Lipids

A lipid is a hydrophobic or amphiphilic organic substance that is soluble in nonpolar solvents (e.g. ether, benzene, and chloroform). The main biological functions of lipids include storing energy, signaling, and acting as structural components of cell membranes. Although humans and other mammals use various biosynthetic pathways both to break down and to synthesize lipids, some essential lipids cannot be made this way and must be obtained from the diet.

Lipids classification

1-Simple lipids

- **Fats**
- **Waxes**

2- Complex lipids

- **Phospholipids:** lipids containing, in addition to fatty acids and an alcohol, a phosphoric acid residue.
- **Glycolipids** (**glycosphingolipids**)**:** lipids containing a fatty acid, sphingosine, and carbohydrate.
- **Other complex lipids:** lipids such as sulfolipids, aminolipids, and lipoproteins.

3- Derived lipids: these include fatty acids, glycerol, terpenes, steroids, carotenoids, lipid-soluble vitamins (such as vitamins A, D, E, and K), and hormones.

Categories of Lipids

1-Fatty acids: are a hydrocarbon chain "tail" that terminates with a carboxylic acid group "head"; this arrangement confers the molecule with a polar, hydrophilic end, and a nonpolar, hydrophobic end that is insoluble in water. Fatty acid is either **saturated** (without double bonds e.g. stearic acid, palmitic acid, lauric acid, and arachidic acid) or **unsaturated** (has carbon-carbon double bonds e.g. oleic acid, linoleic acid, linolenic acid, and arachidonic acid) (Figure 3.1), and may be attached to functional groups containing oxygen, halogens, nitrogen, and sulfur. Fatty acids are important dietary

sources of fuel for animals because, when metabolized, they yield large quantities of ATP. Many cell types can use either glucose or fatty acids for this purpose.

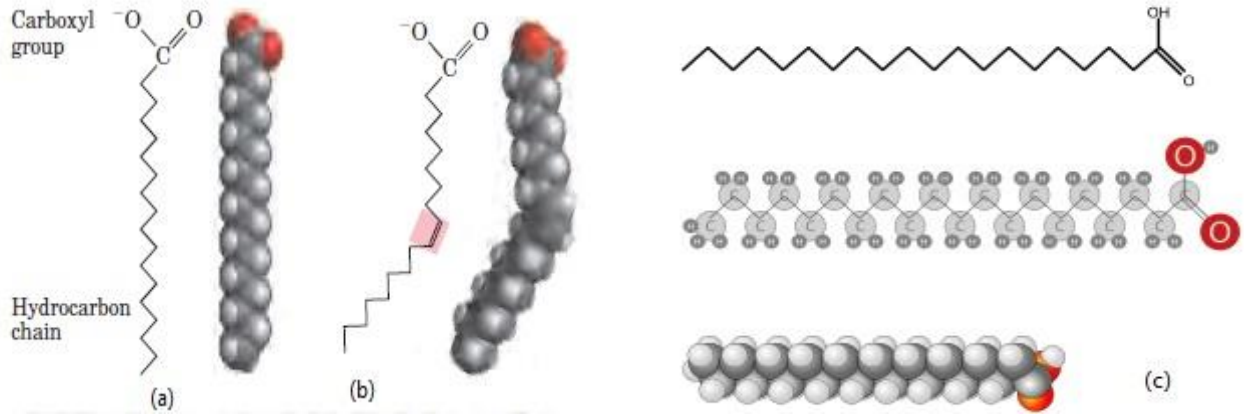

Figure 3.1: (a) Stearic acid, a saturated fatty acid (b) Oleic acid, an unsaturated fatty acid, the double bond is shaded, (c) Arachidic acid, a saturated fatty acid.

2- Glycerolipids: called triglyceride (TG), triacylglycerol (TAG), or triacylglyceride. Triglyceride is an ester derived from glycerol and three fatty acids. If all three fatty acid groups are the same the molecule is called a simple triacylglycerol, mixed triacylglycerol contain two or three different fatty acids (Figure 3.2). Triglycerides are the main constituents of body fat in humans and other animals, as well as vegetable fat. Additional subclasses of glycerolipids are represented by glycosylglycerols, which are characterized by the presence of one or more sugar residues attached to glycerol via a glycosidic linkage.

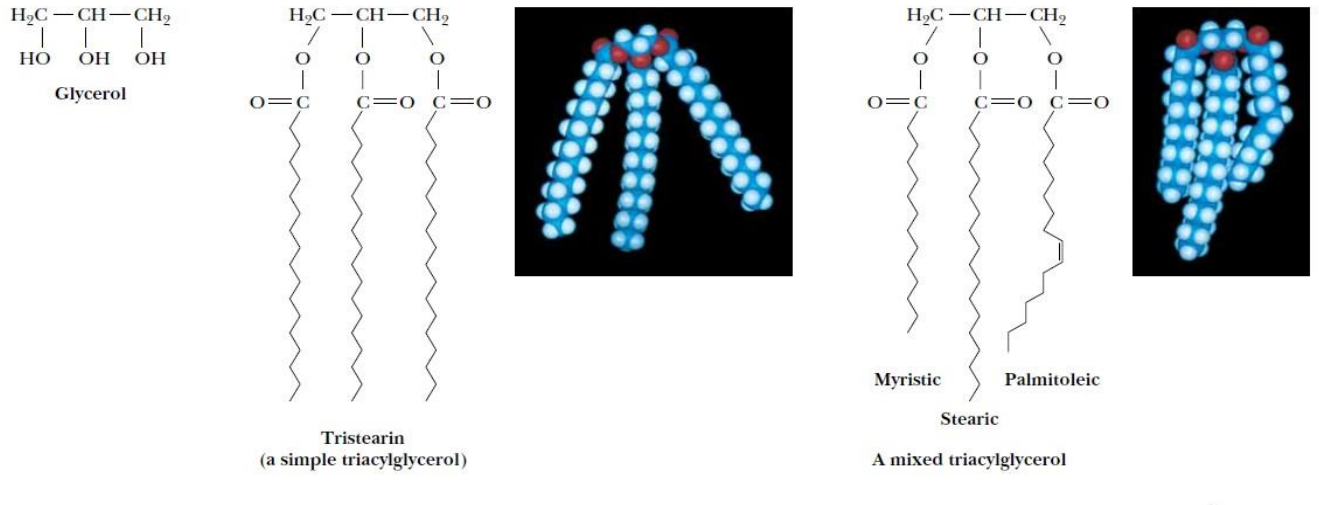

Figure 3.2: Triacylglycerols are formed from glycerol and fatty acids.

3- Glycerophospholipids: usually referred to as phospholipids (though sphingomyelins are also classified as phospholipids), also known as a phosphoglyceride or a glycerol phosphatide. The structure of the phospholipid molecule generally consists of two hydrophobic fatty acid "tails" and a hydrophilic "head" consisting of a phosphate group, the two components are joined together by a glycerol molecule (Figure 3.3). These lipids form one of the largest classes of natural lipids and one of the most important. They are essential components of cell membranes and are found in small concentrations in other parts of the cell. Neural tissue (including the brain) contains relatively high amounts of glycerophospholipids, and an alteration in their composition has been implicated in various neurological disorders.

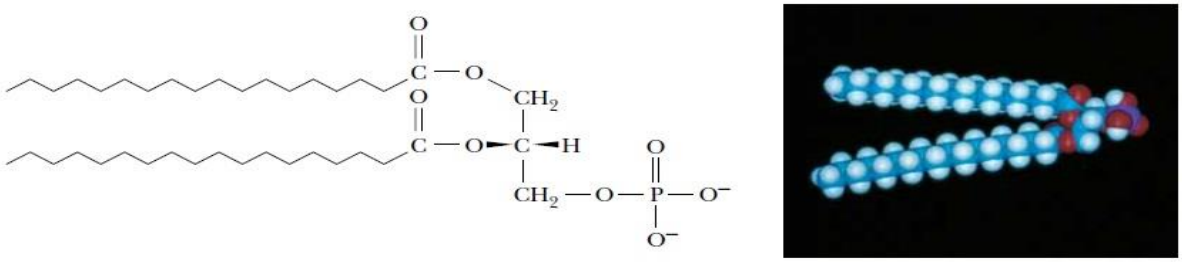

Figure 3.3: Phosphatidic acid, the parent compound for glycerophospholipids.

The venoms of poisonous snakes contain (among other things) a class of enzymes known as **phospholipases**, enzymes that cause the breakdown of phospholipids and led to dissolve the membranes of red blood cells, causing them to rupture. Indian cobras kill several thousand people each year.

4-Sphingolipids: Sphingolipids, or glycosylceramides represent another class of lipids found frequently in biological membranes. An 18-carbon amino alcohol (sphingosine) forms the backbone of these lipids rather than glycerol. Typically, a fatty acid is joined to a sphingosine via an amide linkage to form a ceramide. Sphingomyelins represent a phosphorus-containing subclass of sphingolipids and are especially important in the nervous tissue of higher animals. A sphingomyelin is formed by the esterification of a phosphorylcholine or a phosphorylethanolamine to the 1-hydroxy group of a ceramide. Glycosphingolipids are consisting of a ceramide with one or more sugar residues in a β-glycosidic linkage at the 1-hydroxyl moiety, when a single glucose or galactose is bound in this manner, the molecule is a cerebroside. Gangliosides are more complex glycosphingolipids that consist of a ceramide backbone with three or more sugars esterified, one of these being a sialic acid such as N-acetylneuraminic acid (Figure 3.4). These latter compounds are referred to as acidic glycosphingolipids, and they have a net negative charge at neutral pH.

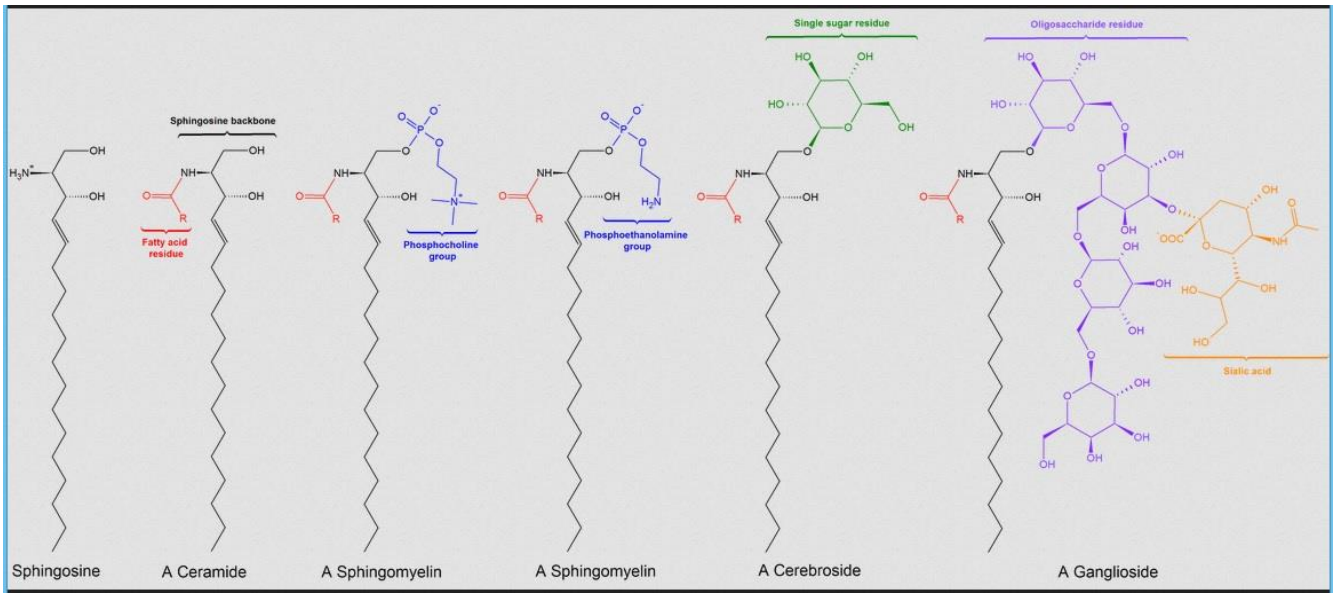

Figure 3.4: General structures of sphingolipids.

Sphingolipids are commonly believed to protect the cell surface against harmful environmental factors by forming a mechanically stable and chemically resistant outer leaflet of the plasma membrane lipid bilayer. Certain complex glycosphingolipids were found to be involved in specific functions, such as cell recognition and signaling.

5-Steroids: an organic compound with four rings. Examples include the cholesterol, the sex hormones, and the anti-inflammatory drug dexamethasone. Steroids have two principal biological functions: certain steroids (such as cholesterol) are important components of cell membranes which alter membrane fluidity, and many steroids are signaling molecules which activate steroid hormone receptors.

The steroid core structure is composed of seventeen carbon atoms, bonded in four "fused" rings: three six-member cyclohexane rings (rings A, B and C) and one five-member cyclopentane ring (the D ring) (Figure 3.5). Steroids vary by the functional groups attached to this four-ring core and by the oxidation state of the rings. **Sterols** are forms of steroids with a hydroxyl group at position three and a skeleton derived from cholestane. Hundreds of steroids are found in plants, animals and fungi. All steroids are manufactured in cells from the sterols lanosterol (animals and fungi) or cycloartenol (plants).

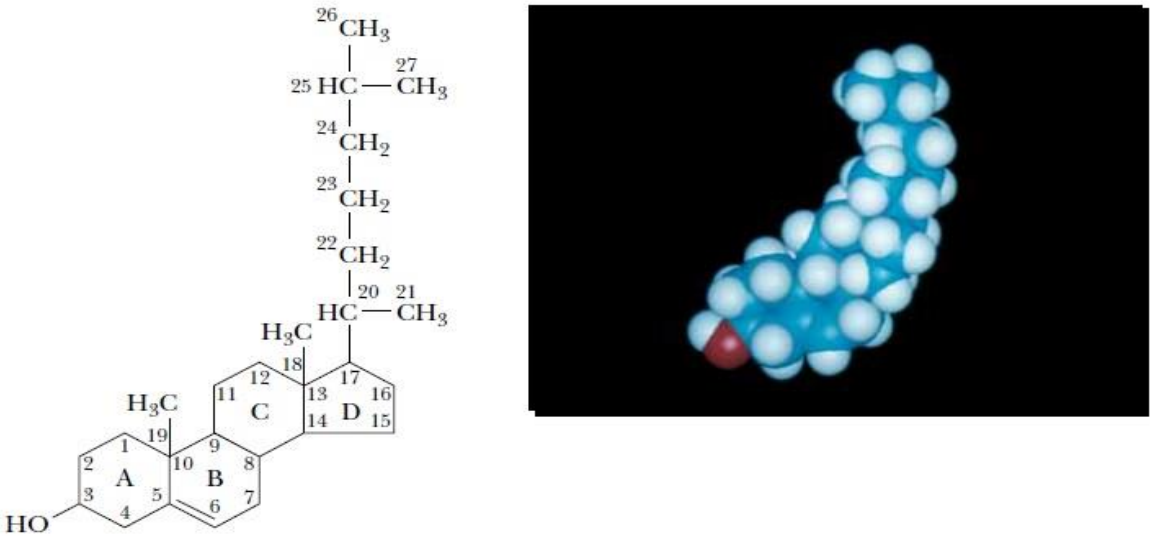

Figure 3.5: The structure of cholesterol, shown with steroid ring designations and carbon numbering.

6-Terpenes: are a class of lipids formed from combinations of two or more molecules of isoprene (C5H8). A monoterpene (C10) consists of two isoprene units, a sesquiterpene (C15) consists of three isoprene units, a diterpene (C20) has four isoprene units, and so on. Monoterpenes occur in all higher plants, while sesquiterpenes and diterpenes are less widely known. The triterpenes are C30 terpenes and include squalene and lanosterol, two of the precursors of cholesterol and other steroids. Tetraterpenes (C40) are less common but include the carotenoids, a class of colorful photosynthetic pigments; β-Carotene is the precursor of vitamin A. Long-chain polyisoprenoid molecules with a terminal alcohol moiety are called polyprenols.

7-Saccharolipids: describe compounds in which fatty acids are linked directly to a sugar backbone. The most familiar saccharolipids are the acylated glucosamine precursors of the Lipid A component of the lipopolysaccharides in Gram-negative bacteria.

8-Polyketides: are synthesized by polymerization of acetyl and propionyl subunits by enzymes. They comprise a large number of secondary metabolites and natural products from animal, plant, bacterial, fungal and marine sources, and have great structural diversity. Many commonly used anti-microbial, anti-parasitic, and anti-cancer agents are polyketides or polyketide derivatives, such as erythromycins, tetracyclines, avermectins, and antitumor epothilone.

Biological functions of lipids

1-Membranes: The **glycerophospholipids** are the main structural component of biological membranes, such as the cellular plasma membrane and the intracellular membranes of organelles; in animal cells. The glycerophospholipids are amphipathic molecules (containing both hydrophobic and hydrophilic regions). Sphingomyelin and sterols (mainly cholesterol in animal cell membranes) are also found in biological membranes.

2-Energy storage: Triglycerides, stored in adipose tissue, are a major form of energy storage both in animals and plants. The complete oxidation of fatty acids provides high caloric content, about 9 kcal/g, compared with 4 kcal/g for the breakdown of carbohydrates and proteins.

3-Signaling: Several different lipid categories have been identified as signaling molecules and cellular messengers.

4-Other functions:

The fat-soluble vitamins (A, D, E and K) are isoprene-based lipids, with a diverse range of functions. Lipids also form the basis of steroid hormones.

Lipid metabolism

Lipid metabolism is the synthesis and degradation of lipids in cells. Lipogenesis is the process of synthesizing these fats. The majority of lipids found in the human body from ingesting food are triglycerides. Other types of lipids found in the body are fatty acids, cholesterol and membrane lipids. There are three sources from which body can get fueled by fats: consumed dietary fats, storage fats, and the biosynthesis of the fats. Lipid metabolism often begins with hydrolysis, the second step is the absorption of broken down fatty acids into the epithelial cells of the intestinal wall. In the epithelial cells, the breakdown products of fatty acids are packaged and transported to the rest of the body.

Lipid degradation

Digestion is the first step to lipid metabolism, and is the process of breaking the triglycerides down into separate free fatty acids and glycerol units with the help of lipase enzymes. The second step in lipid metabolism is the absorption of fats. Fatty acids are absorbed into the epithelial cells lining the small intestine to be packaged and sent to the adipose tissues in the body. Fatty acids are oxidized to release energy for the cells. The main steps of catabolism occur in the mitochondria.

Beta oxidation is the metabolic process by which fatty acids are broken down in the mitochondria or in peroxisomes to generate acetyl-CoA. The acetyl-CoA is then ultimately converted into ATP, CO2, and H2O using the citric acid cycle and the electron transport chain. Hence the citric acid cycle can start at acetyl-CoA when fat is being broken down for energy if there is little or no glucose available.

Lipid biosynthesis

In animals, when there is an oversupply of dietary carbohydrate, the excess carbohydrate is converted to triglycerides. This involves the synthesis of fatty acids from acetyl-CoA and the esterification of fatty acids in the production of triglycerides, a process called lipogenesis.

Medical and biological importance of lipids

1- Fat under skin serve as thermal insulator against cold.
2- Fat around kidney serve as padding against injury.
3- Fat serve as a source of energy for man like carbohydrates.
4- Fat is an ideal form for storing energy in the human body compared to carbohydrates and proteins because energy content of fat is higher.
5- Lipids are structural components of cell membrane and nervous tissue.
6- Some lipids serve as precursors for the synthesis of complex molecules, for example, acetyl-Co A is used for the synthesis of cholesterol.
7- Lipoproteins, which are complex of lipids and proteins, are involved in transport of lipids in the blood and components of cell membrane.
8- Some lipids serve as hormones and fat soluble vitamins are lipids.
9- Fats are essential for the absorption of fat soluble vitamins.
10- Fats serve as surfactants by reducing surface tension.