23.1: Structure and Classification of Lipids

Learning Objectives

- Define lipids and recognize the different classes.

Fats and oils, found in many of the foods we eat, belong to a class of biomolecules known as **lipids**. Gram for gram, they pack more than twice the caloric content of carbohydrates: the oxidation of fats and oils supplies about 9 kcal of energy for every gram oxidized, whereas the oxidation of carbohydrates supplies only 4 kcal/g. Although the high caloric content of fats may be bad news for the dieter, it says something about the efficiency of nature's designs. Our bodies use carbohydrates, primarily in the form of glucose, for our *immediate* energy needs. Our capacity for storing carbohydrates for later use is limited to tucking away a bit of glycogen in the liver or in muscle tissue. We store our *reserve* energy in lipid form, which requires far less space than the same amount of energy stored in carbohydrate form. Lipids have other biological functions besides energy storage. They are a major component of the membranes of the 10 trillion cells in our bodies. They serve as protective padding and insulation for vital organs. Furthermore, without lipids in our diets, we would be deficient in the fat-soluble vitamins A, D, E, and K.

Lipids are not defined by the presence of specific functional groups, as carbohydrates are, but by a physical property—solubility. Compounds isolated from body tissues are classified as lipids if they are more soluble in organic solvents, such as dichloromethane, than in water. By this criterion, the lipid category includes not only fats and oils, which are esters of the trihydroxy alcohol glycerol and fatty acids, but also compounds that incorporate functional groups derived from phosphoric acid, carbohydrates, or amino alcohols, as well as steroid compounds such as cholesterol (Figure 23.1.1 presents one scheme for classifying the various kinds of lipids). We will discuss the various kinds of lipids by considering one subclass at a time and pointing out structural similarities and differences as we go.

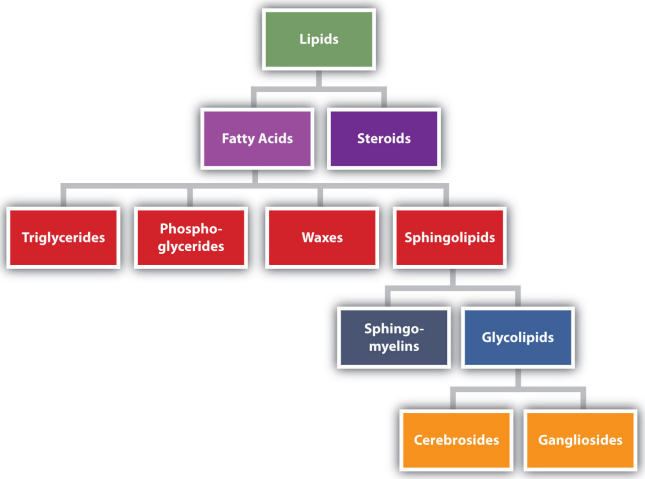


Figure 23.1.1: Lipid Organization Based on Structural Relationships

Lipids Formed from Fatty Acids

Fatty acids are carboxylic acids with 12-22 carbon atoms connected in a long, unbranched chain. As shown in the diagram above, most lipids are classified as *esters* or *amides* of fatty acids.

- *Waxes* are esters formed from long-chain fatty acids and long-chain alcohols. Most natural waxes are mixtures of such esters.
- *Triacylglycerol* (triglycerides) are esters of glycerol, a trialcohol, and three fatty acids. Many organisms store energy in this form.
- *Glycerophospholipids* are esters of glycerol formed from two fatty acid chains and a charged phosphate.

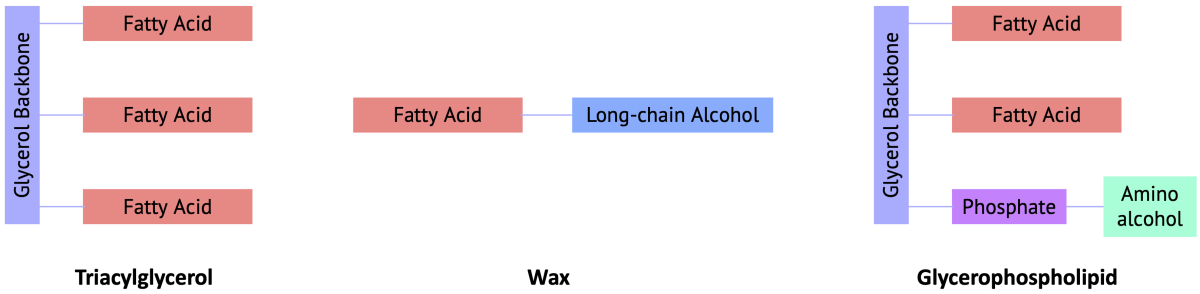


Figure 23.1.2: Esters of Fatty Acids: Triglycerides, Waxes, and Glycerophospholipids.

- *Sphingolipids* are fatty acid amides formed from a fatty acid attached to an amino alcohol backbone, called sphingosine, along with either a phosphate (*sphingomyelin*) or a carbohydrate (*glycolipid*). These along with glycerophospholipids are important for the structure and function of cellular membranes.

Other Lipids

Not all lipids contain fatty acid groups:

- *Sterols* (also classified as steroids) all contain the steroid nucleus, which is four fused rings. *Cholesterol* is the most commonly known sterol and is also an important lipid in cell membranes.
- *Eicosanoids* are important chemical messengers that include *prostaglandins*, which have a five-member ring and a carboxylic acid chain.

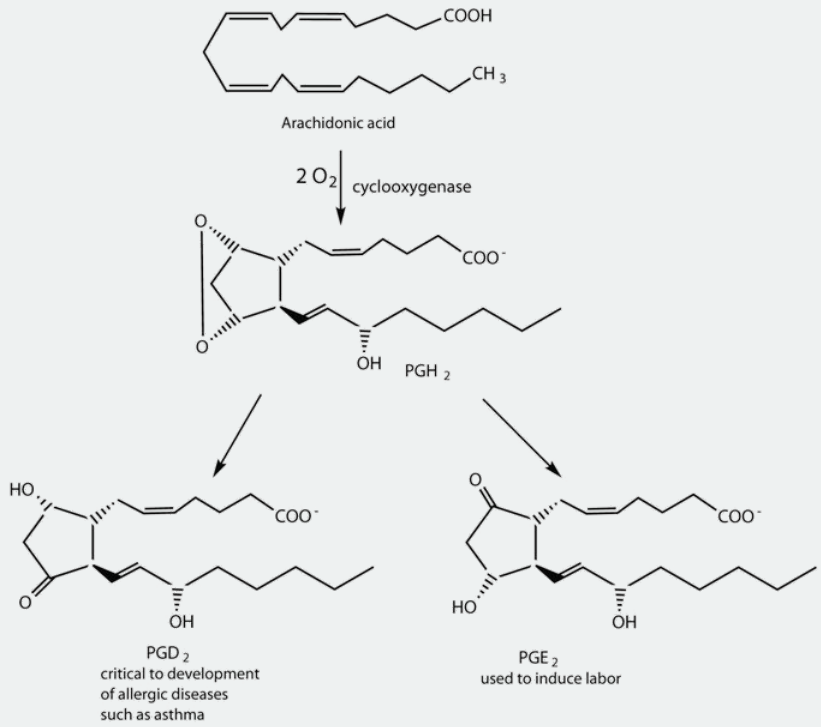
Figure 23.1.3: Other Lipids: Cholesterol contains the steroid nucleus (top) and a prostaglandin (bottom).

In the next sections of this chapter you will learn more about the structure, properties, and functions of each of these types of lipid.

To Your Health: Prostaglandins

Prostaglandins are chemical messengers synthesized in the cells in which their physiological activity is expressed. They are unsaturated fatty acids containing 20 carbon atoms and are synthesized from arachidonic acid—a polyunsaturated fatty acid—when needed by a particular cell. They are called *prostaglandins* because they were originally isolated from semen found in the prostate gland. It is now known that they are synthesized in nearly all mammalian tissues and affect almost all organs in the body. The five major classes of prostaglandins are designated as PGA, PGB, PGE, PGF, and PGI. Subscripts are attached at the end of these abbreviations to denote the number of double bonds outside the five-carbon ring in a given prostaglandin.

The prostaglandins are among the most potent biological substances known. Slight structural differences give them highly distinct biological effects; however, all prostaglandins exhibit some ability to induce smooth muscle contraction, lower blood pressure, and contribute to the inflammatory response. Aspirin and other nonsteroidal anti-inflammatory agents, such as ibuprofen, obstruct the synthesis of prostaglandins by inhibiting cyclooxygenase, the enzyme needed for the initial step in the conversion of arachidonic acid to prostaglandins.



Their wide range of physiological activity has led to the synthesis of hundreds of prostaglandins and their analogs. Derivatives of PGE_2 are now used in the United States to induce labor. Other prostaglandins have been employed clinically to lower or increase blood pressure, inhibit stomach secretions, relieve nasal congestion, relieve asthma, and prevent the formation of blood clots, which are associated with heart attacks and strokes.
