Headline news

Chemical and Physical Structure of Fatty Acids

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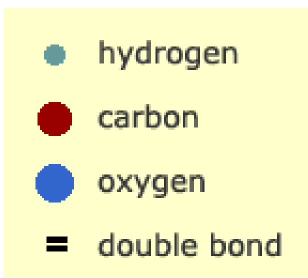
by Wyn Snow, Managing Editor

The terminology surrounding fatty acids can be confusing.

We hear about saturated, mono-unsaturated, poly-unsaturated, and trans fats. There are monoglycerides, diglycerides, and triglycerides—which our doctors tell us are a bad thing to have running rampant in our veins and arteries. How do we tell which are the "good fats" and which are the "bad" ones?

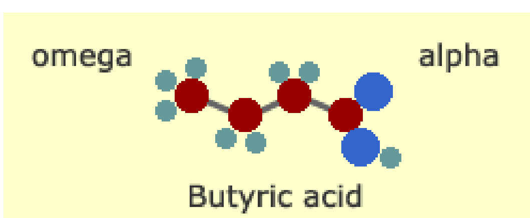
Looking at the structure of fatty acids can clear up a lot of this confusion. In the diagrams, the red circles are carbon atoms, forming the spine at the center of the molecules. The blue circles are oxygen, and the green are hydrogen.



The following diagrams show a 2-dimensional rendering of a 3-dimensional structure, as if the molecule has been mashed flat.

At the core of all fatty acids: a chain of carbon atoms

One of the simplest fats is butyric acid—found in butter. All fats have a COOH acid at the beginning of the chain, also known as the "alpha" end. The opposite end is called the omega (following the Greek alphabet, which begins with alpha and ends with omega).



Butyric acid is a saturated fat, which means that all the carbon bonds in the middle of the chain are "filled" with hydrogen. It's also one of the shortest fats, with only four carbon atoms.

A smorgasbord of fats

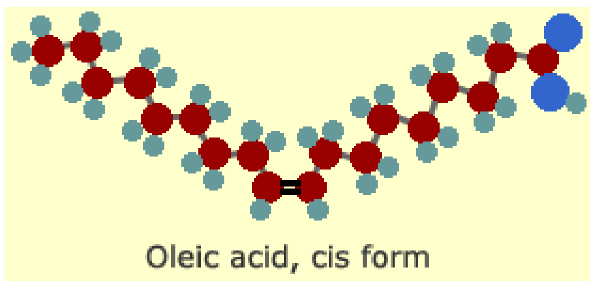
Fatty acids come in many lengths with many names. The three major omega-3s are alpha-linolenic acid (ALA, the essential fatty acid that the body cannot make) and the two fish oils eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These "fancy names" for EPA and DHA are based the Greek words for 20 and 22, which are the number of carbon atoms in them.

Fatty acids are the simplest of the fats. Glycerides occur when one or more strings of fatty acids become attached to a glycerol molecule. There can be one fatty acid string (monoglycerides), two (diglycerides), or three (triglycerides) attached to the glycerol.

All saturated fats are essentially straight, and the molecules can be packed tightly together. This makes them relatively dense, and solid at room temperature.

Unsaturated fats have "missing" hydrogen

In butyric acid and other saturated fats, each of the carbon atoms in the middle of the chain is bonded with two hydrogen atoms. In unsaturated fats, some of these hydrogen atoms are "missing." This always occurs in adjacent pairs of carbon atoms, which then form a double bond with each other. (Carbon atoms form 4 bonds with other atoms. Oxygen forms 2 bonds and hydrogen 1.)



Oleic acid is a common fatty acid found in most animal and vegetable fats. It contains one double bond (at the bottom of the "v"). Note that each of those carbon atoms is linked to only one hydrogen atom, instead of two. Oleic acid is a mono-unsaturated fat, which means it has only one double bond. Poly-unsaturated fats contain two or more double bonds.

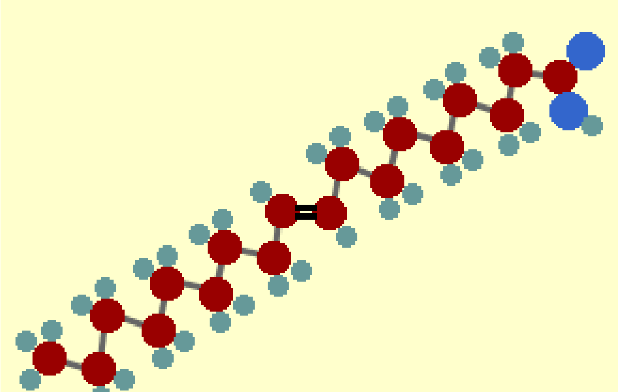
Fatty acids can be short, medium, or long—containing anywhere from 4 to 28 carbon atoms in the chain. Butyric acid contains 4 carbon atoms and is saturated with hydrogen atoms. The omega-3 called docosahexaenoic acid (DHA), which is commonly found in fish oil, contains 22 carbon atoms and 6 double-bond kinks, making it extremely polyunsaturated indeed.

Because unsaturated fats have this "kink" or bend, the molecules do not stack together easily—so they stay fluid at room temperature. Some mono-unsaturated fats, such as olive oil, will solidify when cooled in the refrigerator. Poly-unsaturated fats, which have more double-bonds and therefore more bends in their physical structure, stay fluid even when refrigerated.

Why trans-fats are so bad for us

When plants or animals make unsaturated fats, they mostly build this kinked "cis" form. However, food manufacturers discovered that bubbling hydrogen through polyunsaturated oils created "partially hydrogenated" fats that were less vulnerable to becoming rancid than the original oils and therefore had a longer shelf life. These partially hydrogenated margarines and shortenings are now present in almost all baked goods and commercial peanut butter.

This hydrogenation process also converts the bent "cis" form to a straightened "trans" form, which looks like this:



Oleic acid, trans form

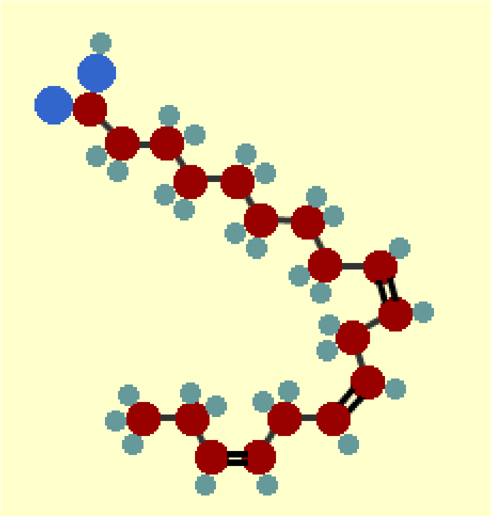
The chemical structure is the same. It has the same number of carbon, oxygen and hydrogen atoms, the same COOH acid at the alpha end, and the double bond is in the same place—but now it's straight instead of kinked.

The body recognizes this chemical structure and tries to use it in the same places and for the same purposes that it uses the bent cis form. But the trans form stacks together just like saturated fats, which sabotages the flexible, porous functionality the body needs from unsaturates.

Exposure to prolonged heat (as in deep fat frying) also creates trans fats by loosening the double bond and allowing it to "flip" into the straight form.

Poly-unsaturated fats

In poly-unsaturated fats, more than one hydrogen pair is missing. The more pairs that are missing, the more kinks in the chain and the more fluid the oil.



Alpha-Linolenic acid

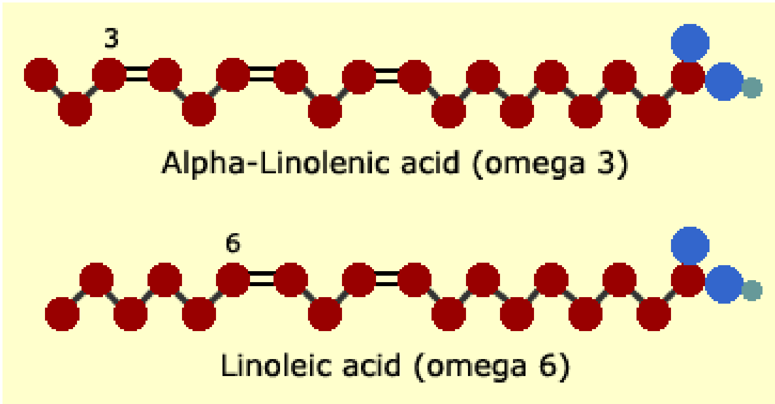
These kinks in the structure make our cell membranes flexible and permeable, allowing nutrients to enter the cell and waste products to leave. When the body uses trans fats in place of the cis-form of unsaturates, our cells can become insulin resistant, which can lead to type 2 diabetes.

Omega-3, omega-6 and omega-9

Whether an unsaturated fat is an omega-3 or -6 or -9 depends on the location of the first kink or double bond. The acid end of the molecule is called the "alpha", and its opposite is the "omega" end.

The first double-bond kink in an omega-3 fatty acid occurs between the third and fourth carbon atoms away from the omega end. For an omega-6, between the sixth and seventh. And for omega-9, between the ninth and tenth. Oleic acid (shown earlier) is an omega-9 fatty acid.

The following simplified diagrams show the structure that is typical of omega-3s and omega-6s.



These two fatty acids—alpha-linolenic acid (ALA, an omega-3) and linoleic acid (an omega-6)—are the two essential fatty acids that the human body needs and cannot manufacture. When sufficient ALA is supplied in the diet, the body can make enough DHA and EPA for the eicosanoids that form our metabolic "thermostat" system—or the body can use DHA and EPA directly from diet as well.

The bottom line on fats

Excessive amounts of saturated fat in the diet have been linked to heart disease. Trans fatty acids have been linked to increased insulin resistance and type 2 diabetes—as well as heart disease. They appear to be worse for our health than saturated fats, largely because the body tries to use them in ways that evolution designed for unsaturated fats. Consumption of trans fats also raises LDL cholesterol and lowers HDL—the exact opposite of what one wants.

In reading labels, steer clear of "partially hydrogenated" fats, because these contain trans fats. In the future, food labels will be required to display the trans fat content, making it easier to identify foods that are bad for our health.

The dietary move away from saturated fats to vegetable oils has supplied plenty of the essential omega-6 fatty acid, linoleic acid, which is present in almost all vegetable oils.

However, obtaining enough of the omega-3 essential fatty acids has become a challenge for most Americans. Eating more fish is one recommended solution. Supplementing one's diet with omega-3 fish oils and/or flaxseed oil is another.

Because these omega-3 and -6 oils are polyunsaturated, they are especially vulnerable to becoming rancid through exposure to light and heat. Store such oils in the refrigerator—and when possible, purchase brands with opaque containers. To be doubly safe with flaxseed oil, keep it in the refrigerator even before opening the bottle.

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