Almost 2/3 of the dry weight of the human brain is made up of lipids

FATTY ACIDS, FATS, AND OTHER LIPIDS

By

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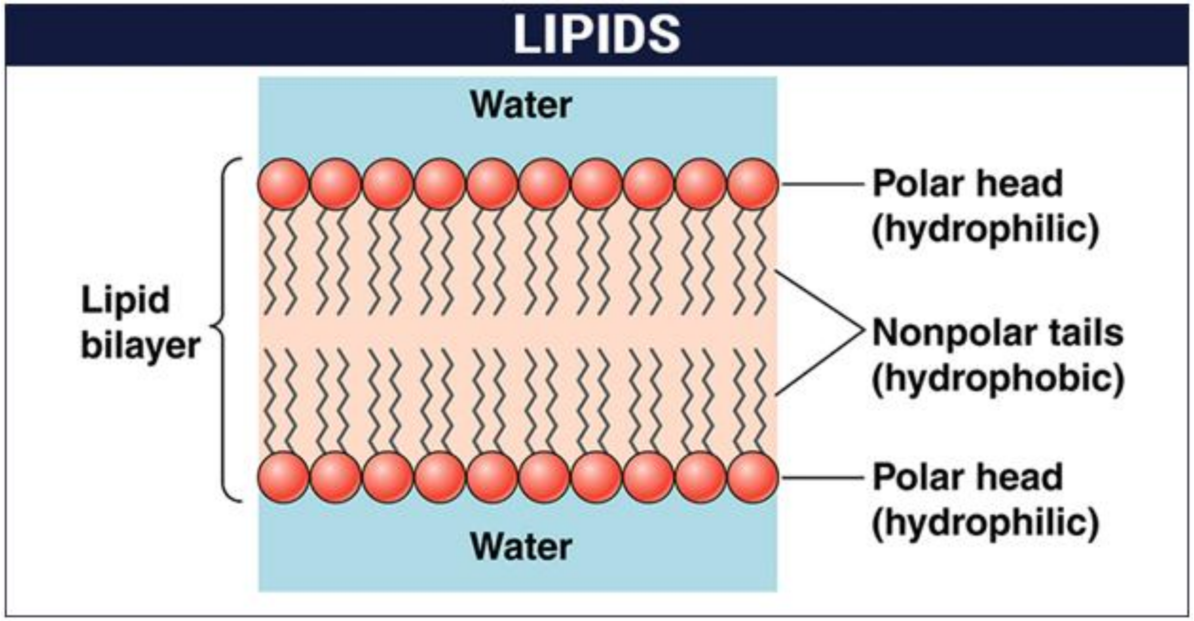
Lipids—a varied group that includes fats, oils, waxes, steroids, hormones, and even some vitamins—are essential for life. Many lipids lack nitrogen and are built with the same 3 elements as carbohydrates; others do include nitrogen, meaning that they build using the same 4 basic elements as proteins. But what unites all lipids and defines them as a distinct group is that they are molecules with at least one part that is hydrophobic and that overall are not hydrophilic.

What are Lipids?

organic compounds are nonpolar molecules, which are soluble only in nonpolar solvents and insoluble in water because water is a polar molecule. In the human body, these molecules can be synthesized in the liver and are found in oil, butter, whole milk, cheese, fried foods and also in some red meats.



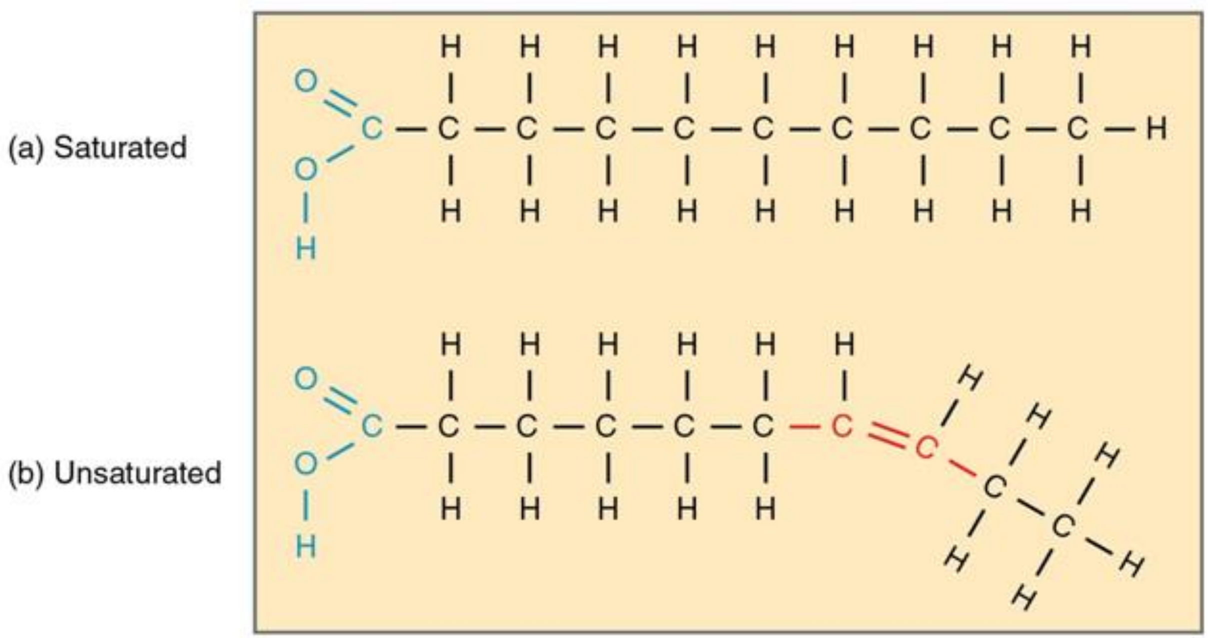
Properties of Lipids

Lipids are a family of organic compounds, composed of fats and oils. These molecules yield high energy and are responsible for different functions within the human body. Listed below are some important characteristics of Lipids.

1. Lipids are oily or greasy nonpolar molecules, stored in the adipose tissue of the body.
2. Lipids are a heterogeneous group of compounds, mainly composed of hydrocarbon chains.
3. Lipids are energy-rich organic molecules, which provide energy for different life processes.
4. Lipids are a class of compounds characterized by their solubility in nonpolar solvents and insolubility in water.
5. Lipids are significant in biological systems as they form a mechanical barrier dividing a cell from the external environment known as the cell membrane.

Lipid Structure

Lipids are the polymers of fatty acids that contain a long, non-polar hydrocarbon chain with a small polar region containing oxygen. The lipid structure is explained in the diagram below:



Classification of Lipids

Lipids can be classified into two main classes:

1- Nonsaponifiable Lipids

A nonsaponifiable lipid cannot be disintegrated into smaller molecules through hydrolysis. Nonsaponifiable lipids include cholesterol, prostaglandins, etc

2- Saponifiable Lipids

A saponifiable lipid comprises one or more ester groups, enabling it to undergo hydrolysis in the presence of a base, acid, or **enzymes**, including waxes, triglycerides, sphingolipids and phospholipids. Further, these categories can be divided into non-polar and polar lipids. Nonpolar lipids, namely triglycerides, are utilized as fuel and to store energy. Polar lipids, that could form a barrier with an external water environment, are utilized in membranes. Polar lipids comprise sphingolipids and glycerophospholipids. Fatty acids are pivotal components of all these lipids.

Types of Lipids

Within these two major classes of lipids, there are numerous specific types of lipids, which are important to life, including fatty acids, triglycerides, glycerophospholipids, sphingolipids and steroids. These are broadly classified as simple lipids and complex lipids.

Simple Lipids

Esters of fatty acids with various alcohols.

Fats: Esters of fatty acids with glycerol. Oils are fats in the liquid state

Waxes: Esters of fatty acids with higher molecular weight monohydric alcohols

Complex Lipids

Esters of fatty acids containing groups in addition to alcohol and fatty acid.

Phospholipids: These are lipids containing, in addition to fatty acids and alcohol, phosphate group. They frequently have nitrogen-containing bases and other substituents, eg, in glycerophospholipids the alcohol is glycerol and in sphingophospholipids the alcohol is sphingosine. **Glycolipids (glycosphingolipids)**: Lipids containing a fatty acid, sphingosine and carbohydrate. **Other complex lipids**: Lipids such as sulfolipids and amino lipids. Lipoproteins may also be placed in this category.

Precursor and Derived Lipids

These include fatty acids, glycerol, steroids, other alcohols, fatty aldehydes, and ketone bodies, hydrocarbons, lipid-soluble vitamins, and hormones. Because they are uncharged, acylglycerols (glycerides), cholesterol, and cholesteryl esters are termed neutral lipids. These compounds are produced by the hydrolysis of simple and complex lipids.

Fatty Acids

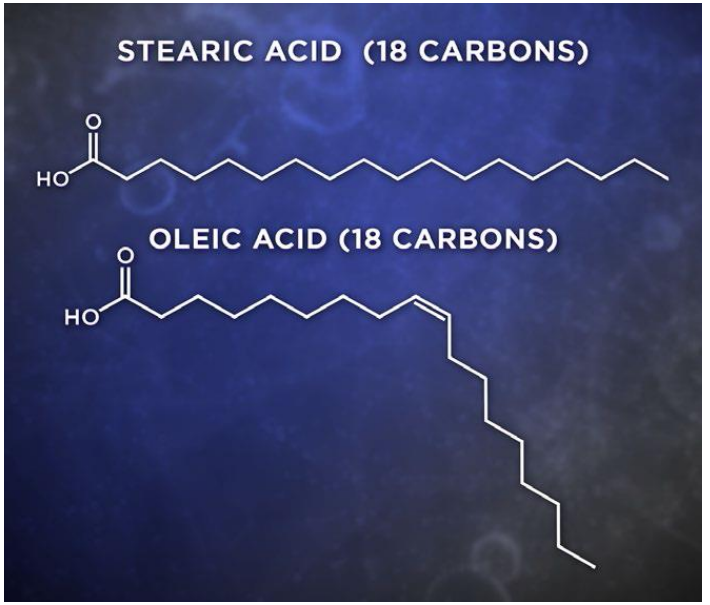
Lipids do not play in the watery neighborhoods that other biomolecules do. Some lipids, such as fats and cholesterol, are fully phobic about water. Others, such as membrane lipids, are ambivalent—a part of them fears water, but another is drawn to it.

Unlike proteins, carbohydrates, and nucleic acids, lipids are not polymers. Their molecules are also smaller. Most fats, for example, have molecular weights of less than 1000 grams per mole, whereas even a small protein has a molecular weight of 64,000 grams per mole. Fatty acids are the smallest, simplest lipids. They consist of a single chain of 2 to 28 carbons and are amphiphilic: One end of a fatty acid, called the head, has a hydrophilic carboxyl group, while the remainder of the molecule, called its tail, is hydrophobic, being made up of only nonpolar carbon/hydrogen bonds. Fatty acids come in 2 forms: saturated and unsaturated. Saturated fatty acids, such as stearic acid, have long, straight hydrocarbon tails with no double bonds between carbons.

By contrast, unsaturated fatty acids, such as oleic acid, have one or more carbon double bonds in their tails.

Fatty acids with just one double bond, such as oleic acid, are called monounsaturated fatty acids. Those with more than one double bond, such as linoleic acid, are called polyunsaturated.

For oleic acid, which is the leading component of olive oil, the double bond between the carbons has the 2 hydrogen atoms on the same side of the bond. This sort of double bond where hydrogens are on the same side is called a cis double bond. Cis bonds create kinks in fatty acids.



But if the 2 hydrogens are on opposite sides of the double bond, it is called a trans double bond, and the fatty acid is described as a trans fatty acid. Trans fatty acids are found in small amounts in nature, but most of them are created by the industrial production of food. The process called partial hydrogenation uses hydrogen to convert some of the double bonds in fatty acids to single bonds. This increases the saturation, which raises the melting point. This was used originally to make vegetable shortening and margarine as substitutes for more heavily saturated fats, such as butter or lard.

Unfortunately, trans fatty acids, whose unsaturated bonds are in the trans configuration, are by-products of partial hydrogenation. These unsaturated bonds lack a kink, and it leads to their association with cardiovascular problems.

Examples of Lipids

There are different types of lipids. Some examples of lipids include butter, ghee, vegetable oil, cheese, cholesterol and other steroids, waxes, phospholipids, and fat-soluble vitamins. All these compounds have similar features, i.e. insoluble in water and soluble in organic solvents, etc.

Triacylglycerols

Our bodies can make most, but not all, of the fatty acids we need. Two classes of polyunsaturated fatty acids we cannot make are omega-3 and omega-6 fatty acids, and this makes them essential to get from the food we eat. Triacylglycerols are the densest energy storage form in our body. When fatty acids are attached to glycerol, their polar head groups get hidden in the bonds with the glycerol. As a result, triacylglycerols, unlike fatty acids, are uniformly fully hydrophobic, making them insoluble in water.

Think of how oil mixed with vinegar in a salad dressing eventually separates. Left to their own chemistry, fats in your body would do the same thing and separate in the blood. To prevent this, fats are stored in specialized cells called adipocytes that contain a fat/oil droplet surrounded by cytoplasm. Fat cells grow in size, to a point, as obesity increases.

In the body, fats must move from the adipocytes they are stored in to tissues that need their energy. This movement occurs in the bloodstream in special micromolecular care packages called lipoprotein complexes. These complexes, which have an outer shell of proteins, contain an inner shell of fats and other lipids. These complexes are why your blood results come back with information about your high-density and low-density lipoproteins (HDLs and LDLs)—the concentration of bundled-up care packages.

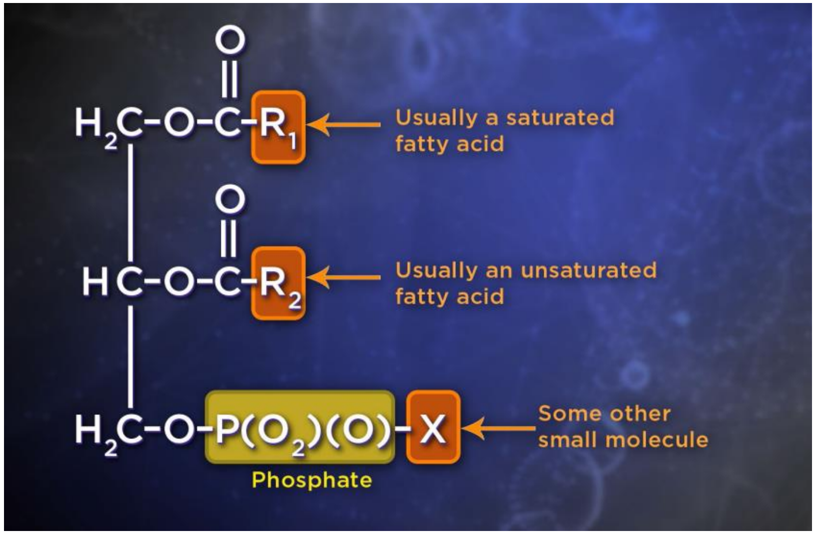
Triacylglycerols make up solid cooking fats, such as butter, as well as liquid oils, such as olive oil. The differences between these compounds arise only from the kinds of fatty acids that are bundled to the triacylglycerols.

If the bundles of fatty acids are mostly saturated fatty acids, with their straight hydrocarbon tails, the fats can pack closely together. The tight packing of saturated fatty acids is why butter is solid at room temperature. Saturated fats are generally more abundant in fats of animal origin, such as butter, lard, and beef tallow—all of which are solid.

If, instead, the fatty acids bundled together are mostly the kinky, unsaturated ones, the kinks in the tails keep them from being able to line up neatly. Because of this, triacylglycerols with unsaturated fatty acids can’t be packed as easily. Most plant-derived oils have a high proportion of the loosely packed unsaturated fatty acids that make them liquid. Olive oil and safflower oils are common examples.

- **Glycerophospholipids**

A related group of molecules have only 2 fatty acids attached to a glycerol, and in the place of the third one, they have small molecules linked to a phosphate at that position. These are called glycerophospholipids, or phosphoglycerides. They have a family resemblance to the triacylglycerols but differ by featuring a phosphate in place of one of the 3 fatty acids.



This small difference makes glycerophospholipids different from triacylglycerols in a crucial way. The phosphate groups, which are negatively charged, allow phospholipids to be hydrophilic at the phosphate end. They're still hydrophobic on the long hydrocarbon tails of the fatty acids, but overall they are amphiphilic—no longer fully hydrophobic.

Simple amphiphilic molecules like fatty acids arrange themselves in water so that the hydrophilic portions face outward toward water, while the hydrophobic portions face inward and associate with each other to the exclusion of water. Individual fatty acids are long, skinny molecules that form spherical structures called micelles.

However, glycerophospholipids are not skinny and cannot readily form micelles. Instead, these compounds arrange themselves in water into lipid bilayers. Interestingly, lipid bilayers form spontaneously. They don't require anything but a solution of water and phospholipids and result simply from the tendency of the hydrophilic heads of glycerophospholipids to face water while their hydrophobic tails hide from water. This property of phospholipids creates the most important cellular structure: the cell membrane, which regulates traffic in and out of cells.

Sphingolipids

Another important group of amphiphilic membrane lipids is the sphingolipids. These molecules get made by joining the amino acid serine to a 16-carbon fatty acid known as palmitic acid followed by several modifications. The amine of serine provides an attachment point for a second acyl group, so sphingolipids, like glycerophospholipids, contain 2 fatty acids. Though some sphingolipids, such as sphingomyelin, also contain a phosphate like the glycerophospholipids, most of them do not and instead have one or more sugar residues linked in place of the phosphate. Either way, most sphingolipids, like all glycerophospholipids, have an amphiphilic nature.

Fatty acids are also the starting point for a variety of other molecules that affect us in significant ways. Two essential fatty acids that our cells cannot make are linoleic acid and alpha linolenic acid, both of which are polyunsaturated 18-carbon molecules and each of which is a starting point for synthesis of other lipids.

Linoleic acid can be used by cells to make a 20-carbon polyunsaturated fatty acid called arachidonic acid. The compounds derived from arachidonic acid are a diverse group of important molecules called eicosanoids, all of which have 20 carbons, like their parent compound, arachidonic acid.

Eicosanoids include 2 important groups of molecules—one that is involved in pleasure and another that is involved in pain. Endocannabinoids play roles in mediating pleasure/reward pathways and regulation of the appetite, among other things. Arachidonic acid also gives rise to molecules that mediate pain and inflammation, a group called the prostanoids.

Fatty acids also play important roles specific to plants. Linolenic acid, one of 2 fatty acids we have to obtain in our diet, is made in plants, such as walnuts, flaxseed, soybeans, and several vegetable oils.