox potential** Enzymes are sensitive to redox-potential of the cell. Many enzymes are affected by redox potential due to the presence of oxidisable SH-group.

Enzyme Inhibition

Reduction or stoppage of enzyme activity due to certain adverse conditions or chemicals is called **enzyme inhibition** and the chemicals which interferes or inhibits the process are called **inhibitor**. Enzyme inhibition can be of following types

- **Competitive inhibition** It is a reversible process due to substrate or enzyme analogue in which K_m increases, but V_{max} remains the same.
- **Non-competitive inhibition** In this inhibitor forms a complex with enzyme other than the active site and V_{max} decreases.
- **Feedback inhibition** Where the end product or intermediates functions as temporary inhibitor which combines with a regulatory site (also known as allosteric site) of the enzyme and thus, functions as negative modulator. This is also called **allosteric modulation**.

NOTE Being large sized protein molecule, enzyme exists as colloid. Substrate molecule changed per minute into product is called turnover number, e.g. 36 millions for carbonic anhydrase, 5 millions for catalase, etc.

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 Which two functional groups are characteristic of sugars? ➜ NEET 2018

(a) Carbonyl and phosphate (b) Carbonyl and methyl
(c) Hydroxyl and methyl (d) Carbonyl and hydroxyl

2 The chitinous exoskeleton of arthropods is formed by the polymerisation of ➜ CBSE-AIPMT 2015

(a) keratin sulphate and chondroitin sulphate
(b) D–glucosamine
(c) N–acetyl glucosamine
(d) lipoglycans

3 Which one of the following is a non-reducing carbohydrate? ➜ CBSE-AIPMT 2014

(a) Maltose (b) Sucrose
(c) Lactose (d) Ribose 5-phosphate

4 Which of the following is not correct?

(a) Plant cell wall is made up of cellulose
(b) Paper made from plant pulp is cellulose
(c) Cotton fibre is cellulose
(d) Cellulose gives blue colour with iodine test

5 Which of the following is not correct?

(a) All monosaccharides are reducing sugars
(b) Fehling's test is used for detecting reducing sugars
(c) Maltose and lactose are non-reducing sugars
(d) Sucrose occurs in sugarcane and sugarbeet, is a non-reducing sugars

6 Sugars are technically called carbohydrates, referring to the fact that their formulae are only multiple of $C(H_2O)$. Hexoses therefore have six carbons, twelve hydrogens and six oxygen atoms. Glucose is a hexose. Choose from among the following another hexose.

(a) Fructose (b) Erythrose
(c) Ribulose (d) Ribose

7 Cellulose is a homoglycan hexosan. Almost pure cellulose is found in

(a) cotton (b) apple
(c) orange (d) jute

8 Carbohydrates, the most abundant biomolecules on earth are produced by

(a) all bacteria, fungi and algae
(b) fungi, algae and green plant cells
(c) some bacteria, algae and green plant cells
(d) viruses, fungi and bacteria

9 The covalent linkage of a carbohydrate to a protein or lipid is termed as

(a) glycoprotein (b) glycolipid
(c) proteoglycan (d) glycoconjugate

10 Which of the following sugars is found in nucleic acid?

(a) Dextrose (b) Glucose
(c) Levulose (d) Deoxyribose

11 Cellulose is a polymer of

(a) α-glucose (b) β-glucose
(c) α-fructose (d) β -fructose

12 Which of the following is the least likely to be involved in stabilising the three-dimensional folding of most proteins? ➜ NEET-II 2016

(a) Hydrogen bonds
(b) Electrostatic interaction
(c) Hydrophobic interaction
(d) Ester bonds

13 Which one is the most abundant protein in the animal world?

(a) Trypsin (b) Haemoglobin
(c) Collagen (d) Insulin

14 Which of the following is not correct?

(a) Peptide bond is formed when *R*-group of one amino acid reacts with carboxyl (COOH) group of another amino acid
(b) Glycosidic bond is formed by dehydration between two carbon atoms of two adjacent monosaccharides
(c) The bond between the phosphate and hydroxyl group of sugar is an ester bond
(d) None of the above

15 Which of the following is correct?

(a) Peptide bond is the linkage between two amino acids of protein
(b) Glycosidic bond is the linkage between two monosaccharides in a polysaccharide
(c) Phosphodiester bond is the linkage between two nucleotides
(d) All of the above

16 Amino acids as the name suggests have both an amino group and a carboxyl in their structure. In addition, all naturally occurring amino acids (those which are found in protiens) are called L-amino acids. From this, can you guess from which compound can the simplest amino acid be made?

(a) Formic acid (b) Methane
(c) Phenol (d) Glycine

17 GLUT-4 is a protein, which

(a) fights against infectious agents
(b) enables glucose transport into cells
(c) acts as enzyme
(d) acts as hormone

18 Which of the following macromolecules constitute the major portion of cellular mass?
(a) Proteins (b) Carbohydrates
(c) Lipids (d) Nucleic acids

19 Many organic substances are negatively charged, e.g. acetic acid, while others are positively charged, e.g. ammonium ion. An amino acid under certain conditions would have both positive and negative charges simultaneously in the same molecule. Such a form of amino acid is called
(a) positively charged form (b) negatively charged form
(c) neutral form (d) zwitter ionic form

20 Hydrogen bonds play an important role in
(a) α-helix
(b) β-pleated sheets
(c) between two strands of DNA
(d) All of the above

21 Basic structure of protein was given by
(a) WM Stanley (b) Nicholson
(c) Watson (d) F Sanger

22 Which of the following is the most abundant protein in the whole of the biosphere?
(a) Collagen (b) Insulin
(c) RuBisCO (d) Trypsin

23 The tertiary structure of the proteins containing amino acid cysteine is achieved through
(a) hydrogen bonds (b) disulphide bonds
(c) covalent bonds (d) ionic bonds

24 A pure protein should normally have
(a) two ends (b) one end
(c) three ends (d) no ends

25 Even after disruption of all the hydrogen bonds, which structural level of a protein molecule still remains intact?
(a) Tertiary structure (b) Primary structure
(c) Secondary structure (d) Quaternary structure

26 Which of the following are not polymeric? ➜ NEET 2017
(a) Nucleic acid (b) Proteins
(c) Polysaccharides (d) Lipids

27 A typical fat molecule is made up of ➜ NEET-I 2016
(a) one glycerol and three fatty acid molecules
(b) one glycerol and one fatty acid molecule
(c) three glycerol and three fatty acid molecules
(d) three glycerol molecules and one fatty acid molecule

28 Phospholipids are ➜ NEET 2013
(a) amphipathic (b) amphibolic
(c) hydrophobic (d) hydrophilic

29 A phosphoglyceride is always made up of ➜ NEET 2013
(a) only an unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached.
(b) a saturated or unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached
(c) a saturated or unsaturated fatty acid esterified to a phosphate group which is also attached to a glycerol molecule
(d) only a saturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached

30 Which of the following is an essential fatty acid in mammals?
(a) Stearic acid
(b) Acetic acid
(c) Palmitic acid
(d) Gamma linolenic acid

31 Paraffin wax is
(a) ester (b) acid
(c) monohydric alcohol (d) cholesterol

32 Which of the following biomolecules does have a phosphodiester bond? ➜ CBSE-AIPMT 2015
(a) Fatty acids in a diglyceride
(b) Monosaccharides in a polysaccharide
(c) Amino acids in a polypeptide
(d) Nucleic acids in a nucleotide

33 Purines and pyrimidines occur in equal proportion in
(a) DNA (b) RNA
(c) carbohydrates (d) lipids

34 The two polynucleotide chains in DNA are
(a) parallel (b) discontinuous
(c) antiparallel (d) semiconservative

35 RNA differs from DNA in having
(a) uracil (b) thymine (c) adenine (d) guanine

36 When you take cells or tissue pieces and grind them with an acid in a mortar and pestle, all the small biomolecules dissolve in the acid. Proteins, polysaccharides and nucleic acids are insoluble in mineral acid and get precipitated. The acid soluble compounds include amino acids, nucleosides, small sugars, etc. When one adds a phosphate group to all nucleosides, one gets another acid soluble biomolecule called
(a) nitrogen base (b) adenine
(c) sugar phosphate (d) nucleotide

37 Nucleotides are building blocks of nucleic acids. Nucleotide is a composite molecule formed by
(a) $(\text{base} - \text{sugar} - \text{phosphate})_n$
(b) base – sugar –OH
(c) base – sugar – phosphate
(d) sugar – phosphate

38 Which of the following is not correct about DNA structure?
(a) DNA double helical model was proposed by Watson and Crick
(b) Two strands of DNA are antiparallel, i.e. run in opposite directions
(c) The DNA backbone is formed by the sugar-phosphate-sugar chain
(d) There are three hydrogen bonds between A and T, while two between G and C

39 RNA and DNA are similar in
(a) having similar sugars
(b) having similar pyrimidine base
(c) being capable to replicate
(d) being polymers of nucleotides

40 Antiparallel strands of a DNA molecule means that
(a) one strand turns anti-clockwise
(b) the phosphate groups of two DNA strands, at their ends share the same position
(c) the phosphate groups at the starting of two DNA strands are in opposite position (pole)
(d) one strand turns clockwise

41 DNA of which of the following organisms has no ends?
(a) Human DNA
(b) *E. coli* DNA
(c) Monkey DNA
(d) Fruitfly DNA

42 DNA molecules that make up the centromere and telomeres are
(a) coding DNA (b) non-coding DNA
(c) circular DNA (d) None of these

43 Which form of RNA has a structure resembling clover leaf?
(a) *r*RNA (b) *hn*RNA
(c) *m*RNA (d) *t*RNA

44 Induced fit theory of enzyme activity was given by
(a) Fischer
(b) Summer
(c) Northrop
(d) Koshland

45 A non-proteinaceous enzyme is ➜ NEET-II 2016
(a) lysozyme
(b) ribozyme
(c) ligase
(d) deoxyribonuclease

46 Transition state structure of the substrate formed during an enzymatic reaction is ➜ NEET 2013
(a) transient but stable
(b) permanent but unstable
(c) transient and unstable
(d) permanent and stable

47 The essential chemical components of many coenzymes are ➜ NEET 2013
(a) proteins (b) nucleic acids
(c) carbohydrates (d) vitamins

48 Which one of the following statements is correct, with reference to enzymes? ➜ NEET 2017
(a) Apoenzyme = Holoenzyme + Coenzyme
(b) Holoenzyme = Apoenzyme + Coenzyme
(c) Coenzyme = Apoenzyme + Holoenzyme
(d) Holoenzyme = Coenzyme + Cofactor

49 Select the option which is not correct with respect to enzyme action. ➜ CBSE-AIPMT 2014
(a) Substrate binds with enzyme as its active site
(b) Addition of lot of succinate does not reverse the inhibition of succinic dehydrogenase by malonate
(c) A non-competitive inhibitor binds the enzyme at a site distinct from that which binds the substrate
(d) Malonate is a competitive inhibitor of succinic dehydrogenase

50 Which statement is not true about the effects of various conditions on the activity of an enzyme?
(a) Higher temperatures generally increase the activity of an enzyme up to a point
(b) Above a certain range of temperatures, the protein of an enzyme is denatured
(c) A change in pH can cause an enzyme to be inactivated
(d) An enzyme's activity is generally reduced by an increase in substrate concentration

51 Which of the following statements about enzymes is not true?
(a) Competitive inhibitors act away from the active site
(b) Allosteric inhibitors act away from the active site
(c) Allosteric inhibitors can change the size of the active site
(d) Competitive inhibitors usually resemble the substrate

52 Enzymes isolated from thermophilic organisms found in hot vents and sulphur springs are stable and retain their catalytic power even at high temperature up to
(a) 80-90°C
(b) 100-200°C
(c) 300-500°C
(d) 900-1000°C

53 Which statement describes the currently accepted theory of how an enzyme and its substrate fit together?
(a) As the product is released, the enzyme breaks down
(b) The enzyme is like a key that fits into the substrate, which is like a lock
(c) The active site is permanently changed by its interaction with the substrate
(d) As the substrate binds to the enzyme, the shape of the enzyme site changes to accommodate the reaction

54 As per the rule of thumb, rate of chemical reaction doubles or decreases by half for every
(a) 10°C change in temperature
(b) 20°C change in temperature
(c) 30°C change in temperature
(d) 40°C change in temperature

55 In non-competitive inhibition, the allosteric inhibitor
(a) attaches to the substrate, preventing it from attaching to the active site
(b) changes the pH of the environment, thus preventing enzyme-substrate complex formation

(c) causes the substrates to polymerise, preventing individual enzyme-substrate attachment
(d) attaches to the enzyme at a site away from the active site, altering the shape of the enzyme

56 Match the following columns.

	Column I		Column II
A.	Carbonic anhydrase	1.	Sugar alcohol
B.	Creatinine phosphate	2.	Non-reducing sugar
C.	Mannitol	3.	High energy phosphate
D.	Sucrose	4.	Reducing sugar
		5.	Red blood cells

Codes

	A	B	C	D
(a)	5	3	1	2
(b)	1	2	3	4
(c)	2	1	3	4
(d)	5	4	1	2

57 Match the following columns.

	Column I		Column II
A.	*t*RNA	1.	Linking of amino acids
B.	*m*RNA	2.	Transfer of genetic information
C.	*r*RNA	3.	Nucleolar organising region
D.	Peptidyl transferase	4.	Transfer of amino acid from cytoplasm of ribosome

Codes

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	1	4	3	2
(c)	1	2	3	4	(d)	1	3	2	4

58 **Assertion** Sucrose is a reducing sugar.
Reason All disaccharides are reducing sugars.
(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion
(b) If both Assertion and Reason are true, but Reason is not the correct explanation of Assertion
(c) If Assertion is true, but Reason is false
(d) If both Assertion and Reason are false

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 Choose the type of enzyme involved in the following reaction
S — G + S' → S + S — G
(a) Dehydrogenase (b) Transferase
(c) Hydrolase (d) Isomerase

2 Which of the following scientists discovered the triple helical structure of collagen?
(a) GN Ramchandran
(b) Antonie van Leeuwenhoek
(c) Matthias Schleiden
(d) Theodar Schwann

3 Amino acids have both an amino group and a carboxyl group in their structure. Which amongst the following is an amino acid?
(a) Formic acid (b) Glycerol
(c) Glycolic acid (d) Glycine

4 A mucopolysaccharide is
(a) smile, physocolloid and pectin
(b) mucin, callose and heparin
(c) hemicellulose, pectin and mucin
(d) hyaluronic acid, chondroitin sulphate and keratin

5 A homopolymer has only one type of building block called monomer repeated '*n*' number of times. A heteropolymer has more than one type of monomer. Proteins are heteropolymers usually made of
(a) 20 types of monomers (b) 40 types of monomers
(c) 30 types of monomers (d) only one type of monomer

6 The melting point of unsaturated fatty acids
(a) increases with increase in double bonds
(b) decreases with increase in double bonds
(c) rises in some and falls in others
(d) there is no relationship between unsaturation and melting point

7 Proteins perform many physiological functions. For example, some function as enzymes. One of the following represents an additional function that some proteins discharge
(a) antibiotics
(b) pigment conferring colour to skin
(c) pigments making colour of flowers
(d) hormones

8 Which of the following statements regarding fats is true?

(a) Arachidonic acid has 20 carbons excluding the carbonyl carbon

(b) Glycerol is trihydroxy propane

(c) Palmitic acid has 18 carbons including the carboxyl carbon

(d) Oils have higher melting point than fats

(e) Lipids are generally water soluble

9 Which one of the following combinations of all these fatty acids are essential for human beings?

(a) Oleic acid, linoleic acid and linolenic acid

(b) Palmitic acid, linoleic acid and linolenic acid

(c) Oleic acid, linoleic acid and arachidonic acid

(d) Linoleic acid, linolenic acid and arachidonic acid

10 Match the following columns.

	Column I		Column II
A.	Oxidoreductases	1.	Linking of two compounds
B.	Isomerases	2.	Removal of group from substrates
C.	Ligases	3.	Interconversion of isomers
D.	Lyases	4.	Dehydrogenases
		5.	Hydrolysis

	A	B	C	D
(a)	4	1	3	2
(b)	4	3	1	5
(c)	3	4	2	5
(d)	2	5	3	1

11 Which of the following can bring about the denaturation of proteins?

I. Exposure to salts of heavy metal ions.

II. Exposure to acid and bases.

III. Exposure to inorganic neutral salts.

IV. Exposure to temperature below – 5°C.

Codes

(a) Only I (b) Only II

(c) None of these (d) I and III

12 Coenzymes

I. are needed for the function of particular enzymes.

II. are inorganic molecules.

III. are organic molecules.

IV. FAD and FMN contain niacin, while NAD and NADP contain riboflavin.

Codes

(a) I

(b) II and IV

(c) IV

(d) I and III

13 Cellulose, the most important constituent of plant cell wall is made up of

(a) branched chain of glucose molecules linked by a α-1, 6 glycosidic bond at the site of branching

(b) unbranched chain of glucose molecules linked by β-1, 4 glycosidic bond

(c) branched chain of glucose molecules linked by β-1,4 glycosidic bond in straight chain and α-1, 6 glycosidic bond at the site of branching

(d) unbranched chain of glucose molecules linked by β-1, 4 glycosidic bond

14 Identify the correct pair of statements.

I. Alternate name of thymine is 5-methyl uracil.

II. Arachidonic acid molecule contains less number of carbons than palmitic acid.

III. Cellulose contains complex halices.

IV. Aquaporin is a polypeptide.

(a) II and II (b) I and II (c) II and IV (d) I and IV

15 The equation shows how the enzyme glutamine synthetase removes the ammonia produced during plant metabolism.

$$\text{Ammonia} + \text{Glutamate} \xrightarrow[\text{Synthetase}]{\text{Glutamine}} \text{Glutamine}$$

Some herbicides contain an active agent, which resembles glutamate. What is likely the mode of action of this agent?

(a) It acts as an end-product inhibitor

(b) It acts as a competitive inhibitor

(c) It decreases levels of ammonia

(d) It increases levels of glutamate

16 Match the following columns.

	Column I		Column II
A.	Triglycerides	1.	Galactose
B.	Lactose	2.	Glycerol
C.	RNA	3.	Palmitic acid
D.	β-pleats	4.	Uracil
E.	Beeswax	5.	Secondary structure

Codes

	A	B	C	D	E
(a)	4	1	5	2	3
(b)	5	1	4	2	3
(c)	3	1	4	5	2
(d)	2	1	4	5	3

17 In a protein molecule, amino acids are linked by a peptide bond, which is formed by the reaction of

(a) —COOH group of one amino acid with $—NH_2$ group of next amino acid

(b) $—NH_2$ group of one amino acid with —COOH group of next amino acid

(c) —COOH group of two amino acids

(d) $—NH_2$ group of two amino acids

18 Which of the following statements are correct?

I. Monosaccharides are the simplest carbohydrates.
II. Oligosaccharides on hydrolysis yield 3-9 monosaccharide units.
III. Polysaccharides on hydrolysis give 10-15 monosaccharide units.
IV. Polysaccharides on hydrolysis yield many oligosaccharide units.

Codes

(a) Only I (b) Only III
(c) I and II (d) I and III

19 Find out the mismatched pair.

(a) Agar – Polymer of glucose and sulphur containing carbohydrates
(b) Chitin – Polymer of glucosamine
(c) Peptidoglycan–Polysaccharide linked to peptides
(d) Lipopolysaccharides–a complex of lipid and polysaccharide

20 Which of the following statements is/are not true?

I. Glycerol is a 3 carbon alcohol with 3 — OH groups that serve as binding sites.
II. Waxes are esters formed between a long chain alcohol and saturated fatty acids.
III. The term protein was coined by Gerardus Johannes Mulder.
IV. Agar is an indispensable polysaccharide and it is a complex polymer of glucose and sulphur containing carbohydrates.

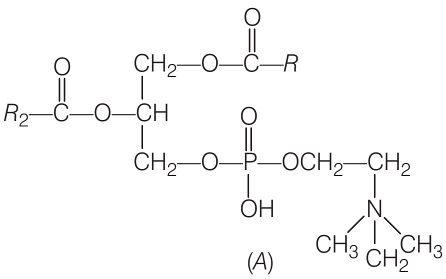
(a) I and III (b) I and IV (c) I, II and IV (d) Only IV

21 Arrange the steps of catalytic action of an enzyme in order and choose the correct option.

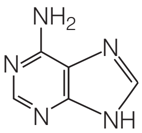
I. The enzyme releases the products of the reaction and the enzyme is free for another substrate.
II. The active site of enzyme is in close proximity of the substrate and breaks of chemical bonds of the substrate.
III. The binding of substrate induces the enzyme to alter its shape fitting more tightly around the substrate.
IV. The substrate binds to the active site of the enzyme fitting into the active site.

(a) IV, III, II, I (b) III, II, I, IV
(c) IV, II, I, III (d) II, I, IV, III

22 Which one of the following structural formulae of two organic compounds is correctly identified along with its related function?



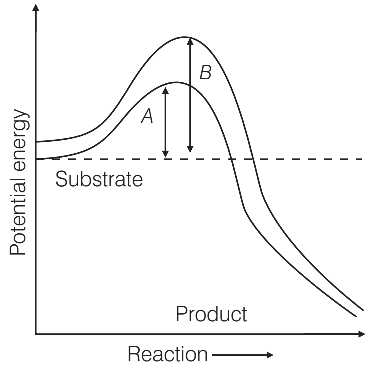
(A)



(B)

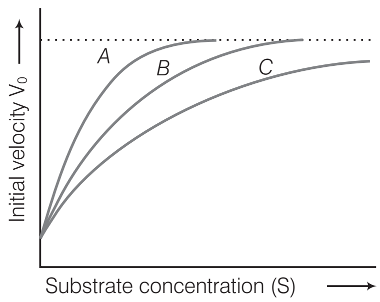
(a)	*A*	—	Triglyceride	—	Major source of energy
(b)	*B*	—	Uracil	—	A component of DNA
(c)	*A*	—	Lecithin	—	A component of cell membrane
(d)	*B*	—	Adenine	—	A nucleotide that makes up nucleic acids

23 Which of the following describes the given graph correctly?



(a) Endothermic reaction with energy *A* in the presence of enzyme and *B* in the absence of enzyme
(b) Exothermic reaction with energy *A* in the presence of enzyme and *B* in the absence of enzyme
(c) Endothermic reaction with energy *A* in the absence of enzyme and *B* in the presence of enzyme
(d) Exothermic reaction with energy *A* in the absence of enzyme and *B* in the presence of enzyme

24 The figure given below shows three curves, i.e. velocity, substrate, concentration curves for an enzyme reaction. What do the curves *A*, *B* and *C* depict respectively?



(a) *A*–Normal enzyme reaction, *B*–Competitive inhibition, *C*–Non-competitive inhibition
(b) *A*–Enzyme with an allosteric modulator added, *B*–Normal enzyme activity, *C*–Competitive inhibition
(c) *A*–Enzyme with an allosteric stimulus, *B*–Competitive inhibitor added, *C*–Normal enzyme reaction
(d) *A*–Normal enzyme reaction, *B*–Non-competitive inhibitor added, *C*–Allosteric inhibitor added

Directions (Q. No. 25-26) *In each of the following questions a statement of Assertion is given followed by a corresponding statement of Reason just below it. Of the statements, mark the correct answer as*

(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion
(b) If both Assertion and Reason are true, but Reason is not the correct explanation of Assertion
(c) If Assertion is true, but Reason is false
(d) If both Assertion and Reason are false

25 **Assertion** Amino acids are amphoteric in their function.

Reason All amino acids are necessary for our body.

26 **Assertion** A coenzyme or metal ion that is very tightly bound to enzyme protein is called prosthetic group.

Reason A complete catalytically active enzyme together with its bound prosthetic group is called apoenzyme.

ANSWERS

SESSION 1	**1** (d)	**2** (b)	**3** (b)	**4** (d)	**5** (c)	**6** (a)	**7** (a)	**8** (c)	**9** (d)	**10** (d)
	11 (b)	**12** (d)	**13** (c)	**14** (d)	**15** (d)	**16** (b)	**17** (d)	**18** (a)	**19** (d)	**20** (d)
	21 (d)	**22** (c)	**23** (b)	**24** (a)	**25** (b)	**26** (d)	**27** (a)	**28** (a)	**29** (b)	**30** (d)
	31 (a)	**32** (d)	**33** (a)	**34** (c)	**35** (a)	**36** (d)	**37** (c)	**38** (d)	**39** (d)	**40** (c)
	41 (b)	**42** (b)	**43** (d)	**44** (d)	**45** (b)	**46** (c)	**47** (d)	**48** (b)	**49** (b)	**50** (d)
	51 (a)	**52** (a)	**53** (d)	**54** (a)	**55** (d)	**56** (a)	**57** (a)	**58** (d)		
SESSION 2	**1** (b)	**2** (a)	**3** (d)	**4** (d)	**5** (a)	**6** (a)	**7** (d)	**8** (b)	**9** (d)	**10** (b)
	11 (d)	**12** (d)	**13** (d)	**14** (d)	**15** (b)	**16** (d)	**17** (a)	**18** (c)	**19** (a)	**20** (d)
	21 (a)	**22** (a)	**23** (b)	**24** (a)	**25** (a)	**26** (c)				