proprep

Workbook

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Lipids

Fatty Acids

Questions

1) Which statement is false about lipids?

A. They belong to one of the 4 major groups of biomolecules found in all cells.
B. They are not polymeric yet they do aggregate.
C. They exhibit greater structural variety than the other classes of biological molecules.
D. The common and defining feature is their insolubility in water.
E. The biological functions are not as diverse as their chemistry.

2) We listed 3 general biological functions that lipids perform, list and expand on these.

3) Mention 3 defining characteristics of lipids.

4) What are essential fatty acids, and give an example for this?

5) What are fatty acids?

6) Explain the nomenclature used for fatty acids using the example below:

- $20:2(\Delta^{9,12})$.

7) Which statement is false?

A. The most commonly occurring fatty acids have even numbers of carbon atoms in an unbranched chain of 12 to 24 carbons.
B. The even number of carbons results from the hydration of two-carbon (acetate) units.
C. There is a common pattern in the location of double bonds.
D. In most monounsaturated fatty acids the double bond is between C-9 and C-10 (Δ^9).
E. The physical properties of the fatty acids, are determined by the length and degree of unsaturation.

8) What are trans fatty acids and how are they produced?

9) Fill in the blanks with regard to the physical properties of fatty acids:

I. The physical properties of the fatty acids are largely determined by the ______ and _______ of unsaturation of the hydrocarbon chain.
II. The _________ hydrocarbon chain accounts for the _______ solubility of fatty acids in water.
III. The _______ the fatty acyl chain and the _______ the double bonds, the lower is the solubility in water.
IV. The carboxylic acid group is ________ and accounts for the slight solubility of short-chain fatty acids in water.

Answer Key

1) **E** – to make this statement correct:

The biological functions **are as** diverse as their chemistry.

2) 1. Lipid molecules in the form of lipid bilayers are external components of biological membranes
   - Phospholipids and sterols are major structural elements of biological membranes.
2. Lipids containing hydrocarbon chains serve as energy stores.
   - Fats and oils are the principal stored forms of energy in many organisms.
3. Many intra- and intercellular signaling events involve lipid molecules.
   - Other lipids, play crucial roles as enzyme cofactors, electron carriers, light-absorbing pigments, hydrophobic anchors for proteins, “chaperones” to help membrane proteins fold, emulsifying agents in the digestive tract, hormones, and intracellular messengers.

3) The common and defining feature of the group of biological molecules called lipids is their insolubility in water.

- lipids constitute an all-encompassing category of substances that are similar only in that they are largely hydrophobic and only sparingly soluble in water.
    - This hydrophobic nature is usually determined by hydrocarbon chains of various lengths (these are the fatty acids) or fused cyclohexane rings (steroids).

Some basic characteristics:

- Nonpolar
- Hydrophobic - insoluble in water
- Soluble in hydrophobic solvents
- Most lipids in biological systems are derived from fatty acids

Fats, oils, certain vitamins and hormones, and most nonprotein membrane components are lipids.

4) Essential fatty acids are fatty acids required but not synthesized by the human body.

- They have to be supplemented through ingestion.

➢ For example, Omega-6 fatty acid & omega-3 fatty acid.

5) Fatty Acids Are Hydrocarbon Derivatives

- Fatty acids are carboxylic acids with hydrocarbon chains ranging from 4 to 36 carbons long (C_4 to C_{36}).
  - In some fatty acids, this chain is unbranched and fully saturated.
  - In others the chain contains one or more double bonds.
  - A few contain three-carbon rings, hydroxyl groups, or methyl-group branches.

6)

- nomenclature for these compounds specifies the chain length and number of double bonds, separated by a colon:
  - ➢ A 20-carbon fatty acid with 2 double bonds

- The positions of any double bonds are specified by superscript numbers following Δ (delta):
  - ➢ A 20-carbon fatty acid with one double bond between C-9 and C-10 and another between C-12 and C-13.

7) **B**.

To make the statement true:

The even number of carbons results from the **condensation** of two-carbon (acetate) units.

8)

- Trans fatty acids are produced by fermentation in the rumen of dairy animals.
- They are also produced during hydrogenation of fish or vegetable oils. Trans fat, also called trans-unsaturated fatty acids or trans fatty acids, is a type of unsaturated fat that naturally occurs in small amounts in meat and milk fat. Trans-fatty acids are manufactured fats created during a process called hydrogenation, which is aimed at stabilizing polyunsaturated oils.

9)

I. The physical properties of the fatty acids, are largely determined by the **length** and **degree** of unsaturation of the hydrocarbon chain.
II. The **nonpolar** hydrocarbon chain accounts for the **poor** solubility of fatty acids in water.
III. The **longer** the fatty acyl chain and the **fewer** the double bonds, the lower is the solubility in water.
IV. The carboxylic acid group is **polar** and accounts for the slight solubility of short-chain fatty acids in water.

Storage Lipids

Questions

1) What are simple triacylglycerols?

2) What are the most naturally occurring triacylglycerols?

3) What are characteristics of triacylglycerols?

4) What are adipocytes?

5) What area the advantages of triacylglycerols as stored fuels?

6) Where are fat cells stored in organisms and what function do they serve?

7) What are biological waxes?

8) Describe a couple of functions of wax.

Answer Key

1) The simplest lipids constructed from fatty acids are the triacylglycerols, also referred to as **triglycerides**, fats, or neutral fats.
   - Triglycerides are composed of 3 fatty acids each in ester linkage with a single glycerol.
   - Those containing the same kind of fatty acid in all 3 positions are called simple triglycerides and are named after the fatty acid they contain.

2) The most naturally occurring triglycerides are mixed –they contain two or more different fatty acids.
   - To name these compounds the name and position of each fatty acid must be specified.

3) Triglycerides have polar hydroxyls from the glycerol and polar carboxylates of the fatty acids, which are bound in ester linkages, and thus result in triacylglycerols being nonpolar, hydrophobic molecules.
   - Lipids have lower specific gravities than water.

4) In vertebrates, specialized cells called adipocytes, or fat cells, store large amounts of triacylglycerols as fat droplets.
   - Adipocytes contain **lipases**, enzymes that catalyze the hydrolysis of stored triacylglycerols, releasing fatty acids for export to sites where they are required as fuel.

5) There are two significant advantages to using triacylglycerols as stored fuels:

I. Triacylglycerols yields more than twice as much energy, gram for gram, as carbohydrates.

II. Triacylglycerols are hydrophobic - does not carry the extra weight of water that is associated with stored polysaccharides.

- Moderately obese people could meet their energy needs for months by drawing on their fat stores.
- The human body can store less than a day's energy supply in the form of glycogen.

6)

- Animals and Humans have fat tissue under the skin, in the abdominal cavity, and in the mammary glands.
- In some animals, triacylglycerols stored under the skin serve as insulation against low temperatures.
- In hibernating animals' fat reserves serve the dual purposes of insulation and energy storage.

7) Waxes Serve as Energy Stores and Water Repellents in organisms.

- Biological waxes are esters of long-chain (C_{14} to C_{36}) saturated and unsaturated fatty acids with long-chain (C_{16} to C_{30}) alcohols.

8) Waxes serve a diversity of functions other than energy:

I. Skin glands of vertebrates secrete waxes to protect hair and skin and keep it pliable, lubricated, and waterproof.

II. Birds, secrete waxes from their glands to keep their feathers water-repellent.

III. The shiny leaves of many plants are coated with a thick layer of waxes, which prevents excessive evaporation of water and protects against parasites.

IV. Biological waxes find a variety of applications in the industries: Lanolin (from lamb's wool), beeswax, carnauba wax (from a Brazilian palm tree), and wax extracted from spermaceti oil are widely used in the manufacture of lotions, ointments, and polishes.

Structural Lipids

Questions

1)

A. The central architectural feature of biological membranes is a _______ layer of lipids, which acts as a _______ to the passage of polar molecules and ions.

B. Membrane lipids are _______: one end of the molecule is hydrophobic, the other hydrophilic.

C. Their ________ interactions with each other and their ______ interactions with water direct their packing into sheets called membrane bilayers.

2) In this section we described 5 general types of membrane lipids, what are they?

3) What are Glycerophospholipids?

4) Fill in the blanks:

I. The head group is joined to glycerol through a ________ bond.

II. The polar alcohol may be __________, ____________ or __________charged.

5) What can be said about the fatty acids in glycerophospholipids?

6) What are the 2 types of lipids found in plant membranes and what is the difference between them?

7) Part I

Which statement is true?

A. Galactolipids are localized in the outer plant cell membranes.
B. Galactolipids make up 50% of the total membrane lipids of a vascular plant.
C. Galactolipids are likely the most abundant membrane lipids in mammals.
D. Plant membranes also contain sulfolipids in which the sulfonate on the head group bears a fixed negative charge like that of the phosphate group in phospholipids.
E. All of the above.

Part II

Correct the false statements.

A. Galactolipids are localized in the **thylakoid membranes (inner membranes) of chloroplasts.**
B. They make up **70% to 80%** of the total membrane lipids of a vascular plant.
C. They are likely the most abundant membrane lipids in the **biosphere**.
D. Plant membranes also contain sulfolipids in which the sulfonate on the head group bears a fixed negative charge like that of the phosphate group in phospholipids. **Correct, no need to change.**

8) What are the membrane lipids found in archaebacteria?

9) Define ceramide.

10) Part I

There are three subclasses of sphingolipids, what are they and how do they differ chemically?

Part II

Characterize each one of these 3 classes of sphingolipids.

11) What are sterols vs. steroids?

12) Describe the most abundant steroid in animals.

13) Describe the structure of a sterol.

Answer Key

1)

A. The central architectural feature of biological membranes is a **double** layer of lipids, which acts as a **barrier** to the passage of polar molecules and ions.
B. Membrane lipids are **amphipathic**: one end of the molecule is hydrophobic, the other hydrophilic.
C. Their hydrophobic interactions with each other and their **hydrophilic** interactions with water direct their packing into sheets called membrane bilayers.

2) The 5 general types of membrane lipids are:

1. Glycerophospholipids, in which the hydrophobic regions are composed of two fatty acids joined to glycerol.
2. Galactolipids and sulfolipids, which contain two fatty acids esterified to glycerol, but lack the characteristic phosphate of phospholipids.
3. Archaebacterial tetraether lipids, in which two very long alkyl chains are ether-linked to glycerol at both ends.
4. Sphingolipids, in which a single fatty acid is joined to a fatty amine, sphingosine.
5. Sterols, compounds characterized by a rigid system of four fused hydrocarbon rings.

3) Glycerophospholipids, also called **phosphoglycerides**, are membrane lipids in which two fatty acids are attached in ester linkage to the 1st and 2nd carbons of glycerol, and a highly polar or charged group is attached through a phosphodiester linkage to the 3rd carbon.

- Glycerol is prochiral; attachment of phosphate at one end converts it into a chiral compound, named either L-glycerol 3-phosphate, D-glycerol 1-phosphate, or *sn*-glycerol 3-phosphate.

Glycerophospholipids are named as derivatives of phosphatidic acid according to the polar alcohol in the head group.

4)

I. The head group is joined to glycerol through a **phosphodiester** bond.
II. The polar alcohol may be **negatively, neutral,** or **positively** charged.

5)

- The fatty acids in glycerophospholipids can be any of a wide variety, so a given phospholipid may consist of a number of molecular species, each with its unique complement of fatty acids.
- Glycerophospholipids contain a C_{16} or C_{18} saturated fatty acid at C-1 and a C_{18} to C_{20} unsaturated fatty acid at C-2.
- With few exceptions, the biological significance of the variation in fatty acids and head groups is not yet understood.

6) The two types of lipids that predominate in plant cells are found in the internal membranes of chloroplasts. These are:

1. The **galactolipids** - 1 or 2 galactose residues are connected by a glycosidic linkage to C-3 of a 1,2-diacylglycerol.
2. Plant membranes also contain **sulfolipids** - a sulfonated glucose residue is joined to a di-acylglycerol in glycosidic linkage.

7) Part I

D-

Plant membranes also contain sulfolipids in which the sulfonate on the head group bears a fixed negative charge like that of the phosphate group in phospholipids.

Part II

Answer on the video.

8) Archaebacteria Contain Unique Membrane Lipids - GDGTs

The archaebacteria—have membrane lipids containing long-chain (32 carbons) branched hydrocarbons linked at each end to glycerol.

- The general name for these compounds, glycerol dialkyl glycerol tetraethers (GDGTs), reflects their unique structure.
- These linkages are through ether bonds.
- In their fully extended form, twice the length of phospholipids and sphingolipids and span the width of the surface membrane.
- At each end of the extended molecule is a polar head consisting of glycerol linked to either phosphate or sugar residues.

9) Ceramides are a family of waxy lipid molecules – they are the structural parent of all sphingolipids.

- When a fatty acid is attached in amide linkage to the --NH_2 on C-2, the resulting compound is a **ceramide**, which is structurally similar to a diacylglycerol.

1. A ceramide is composed of sphingosine and a fatty acid.

- Ceramides are found in high concentrations within the cell membrane of eukaryotic cells,

1. They make up sphingomyelin, one of the major lipids in the lipid bilayer.
2. Ceramides are found in skin cells.

10)<u>Part I</u>

There are three subclasses of sphingolipids, all derivatives of ceramide but differing in their head groups: **sphingomyelins**, **neutral** (uncharged) **glycolipids**, and **gangliosides**.

1. **Sphingomyelins** contain phosphocholine or phosphoethanolamine as their polar head group and are classified as phospholipids.
2. **Glycosphingolipids**, which occur largely in the outer face of plasma membranes, have head groups with one or more sugars connected directly to the OOH at C-1 of the ceramide moiety; they do not contain phosphate.

- These are sometimes called **neutral glycolipids**, as they have no charge at pH 7.

3. **Gangliosides**, the most complex sphingolipids, have oligosaccharides as their polar head groups and one or more residues of *N*-acetylneuraminic acid (Neu5Ac), a sialic acid (often simply called “sialic acid”), at the termini.

- Sialic acid gives gangliosides the negative charge at pH 7.

Part II

1. **Sphingomyelins** resemble phosphatidylcholines in their general properties and three-dimensional structure, and in having no net charge on their head groups.
   - Sphingomyelins are present in the plasma membranes of animal cells and are especially prominent in myelin.
2. **Glycosphingolipids** which occur largely in the outer face of plasma membranes, have head groups with one or more sugars connected directly to the OOH at C-1 of the ceramide moiety; and do not contain phosphate. There are the two types:
   I. **Cerebrosides** have a single sugar linked to ceramide;
      i. those with galactose are characteristically found in the plasma membranes of cells in neural tissue.
      ii. those with glucose in the plasma membranes of cells in nonneural tissues.
   II. **Globosides** are neutral (uncharged) glycosphingolipids with two or more sugars.
   - Cerebrosides and globosides are sometimes called **neutral glycolipids**, as they have no charge at pH 7.
3. **Gangliosides**, the most complex sphingolipids, have oligosaccharides as their polar head groups and one or more residues of *N*-acetylneuraminic acid (Neu5Ac), a sialic acid (often simply called "sialic acid"), at the termini.
   - Sialic acid gives gangliosides the negative charge at pH 7 that distinguishes them from globosides.
   - Gangliosides with one sialic acid residue are in the GM (M for mono-) series, those with two are in the GD (D for di-) series, and so on (GT, three sialic acid residues; GQ, four).

11) Sterols are a subgroup of steroids.

- A sterol is any [member of a class of] steroid containing a hydroxyl group in the 3-position of the a-ring.
  - They are found in all animal and plant tissue and play an important role in hormone chemistry.
- Steroids which are mostly of eukaryotic origin, are a class of organic compounds having a structure of 17 carbon atoms arranged in four fused nonplanar rings.
  - they are lipids, and occur naturally as sterols, bile acids, adrenal and sex hormones, and some vitamins.

12) Cholesterol, is the most abundant steroid in animals.

- It is further classified as a sterol, and is a major component of animal plasma membranes – typically consisting of 30-40 mol % of plasma membrane lipids.
    - Its polar OH group gives it a weak amphiphilic character,
    - its fused ring provides it with greater rigidity than other membrane lipids.
- Plants contain little cholesterol but synthesize other sterols.
- In mammals cholesterol is the metabolic precursor of steroid hormones.
- Cholesterol, is amphipathic, with a polar head group and a nonpolar hydrocarbon body.

13) Sterols are structural lipids present in the membranes of most eukaryotic cells.

- The characteristic structure of this fifth group of membrane lipids is:
  - the steroid nucleus, consisting of four fused rings arranged in four rings, three with six carbons and one with five.
  - The steroid nucleus is almost planar and is relatively rigid;
  - the fused rings do not allow rotation about C-C bonds.
  - A sterol contains a hydroxyl group in the 3-position of the a-ring.

Active Lipids

Questions

1) What percent of cells do storage lipids and structural lipids compose?

2) A class of functional lipids was introduced, explain these and the main difference from the 2 types of lipids taught thus far.

3) List the 3 main groups of function that the group of lipids introduced in this lesson belong to.

4) Which statement is false?

A. Phosphatidylinositol in the cytoplasmic face of plasma membranes serves as a specific binding site for certain cytoskeletal proteins.
B. Phosphatidylinositol serves as a reservoir of messenger molecules that are released in response to extracellular signals.
C. The signals act through a series of steps that begins with enzymatic removal of a phospholipid head group and ends with activation of an enzyme (protein kinase C).
D. Membrane sphingolipids also can serve as sources of intracellular messengers.
E. All of the above.

5) We mentioned 2 molecules in the context of sphingolipids, name these and state their functions.

6) Define Eicosanoids.

7) List and define the three classes of eicosanoids.

8) What are steroids vs. sterols?

9) Part I

What are the major groups of steroid hormones?

Part II

Describe and define prednisone and prednisolone.

10) Mention at least 3 characteristics of steroids that were mentioned in the lesson.

11) Define and characterize cholesterol.

12) List and describe the 3 types of compounds used by plants for signaling.

13) Define vitamins and the 2 general classes identified for these.

14) For the fat-soluble vitamins, how many vitamin groups were established and what are the common characteristics for all?

15) What are tocopherols?

16) Part I

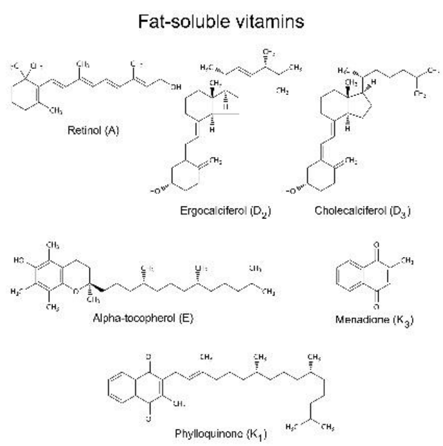
Which statement relating to vitamin K is true?

A. The aromatic ring of vitamin K undergoes a cycle of oxidation and reduction after the formation of active prothrombin.
B. Henrik Dam and Edward A. Doisy independently discovered that vitamin K deficiency triggers blood clotting, which can be fatal.
C. Vitamin K deficiency is very common in humans.
D. Vitamin K1 (phylloquinone) is found in bacteria residing in the vertebrate intestine, and [a related form,] vitamin K2 (menaquinone) is formed green plant leaves.
E. Vitamin K belongs to the fat-soluble group.

Part II

Adjust the false statements to make them correct.

17) What characteristics do the vitamins shown below have?



Answer Key

1) The 2 functional classes of lipids (storage lipids and structural lipids) are major cellular components.

- Membrane lipids make up 5% to 10% of the dry mass of most cells.
- Storage lipids make up more than 80% of the mass of an adipocyte.
- These lipids play a passive role in the cell.
    - Lipid fuels are stored until oxidized by enzymes.
    - Membrane lipids form impermeable barriers around cells and cellular compartments.

2) The 2 functional classes of lipids (storage lipids and structural lipids) are major cellular components that play a passive role in the cell:

    - Lipid fuels are stored until oxidized by enzymes.
    - Membrane lipids form impermeable barriers around cells and cellular compartments.
- Another group of lipids, present in much smaller amounts, have active roles in the metabolic traffic as metabolites and messengers.
    - These specialized lipids are derived from lipids of the plasma membrane or from the fat-soluble vitamins A, D, E, and K.

3)

1. Some serve as signals—as hormones, carried in the blood from one tissue to another, or as intracellular messengers generated in response to an extracellular signal (hormone or growth factor).
2. Others function as enzyme cofactors in electron-transfer reactions in chloroplasts and mitochondria, or in the transfer of sugar moieties in a variety of glycosylation reactions.
3. A third group consists of lipids with a system of conjugated double bonds: pigment molecules that absorb visible light.
    - Some of these acts as light-capturing pigments in vision and photosynthesis.
    - others produce natural colorations.

4) E – since all these statements are true.

5) Membrane sphingolipids can serve as sources of intracellular messengers.

The 2 mentioned are: Ceramide and sphingomyelin

- Both ceramide and sphingomyelin are regulators of protein kinases.
- Ceramide or its derivatives are known to be involved in the regulation of cell division, differentiation, migration, and programmed cell death.

6)

- Eicosanoids are paracrine hormones, substances that act only on cells near the point of hormone synthesis.
- These fatty acid derivatives have a variety of effects on vertebrate tissues.
    - They are involved in reproductive function; in the inflammation, fever, and pain associated with injury or disease; in the formation of blood clots and the regulation of blood pressure; in gastric acid secretion; and in a variety of other processes important in human health or disease.
- Are derived from arachidonic acid (20:4(5,8,11,14))
    - A 20-carbon polyunsaturated fatty acid.

7) There are three classes of eicosanoids:

1. Prostaglandins - Prostaglandins (PG) contain a five-carbon ring.
    - Their name derives from the prostate gland.
2. Thromboxanes - The thromboxanes have a six-membered ring containing an ether.
    - They are produced by platelets [(also called] thrombocytes).
    - act in the formation of blood clots and the reduction of blood flow to the site of a clot.
3. Leukotrienes - Leukotrienes, first found in leukocytes, contain three conjugated double bonds.
    - They are biological signals.

8) Steroids are oxidized derivatives of sterols.

- They have the sterol nucleus but lack the alkyl chain attached to ring D of cholesterol.
- Are more polar than cholesterol.

9) Part I

The major groups of steroid hormones are the male and female sex hormones (estrogen and testosterone) and the hormones produced by the adrenal cortex: cortisol and aldosterone.

Part II

Prednisone and prednisolone are steroid drugs with potent antiinflammatory activities.

- These are mediated in part by the inhibition of arachidonate release by phospholipase A2 and consequent inhibition of the synthesis of leukotrienes, prostaglandins, and thromboxanes.
  - They have a variety of medical applications, including the treatment of asthma and rheumatoid arthritis.

10) Steroid characteristics:

- Four fused carbon rings.
- Hydrophobic.
- Many have a OH functional group (sterols).
- Some have a short tail.

11) Cholesterol

This is a type of lipid that falls in the steroid group.

- Has an OH functional group (sterols).
- Has a tail.
- Maintains membrane fluidity.
- Precursor of steroid hormones.
- Associated with cardiovascular disease.

12) Plants use Phosphatidylinositols, Steroids, and Eicosanoidlike Compounds in Signaling.

I. **Phosphatidylinositols:** Vascular plants contain **phosphatidylinositol** 4,5-bisphosphate, as well as the phospholipase that releases IP3, which they use to regulate the intracellular concentration of $Ca2^{+}$.

II. **Steroids:** Brassinolide and the related group of brassino**steroids** are potent growth regulators in plants, affecting stem elongation and cellulose microfibrils.

III. **Eicosanoidlike: Jasmonate**, derived from the fatty acid 18:3($\Delta^{9,12,15}$) in membrane lipids, is chemically **similar to the eicosanoids** of animal tissues and also serves as a powerful signal.
   - Triggering the plant's defenses in response to insect-inflicted damage.
   - The methyl ester of jasmonate gives the characteristic fragrance of jasmine oil.

13) Vitamins are essential compounds to the health of humans and other vertebrates, but cannot be synthesized by these animals, and must therefore be obtained in the diet.

- Early nutritional studies identified 2 general classes of such compounds:
  1. those soluble in nonpolar organic solvents (fat-soluble vitamins).
  2. those that could be extracted from foods with aqueous solvents (water-soluble vitamins).

14) The fat-soluble vitamins group was resolved into the 4 vitamin groups A, D, E, and K.

- Are isoprenoid compounds synthesized by the condensation of multiple isoprene units.
- Two of these: D and A serve as hormone precursors.
- Vitamins E and K Are Oxidation-Reduction Cofactors.
- Deficiency of these vitamins can result in a variety of symptoms in humans.

15)Tocopherols are a group of closely related lipids that share the collective name: **Vitamin E**

- All contain a substituted aromatic ring and a long isoprenoid side chain
- They are hydrophobic, therefore tocopherols associate with cell membranes, lipid deposits, and lipoproteins in the blood.
- Tocopherols are biological antioxidants.
    - The aromatic ring reacts with and destroys the most reactive forms of oxygen radicals and other free radicals.
- Tocopherols are found in eggs and vegetable oils and are especially abundant in wheat germ.

16)<u>Part I</u>

E is the correct statement.

<u>Part II</u>

A. The aromatic ring of vitamin K undergoes a cycle of oxidation and reduction **during** the formation of active prothrombin.
B. Henrik Dam and Edward A. Doisy independently discovered that vitamin K deficiency **slows** blood clotting, which can be fatal.
C. Vitamin K deficiency is very **uncommon** in humans.
D. Vitamin K1 (phylloquinone) is found in **green plant leaves**, and vitamin K2 (menaquinone), is **formed by bacteria residing in the vertebrate intestine**.

17) The are vitamins that belong to the fat-soluble group:

- A, D, E, and K.
- Are isoprenoid compounds synthesized by the condensation of multiple isoprene units.
  - Two of these (D and A) serve as hormone precursors.
    - Deficiency in either can result in disease/health risks.
  - Vitamins E and K are Oxidation-Reduction Cofactors.