

Question 1:

1. (a) Identify the following statements as true or false and justify your answer:

- (i) All other amino acids except proline are optically active.
 - False. Glycine is also not optically active. It has two hydrogen atoms on the alpha-carbon, making it achiral. All other standard amino acids have four different groups attached to the alpha-carbon, making them chiral and thus optically active.
- (ii) Melting point of DNA is directly related to GC content.
 - True. Guanine-cytosine (GC) base pairs are linked by three hydrogen bonds, whereas adenine-thymine (AT) base pairs are linked by two hydrogen bonds. More hydrogen bonds require more energy to break, thus DNA with a higher GC content has a higher melting temperature (T_m).
- (iii) Glycine acts as biological buffer at physiological pH.
 - False. The pK_a values of glycine are approximately 2.34 (for the carboxyl group) and 9.60 (for the amino group). Physiological pH is around 7.4. Glycine does not have a pK_a close to physiological pH, therefore it is not an effective biological buffer at this pH.
- (iv) Chitin is an example of storage polysaccharides.
 - False. Chitin is a structural polysaccharide, forming the main component of the exoskeletons of arthropods and the cell walls of fungi. Starch and glycogen are examples of storage polysaccharides.
- (v) At pH more than p_i amino acids exists in negatively charged form.

- True. The isoelectric point (pI) is the pH at which an amino acid exists predominantly in its zwitterionic form with no net charge. If the pH is increased above the pI, the amino acid will lose protons from its amino group (and any basic side chains), resulting in a net negative charge.
- (vi) Oleic acid has a higher melting point than stearic acid.
 - False. Oleic acid is an unsaturated fatty acid with a cis double bond, which introduces a "kink" in its hydrocarbon chain, preventing efficient packing and thus lowering its melting point. Stearic acid is a saturated fatty acid, allowing for close packing and stronger van der Waals interactions, resulting in a higher melting point.

2. (b) Name the following:

- (i) Methyl donor in biological reaction
 - S-Adenosylmethionine (SAM)
- (ii) Most abundant polysaccharide in biosphere
 - Cellulose
- (iii) Active form of vitamin B1
 - Thiamine pyrophosphate (TPP)
- (iv) An unusual base found in tRNA
 - Inosine or Dihydrouridine or Pseudouridine (any one is sufficient)
- (v) An example of ω -3 fatty acid
 - α -Linolenic acid (ALA) or Eicosapentaenoic acid (EPA) or Docosahexaenoic acid (DHA)
- (vi) A hormone derived from amino acid

- Adrenaline (epinephrine) or Noradrenaline (norepinephrine) or Thyroxine or Serotonin or Histamine (any one is sufficient)

Question 2: 2. Differentiate between the following: *

(a) Proteoglycans and Glycoproteins

* Proteoglycans: *

- * Consist of a core protein covalently linked to one or more glycosaminoglycan (GAG) chains.
- * Carbohydrate content is typically very high (up to 95% or more by weight).
- * GAG chains are long, unbranched polysaccharides containing repeating disaccharide units, usually with an amino sugar and a uronic acid, and are often sulfated, giving them a high negative charge.
- * Primarily found in the extracellular matrix, where they contribute to the structural integrity and hydration of tissues.

* Glycoproteins: *

- * Consist of a protein covalently linked to one or more oligosaccharide chains (glycans).
- * Carbohydrate content is typically lower (from less than 1% to about 60% by weight).
- * Glycans are shorter, branched or unbranched oligosaccharides that do not contain repeating disaccharide units characteristic of GAGs and are generally not sulfated.
- * Found on cell surfaces, in the extracellular matrix, and in various secretions, performing diverse functions such as cell recognition, cell adhesion, and immune responses.

(b) Glycerophospholipids and Sphingophospholipids

* Glycerophospholipids: *

- * Core structure is glycerol-3-phosphate.
- * Two fatty acyl chains are attached via ester linkages to the hydroxyl groups at C1 and C2 of glycerol.
- * A polar head group (e.g., choline, ethanolamine, serine, inositol) is attached to the phosphate group.
- * Most abundant type of phospholipid in biological membranes.

* Sphingophospholipids: *

- * Core structure is sphingosine, an 18-carbon amino alcohol.
- * One fatty acyl chain is attached via an amide linkage to the amino group of sphingosine.
- * A phosphate group and a polar head group (e.g., choline, ethanolamine) are attached to the hydroxyl group at C1 of sphingosine.
- * Important components of cell membranes, particularly in myelin sheaths.

(c) Standard and non-standard amino acid

* Standard amino acids: *

- * There are 20 standard (or common) amino acids encoded by the genetic code.
- * These are the amino acids primarily used in protein synthesis.
- * They possess a central carbon atom (alpha-carbon) bonded to an amino group, a carboxyl group, a hydrogen atom, and a unique side

chain (R-group). * Non-standard amino acids: * These are amino acids that are not among the 20 standard amino acids. * They can be modifications of standard amino acids (e.g., hydroxyproline, phosphoserine) or entirely different amino acid structures (e.g., ornithine, citrulline). * Some non-standard amino acids are incorporated into proteins through post-translational modification, while others function as metabolic intermediates or in specialized roles (e.g., neurotransmitters). * (d) B-DNA and Z-DNA * B-DNA: * Right-handed helix. * Most common and stable form of DNA under physiological conditions. * Has a wider and more regular major groove and a narrower minor groove. * Approximately 10-10.5 base pairs per turn. * Z-DNA: * Left-handed helix. * Less common and typically found in specific sequences (e.g., alternating purine-pyrimidine stretches like GCGCGC). * Has a single, narrow groove and a zigzag backbone. * Approximately 12 base pairs per turn. * (e) Water soluble and Fat-soluble vitamins * Water-soluble vitamins: * Include B vitamins (B1, B2, B3, B5, B6, B7, B9, B12) and Vitamin C. * Dissolve in water and are generally not stored in the body in significant amounts (except B12). * Excess amounts are typically excreted in urine. * Require regular intake. * Fat-soluble vitamins: * Include Vitamins A, D, E, and K. * Dissolve in fats and oils and are stored in the body's fatty tissues and liver. * Not readily excreted, and excessive intake can lead to toxicity. * Do not require daily intake as body stores can last for some time.

Question 3: 3. (a) Explain why: * (i) Glucose is not stored in monomeric form. * Glucose is not stored in monomeric form because it is osmotically active. If glucose were stored as individual molecules, it would significantly increase the intracellular osmotic pressure, leading to excessive water influx into the cells and potentially causing them to lyse. Instead, glucose is stored as large, insoluble polysaccharides like glycogen (in animals) or starch (in plants), which are osmotically inert. This allows for the storage of a large amount of glucose energy without affecting the cell's osmotic balance. * (ii) Glycosaminoglycans have gel like consistency. * Glycosaminoglycans (GAGs) have a gel-like consistency due to their highly anionic nature and ability to bind large amounts of water. They contain numerous negatively charged sulfate and carboxyl groups, which repel

each other, causing the GAG chains to extend and occupy a large volume. These negative charges also attract and bind a large number of water molecules, forming a hydrated, viscous gel. This property is crucial for their function as lubricants and shock absorbers in connective tissues. * (iii) Amino acid can act as both acid and base. * Amino acids can act as both an acid and a base (amphoteric) because they contain both a carboxyl group (-COOH), which can donate a proton (act as an acid), and an amino group (-NH_2), which can accept a proton (act as a base). At physiological pH, amino acids typically exist as zwitterions, where the carboxyl group is deprotonated (COO^-) and the amino group is protonated (NH_3^+), carrying both a positive and negative charge, but with an overall neutral net charge. * (iv) Arginine is highly soluble in water however tryptophan is poorly soluble. * Arginine is highly soluble in water because its side chain contains a guanidinium group, which is highly basic and can be protonated to a positive charge ($\text{NH}_2^+ = \text{C}(\text{NH}_2)\text{NH}_2^+$). This charged group allows it to form multiple hydrogen bonds and electrostatic interactions with water molecules, making it very hydrophilic. Tryptophan, on the other hand, has a large, bulky indole ring in its side chain, which is largely nonpolar and hydrophobic. While the nitrogen in the indole ring can form some hydrogen bonds, the overall nonpolar nature of the ring dominates, making tryptophan poorly soluble in water compared to arginine. * (v) DNA is resistant to alkali hydrolysis. * DNA is resistant to alkali hydrolysis primarily because it lacks a 2'-hydroxyl group on its deoxyribose sugar. In contrast, RNA, which has a 2'-hydroxyl group on its ribose sugar, is susceptible to alkali hydrolysis. The 2'-hydroxyl group in RNA can act as a nucleophile, attacking the phosphodiester bond in a transesterification reaction, leading to cleavage of the phosphodiester backbone. The absence of this group in DNA prevents such an intramolecular attack, making DNA much more stable under alkaline conditions. * (vi) Vitamin K is called an anti-hemorrhagic vitamin. * Vitamin K is called an anti-hemorrhagic vitamin because it plays a crucial role in blood clotting (hemostasis). It is a coenzyme for the enzyme γ -glutamyl carboxylase, which catalyzes the post-translational carboxylation of specific glutamic acid residues in several blood clotting factors (factors II, VII, IX, and X, as well as proteins C and S).

This carboxylation is essential for these clotting factors to bind calcium ions, which is a prerequisite for their activation and assembly into the enzyme complexes necessary for proper blood coagulation. A deficiency in Vitamin K leads to impaired blood clotting, resulting in excessive bleeding or hemorrhage.

3. (b) Give the active form of vitamin D along with its deficiency diseases.

- Active form of vitamin D:
 - 1,25-Dihydroxycholecalciferol (Calcitriol)
- Deficiency diseases:
 - Rickets (in children)
 - Osteomalacia (in adults)

Question 4: 4. (a) Draw the structure of the following: * (i) N-acetyl D glucosamine * A glucose derivative where the hydroxyl group at C2 is replaced by an N-acetyl amino group. * Structure: [Imagine a six-membered pyranose ring of glucose. The anomeric carbon (C1) can be alpha or beta. At C2, replace -OH with -NH-CO-CH₃. The rest of the glucose structure remains, including -OH at C3, C4, and C6.] * (ii) Trehalose * A disaccharide formed by two glucose units linked by an α, α -1,1-glycosidic bond. Both anomeric carbons are involved in the glycosidic bond. * Structure: [Imagine two glucose pyranose rings. The C1 of the first glucose is linked via an alpha-glycosidic bond to the C1 of the second glucose, which is also in an alpha configuration.] * (iii) Lysine * An amino acid with a long, positively charged side chain ending in an amino group. * Structure: [Imagine the basic amino acid structure: H₂N-CH(COOH)-R. For Lysine, R is -(CH₂)₄-NH₂.] * (iv) Aspartic acid * An amino acid with a negatively charged carboxyl group in its side chain. * Structure: [Imagine the basic amino acid structure: H₂N-CH(COOH)-R. For Aspartic acid, R is -CH₂-COOH.] * (v) Phosphatidyl Choline * A glycerophospholipid with choline as the head group. * Structure: [Imagine a glycerol backbone. Two fatty acyl chains are esterified to C1 and C2. At C3, a phosphate group is esterified, and choline

($\text{N}^+(\text{CH}_3)_3\text{-CH}_2\text{-CH}_2\text{-OH}$) is esterified to the phosphate group.] * (vi) 7-methyl Guanosine * A modified nucleoside where a methyl group is attached to the N7 position of the guanine base. * Structure: [Imagine a guanine base attached to a ribose sugar. A methyl group is attached to the nitrogen at position 7 of the guanine ring. This nitrogen will carry a positive charge.]

4. (b) Triglycerides are considered as an ideal storage molecule.
Comment.

- Triglycerides (also known as triacylglycerols) are considered an ideal storage molecule for several reasons:
 - High energy yield: They are highly reduced molecules, meaning they have many C-H bonds and relatively few oxygen atoms. This allows them to yield more than twice the energy per unit weight compared to carbohydrates (approximately 9 kcal/g for fat vs. 4 kcal/g for carbohydrates).
 - Anhydrous storage: Triglycerides are hydrophobic and stored in an anhydrous (water-free) form. This significantly reduces the weight and volume needed for energy storage compared to glycogen, which is highly hydrated (each gram of glycogen is stored with about 2 grams of water). This anhydrous nature makes them efficient for compact energy storage.
 - Metabolic water production: During their oxidation, triglycerides produce a significant amount of metabolic water, which can be crucial for organisms in arid environments (e.g., desert animals, migrating birds).
 - Insulation and shock absorption: Besides energy storage, triglycerides stored in adipose tissue also serve as thermal insulation against cold and as shock absorbers for vital organs, providing physical protection.

5. (c) What do you mean by mutarotation? Explain with the help of example.

○ Mutarotation:

- Mutarotation is the change in the optical rotation of a solution when a pure anomer of a sugar is dissolved in it, reaching an equilibrium mixture of α and β anomers. This change is due to the interconversion between the anomeric forms (alpha and beta) of a cyclic monosaccharide in solution, through the open-chain aldehyde or ketone intermediate.

○ Explanation with example (Glucose):

- When D-glucose is dissolved in water, it exists primarily in its cyclic pyranose forms: α -D-glucopyranose and β -D-glucopyranose.
- Pure α -D-glucopyranose has a specific optical rotation of $+112.2^\circ$.
- Pure β -D-glucopyranose has a specific optical rotation of $+18.7^\circ$.
- When either pure α -D-glucopyranose or pure β -D-glucopyranose is dissolved in water, their optical rotation gradually changes over time until it reaches a constant value of $+52.7^\circ$. This stable value corresponds to the equilibrium mixture, which in the case of glucose, is approximately 36% α -anomer and 64% β -anomer (and a very small percentage of the open-chain form).
- The mechanism involves the opening of the ring structure to the acyclic aldehyde form, which then re-closes to either the α or β anomer. This continuous interconversion through the open-chain form is what leads to the

observed change in optical rotation until equilibrium is established.

Question 5: 5. (a) What are eicosanoids? Briefly describe the function of three classes of eicosanoids. * Eicosanoids: * Eicosanoids are a class of signaling molecules derived from 20-carbon (eicosa-) polyunsaturated fatty acids, primarily arachidonic acid. They are potent, short-lived, local mediators that act as autocrine (acting on the same cell that produced them) or paracrine (acting on nearby cells) hormones. They are involved in a wide range of physiological processes, including inflammation, pain, fever, blood pressure regulation, blood clotting, and reproduction. * Functions of three classes of eicosanoids: * Prostaglandins (PGs): * Functions: Involved in inflammation, pain sensation, fever, sleep-wake cycle regulation, blood pressure control, and smooth muscle contraction (e.g., uterine contractions during childbirth, constriction/dilation of blood vessels). For example, PGE_2 plays a key role in inflammatory responses and fever, while PGI_2 (prostacyclin) is a vasodilator and inhibits platelet aggregation. * Thromboxanes (TXs): * Functions: Primarily involved in blood clotting (thrombosis) and vasoconstriction. TXA_2 is a potent inducer of platelet aggregation and a powerful vasoconstrictor. It plays a crucial role in forming a platelet plug during injury. * Leukotrienes (LTs): * Functions: Primarily involved in inflammatory and allergic responses, particularly in the respiratory system. They are potent bronchoconstrictors and increase vascular permeability, contributing to the symptoms of asthma and allergic reactions. For example, LTC_4 , LTD_4 , and LTE_4 (components of slow-reacting substance of anaphylaxis, SRS-A) are strong mediators of asthmatic attacks.

5. (b) Give the biological function of different forms of RNA.

- Messenger RNA (mRNA):
 - Carries genetic information from DNA in the nucleus to the ribosomes in the cytoplasm. It serves as a template for protein synthesis (translation), dictating the amino acid sequence of a polypeptide.

- Ribosomal RNA (rRNA):
 - A major component of ribosomes, the cellular machinery responsible for protein synthesis. rRNA molecules have catalytic activity (ribozyme), forming the peptidyl transferase center that catalyzes the formation of peptide bonds between amino acids during translation. They also play a structural role in the ribosome.
- Transfer RNA (tRNA):
 - Acts as an adaptor molecule that decodes the mRNA sequence into a specific amino acid sequence during protein synthesis. Each tRNA molecule carries a specific amino acid at one end and has an anticodon loop at the other end that recognizes and binds to a complementary codon on the mRNA.
- Small Nuclear RNA (snRNA):
 - Involved in the processing of pre-mRNA in eukaryotes, particularly in splicing, where introns are removed and exons are ligated to form mature mRNA. They are components of spliceosomes.
- Small Nucleolar RNA (snoRNA):
 - Primarily involved in the chemical modification (e.g., methylation, pseudouridylation) of ribosomal RNA (rRNA) and some other RNA molecules within the nucleolus. They guide the modification enzymes to specific sites on their target RNAs.
- Micro RNA (miRNA):
 - Small, non-coding RNA molecules that regulate gene expression by binding to specific mRNA molecules, leading to their degradation or inhibition of translation.

They play crucial roles in development, cell differentiation, and various biological processes.

- Small Interfering RNA (siRNA):
 - Similar to miRNAs, siRNAs are short, double-stranded RNA molecules involved in RNA interference (RNAi), a mechanism that silences gene expression by targeting specific mRNA molecules for degradation. They are often involved in defense against viruses and maintaining genome stability.

6. (c) Draw the titration curve of glycine and discuss the information you obtained from the titration curve.

- Titration Curve of Glycine:
 - [Imagine a graph with pH on the y-axis (ranging from approximately 1 to 12-13) and equivalents of OH⁻ added (or volume of strong base added) on the x-axis (ranging from 0 to 2 equivalents).
 - The curve starts at a low pH (e.g., around 1-2), representing the fully protonated form of glycine (Glycine⁺).
 - As OH⁻ is added, there's a buffering region around pH 2.34 (pK_{a1}), where the carboxyl group is being deprotonated (from -COOH to -COO⁻).
 - After this, there's a steep rise in pH until it reaches the isoelectric point (pI) at approximately 5.97, where glycine is predominantly in its zwitterionic form (NH₃⁺-CH₂-COO⁻).
 - As more OH⁻ is added, another buffering region appears around pH 9.60 (pK_{a2}), where the amino group is being deprotonated (from NH₃⁺ to NH₂).

- Finally, the pH rises steeply again as all groups are deprotonated and the solution becomes strongly alkaline.]
- Information obtained from the titration curve:
 - pKa values: The titration curve clearly shows two inflection points, which correspond to the pKa values of the ionizable groups of glycine.
 - pKa1 (for the carboxyl group): Approximately 2.34. This is the pH at which 50% of the carboxyl groups are deprotonated.
 - pKa2 (for the amino group): Approximately 9.60. This is the pH at which 50% of the amino groups are deprotonated.
 - Buffering regions: The relatively flat regions around the pKa values indicate the buffering capacity of glycine. In these regions, glycine can resist changes in pH by protonating or deprotonating its functional groups.
 - Isoelectric point (pI): The midpoint between the two pKa values, where the net charge of the glycine molecule is zero, is the isoelectric point (pI). For glycine, $pI = (pKa1 + pKa2) / 2 = (2.34 + 9.60) / 2 = 5.97$. At this pH, glycine exists predominantly as a zwitterion.
 - Ionization states: The curve illustrates the different ionization states of glycine at various pH values:
 - Below pKa1: Fully protonated (net charge +1).
 - Between pKa1 and pKa2: Zwitterionic form (net charge 0).
 - Above pKa2: Fully deprotonated (net charge -1).

- Quantitative analysis: The curve allows for the calculation of the concentration of glycine if the volume and concentration of the titrant are known. It also demonstrates the quantitative relationship between pH and the ionization state of weak acids and bases.

Question 6: 6. Write short notes on the following: *

(a) Lectins * Lectins are a diverse group of proteins (and glycoproteins) that bind specifically and reversibly to carbohydrates. They are non-enzymatic and non-immune in origin. Lectins play crucial roles in various biological processes, including cell-cell recognition, cell adhesion, host-pathogen interactions (e.g., viral entry into cells, bacterial adhesion to host tissues), and immune responses. They are found in all types of organisms, from viruses and bacteria to plants and animals. Examples include concanavalin A from jack beans, which binds to mannose and glucose residues, and selectins in animals, which mediate cell adhesion in immune responses. *

(b) Biologically important nucleotides * Biologically important nucleotides are organic molecules composed of a nitrogenous base (purine or pyrimidine), a five-carbon sugar (ribose or deoxyribose), and one or more phosphate groups. They serve as the monomeric units of nucleic acids (DNA and RNA), where their primary function is to store and transmit genetic information. Beyond their role in genetic material, nucleotides have numerous other vital biological functions: * Energy currency: ATP (adenosine triphosphate) is the primary energy currency of the cell, driving various cellular processes. GTP (guanosine triphosphate) is also important in energy transfer and signaling. * Coenzymes: Nucleotides are components of several important coenzymes, such as NAD^+/NADH , FAD/FADH_2 (involved in redox reactions), and Coenzyme A (involved in acyl group transfer). * Signaling molecules: Cyclic AMP (cAMP) and cyclic GMP (cGMP) act as important second messengers in intracellular signaling pathways, mediating the effects of hormones and other extracellular signals. * Metabolic regulation: Nucleotides can act as allosteric regulators of enzyme activity, influencing metabolic pathways. *

(c) Glycolipids * Glycolipids are lipids that have a carbohydrate (sugar) covalently attached. They lack a phosphate group, distinguishing them from phospholipids. The lipid component is typically ceramide (a sphingosine backbone with a fatty acid attached) or diacylglycerol. Glycolipids are integral components of cell membranes, particularly in the outer leaflet of the plasma membrane, where their carbohydrate portions extend into the extracellular space. They play significant roles in cell recognition, cell adhesion, cell signaling, and tissue and organ specificity. Examples include cerebrosides (single sugar attached to ceramide) and gangliosides (complex oligosaccharide chains containing sialic acid attached to ceramide), which are abundant in nerve cell membranes and contribute to neuronal function. *

(d) Waxes * Waxes are complex lipids formed by the esterification of a long-chain fatty acid with a long-chain alcohol. They are characterized by their extreme hydrophobicity, water repellency, and solid or semi-solid consistency at room temperature. Waxes serve various protective functions in biological systems. In plants, they form a protective coating (cuticle) on the surface of leaves, stems, and fruits, preventing water loss and protecting against pathogens. In animals, waxes are found in the fur, feathers, and skin, providing waterproofing and lubrication (e.g., beeswax, lanolin, earwax). They are generally not used for energy storage due to their chemical stability and difficulty in metabolism.