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**April/May 2015 Teacher's Guide for**

***The Skinny on Fats***

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# About the Guide

Teacher’s Guide editors William Bleam, Regis Goode, Donald McKinney, Barbara Sitzman and Ronald Tempest created the Teacher’s Guide article material. E-mail: [bbleam@verizon.net](mailto:bbleam@verizon.net)

Susan Cooper prepared the anticipation and reading guides.

Patrice Pages, *ChemMatters* editor, coordinated production and prepared the Microsoft Word and PDF versions of the Teacher’s Guide. E-mail: [chemmatters@acs.org](mailto:chemmatters@acs.org)

Articles from past issues of *ChemMatters* can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013.

The *ChemMatters* DVD also includes Article, Title and Keyword Indexes that covers all issues from February 1983 to April 2013.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558.

Purchase information can be found online at [www.acs.org/chemmatters](http://chemistry.org/chemmatters/cd3.html).

# Student Questions

**(taken from article)**

**The Skinny on Fats**

* 1. What kind of fat was associated with a greater risk of heart disease in the 1970 study of more than 12,000 men from seven countries?
  2. What is the chemical term for fat, according to the article?
  3. Name the two component parts of triglycerides.
  4. What is the chemical notation for a carboxyl group?
  5. What is the energy density of fat?
  6. Identify the intermolecular forces that hold saturated fat molecules close together.
  7. How do intermolecular forces in saturated fats vary with molecular size?
  8. What is unique about the chemical bonding in unsaturated fats?
  9. Compare the strength of intermolecular forces in unsaturated fats with those in saturated fats.
  10. The article says that saturated fats raise cholesterol levels. Which kind of cholesterol, LDL or HDL, is raised?
  11. According to the article, despite the decline in fats intake in our diet, two health issues have increased. Name them.
  12. The article connects decreased dietary fat consumption since the 1970s with an increase in type 2 diabetes in the U.S. Give one possible explanation for this that is offered by the article.

# Answers to Student Questions

**(from article)**

* + 1. **What kind of fat was associated with a greater risk of heart** **disease in the 1970 study of more than 12,000 men from seven countries?**

*The 1970 study linked heart disease with saturated fats like that found in red meat and other animal products.*

* + 1. **What is the chemical term for fat, according to the article?**

*The chemical term for fat is triglyceride.*

* + 1. **Name the two component parts of triglycerides.**

*The two component parts of triglycerides are glycerol and three fatty acid molecules.*

* + 1. **What is the chemical notation for a carboxyl group?**

*The article uses the notation –COOH for the carboxyl group.*

* + 1. **What is the energy density of fat?**

*The energy density is the number of calories per gram of a substance. For fat the value is 9 cal/g.*

* + 1. **Identify the intermolecular forces that hold saturated fat molecules close together.**

*The forces holding saturated fat molecules together are called dispersion forces.*

* + 1. **How do intermolecular forces in saturated fats vary with molecular size?**

*Dispersion forces increase in strength as molecular size increases. Therefore, the temperature needed to melt the molecules increases. In general saturated fats melt at higher temperatures as a result.*

* + 1. **What is unique about the chemical bonding in unsaturated fats?**

*Unsaturated fats are triglycerides in which the fatty acids contain one or more double bonds.*

* + 1. **Compare the strength of intermolecular forces in unsaturated fats with those in saturated fats. Explain this.**

*Unsaturated fats have weaker dispersion forces between molecules than do saturated fats. This results in lower melting temperatures for unsaturated fats, making them liquids at room temperature, while saturated fats tend to be solids. The weaker dispersion forces for unsaturated fats are due to double bonds in unsaturated fats creating kinks or bends in the shape of unsaturated fat molecules that prevents them from packing closely together, which results in weaker attractive forces.*

* + 1. **The article says that saturated fats raise cholesterol levels. Which kind of cholesterol, LDL or HDL, is raised?**

*Both “good” (HDL) and “bad” (LDL) cholesterol levels are raised by saturated fats.*

1. **According to the article, despite the decline in fats intake in our diet, two health issues have increased. Name them.**

*The two health issues are increases in both obesity and type 2 diabetes.*

1. **The article connects decreased dietary fat consumption since the 1970s with an increase in type 2 diabetes in the U.S. Give one possible explanation for this that is offered by the article.**

*The article explains the increase in type 2 diabetes by saying that,* ***“****Some nutritionists speculate that the replacement of fat by carbohydrates, especially sugar, may have exacerbated the problems they were intended to solve. Products such as low-fat cookies, crackers, and cakes may seem healthier because they do not contain fats, but they still increase caloric intake. Also, people who are on a diet rich in fats feel full more easily than when they are on a diet high in carbohydrates. As a result, people on a low-fat diet can be hungrier and end up eating more*.”

# Anticipation Guide

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions:**  *Before reading*, in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. A 2013 study showed that children who consumed 2% or whole milk were more likely to be overweight than children who drank low-fat milk. |
|  |  | 1. The original study linking saturated fat to cardiovascular disease was published in 1990. |
|  |  | 1. All fats are triglycerides. |
|  |  | 1. Fats have the same number of calories per gram as proteins and carbohydrates. |
|  |  | 1. Unsaturated fats come from plant sources. |
|  |  | 1. Unsaturated fats have double bonds that cause molecules to bend. |
|  |  | 1. Saturated fats are often solids at room temperature, while unsaturated fats are liquids at room temperature. |
|  |  | 1. Cholesterol is found in foods containing animal fat. |
|  |  | 1. HDL and LDL cholesterol particles function the same. |
|  |  | 1. Fat consumption has risen since the 1970s. |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading and writing strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

***Teaching Strategies:***

1. Links to **Common Core Standards for Reading**:
   1. ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
   2. ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
2. Links to **Common Core Standards for Writing**:
   1. ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
   2. ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.
3. **Vocabulary** and **concepts** that are reinforced in this issue: Chirality; Enantiomer; Amino acid; Protein; Enzyme; and Organic molecular structures.
4. To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.

***Directions*:** As you read the article, complete the graphic organizer below using your own words to describe substances found in fats.

|  |  |  |
| --- | --- | --- |
| **Substance** | **Structure (draw or describe)** | **Source or Examples** |
| **Triester** |  |  |
| **Saturated fat** |  |  |
| **Unsaturated fat** |  |  |
| **LDL cholesterol** |  |  |
| **HDL cholesterol** |  |  |

* **After reading the article, what concerns do you have about eating fats? Please explain.**

# Background Information

**(teacher information)**

**More on** **the article and its context**

This Teacher’s Guide accompanies an article about the controversial role of fat in the American diet. The article says, “Many of us avoid fatty foods, guided by what our parents have told us, by nutritional guidance, or just by a general feeling that fat is bad. But recent scientific breakthroughs have cast doubt on fat’s bad reputation, making these decisions more complicated. According to this new scientific evidence, eating a moderate amount of fat may actually help you stay lean and healthy.” (p. 16)

The segment of the U.S. population that chooses to eat healthy often relies on the dietary guidelines issued by government agencies and professional organizations, each of which relies on researchers to deliver scientific evidence for the guidelines. In a political atmosphere that seems to distrust science and research, this article presents an opportunity to discuss with students not only the chemistry of fats but also the way in which scientific evidence makes its way into the national consciousness. There are many families—and students—who either know very little about national dietary guidelines and healthy eating or do not have healthy food readily available to them. These students will benefit from a discussion of this article.

You may want to begin the discussion by asking students what they know about some of the fat-related ideas in the article. Some of those questions could be:

* What is the difference between whole milk and skim milk?
* What are saturated and unsaturated fats, and what foods contain significant amounts of each?
* How are fats related to cholesterol levels?
* How are obesity and diabetes related to dietary fat?

Many students will recognize these kinds of questions but may not have good answers due to the controversies described in the article. This kind of introduction will enable you to discover what student misconceptions exist and provide a basis for discussion of the chemistry involved.

In this Teacher’s Guide we will look at the chemistry of fats and their role in our diets and also examine the history of dietary guidelines in America.

**More on** **lipid components**

Lipids are a class of organic compounds that include fats, oils, waxes, phospholipids and steroids, and assorted other compounds. What they have in common is that they are all hydrophobic. That is, they are insoluble in water. Your students will recognize fats as one of the “big three” macronutrients along with carbohydrates and proteins. Lipids or fats are stored in cells throughout the body in special kinds of connective tissue called adipose tissue, where they may make up as much as 90% of the cell volume. Fats serve as energy-storing compounds, insulate the body from extreme temperature changes and also provide cushioning and support for vital organs like the heart, liver and kidneys.

Although not mentioned in the article, there are several types of compounds included in the lipid category. Triglycerides are triesters of long-chain fatty acids and glycerol. A second type of lipid which is more complex, includes phospholipids (mentioned in the article) and glycolipids. Phospholipids are esters of fatty acids, glycerol and phosphoric acid. Glycolipids are lipid molecules that contain carbohydrates, usually simple sugars. Still another type of lipid is steroids, which have a basic four-ring structure in common—three six-sided (cyclohexane) rings along with one five-sided (cyclopentane) ring. Functional groups are added to the ring structure. And finally, waxes, also part of the lipid family, are esters of long-chain fatty acids and long chain alcohols.

**More on fatty acids**

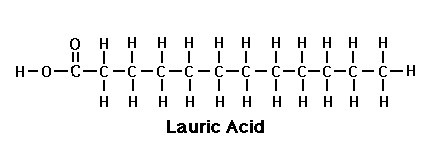
Let’s look at the chemistry of lipids, starting with their basic structure. Think of the molecule as having two parts—a fatty acid component and a glycerol component. Fatty acids are just carboxylic acids with long carbon chains (see diagram). The example in the diagram is palmitic acid.



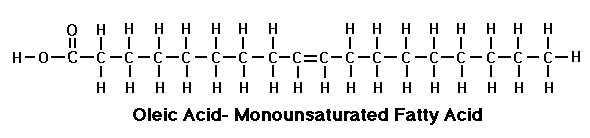
([*http://www.longevinst.org/nlt/nlt15fattyacid.htm*](http://www.longevinst.org/nlt/nlt15fattyacid.htm))

This 15-carbon alkane chain is a typical example since most fatty acids have chains from 10–30 carbons. The part of the structure at right in the diagram is a carboxylic acid functional group made up of a carbon atom, two oxygen atoms and a hydrogen atom. The carboxylic acid “end” of the molecule has acid properties and is polar, but the long alkane chain is non-polar. For fatty acids with longer hydrocarbon chains, the entire molecule is nonpolar, which makes it hydrophobic.

The long hydrocarbon chains in fatty acids may contain all single covalent bonds between the carbon atoms, or one or more of the carbon-carbon bonds may be double covalent bonds. If all the carbon-carbon bonds are single covalent bonds then the molecule is considered saturated. If one or more of the bonds is a double covalent bond, the molecule is unsaturated. An example of a saturated fatty acid and an unsaturated fatty acid are shown in the diagrams below. Lauric acid is a saturated fatty acid. Notice that all the C-C bonds are single bonds.

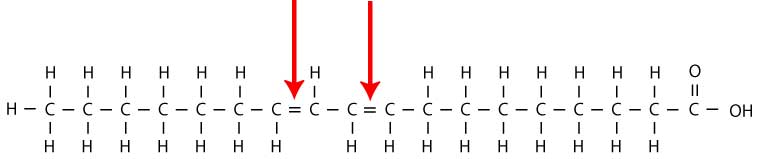


([*http://www.raw-milk-facts.com/fatty\_acids\_T3.html*](http://www.raw-milk-facts.com/fatty_acids_T3.html))



([*http://www.foodnetworksolution.com/wiki/word/1643/oleic-acid*](http://www.foodnetworksolution.com/wiki/word/1643/oleic-acid))

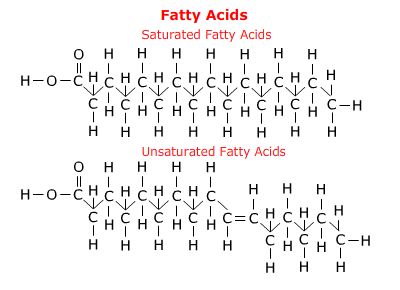
Oleic acid is an unsaturated fatty acid because there is one double bond between two of the carbon atoms in the chain. In the diagram oleic acid is labeled as a “monounsaturated” fatty acid because there is only one double bond. If there were more than one double bond in the molecule, it would be a polyunsaturated fatty acid. Such a fatty acid, alpha-linoleic acid, is polyunsaturated as shown below by the arrows pointing to the two double bonds.



([*http://modernherbalmedicine.com/articles/fat-facts-2.html?page=3*](http://modernherbalmedicine.com/articles/fat-facts-2.html?page=3))

So we can have saturated fatty acids or unsaturated fatty acids, and within the latter category we can have monounsaturated and polyunsaturated compounds. This nomenclature carries through to fats themselves. More on this later.

Another important factor in the chemistry of fatty acids (and fats) is the fact that saturated and unsaturated fatty acids differ in their molecular geometry. Molecules of saturated fatty acids have a more linear configuration. The C-C bonds in the molecule are sp3 hybrids with resulting bond angle of 109.47 o. The chains of carbon atoms, however, form a general straight-line shape, allowing adjacent molecules to “pack” close together. This closer packing results in somewhat stronger intermolecular forces between molecules of saturated fatty acids. The forces are, in fact, dispersion forces. Recall that London dispersion forces are temporary attractive forces that result from the electrons in two adjacent atoms occupying positions that make the atoms form temporary instantaneous dipoles.

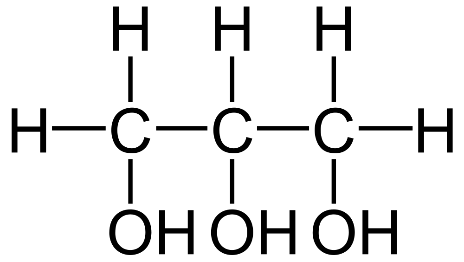


([*http://telstar.ote.cmu.edu/biology/MembranePage/index2.html*](http://telstar.ote.cmu.edu/biology/MembranePage/index2.html))

London forces are the attractive forces in nonpolar substances, like the long chains in fatty acids, as shown in the upper diagram, above right. They are the weakest of the van der Waals forces. Because these dispersion forces in saturated fatty acids are stronger than they are in unsaturated fatty acids, saturated fatty acids are mostly solids at room temperature. On the other hand, unsaturated fatty acid molecules have one or more “kinks” or bends resulting from the shape of the double bond(s)—see lower diagram, above right. These molecules cannot pack as closely and, therefore, exhibit weaker dispersion forces. Most of these fatty acids are liquids at room temperature.

**More on Glycerol**

The other major component of fats is glycerol, which is an organic alcohol, meaning   
that within the chemical structure there is at least one alcohol functional groups, –OH. Glycerol is a  
tri-alcohol, so there are three –OH groups. The structure for glycerol is shown at right. It is also known as glycerine, and its IUPAC name is   
1,2,3-trihydroxypropane.



[(*http://www.kullabs.com/class-10/science/chemistry/hydrocarbon-and-their-derivatives/glycerol-and-ether*](file:///\\acs.org\..\Don\AppData\Local\Microsoft\Windows\Temporary%20Internet%20Files\TG%20Drafts\(http:\www.kullabs.com\class-10\science\chemistry\hydrocarbon-and-their-derivatives\glycerol-and-ether))

In its pure form glycerol has the following properties:

Formula: C3H8O3

Molar mass: 92.09 g/mol

Appearance: colorless liquid

Taste: sweet

Odor: odorless

Density: 1.261 g/mL

M.P: 17.8 oC

B.P.: 290 oC

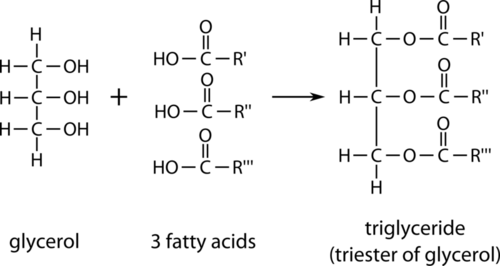
Soluble in water

Forms orthorhombic crystals when cooled below 0 oC

Industrially it can be produced from plants like soybean. More than 950,000 tons of glycerol are produced in the U.S. each year. In food and beverages it is used as a humectant (a moistener) and a sweetener, where it has an energy density similar to sugar. It serves to improve smoothness in personal-care products like cough syrups, toothpastes, hair-care products and soaps. At one time it was a component of anti-freeze, where it interferes with water-water hydrogen bonds to lower the freezing point of the mixture.

**More on Fats**

All fats are a combination of a glycerol backbone and three fatty acid chains in what is chemically an ester. As illustrated in the diagram below, the fatty acid molecules are added to the glycerol backbone by means of ester bonding. The reaction is a condensation reaction in which the glycerol gives up a hydrogen atom from the alcohol functional group and the fatty acid gives up its hydroxyl group to form water and results in a –C-O-C– ester bond that links the fatty acid to the glycerol. Since there are three of these bonds in every lipid or fat molecule, they are commonly known as triglycerides.



([*http://www.ck12.org/book/CK-12-Chemistry-Intermediate/section/26.3/*](http://www.ck12.org/book/CK-12-Chemistry-Intermediate/section/26.3/))

Even though the glycerol is polar and water soluble, the longer fatty acid chains are non-polar and insoluble, and the properties of lipids tend to be dominated by fatty acid properties. So what we need to focus on are the lipid properties that result from those fatty acid properties.

Your students will likely remember from biology class that fat molecules store more than twice as much energy as carbohydrates or proteins—37.8 kJ/g (9 kcal/g) for fats vs. 16.7 kJ/g (4 kcal/g) for carbohydrates and proteins. There is only passing mention of the role of fats in the energy balance in the body, but because the body stores energy primarily as fat, it is worth noting, as the article does, that restricting fats in the diet is often seen as a healthy step. Taking into account the fact that most of the energy supplied to the body is the result of the oxidation of fats and carbohydrates, restricting fat intake might not be a good idea. In fact, people who adhere to a low-fat or fat-free diet often increase their carbohydrate intake in order to maintain their energy, as the article mentions.

A *ChemMatters* article reviews many of the issues that fats have traditionally presented for American diets:

The term “fat” does not refer to one particular molecule, but rather to a large number of possible molecules with similar structures. All fat molecules—whether in solid or liquid fat—are formed by attaching three molecules of fatty acids to one molecule of glycerol.

Fats get their special chemical properties and health effects from the kinds of fatty acids they contain. Fatty acids are carbon chains that may have from 3 to 18 carbon atoms. The chain may also contain one or more carbon–carbon double bonds. Fatty acids are called polyunsaturated if there are two or more double bonds; monounsaturated, if there is one, and saturated, if there are none. Saturated means that the carbon atoms in the hydrocarbon chain are bonded to the maximum possible number of hydrogen atoms—not the case when there are double bonds present.

Polyunsaturated fats like corn and safflower oil and monounsaturated fats like olive and canola oil tend to be liquids at room temperature. Saturated fats like butter and lard are solids.

The article continues:

One important step toward lowering the risk of heart disease is to reduce the amount of *trans* fatty acids we consume. When a carbon–carbon double bond exists in a hydrocarbon chain, there are two different ways of arranging the hydrogen atoms attached to the two carbons. They can be placed on the same side of the double bond, an arrangement called the cis configuration, or they can be placed on opposite sides of the carbon–carbon double bond—the *trans* configuration.

Natural unsaturated fats have double bonds in the cis configuration. During food manufacturing, however, that cis configuration can be altered. In preparing many products—margarine, for example—manufacturers expose polyunsaturated oils to hydrogen. This process, called hydrogenation, is used to convert the liquid oil to a solid spreadable product. Hydrogenation eliminates some of the double bonds by saturating them with hydrogen. The remaining double bonds are converted to the *trans* configuration.

Several studies now suggest that *trans* fatty acids tend to raise blood cholesterol levels more than cis fatty acids, although not as much as saturated fats. Based on these studies, authorities like the American Heart Association have recommended that people try to use oils that haven’t been hydrogenated.

(Banks, P. Fats—Fitting Them into a Healthy Diet. *ChemMatters* **2000**, *18* (3), pp 6–8)

The summary above and the Pickett fats article both include multiple considerations related to fats in our diet—saturated vs. unsaturated, how fats contribute to our diet, the fat-cholesterol connection and *trans* fats. In addition, the current article also focuses on phospholipids so we will include a little background chemistry for these substances.

First, a very brief review of the language and names of compound classes would probably be helpful. As noted above, the term “lipid” is a very general term to designate organic compounds that include fats, oils, waxes and steroids, and assorted other compounds. What they have in common is that they are all hydrophobic, as noted above. This is not a very satisfying or specific definition. Among chemists a better definition would be“Lipids are fatty acids and their derivatives, and substances related biosynthetically or functionally to these compounds.” Triglycerides, then, are esters made up of a glycerol—an organic alcohol—backbone and three fatty acids.

In most common uses, the term “triglyceride” and the term “fat” are synonymous. Fats can be either unsaturated or saturated, as noted above, and saturated fats may be monounsaturated (one double bond in the molecule) or polyunsaturated (more than one double bond). Saturated fats have different health implications from unsaturated fats. And if the fat is unsaturated the molecule may exist in more than one isomeric form, called either *cis* or *trans.* In the *cis* isomer the atoms attached to the doubled bonded carbons are arranged on the same side of the double bond and in the *trans* isomer those atoms are on opposite sides of the double bond. This shift also changes the properties of the molecules. Your students will have seen a reference to this issue because of the negative publicity about “*trans*-fats.”

**Saturated Fats** – Recall from earlier in this section of the Teacher’s Guide that fats (triglycerides) are made up of three fatty acid molecules and a glycerol molecule that acts as a backbone for the larger molecule. Because the fatty acid components of fat molecules tend to be longer –C-C– chains, the properties of these fatty acids determine the overall properties of the molecule. As we think about fats and diet and health, we need to remember that fatty acids (and, therefore, fats) may be either saturated or unsaturated. Also recall that these molecules are generally linear in shape and so “stack” together so that there are relatively strong London dispersion forces between them. The existence of these attractive forces means that the melting points of saturated fats are high relative to other fats, and this, in turn, means that saturated fats tend to be solids at room temperature. So we find saturated fats in foods like the ones listed on the American Heart Association web site:

Saturated fats occur naturally in many foods. The majority come mainly from animal sources, including meat and dairy products. Examples are:

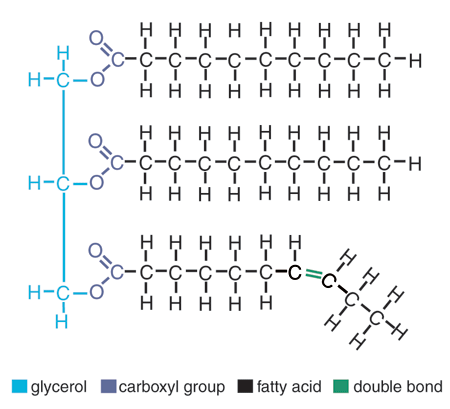
* http://upload.wikimedia.org/wikipedia/commons/f/fd/Western-pack-butter.jpgfatty beef,
* lamb,
* pork,
* poultry with skin,
* beef fat (tallow),
* lard and cream,
* butter,

([*http://en.wikipedia.org/wiki/Butter*](http://en.wikipedia.org/wiki/Butter))

* cheese and
* other dairy products made from whole or reduced-fat (2 percent) milk.

(<https://www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyEating/Saturated-Fats_UCM_301110_Article.jsp>)

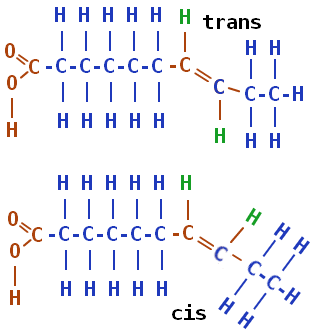
**Unsaturated fats** – Fats that contain one or more double covalent bonds are labeled “unsaturated” because additional hydrogen atoms could be added to some of the carbon atoms. There may be one double bond (monounsaturated) or multiple double bonds (polyunsaturated) in the molecule. The existence of double bonds has an effect on the molecular geometry. Molecules   
of unsaturated fats have slight bends or “kinks” in them, making it difficult for neighboring molecules to pack tightly together as saturated molecules can.



([*http://creationwiki.org/pool/images/7/74/Triglyceride.gif*](http://creationwiki.org/pool/images/7/74/Triglyceride.gif))

The molecule diagrammed at right shows the bending of the fat molecule at the double bond. As a result the London dispersion forces between unsaturated molecules are weaker, resulting in lower melting points. So, unsaturated fats tend to be liquids at room temperature. Sources of unsaturated fats include canola oil, peanut oil, olive oil, avocados, almonds, hazelnuts, pecans, pumpkin seeds, sesame seeds, sunflower oil, corn oil, soybean oil, flax seeds, walnuts, and fish.

**Trans fat** – This type of fat is man-made (although some animals produce small amounts) and the least healthy type. It can lead to serious health problems The major issue is that *trans* fat tends to raise "bad" LDL- cholesterol and lower "good" HDL- cholesterol, although not as much as saturated fat.

 To the right is a diagram of *cis* and *trans* isomers for a fatty acid. The position of the hydrogen atoms (in green) that are attached to the double-bonded carbon atoms determine the isomer. In the lower structure both hydrogen atoms are on the same “side” of the double bond, making it the *cis* isomer. The upper diagram shows those hydrogen atoms on opposite sides of the double bond in the *trans* configuration. Biologically the two isomers have different properties.

([*http://chemistry.tutorvista.com/organic-chemistry/alkene-nomenclature.html*](http://chemistry.tutorvista.com/organic-chemistry/alkene-nomenclature.html))

A December 2007 *ChemMatters* article describes the problems with *trans* fat and the form of isomerism involved in the conversion of unsaturated fats to partially hydrogenated fats that produces *trans* fat.

In naturally occurring unsaturated fats, the double bonds are *cis* double bonds. *Cis* comes from Latin and means “on this side.” This means that both hydrogen atoms are on the same side of the double bond, and both ends of the long carbon chains are on the same side. The opposite of a *cis* double bond is one that is *trans*—also Latin, meaning “across.” In a *trans* double bond the hydrogen atoms are on opposite sides of the double bond, and the chains are on opposite sides.

One very interesting feature about the *cis* double bonds found in unsaturated fats is that the chains with *cis* bonds are not three dimensional long tubes like saturated fatty acids. The *cis* bonds create “kinks” in the chains, so the chains don’t stack up in a nice well-behaved, orderly fashion like saturated fats. With less attractive molecular surface in contact with neighboring molecules, these plant fats or oils are not solids, but rather are liquids at room temperature.

Think corn oil, peanut oil, or olive oil. The other feature of naturally occurring unsaturated fats is important from a food production and shelf-life standpoint. Fats with *cis* double bonds are more likely to react with the oxygen in the air (oxidation) than those with either *trans* double bonds or all single bonds (saturated fats).

This is linked to the fact that *cis* fats are less stable and more reactive than *trans* fats or saturated fats. Oxidation of fats breaks the long chains into shorter chains to yield stinky and unpleasant tasting products—in other words, *rancid*. No one wants to eat a rancid potato chip! Manufacturers are well aware of the problem.

On the one hand, companies understand the importance of positive health claims. On the other hand, if they use healthier natural unsaturated fats, they run the risk of having the product turn rancid before it finds its way into the vending machine or convenience store.

So what is a manufacturer to do? To the rescue: *partial* hydrogenation! . . . . During hydrogenation, a *cis* fat is heated at high pressure in the presence of hydrogen gas, H2 (g), and a metal catalyst, such as nickel. In the process, hydrogen is added across the double bond, one H atom to each carbon atom, and the carbon-carbon double bond becomes a single bond. If all the double bonds are hydrogenated, the unsaturated fat becomes saturated. However, if only some of the double bonds are hydrogenated, the fat is described as “partially hydrogenated”.

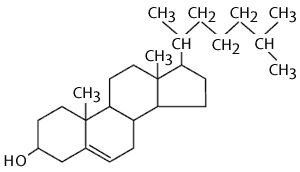
But another important thing happens to the double bonds in the partial hydrogenation process: The double bonds that are NOT hydrogenated are converted from *cis* to *trans*. Overall, the fat is still unsaturated, but now the double bonds are *trans* rather than *cis*.

(Kimbrough, D. The Solid Facts about Trans Fats. *ChemMatters* **2007**, *25* (4), pp 15–16)

Historically, hydrogenation chemistry was developed in the late 1890s by French chemist and Nobel laureate Paul Sabatier. The German chemist Wilhelm Normann showed in 1901 that liquid oils could be hydrogenated, and he patented the process in 1902. In 1909, Procter & Gamble acquired the U.S. rights to the Normann patent, and in 1911 they began marketing the first hydrogenated shortening, Crisco (composed largely of partially hydrogenated cottonseed oil). Production of hydrogenated fats increased steadily until the 1960s, as processed vegetable fats replaced animal fats in the U.S. There were suggestions in the scientific literature as early as 1988 that *trans* fats could be a cause of the large increase in coronary artery disease. In 1994, it was estimated that *trans* fats caused 30,000 deaths annually in the U.S. from heart disease.

On January 1, 2006, the U.S. Food and Drug Administration required labels to include the amount of *trans* fat in foods. Even though there have been attempts to limit the use of *trans* fats in food products, it can still be found in many processed foods including fried foods like doughnuts, baked goods, pie crusts, biscuits, frozen pizza, cookies, crackers, and stick margarines. Even though the nutrition label may not say “*trans* fat” look for terms like “partially hydrogenated oils” on the label.

**Cholesterol** – Cholesterol is considered a lipid. It is found in all animal cells as part of the cell membrane. The brain actually contains more cholesterol than any other organ. Structurally it has four hydrocarbon rings, three of which are 6-carbon rings and one of which is a 5-carbon ring. As you can see from the diagram at left, there is also a hydrocarbon chain attached to the 5-carbon ring and a hydroxyl group attached to one of the 6-carbon rings. Most of the molecule is nonpolar and, therefore, cholesterol is considered only very slightly soluble in water. The hydroxyl radical, although only a small part of the cholesterol molecule, is polar and allows cholesterol to react with phospholipids and become water soluble, as described below.



([*http://sphweb.bumc.bu.edu/otlt/MPH-Modules/PH/PH709\_BasicCellBiology/PH709\_BasicCellBiology24.html*](http://sphweb.bumc.bu.edu/otlt/MPH-Modules/PH/PH709_BasicCellBiology/PH709_BasicCellBiology24.html))

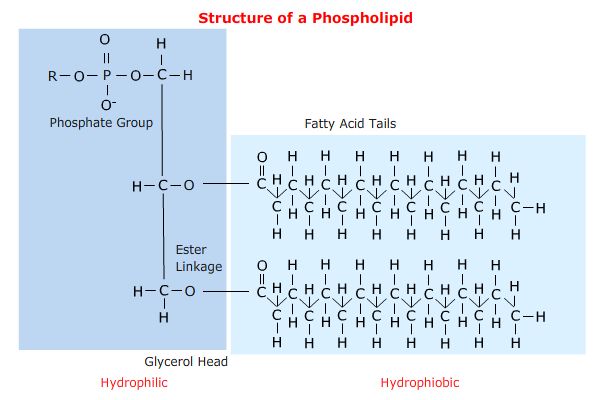
Cholesterol can also react with fatty acids in esterification reactions.

**More on phospholipids, lipoproteins and cholesterol**

The Pickett article describes the relationship of fats and cholesterol, one of the key fat-related relationships in the national discussion of heart health. Physicians warn us that too much cholesterol in our blood is a warning sign for heart attack or stroke. But we know that in order for substances like cholesterol or fats to be in our blood, they must be water soluble. We already know that fats are insoluble in water, and the article tells us that cholesterol is only slightly soluble. How are these substances transported via the blood throughout the body?

There are two parts to this answer. Fat molecules are very large. In order to pass through the intestinal wall the molecules must be broken up*.* Fats are mixed with a biological detergent called bile, which is produced in the liver and stored in the gall bladder. The mixing (emulsifying) of the detergent with the fats allows for the non-polar end of the detergent to interact with the non-polar end of the fat (the fatty acid end) while the polar end of the detergent bonds with the polar end of the fat (the glyceride end) just as regular soaps and detergents would do when you wash greasy dishes with soap or detergent. Once the fat is emulsified in the digestive “juices”, it can be broken apart by hydrolysis to yield water soluble fatty acids, glycerols and mono- and di-glycerides which are then small enough and soluble enough to pass through the intestinal wall into the blood stream.

In intestinal cells, the parts are reassembled and the resulting fats are combined with phospholipids, simply modified triglycerides in which one of the fatty acid chains is replaced with a phosphate radical as shown in the diagram at right. The phosphate is polar, and as a result the phosphate “end” of the phospholipid molecule is polar and hydrophilic and the fatty acid “end” is nonpolar and hydrophobic. When they interact with fats and cholesterol they orient themselves so that the polar heads are facing the water molecules and the hydrophobic fatty acids are oriented toward the cholesterol. The phospholipid acts as a bio-emulsifier connecting blood (water) and cholesterol so that the cholesterol can be transported through the blood. This unit combines with specialized carrier molecules called apoproteins and the resulting globular structure is called a lipoprotein (see diagram at right, below). The hydrophilic phospholipid layer forms the outer shell and interacts with water via hydrogen bonding while the hydrophobic fat and cholesterol are in the interior of the globule and are attracted to the phospholipid via dispersion forces.



([*http://telstar.ote.cmu.edu/biology/MembranePage/index2.html*](http://telstar.ote.cmu.edu/biology/MembranePage/index2.html))

Some of these carrier units are more dense and some are less dense, due to differences in the percent of fat in the unit. We know the lower density units as LDL or low density lipoprotein, and we know the high density units as HDL or high density lipoprotein. Your students may recognize LDL as the so-called "bad cholesterol," which carries cholesterol away from the liver, to various organs. In contrast, HDL's tendency to remove excess cholesterol from arteries to return it to the liver has earned it the name "good cholesterol".



([*http://users.atw.hu/blp6/BLP6/HTML/C0389780323045827.htm*](http://users.atw.hu/blp6/BLP6/HTML/C0389780323045827.htm))

In addition to the well-known HDL and LDL lipoproteins, there are three other classes of smaller globular lipoprotein formations called intermediate density lipoproteins, very low density lipoproteins and chylomicrons. The table below shows the per cent makeup of each of the lipoprotein structures. Note that the LDL has twice the percent of fat (“triacylglycerol” on the table) as HDL. The lower density is the result of fat’s lower density.

For a young healthy research subject with weight about 154 pounds, the following applies:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Density**  (g/m[L](http://en.wikipedia.org/wiki/Litre)) | **Class** | Diameter (nm) | % protein | % cholesterol | % phospholipid | % triacylglycerol & cholesterol ester |
| >1.063 | [HDL](http://en.wikipedia.org/wiki/High-density_lipoprotein) | 5–15 | 33 | 30 | 29 | 4 |
| 1.019–1.063 | [LDL](http://en.wikipedia.org/wiki/Low-density_lipoprotein) | 18–28 | 25 | 50 | 21 | 8 |
| 1.006–1.019 | [IDL](http://en.wikipedia.org/wiki/Intermediate-density_lipoprotein) | 25–50 | 18 | 29 | 22 | 31 |
| 0.95–1.006 | [VLDL](http://en.wikipedia.org/wiki/VLDL) | 30–80 | 10 | 22 | 18 | 50 |
| <0.95 | [Chylomicrons](http://en.wikipedia.org/wiki/Chylomicrons) | 100–1000 | <2 | 8 | 7 | 84 |

([*http://en.wikipedia.org/wiki/Lipoprotein*](http://en.wikipedia.org/wiki/Lipoprotein))

**More on fats, diet and health**

There is a long history of recommendations about the kind of diet that is appropriate for American citizens. In 1894, the U.S. Department of Agriculture (USDA) published the first dietary standards for the country (see a digital copy of the document at <http://www.ars.usda.gov/SP2UserFiles/Place/80400530/pdf/hist/oes_1894_farm_bul_23.pdf> ). The first recommendations for daily food consumption appeared in 1917, and there were five food groups listed: milk and meat, cereals, vegetables and fruits, fats and fat foods (note that these were recommended), and sugars and sugary foods. Twelve major food groups were part of a 1933 version of recommended weekly food needs: milk; potatoes and sweet potatoes; dry beans, peas, and nuts; tomatoes and citrus fruits; leafy green and yellow vegetables; other vegetables and fruits; eggs; lean meat, poultry, and fish; flours and cereals; butter; other fats; and sugars.

The National Academy of the Sciences issued the first Recommended Daily Allowances (RDA) tables in 1941, and in 1942 the USDA released its “Basic Seven” daily food requirements, including green and yellow vegetables; oranges, tomatoes, and grapefruit; potatoes and other vegetables and fruit; milk and milk products; meat, poultry, fish, eggs, and dried peas and beans; bread, flour, and cereals; and butter and fortified margarine. These seven food groups were consolidated into four groups in 1956—milk and milk products; meat, fish, poultry, eggs, dry beans, and nuts; fruits and vegetables; and grain products.

Until the 1940s, heart disease and cancer were relatively minor diseases in the United States. In that time the major cause of death was infectious disease, and a high-calorie diet was considered helpful in recovering from illness. By the 1950s, however, heart disease had become a major health risk, accentuated perhaps by the heart attack suffered by President Eisenhower in 1955. According to a 1998 *Journal of Nutrition* article:

Real interest in dietary fat and its effects—particularly with regard to its role in cardiovascular disease—was stimulated by several papers published in the early 1950s. Gofman and his colleagues at the University of California, Berkeley published a paper in Science ([Gofman et al. 1950](http://jn.nutrition.org/content/128/2/449S.long#ref-6)) that detailed findings related to their new technique of separating plasma lipoproteins by ultracentrifugation. They showed that levels of certain of these lipoprotein classes were related to atherosclerotic heart disease and implicated dietary fat as a factor in this relationship. At about the same time Ancel Keys embarked on his worldwide epidemiologic investigations of dietary fat and heart disease prevalence, which showed that the level of dietary fat was related to mortality from heart disease ([Keys 1953](http://jn.nutrition.org/content/128/2/449S.long#ref-13)). In his “Seven Countries” study, [Keys (1970)](http://jn.nutrition.org/content/128/2/449S.long#ref-14) found a significant association between fat and saturated fat intake and heart disease mortality. [Yerushalmey and Hilleboe (1957)](http://jn.nutrition.org/content/128/2/449S.long#ref-34) pointed out that if 21 other countries were included, the association observed by Keys was weak and that a similar association could be advanced between animal protein intake and heart disease.

The role of dietary cholesterol in the etiology of heart disease had been a subject of much earlier research and speculation. The early history is detailed in a book published in 1958 ([Kritchevsky 1958](http://jn.nutrition.org/content/128/2/449S.long#ref-17)). The observation that cholesterol was a constituent of the atherosclerotic plaque was noted in a pathology text published 150 years ago ([Vogel 1847](http://jn.nutrition.org/content/128/2/449S.long#ref-33)). Any number of investigators showed that atherosclerotic aortas contained significantly more cholesterol than normal ones. Others showed that cholesterol feeding alone was sufficient to establish cholesterol-rich lesions in the arteries of rabbits and chickens. Atherosclerotic lesions could be established in rats, dogs and monkeys by cholesterol feeding plus other dietary and hormonal manipulations. Although these findings led to innumerable experimental studies of cholesterol/fat feeding and atherosclerosis, [Stehbens (1989)](http://jn.nutrition.org/content/128/2/449S.long#ref-29) has argued persistently that the human and experimental lesions in animals are different enough to cast doubt on the validity of the experimental lesion as an example of human disease. Although the role of cholesterolemia and hyperlipidemia in the etiology of human atherosclerosis was not accepted unanimously in the 1950s, it was considered sufficient by some authorities to establish a case against high intakes of dietary fat and cholesterol. This was enough to open the door to dietary guidelines offered to the public for possible prevention or amelioration of heart disease.

(<http://jn.nutrition.org/content/128/2/449S.long>) (accessed online February 27, 2015)

The *ChemMatters* Pickett fats article references “the original study” that was done by Dr. Ancel Keys, pictured below, and published in 1970. It is commonly called the Seven Countries Study and it is the basis for the U.S. Dietary Guidelines advice to avoid fatty foods. Keys interest in the relationship between diet and cardiovascular disease began just after World War II. He observed that as food supplies became short in northern Europe after the war, deaths due to coronary artery disease also dropped. Keys conducted a series of small studies during which he theorized that it was high levels of cholesterol in the blood that predicted coronary artery disease and that high levels of dietary fat consumption was the main reason for elevated cholesterol levels.

To test this theory, Keys and colleagues initiated in 1957 a study of 12,000 men in Italy, the Greek Islands, Yugo­slavia, the Netherlands, Finland, Japan, and the United States—the seven countries. Subjects reported their food intake and Keys analyzed chemically the composition of the food reported by the subjects. He found that diets that included higher levels of saturated fats corresponded to both high blood cholesterol levels and death rates from heart attacks. On the other hand, diets that included fresh fruit and vegetables and large quantities of olive oil (what has become known as the Mediterranean diet) led to lower serum cholesterol levels and lower coronary death rates. The saturated fat–high serum cholesterol–coronary heart disease connection became known as the “lipid hypothesis”, and when Keys published the study in 1970, he also managed to convince federal officials to include statements in the U.S. dietary guidelines warning people to limit their consumption of fats, especially saturated fats. This was the beginning of the anti-fat campaign in the United States.

([*http://www.uh.edu/engines/AncelKeys.jpg*](http://www.uh.edu/engines/AncelKeys.jpg))

By the early 2000s researchers had discredited much of Keys’ study, citing, among other things:

* The fact that Keys did not choose countries/subjects randomly—he excluded countries where people consume a lot of fat and are not subject to high rates of coronary disease like France, Sweden, Switzerland and West Germany
* Results from Crete were featured in the report as exemplary. However, Keys took data from Crete during a severe post-World War II food shortage and during Lent when many had given up meat and cheese
* Keys excluded results from many participants without revealing this

By the time these shortcomings were revealed, however, Keys’ ideas were well entrenched in U.S. dietary guidelines and accepted as fact.

Even in the 2005 report *Nutrition and Your Health: Dietary Guidelines for Americans* from theU.S. Department of Agriculture (USDA), fats were still to be avoided. The 2005 version of the guidelines recommended:

* Total fat intake of 20 to 35 percent of calories is recommended for adults and 25 to 35 percent for children age 4 to 18 years. At high intakes of fat (> 35 percent of energy), the risk increases for obesity and coronary heart disease (CHD). This is because fat intakes that exceed 35 percent of energy are associated with both increased calorie and saturated fat intakes.
* The relationship between saturated fat intake and LDL cholesterol is direct and progressive, increasing the risk of cardiovascular disease (CVD). Thus, saturated fat consumption by adults should be as low as possible while consuming a diet that provides 20 to 35 percent calories from fat.
* The relationship between trans fatty acid intake and LDL cholesterol is direct and progressive, increasing the risk of CHD. Trans fatty acid consumption by all population groups should be kept as low as possible, which is about 1 percent of energy intake or less.
* The relationship between cholesterol intake and LDL cholesterol concentrations is direct and progressive, increasing the risk of CHD. Thus, cholesterol intake should be kept as low as possible, within a nutritionally adequate diet.

In 2013 and 2014, new study results were reported indicating no difference in cardiovascular disease between people who ate saturated fats and those eating unsaturated fats. Nutritional science is beginning to question “the lipid hypothesis.” The headlines in popular newspaper and magazines that announced these results claimed that there was no link at all between saturates fat and heart disease, but these kinds of claims are not fully documented and are being debated in science circles. There seems to be little agreement on the current status of fats in our diet.

As the Pickett article suggests, many people have replaced fats with carbohydrates in their diet. The article notes that, “Despite the overall reduction of fat in our diets, obesity and type 2 diabetes have risen. From 1980 to 2000, the incidence of type 2 diabetes in the United States increased by 166%; between 1980 and 2000, obesity rates doubled among adults; and cardiovascular disease remains the leading cause of death in the United States. Fat consumption has been reduced since the 1970s, so what is causing these health problems now?” Some scientists believe that many people have replaced fats with carbohydrates which break down into glucose. As a result, the body produces insulin, a good storer of fat. Additionally, some carbohydrates like fructose cause the liver to produce triglycerides in the blood, and that may lead to heart disease.

So it seems we are in a period of changing attitudes about the role of fats in our diet. More and more is now known about the chemical changes that fats undergo in the body and the chemicals that result. The 2015 Dietary Guidelines will be released later in the year and will likely recommend that no more than 10% of our calories come from saturated fats. It will recommend diets that are rich in vegetables, fruit, whole grains, seafood, legumes, and nuts; moderate in low- and non-fat dairy products, lower in red and processed meat; and low in sugar-sweetened foods and beverages and refined grains.

You can urge students to monitor the debate about dietary nutrients in both the popular press and in the more scientific literature. Use the “Additional Web Sites” below as a starting points for student research.

**More on milk fat**

The article begins its examination of fats with two paragraphs about the fat in milk. It is an apt example of the trend to avoid food items containing fat. Americans drink 37% less milk today than they did in 1970. Per capita consumption of whole milk has decreased by 78% since 1970.

What is the fat content of milk? Milk contains approximately 3.4% total fat. Of this, 65% is saturated, 30% is monounsaturated and 5% is polyunsaturated. The fat in milk is a complex mixture of about twenty individual fats. Some of the fats are present in very small amounts but contribute to the taste of milk or milk product. Below is a more detailed breakdown (by mass) of the fat content of whole milk. Note that the substances listed are actually fatty acids. Many references simply list fatty acids and ignore the glycerol component.

**Saturated fats** –

palmitic acid: 31%

myristic acid: 12%

stearic acid: 11%

lighter saturated fats: 11%

pentadecanoic acid and heptadecanoic acid: traces.

**Unsaturated fats** –

oleic acid: 24%

palmitoleic acid: 4%

linoleic acid: 3%

alpha-linolenic acid: 1%.

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Organic compounds**—All of the fats and related molecules described in this article are organic compounds.
2. **Functional groups**—Many of the compounds in the article can be distinguished or identified, at least by class, according to the functional groups present in each molecule. You can use as examples the carboxyl group –COOH or the alcohol group –OH. These are important in the structure of fatty acids and glycerol respectively. You can point to other functional groups as well.
3. **Double bonds**—Double bonds share two pairs of electrons between them. These bonds are considered unsaturated, and additional atoms such as hydrogen can be added (bonded) producing a different molecule. The difference in such properties between saturated and unsaturated molecules is especially important for health reasons in the case of fats.
4. **Saturated vs. unsaturated**—Molecules that are saturated contain all single bonds between carbon atoms and all unsaturated molecules contain at least one carbon-carbon bond that is double or triple. These molecules can accept additional elements such as hydrogen. This process of accepting additional hydrogen atoms changes the physical characteristics of fats.
5. **Isomers: cis and trans**—This form of isomerism occurs in unsaturated fats. These isomers occur in molecules of the same molecular formula but with different geometric arrangements of groups attached next to each other; if across from each other, then it is a *trans* arrangement; if adjacent, then it is a *cis* form.
6. **Hydrogenation**—This is the process of adding hydrogen atoms (with a metal catalyst and high pressure) to a molecule with double or triple bonds, which reduces or eliminates these bonds, creating single bonds. In the case of many unsaturated fats that are hydrogenated, *trans* fats result.
7. **Triglycerides—**These are esters formed between fatty acids and glycerol. Triglycerides are the molecules of fats and oils.
8. **Molecular polarity**— Fats, as very large carbon-based molecules, tend to be non-polar and will not mix in something like water that is polar. The long fatty acids chains in the fat molecule are nonpolar, making the entire molecule nonpolar. The role of phospholipids, which have a polar site—the phosphate—and a nonpolar site—the two fatty acid chains, is to act as a bioemulsifier. The long fatty acid chains are attracted to other fat molecules, while the phosphate is attracted to water molecules, enabling the fats to be transported via the blood.
9. **Biochemistry**—Chemical reactions play a critical role in living organisms. A continuing area of research lies in understanding the chemical reactions and their effects on the organism.
10. **Chemistry and public health**—The U.S. dietary guidelines are based on the scientific evidence that biochemists can provide to non-scientists who establish public health policy. The Pickett article suggests that some areas of evidence seem contradictory, and resolving these presents future career options for your students.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“All dietary fats are bad.”** *There are both “good” and “bad” fats. Our bodies need fat for a variety of purposes, including synthesizing cell membrane structures, hormones, nerve tissue, and body insulation against temperature changes, among other things. Saturated fats and trans fats have bad effects on cholesterol levels (cholesterol is needed by our bodies but too much is not good), while polyunsaturated fats and monounsaturated fats have good effects on cholesterol levels.*
2. **NOTE: This article causes us to rethink the idea of a “misconception.” The article points out that our pre-occupation with avoiding dietary fat and cholesterol is now being questioned. As a result, students, and, in fact, adults may be harboring misconceptions about fats and cholesterol not out of ignorance but because information presented to them as “fact” may not be factual according to current scientific research. Current students may, in fact, have fewer misconceptions about lipids and cholesterol.**

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“If fats are insoluble in water, how can they be absorbed into the blood stream, which is primarily water?”** *See “*More on phospholipids, lipoproteins and cholesterol” for a complete answer.
2. **“So how can fat be dissolved in milk, which is also mostly water?”** *Fats are made soluble in cows’ milk similar to the process in humans. Fat molecules are combined with lipoproteins and phospholipids to form fat globules of varying size.*
3. **“Are *trans* fats saturated or unsaturated?”** *Most* trans *fats are synthetic. They are produced by hydrogenating unsaturated fats, which exist as cis isomers. In the hydrogenation process two things happen: the fats become saturated and the* cis *isomer is transformed into a* trans *isomer.*

## In-Class Activities

**(lesson ideas, including labs & demonstrations)**

1. This activity is designed to determine the mass of fat in a fast food item like French fries. Observe all safety precautions. (<http://www.chymist.com/Fat%20in%20potato%20chips.pdf>)
2. The Institute of Food Technologists offers the 63-page booklet “Food Chemistry Experiments” at <http://www.accessexcellence.org/pizza/pdf/fcbook.pdf>. It contains a chapter on lipids with a student experiment on extracting lipids from chocolate and potato chips, extensive chemistry background information on lipids, and related puzzles.
3. Students can isolate fats from milk using a procedure found on pages 15–21 of this *ChemSource* document <http://dwb.unl.edu/ChemSource/SourceBook/115FOOD.pdf>.
4. One response to the advice to reduce fat consumption has been the development of margarine and other spreads. This activity enables students to determine the per cent of water in three types of margarine. The video clips in the activity show some of the procedure. Note that you need QuickTime to run these clips. (<http://chemmovies.unl.edu/chemistry/beckerdemos/BD046.html>)

Also see pages 22–23 of the *ChemSource* document from #3, above, <http://dwb.unl.edu/ChemSource/SourceBook/115FOOD.pdf>, for a teacher demonstration version of the activity.

1. Using the general outline given here, <http://umanitoba.ca/Biology/BIOL1020/lab2/biolab2_3.html>, you can demonstrate the solubility of fats in several solvents and by using an emulsifier.
2. You can demonstrate or have students do the experiment by which soap is made. This reaction, saponification, begins with a fat and results in glycerol and the sodium salt of the fatty acid. (<http://www.seattlecentral.edu/faculty/ptran/bastyr/Summer%2006/organic/Organic%20Exp/Experiment4Preparation%20and%20properties%20of%20a%20soap1.pdf>)
3. Use molecular models to illustrate *cis-trans* arrangements; translate molecular formulas into 3-D models.

# Out-of-class Activities and Projects

**(student research, class projects)**

1. You can assign students or teams of students to collect food labels and determine the amount of fats (by category—saturated, unsaturated, *trans*) and cholesterol, and also categorize the labels by food type. Collect class data and look for trends.
2. Students might interview family members and friends to determine whether they restrict fats in their diet in any significant way. Students should be asked to make up the interview questions based on the article and other research.
3. Another variety of survey would be to ask family and friends how much they understand about lipids and cholesterol and their health.
4. Still another type of interview would be to ask community members like physicians, nurses, dieticians and related professionals about the role of lipids in human health.
5. Students can make ball and stick models at home of important lipid molecules and bring them to class to display.
6. There are a lot of articles in the press currently about the new research findings related to cholesterol and lipids and their influence on cardiovascular health. Assign students to collect article and bring them to class for discussion.
7. Students could be asked to track their own food consumption for a specific length of time via their use of a FitBit or similar health-tracking device, or even track it manually using a free Web site like [www.myfitnesspal.com](http://www.myfitnesspal.com). Then they can analyze it for types of food consumed (e.g., calories, carbohydrates, fats, proteins, sodium, and sugars).

# References

**(non-Web-based information sources)**



**30 Years of *ChemMatters***

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**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013 and all available Teacher’s Guides, beginning February 1990). The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [http://ww.acs.org/chemmatters](http://www.acs.org/chemmatters)**. Scroll about half way down the page and click on the *ChemMatters* DVD image at the right of the screen to order or to get more information.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online on the same Web site, above. Simply access the link and click on the “Past Issues” button directly below the “M” in the *ChemMatters* logo at the top of the Web page.**

Baugh, M. Oil Changes. *ChemMatters* **1989,** *7* (4), pp 7–9. The author uses the dietary guidelines in 1989 to examine types of fat—saturated, unsaturated, etc.—and explain the different fat-related terms and explains what these terms mean on a food label.

Benson, K. Fast Food--Fast Fats. *ChemMatters* **1990**, *8* (1), pp 13–15. This article urges students to understand the fat content of favorite foods, like fast food, in order to avoid things like heart disease.

Ruth, C. A Calorie-Free Fat? *ChemMatters* **1999**, *17* (2), pp 9–11. Against the backdrop of the anti-fats dietary guidelines at the time, this article explains the development, structure and properties of olestra, an artificial fat.

Banks, P. Fats—Fitting Them into a Healthy Diet. *ChemMatters* **2000**, *18* (3), pp 6–8. In addition to a brief introduction on the chemistry of fats, the author examines fats in the context of health and the then-existing dietary guidelines.

Kimbrough, D. The Solid facts About Trans Fats. *ChemMatters* **2007**, *25* (4), pp 15–16. This article explains the structure of fats, including saturated and unsaturated fats and also explains the structure and properties of *cis* and *trans* fat isomers and partial hydrogenation.

Nolte, B. Tanking Up with Cooking Oil. *ChemMatters* **2011**, *29* (2) pp 5–7. After a brief explanation of fats and oils, this article features the use of cooking oils as fuels in automobile.

# Web Sites for Additional Information

**(Web-based information sources)**

**More sites on Lipids**

The Lipid Library from AOCS, a professional society devoted to the chemistry of fats and oils, <http://lipidlibrary.aocs.org/>, is just what it sounds like—an online reference to multiple lipid topics including this tutorial on fatty acids and fats: <http://www.lipidmaps.org/resources/tutorials/lipid_tutorial.html#L>.

One of the most helpful sites on lipids and related topics is provided by Elmhurst College in their *Virtual ChemBook*. The homepage for lipids is <http://www.elmhurst.edu/~chm/vchembook/550lipids.html>, and this page provides an introduction to the topic. Other *ChemBook* lipid topics are catalogued below.

* This page provides fatty acid structural formulas and charts showing the amount of saturated and unsaturated fatty acids, both from plant and animal sources in various common foods <http://elmhcx9.elmhurst.edu/~chm/vchembook/551fattyacids.html>.
* This site shows an organizational chart for different classes of lipids. <http://elmhcx9.elmhurst.edu/~chm/vchembook/552triglycerides.html>
* On this page are phospholipid structures, examples and other information <http://www.elmhurst.edu/~chm/vchembook/553phosglycerides.html>

This site supplies a simple summary of important topics related to fats: <http://www.chemistryexplained.com/Di-Fa/Fats-and-Fatty-Acids.html>.

A very nice and complete site on fats, oils, waxes, etc. is provided by the University of Cincinnati’s Claremont College as part of a biology course syllabus: <http://biology.clc.uc.edu/courses/bio104/lipids.htm>.

The tried-and-true “How Stuff Works” has this site on lipids: <http://science.howstuffworks.com/innovation/edible-innovations/fat.htm>.

The *Hyperphysics Textbook* has a page on phospholipids, strangely enough. (<http://hyperphysics.phy-astr.gsu.edu/hbase/organic/phoslip.html>, as part of a site on lipids: <http://hyperphysics.phy-astr.gsu.edu/hbase/organic/lipid.html#c1>)

From Carnegie Mellon University comes this page on lipids with a strong section on phospholipids. (<http://telstar.ote.cmu.edu/biology/MembranePage/index2.html>)

**More sites on *trans* fats**

A reliable source of health information for understanding *trans* fats is found in the Mayo Clinic electronic health newsletter at [www.mayoclinic.com/health/trans-fat/CL00032](http://www.mayoclinic.com/health/trans-fat/CL00032). The article of interest is titled *“Trans Fat: Avoid This Cholesterol Double Whammy”.*

This site from the Elmhurst *Virtual Chembook* illustrates the hydrogenation process with molecular structures in color: <http://www.elmhurst.edu/~chm/vchembook/558hydrogenation.html>.

The United States FDA (Food and Drug Administration) has a very useful website that includes background material on *trans* fats as part of its requirements for labeling the *trans* fat content of food.

(<http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm053479.htm>)

Here is another FDA page on *trans* fats: <http://www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm079609.htm>.

**More sites on dietary guidelines and health**

This United States Department of Agriculture (USDA) site gives a brief history of U.S. dietary guidelines: <http://www.health.gov/dietaryguidelines/dga2005/report/html/G5_History.htm>.

This USDA site provides a more detailed history of the guidelines with links to the guidelines since 1980. (<http://www.nal.usda.gov/fnic/pubs/DGA.pdf>)

The *Journal of Nutrition* gives a lot of background on the changing content and role of U.S. dietary guidelines. <http://jn.nutrition.org/content/128/2/449S.long>

This is an early version of the 2015 proposed dietary guidelines issues during the public comment period. (<http://www.health.gov/dietaryguidelines/2015-scientific-report/PDFs/02-executive-summary.pdf>)

From the Harvard University School of Public Health comes a report, “making the case to end the myth of the low-fat diet.” (<http://www.hsph.harvard.edu/nutritionsource/fats-full-story/>)

Another reference from the FDA that deals specifically with *trans* fats provides a series of questions that people might ask. In addition, there are charts listing a variety of common foods with the % *trans* fat present. Find it here: <http://www.fda.gov/FDAC/features/2003/503_fats.html>.

**More sites on Ancel Keys**

The British Columbia Medical Journal issued this article on Keys and his role in establishing the relationship between lipids and cardiovascular disease: <http://www.bcmj.org/article/ancel-keys-and-lipid-hypothesis-early-breakthroughs-current-management-dyslipidemia>.

This fascinating recounting of the Seven Countries Study was written by University of Minnesota professor Henry Blackburn, who was part of the Keys team that conducted the study: <http://sph.umn.edu/site/docs/epi/SPH%20Seven%20Countries%20Study.pdf>.