

2021 BOTANY — HONOURS

Paper : CC-12 (Biochemistry)

Full Marks : 50

The figures in the margin indicate full marks. Candidates are required to give their answers in their own words as far as practicable.

1. Answer briefly the following (any five) : 2×5

(a) What is epimer? Name the C-2 epimer of glucose

(a) An epimer is a type of stereoisomer that differs in the configuration at only one chiral center<sup>12</sup>. The C-2 epimer of glucose is mannose<sup>3456</sup>.

(b) Distinguish between co-valent and non co-valent bonds.

(b) Covalent bonds are formed by the equal sharing of electrons from both participating atoms<sup>7</sup>. They are stronger than all types of non-covalent bonds<sup>8</sup> Non-covalent bonds do not involve the sharing of electrons, but rather involve more dispersed variations of electromagnetic interactions between molecules or within a molecule<sup>9</sup>. They can be dipole-dipole, ion-ion, ion-dipole, and hydrogen bonds<sup>8</sup>.

(c) Why pH7 is considered as neutral pH?

⊙ pH 7 is considered as neutral because at this pH, a molecule carries an equal amount of positive and negative charge<sup>101112</sup>. In water, the concentration of protons (H<sup>+</sup>) or hydronium ions (H<sub>3</sub>O<sup>+</sup>) and hydroxide ions (OH<sup>-</sup>) is dependent on the temperature, hence the precise “neutral” pH is dependent on temperature and pressure<sup>13</sup>.

(d) Name one organic buffer and write down its components.

(d) An example of an organic buffer is a solution containing acetic acid and sodium acetate<sup>1415</sup>. Sodium acetate is a salt that dissociates into sodium ions and acetate ions in solution. For as long as acetic acid and acetate ions are present in significant amounts a solution, this can resist dramatic pH changes<sup>14</sup>.

(e) What is ‘iso-electric point’? Why it is significant in protein-purification?

(e) The isoelectric point (pI) is the pH at which a molecule carries no net electrical charge or is electrically neutral in the statistical mean<sup>1011</sup>. It is significant in protein purification because it represents the pH where solubility is typically minimal. Here, the protein isoelectric point signifies where mobility in an electro-focusing system is zero—and, in turn, the point where the protein will collect<sup>161718</sup>.

(f) What is rancidity of lipids?.

(f) Rancidity refers to the complete or incomplete hydrolysis or oxidation of fats and oils when exposed to air, light, moisture, and bacterial activity, producing short-chain aldehydes, ketones and free fatty acids<sup>192021</sup>. This generally occurs in food items making them undesirable for consumption.

(g) Distinguish between lyase and ligase enzymes

(g) Lyases are enzymes that catalyze bond-breaking reactions<sup>2223</sup>.

Therefore, a lyase will catalyze the cleavage of a certain molecule. However, this bond breaking does not occur through hydrolysis or oxidation<sup>23</sup>. On the other hand, Ligases are a class of enzymes that are involved in catalyzing bond formation reactions<sup>2223</sup>. Therefore, these enzymes catalyze the formation of compounds that are larger than their starting material or different compounds<sup>23</sup>.

2. Answer any two of the following :

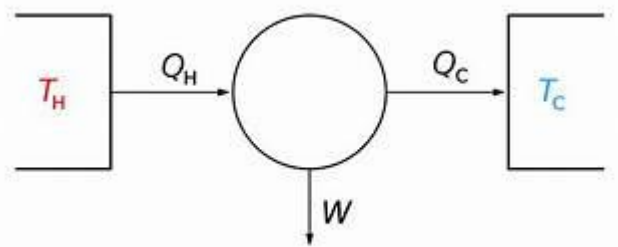
(a) Define free radicals with examples. Mention their significant roles in plant metabolism. 5

(a) Free radicals are atoms or molecules that have one or more unpaired electrons<sup>1234</sup>. Because of their unpaired electron(s), they are highly reactive and unstable<sup>1234</sup>. They can donate an electron or accept an electron from other molecules, therefore, can behave as oxidants or reductants<sup>1234</sup>. Examples of free radicals include singlet oxygen, molecules with a free hydroxy group (-OH), and a methyl radical<sup>1234</sup>.

Free radicals play significant roles in plant metabolism. They are involved in various metabolic processes like electron transport, lipid metabolism, detoxification, and phagocytosis<sup>56</sup>. They often involve in cell-cell communication, apoptosis, ion transportation, and gene expression<sup>7</sup>. However, overwhelming levels

of these free radicals can disrupt the antioxidant defense system in the body, thereby damaging cell membranes and cellular macromolecules such as proteins, lipids, and nucleic acids, leading to cell death or causing mutations<sup>6</sup>. This is why plants are equipped with antioxidants to ensure that any free radicals that “leak” from normal metabolic processes are removed<sup>56</sup>. Unfortunately, such control is challenged if tissues undergo pathological disease, severe stress, and physical injury<sup>5</sup>. Under these circumstances, reduced antioxidant status and metabolic impairment can soon lead to free radical attack of macromolecules (lipids, proteins, and DNA), leading to further metabolic disorder, necrosis, and cell and tissue death<sup>5</sup>.

(b) State the two laws of thermodynamics. Explain exergenic and endergenic reactions in relation to Gibb’s free energy.



the two laws of thermodynamics:

1. **First Law of Thermodynamics:** Also known as the law of conservation of energy, it states that energy can neither be created nor destroyed, but it can be changed from one form to another. The mathematical representation of this law is:

$$\Delta U = q - W$$

where,

- $\Delta U$  is the change in internal energy of the system,
  - $q$  is the algebraic sum of heat transfer between system and surroundings, and
  - $W$  is the work done by the system on the surrounding<sup>1</sup>.
2. **Second Law of Thermodynamics:** This law states that the entropy in an isolated system always increases. Any isolated system spontaneously evolves towards thermal equilibrium—the state of maximum entropy of the system. The mathematical representation of this law is:

$$\Delta S > 0$$

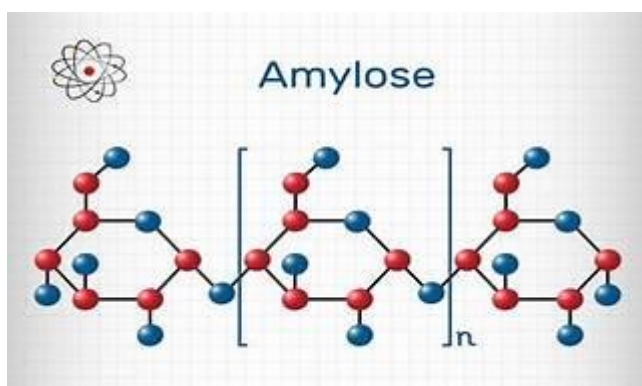
where,  $\Delta S$  is the change in entropy<sup>1</sup>.

Now, let's discuss exergonic and endergonic reactions in relation to Gibbs' free energy:

- **Exergonic Reactions:** These are reactions where the free energy of the products is lower than that of the reactants. They are also called spontaneous reactions, because they can occur without the addition of energy<sup>2</sup>. In these reactions, energy is released to the environment<sup>3</sup>.
- **Endergonic Reactions:** These are reactions where the free energy of the products is higher than that of the reactants<sup>4</sup>. These reactions require an input of energy<sup>2</sup>. In these reactions, energy is stored in the products<sup>3</sup>.

The Gibbs free energy (G) of a system is a measure of the amount of usable energy (energy that can do work) in that system. The change in Gibbs free energy during a reaction provides useful information about the reaction's energetics and spontaneity (whether it can happen without added energy)<sup>2</sup>. The direction of energy flow through the system determines if the reaction is endergonic or exergonic<sup>5</sup>.

(c) All monosaccharides are reducing sugars but not all disaccharides. — Why? Mention the types of polysaccharides with examples.



Explore

All monosaccharides are reducing sugars because they either have an aldehyde group or can tautomerize in solution to form an aldehyde group<sup>12</sup>. This includes common monosaccharides like galactose, glucose, glyceraldehyde, fructose, ribose, and xylose<sup>2</sup>.

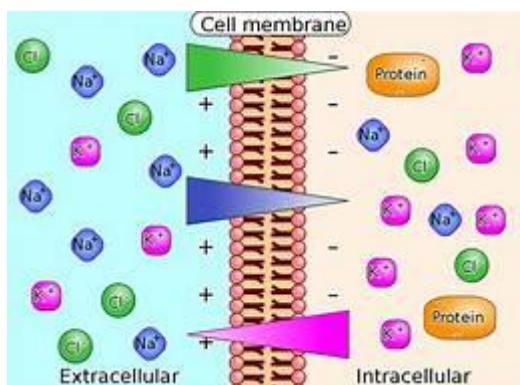
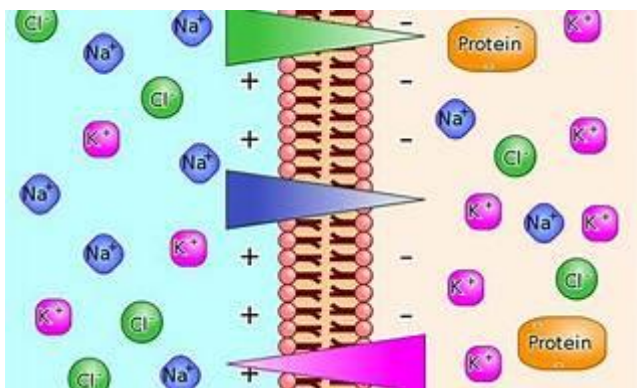
Disaccharides, on the other hand, can be either reducing or non-reducing. This depends on whether their anomeric carbons (the carbons involved in the glycosidic bond) can convert to an open-chain form with an aldehyde group<sup>2</sup>. For example,

maltose and lactose are reducing disaccharides because they have one free anomeric carbon that can form an aldehyde group<sup>1</sup>. However, sucrose is a non-reducing disaccharide because both of its anomeric carbons are involved in the glycosidic bond, preventing the formation of an aldehyde group<sup>1</sup>.

Now, let's discuss the types of polysaccharides:

1. **Homopolysaccharides:** These are polysaccharides that contain the same type of monosaccharides. Examples include:
  - **Starch:** A storage polysaccharide found in plants, fruits, seeds, etc<sup>3</sup>.
  - **Glycogen:** A storage polysaccharide found in animals and fungi<sup>3</sup>.
  - **Cellulose:** A structural polysaccharide that makes up the cell wall of plants<sup>3</sup>.
  - **Inulin:** Made up of a number of fructofuranose molecules linked together in chains. It is found in the tubers of dahlia, artichoke, etc<sup>3</sup>.
2. **Heteropolysaccharides:** These are polysaccharides that contain different types of monosaccharides. Examples include:
  - **Hyaluronic Acid:** Made up of D-glucuronic acid and N-acetyl-glucosamine. It is found in connective tissues and skin<sup>3</sup>.
  - **Heparin:** Made up of D-glucuronic acid, L-iduronic acid, N-sulfo-D-glucosamine and is largely distributed in mast cells and blood<sup>3</sup>.

(d) Discuss redox potential with reference to electrochemical gradient.



Explore

Sure, let's discuss redox potential and electrochemical gradient:

**Redox Potential:** Redox potential, also known as oxidation/reduction potential (ORP), is a measure of the tendency of a chemical species to acquire electrons (and thereby be reduced) or lose electrons (and thereby be oxidised)<sup>1</sup>. It is expressed in volts (V). Each species has its own intrinsic redox potential; the more positive the reduction potential, the greater the species' affinity for electrons and tendency to be reduced<sup>1</sup>.

**Electrochemical Gradient:** An electrochemical gradient is a gradient of electrochemical potential, usually for an ion that can move across a membrane. The gradient consists of two parts<sup>2</sup>:

1. The chemical gradient, or difference in solute concentration across a membrane.
2. The electrical gradient, or difference in charge across a membrane.

When there are unequal concentrations of an ion across a permeable membrane, the ion will move across the membrane from the area of higher concentration to the area of lower concentration through simple diffusion<sup>2</sup>. Ions also carry an electric charge that forms an electric potential across a membrane. If there is an unequal distribution of charges across the membrane, then the difference in electric potential generates a force that drives ion diffusion until the charges are balanced on both sides of the membrane<sup>2</sup>.

**Relation between Redox Potential and Electrochemical Gradient:** The free energy released when a higher-energy electron donor and acceptor convert to lower-energy products, while electrons are transferred from a lower to a higher redox potential, is used by the complexes in the electron transport chain to create an electrochemical gradient of ions<sup>3</sup>. The energy released during the redox reactions is conserved by the vectorial translocation of protons which establishes an electrochemical gradient across the mitochondrial inner membrane<sup>4</sup>. ATP synthase utilizes the pH gradient generated by the redox reactions to produce ATP<sup>4</sup>. In electrochemical cells, or in redox reactions that happen in solution, the thermodynamic driving force can be measured as the cell potential<sup>5</sup>. Chemical reactions are spontaneous in the direction of  $-\Delta G$ , which is also the direction in which the cell potential (defined as  $E_{\text{cathode}} - E_{\text{anode}}$ ) is positive<sup>5</sup>.

3)

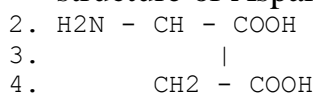
(a) ) Give one example and chemical structure each of acidic amino acid, semi essential amino acid, polar amino acid and ketogenic amino acid.



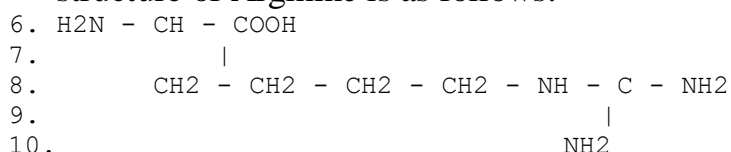
Explore

Sure, let's discuss each of these types of amino acids:

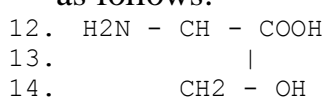
1. **Acidic Amino Acid:** An example of an acidic amino acid is **Aspartic Acid**<sup>1</sup>. It contains an extra carboxylic acid component in its side chain<sup>1</sup>. The structure of Aspartic Acid is as follows:



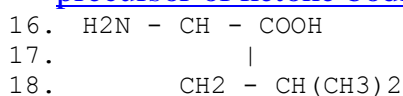
5. **Semi-Essential Amino Acid:** An example of a semi-essential amino acid is **Arginine**<sup>2</sup>. It can be synthesized by adults but not by growing children<sup>2</sup>. The structure of Arginine is as follows:



11. **Polar Amino Acid:** An example of a polar amino acid is **Serine**<sup>3</sup>. It contains a hydroxymethyl group in its side chain<sup>3</sup>. The structure of Serine is as follows:

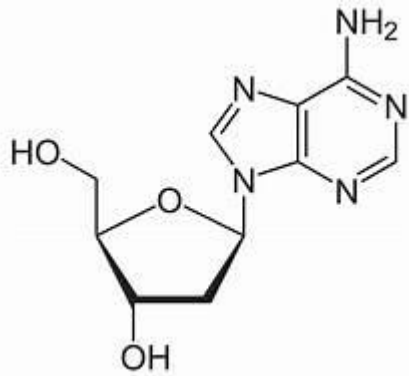


15. **Ketogenic Amino Acid:** An example of a ketogenic amino acid is **Leucine**<sup>4</sup>. It can be degraded directly into acetyl-CoA, which is the precursor of ketone bodies<sup>4</sup>. The structure of Leucine is as follows:



(b) Distinguish between nucleotide and nucleoside with structures. Give two examples of nucleotide derivatives. Give a brief account of non-genetic RNA.





Explore

Sure, let's discuss each of these topics:

### Nucleotide vs Nucleoside:

- **Nucleoside:** A nucleoside consists of a nitrogenous base covalently attached to a sugar (ribose or deoxyribose) but without the phosphate group<sup>1</sup>. It is a basic component of a nucleotide composed of a nitrogenous base and a ribose/deoxyribose sugar linked together by a  $\beta$ -glycosidic bond<sup>2</sup>.
- **Nucleotide:** A nucleotide consists of a nitrogenous base, a sugar (ribose or deoxyribose), and one to three phosphate groups<sup>1</sup>. It consists of a nucleoside in addition to one or more phosphate groups<sup>3</sup>.

### Examples of Nucleotide Derivatives:

1. **Nicotinamide Adenine Dinucleotide (NAD):** NAD is a coenzyme found in all living cells. It is a dinucleotide because it consists of two nucleotides joined through their phosphate groups<sup>4</sup>.
2. **Flavin Adenine Dinucleotide (FAD):** FAD is another coenzyme that is involved in several important metabolic reactions. It is also a dinucleotide and is synthesized from riboflavin (vitamin B2)<sup>4</sup>.

**Non-Genetic RNA:** Non-genetic RNA does not act as genetic materials and is always synthesized from the DNA<sup>5</sup>. There are three types of non-genetic RNA<sup>6,7,8</sup>:

1. **Messenger RNA (mRNA):** It carries the genetic information copied from DNA in the form of a series of three-base code "words," each of which specifies a particular amino acid<sup>6</sup>.
2. **Transfer RNA (tRNA):** It serves as the physical link between the mRNA and the amino acid sequence of proteins<sup>6</sup>.



3. **Ribosomal RNA (rRNA):** It associates with a set of proteins to form ribosomes. [These complex structures, which physically move along an mRNA molecule, catalyze the assembly of amino acids into protein chains<sup>6</sup>.](#)

© Explain uniport, symport and antiport with examples. Distinguish between passive and active ion uptake mechanisms in plants

Sure, let's discuss each of these topics:

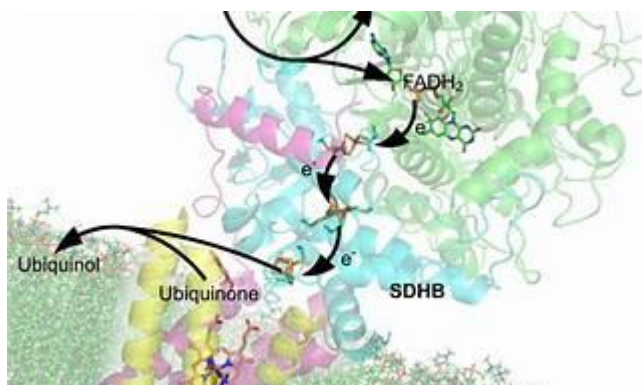
### Uniport, Symport, and Antiport:

- **Uniport:** It is an integral membrane protein that transports a single substrate species across the cell membrane<sup>1</sup>. An example of a uniport is a glucose transporter (GLU 1) present in the membrane of erythrocytes<sup>2</sup>.
- **Symport:** It is another integral membrane protein that transports two types of substrate in the same direction<sup>1</sup>. An example of a symport is the Sodium-glucose symporter present in the lining of the small intestine<sup>2</sup>.
- **Antiport:** It is an integral membrane protein that transports two types of substrate in the opposite direction<sup>1</sup>. An example of an antiport is the Sodium-calcium antiporter present in the cardiac muscle cells<sup>2</sup>.

### Passive and Active Ion Uptake Mechanisms in Plants:

- **Passive Absorption:** It is the absorption of minerals without the direct expenditure of metabolic energy<sup>3</sup>. This type of mineral absorption occurs along the concentration gradient by simple diffusion<sup>4</sup>. Passive absorption includes theories of diffusion, ion exchange, Donnan equilibrium, mass flow, etc<sup>3</sup>.
- **Active Absorption:** It is the absorption of minerals with the direct expenditure of metabolic energy<sup>3</sup>. Active mineral absorption can occur both along and against the concentration gradient by osmosis or through special carrier proteins in the plasma membrane<sup>4</sup>. Active transport mechanisms include primary active transport and secondary active transport<sup>3</sup>. Primary active transport uses ATP as the form of cellular energy to transport molecules across the membrane<sup>3</sup>. Secondary active transport relies on the electrochemical gradient of the ions on either side of the plasma membrane to transport molecules<sup>3</sup>.

(d) Define co-factor, co-enzyme, prosthetic group and apo-enzyme. Graphically describe the effect of substrate concentrations on the velocity of an enzyme catalyzed reaction mentioning  $V_0$ ,  $V_{max}$  and  $K_m$ .



## Explore

Sure, let's discuss each of these terms:

1. **Co-factor:** A cofactor is any molecule that, when complexed with another biological molecule, is necessary for the proper functioning of the protein/enzyme<sup>1</sup>. Cofactors can be inorganic metal ions such as copper and zinc, compounds such as sulfur-iron complexes, or organic molecules such as vitamins<sup>1</sup>.
2. **Co-enzyme:** Coenzymes are small organic molecules that bind to the enzymes, assisting the function of the enzyme<sup>2</sup>. They serve as intermediate carriers of electrons, specific atoms or functional groups that are to be transferred during the catalyzing reaction<sup>2</sup>. Most coenzymes are derived from the water-soluble B vitamins<sup>2</sup>.
3. **Prosthetic Group:** Prosthetic groups are a type of cofactors that bind tightly to enzymes or proteins<sup>2</sup>. They are bound to the enzyme through covalent or non-covalent bonds<sup>2</sup>. Some cofactors tightly bind to all types of enzymes. Others are tightly-bound to some enzymes while loosely-bound to other enzymes<sup>2</sup>.
4. **Apo-enzyme:** The protein part of a conjugate enzyme is known as an apoenzyme<sup>3</sup>. The cofactor, which is tightly bound to an apoenzyme, is known as a prosthetic group<sup>4</sup>.

Now, let's discuss the effect of substrate concentrations on the velocity of an enzyme-catalyzed reaction:

The rate of an enzyme-catalyzed reaction initially increases with increasing substrate concentration<sup>5</sup>. This is because more substrate molecules are available to interact with the enzyme, leading to more frequent collisions and hence a higher reaction rate<sup>5</sup>.

However, as the substrate concentration continues to increase, the rate of reaction begins to level off and eventually reaches a maximum velocity (V<sub>max</sub>)<sup>5</sup>. This is

because the enzyme molecules become saturated with substrate, meaning that every enzyme molecule is occupied with a substrate molecule<sup>5</sup>. At this point, adding more substrate does not increase the reaction rate because there are no free enzyme molecules available to interact with the extra substrate<sup>5</sup>.

The substrate concentration at which the reaction rate is half of V<sub>max</sub> is known as the Michaelis constant (K<sub>m</sub>)<sup>6</sup>. K<sub>m</sub> is a measure of the affinity of the enzyme for its substrate, with a lower K<sub>m</sub> indicating a higher affinity<sup>6</sup>.

The relationship between substrate concentration and reaction rate can be described by the Michaelis-Menten equation<sup>6</sup>:

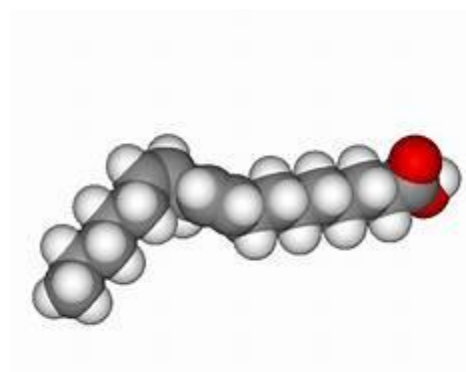
$$V = \frac{V_{\max}[S]}{K_m + [S]}$$

where:

- V is the reaction velocity,
- V<sub>max</sub> is the maximum reaction velocity,
- [S] is the substrate concentration,
- K<sub>m</sub> is the Michaelis constant.

This equation describes a hyperbolic relationship, which can be visualized on a graph with substrate concentration on the x-axis and reaction velocity on the y-axis<sup>6</sup>. The curve starts at the origin (0,0), rises rapidly with increasing substrate concentration, then gradually approaches V<sub>max</sub><sup>6</sup>.

- (e) Why are membrane lipids called amphipathic? What is PUFA? Write down the structure of the fatty acids 18 : 2 (Δ<sup>9</sup>, 12) and 20 : 4 (Δ<sup>5</sup>, 8, 11, 14)



Explore

**Amphipathic Nature of Membrane Lipids:** Membrane lipids are called amphipathic because they have dual characteristics: part of the lipid is ionic and therefore dissolves in water (hydrophilic), whereas the rest has a hydrocarbon

structure and therefore dissolves in nonpolar substances (hydrophobic)<sup>1234</sup>. This allows them to form stable membranes because their hydrophilic “head” is attracted to water molecules, while their hydrophobic “tails” are repelled by them<sup>2</sup>.

**PUFA:** PUFA stands for Polyunsaturated Fatty Acids. These are a type of fat that is good for your heart health. They include omega-3 and omega-6 fatty acids, which can reduce bad cholesterol, lower blood pressure, and prevent heart disease and stroke<sup>56789</sup>.

### **Structure of Fatty Acids:**

1. **18:2 (Δ9, 12):** This is the notation for Linoleic Acid. The structure is as follows:  
2.  $\text{CH}_3 - (\text{CH}_2)_4 - \text{CH}=\text{CH} - \text{CH}_2 - \text{CH}=\text{CH} - (\text{CH}_2)_7 - \text{COOH}$

The double bonds are located at the 9th and 12th carbon atoms from the carboxyl end<sup>1011</sup>.

3. **20:4 (Δ5, 8, 11, 14):** This is the notation for Arachidonic Acid. The structure is as follows:  
4.  $\text{CH}_3 - (\text{CH}_2)_4 - \text{CH}=\text{CH} - \text{CH}_2 - \text{CH}=\text{CH} - \text{CH}_2 - \text{CH}=\text{CH} - \text{CH}_2 - \text{CH}=\text{CH} - (\text{CH}_2)_3 - \text{COOH}$

The double bonds are located at the 5th, 8th, 11th, and 14th carbon atoms from the carboxyl end<sup>1213</sup>.