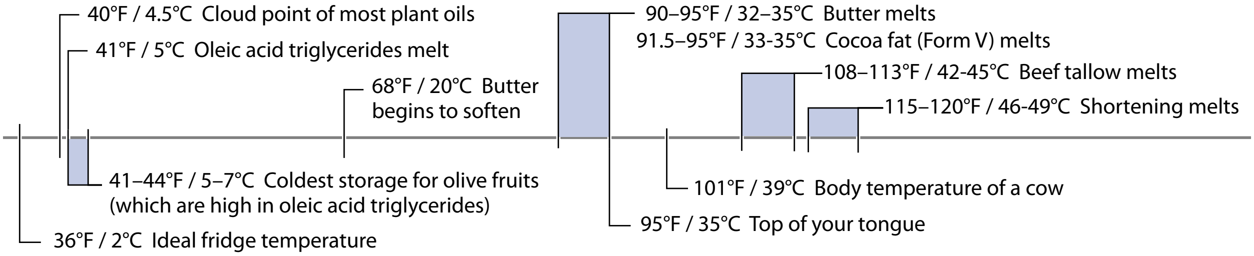
85°F / 30°C: Average Melting Point of Fats

All generalizations are false, including this one.

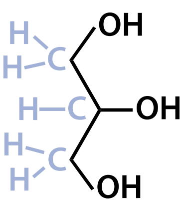
—Mark Twain

Here we are, at the first temperature range of the chapter. There's one housekeeping detail I need to take care of first: the temperatures ranges for chemical reactions in foods are very, *very* tricky to define due to rate of reaction. For practical purposes, the temperature ranges given in this chapter are those that are applicable in cooking. (Collagen, which we'll cover later, can technically denature below 104°F / 40°C, but you wouldn't want to eat the results.) For fats, I'm generalizing their melting point. It's a false generalization, but it's still useful to understand the average for common fatty acids: many fats melt above room temperature but below body temperature. (This is one reason why one chocolate maker can say, "Melts in your mouth, not in your hand.")



Fats and oils are essential to food. They add flavor, like salted butter on top of great bread or a good olive oil on salad. They bring texture, giving cookies and muffins the ability to crumble and ice cream a luscious mouthfeel. And they're used to cook foods, conducting and convecting heat in sautéing and frying. But what is fat? How does it work in cooking and in eating? And what the heck are saturated, omega-3, and trans fats? To answer these questions, we need to start with a few simple chemistry building blocks.

Fats and oils—which are simply fats that are liquid at room temperature, so I'll just say "fats" from now on—are a type of lipid called *triglycerides*. The word *triglyceride* describes the chemical structure of the lipid, and it's this chemical structure that determines a fat's properties. *Tri* is three, but three of what? It's not three glycerides, but rather one glyceride that has three certain things attached to it. A *glyceride* starts with a molecule of glycerol (the molecule gets a new name when it's attached to certain things), so the first part of understanding fat is to look at a glycerol molecule.



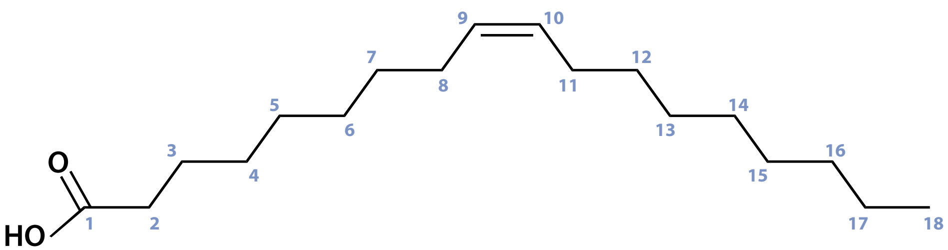
A molecule of glycerol with all the atoms drawn.

This is what chemists call a *line structure*. You needn't be a chemistry geek to understand this! The Os stand for oxygen and the Hs are hydrogen. The lines show where electrons are being shared between the atoms. Every time a line bends, or ends by itself (which doesn't happen in glycerol), that means there's a carbon atom, and usually some hydrogen atoms too.

Carbon-based life forms contain a lot of carbon and hydrogen—about a fifth of you is carbon and a tenth is hydrogen! Those two elements are so common that line structures don't show them when they're by themselves. (Chemists, like cooks, have their equivalent of assuming you'll know to add a pinch of salt.)

I've tinkered with the way this line structure is drawn; normally the shaded parts aren't there. They show the carbon and hydrogen that a chemist would infer from how the lines are drawn. Carbon always has four bonds, so that's why the middle C only has one hydrogen atom hanging off of it. Glycerol, the first building block in fats, has the molecular formula $C_3H_8O_3$—three carbon, eight hydrogen, and three oxygen atoms—so counting all the Os, Hs, and Cs in the diagram will add up to that. (The molecular formula doesn't tell you anything about the layout of the atoms, though!)

So that's the first building block in the chemistry of fats: a glycerol molecule, holding onto three certain somethings. In fats, those somethings are three different *fatty acids*—chains of carbon atoms with a particular acid on one end (carboxylic acid) that happens to attach to those OH points in glycerol. It's pretty simple to understand looking at a picture, so here's what one of the common ones, oleic acid, looks like.



Oleic acid is a carbon chain, 18 carbons long, and has one double bond between the 9th and 10th carbon atoms.

Fatty acids are simple molecules with only two variables: how long the carbon chain is and if any of those connections are doubled up. Oleic acid has 18 carbon atoms (count 'em!) with a *double bond* between the 9th and 10th carbon atoms; you can see where one of the lines is drawn twice. A double bond occurs when the bond between one carbon atom and the adjacent one uses four electrons instead of two. If we were to add a hydrogen atom there, that double bond would become a regular bond, which would change the fatty acid. (In this case, oleic acid would become stearic acid.)

These double bonds are the secret to understanding fat. Saturated and unsaturated fats, omega-3 and omega-6 fats, trans fats, even the melting points of fats: these are all determined by where and how many of those double bonds there are.

Now you know the two building blocks of fats! Three fatty acids, plus a glycerol molecule, snap together to make up fats. (They happen to throw off a water molecule when bonding together—that's why the diagrams are slightly different.)

Fat is three fatty acids attached to a glycerol molecule. This one is common in olive oil, making up about 20–25% of the fat in it, and is polyunsaturated.

There are a few dozen common fatty acids, usually ranging between 8 and 22 carbons long and with 0 to 3 double bonds. Any given fat molecule can be a combination of a few dozen different fatty acids, meaning there are hundreds of possible variations of fat molecules. This is what creates so many complexities in fats!

Now that we've got the chemistry primer out of the way (fortunately, there's no quiz), we can answer all the questions that have always bugged me about fats:

What's the difference between saturated and unsaturated fats?

Fatty acids that have no double bonds between carbon atoms are called *saturated* fatty acids. They're saturated with hydrogen atoms; there's no way to shove more in. Palmitic acid, pictured above, is saturated. If a fatty acid has just one double bond, it's called *monounsaturated*—it's possible to shove exactly one hydrogen molecule into the fatty acid, right where the double bond is. Oleic acid, as you've seen, is monounsaturated. Fatty acids with two or more double bonds in the chain are called *polyunsaturated*. The same definition applies for fats: the example fat pictured has two double bonds in it, making it polyunsaturated. When it comes to health, unsaturated fats are usually better than saturated, but not always. There are good saturated fats and bad unsaturated fats. Plants usually create unsaturated fats, but not always (coconut oil, I'm looking at you); animals usually create saturated fats, but not always.

What determines the melting point of a fat molecule?

Melting point is determined by the shape of the fat molecule, which you can't exactly see in the line structures, and how the molecules pack together. The shape is related to how many double bonds there are. Saturated fatty acids are extremely flexible—they can bend and pivot around each of the carbon links—and they normally stretch out into a straight line that easily stacks together to form solids. Oils have more double bonds, which can't pivot, so they're more "bent out of shape," which makes it harder for them to pack together. More double bonds = less saturated = lower melting point = more likely to be oil. How the molecules pack together also makes a huge difference. Triglycerides can solidify into three possible crystalline structures, each with its own melting point. (There are also some technical differences related to isomerization.) These different crystalline structures are the key to good chocolate, which we'll cover in a few pages.

What's an omega-3 fatty acid? Or omega-6?

This is awesome to understand, given all the talk about their health benefits. Omega-3 fatty acids have a double bond at the third from last carbon atom (on the side opposite from the part that attaches to the glyceride). That's it. Since there's at least one double bond, they can't be saturated fatty acids, by definition! Omega-6 is, as you'd imagine, a fatty acid that has a double bond at the sixth from last carbon atom. Oleic acid is an omega-9 fatty acid: try counting nine atoms in from the right on the diagrams. Your body needs omega-3 and omega-6 fatty acids but can't create them from other fatty acids, which is why they're called essential. (That doesn't mean more is better!)

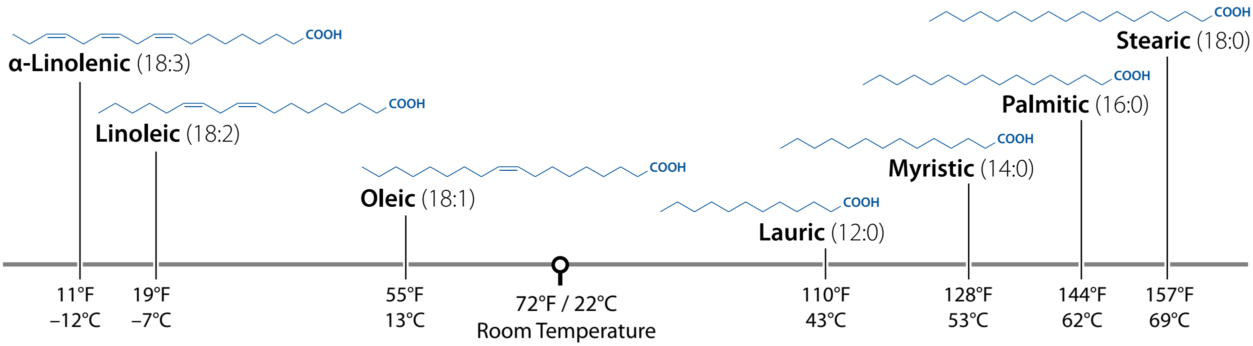
Then what's a trans fat?

Trans is Latin for "across" or "opposite," as opposed to *cis*, which is Latin for "same." A trans fat is one where the carbon connections are on opposite sides of a double bond. Cis fats have the carbon connections on the same side of the double bond, and they're super common—it's how nature makes fatty acids that have double bonds. (Gut bacteria in animals actually convert some cis fat to trans fat, but not a lot—so trans fat does naturally occur. Dosage matters!) If you start with polyunsaturated fats and hydrogenate them—yes, this is the hydrogenated fat that shows up on ingredient labels, patented way back in 1902 by a German chemist—then you're shoving hydrogen atoms into the fatty acids, changing some of the double bonds to regular bonds. This increases the melting point, making the fats solid at room temperature, which prevents them from migrating around the food. (Fun trivia: the name "Crisco" comes from *crys*talized *co*ttonseed oil.) Its higher melting point is why we use butter instead of oil in baked goods; hydrogenating fats stiffens them up, making them suitable for a broader range of applications. But it's also possible to make trans fats during hydrogenation because some processes used to add hydrogen atoms can also relocate existing ones. When this happens, a trans fat is created, and that fat has a structure that can stack on top of other trans fats. In large quantities this leads to health issues. (The molecules are "bent out of shape" in a way that happens to fit together.)

There's one complication in the science of fat for cooks in the kitchen: the fats in animals and plants are mixtures of different types of fat molecules. If you had a container of just fats made of oleic acid (olive oil is mostly oleic acid), it would melt at exactly 41°F / 5°C. But there are other fatty acids in there, which is why a bottle of good olive oil turns cloudy but doesn't solidify when stored in the fridge—some of the fats will solidify, while others will remain liquid.

A candle made from a wick dropped in rendered beef fat. Beef fat is mostly stearic and oleic fatty acids, so it's solid at room temperature. Fat is a great energy source!

Time and Temperature



A few common fatty acids and their melting points—notice the much higher melting points for saturated fats (ones that have no double bonds, shown as ":0") and that longer chains have higher melting points.

Why do some things melt and other things burn?

It depends on the properties of the compounds on hand. Melting is a physical change—a phase transition from solid to liquid that doesn't change the molecular structure. Burning, on the other hand, is a chemical change (usually combustion or pyrolysis). Some substances melt and then burn, others will burn before melting, and yet others may or may not melt or burn. Foods are almost always mixtures of substances, making this more complicated. Take butter: as it's heated, the fats melt first, and then at a higher temperature the milk solids burn.

Fat	Common fatty acids				
	Linoleic acid	Oleic acid	Lauric acid	Myristic acid	Palmitic acid
Butter	4%	27%	2%	11%	30%
Lard	6%	48%	-	1%	27%
Coconut oil	1%	6%	50%	18%	8%
Olive oil	5-15%	65-85%	-	0-1%	7-16%
Canola oil (low erucic/high oleic; a.k.a. rapeseed)	20%	63%	-	-	4%
Safflower oil (high oleic)*	16-20%	75-80%	-	-	4.5%
Safflower oil (high linoleic)	66-75%	13-21%	-	-	3-6%
Egg yolk	16%	47%	-	1%	23%
Cocoa butter	3%	35%	-	-	25%

** Different varieties of the same plants can produce different fatty acid profiles. For example, safflower oil comes in two varieties: high oleic, which is used for cooking, and high linoleic, which is used in paints (and is similar to linseed oil). Some oils use different names to distinguish the varieties—canola is a low erucic acid variety of rapeseed, given a different name by industry. Growing conditions will also change the fatty acid composition.*

What Are the Various Temperatures for Fats?

Pour point

A fat needs to be at least this warm to be "pourable"—what you might think of as melted, but not necessarily completely liquid. Most nut oils have a pour point of around 34°F / 1°C.

Cloud point

This is the temperature below which a fat becomes cloudy while still being pourable. It's not something you'd notice in the kitchen unless you keep oils too cold—it's why we store olive oil on the counter, not in the fridge. Most nut oils become cloudy at around 40°F / 4.5°C.

Melting point

This is the temperature range at which enough fat molecules are melted that the fat is liquid. Almost all fats are mixtures of fatty acids in different crystalline forms, so in reality melting point is the temperature range over which the fat goes from hard to soft to liquid. We typically use fats that are solid at room temperature in baked goods, and fats that are liquid at room temperature (oil!) in salad dressings and dips. (The solidification point is often ~10°F / ~6°C colder.)

~25°F / ~–4°C: Olive oil

90–95°F / 32–35°C: Butter

95–113°F / 35–45°C: Lard

115–120°F / 46–49°C: Shortening

Smoke point

This is the point at which the fat begins to thermally decompose. You'll see wisps of smoke coming off a pan at this temperature, and it's the temperature you want to hit when frying foods. Unrefined oils have particulate matter that burns, lowering the smoke point.

230°F / 110°C: Unrefined canola oil

350–375°F / 177–191°C: Butter, vegetable shortening, lard

400°F / 205°C: Olive oil

450°F / 232°C: Safflower oil

475°F / 245°C: Clarified butter, ghee, refined high oleic canola oil

510°F / 265°C: Refined safflower oil

Flash point

At this temperature, fat can catch fire but isn't hot enough to sustain combustion. If you are sautéing something over a gas burner and you see some of the vapors flame up briefly, that's what you're seeing.

540°F / 282°C: Lard

610°F / 321°C: Olive oil

630°F / 332°C: Canola oil

Fire point

This is the temperature at which a fat will continue to burn if ignited; it's important for candles but definitely not good in the kitchen! If something does catch fire, remove it from the heat and put a lid on it.

666°F / 352°F: Lard

682°F / 361°C: Olive oil

685°F / 363°C: Canola oil

Autoignition point

At this temperature, a substance will spontaneously ignite without being lit. Rather necessary in gas car engines, but something to avoid in the kitchen.

689°F / 365°C: Ethanol (alcohol)

800–905°F / 427–485°C: Wood (pine, oak)

Butter

Butter is fascinating stuff. Unlike other culinary fats, butter isn't pure fat. It's a mixture of milk fats (80–86%) and water (13–19%), where the water contains proteins, minerals, water-soluble vitamins, and any added salt. Butter's remarkable flavor comes from this unlikely combination of water mixed into fat, made possible because of how the glyceride molecules in fat surround water droplets.

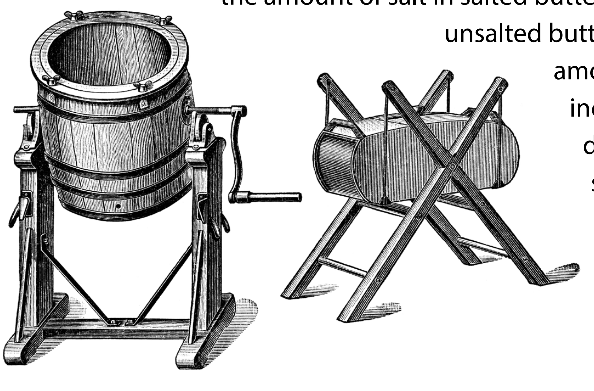
Butter is also remarkable for its melting temperatures. In the fridge, more than two-thirds of the fats are solid; left out on the counter on a warm summer day, only a third of the fats remain solid. This mixture of solid and liquid fats makes butter the only natural fat that's *plastic*—deformable and spreadable while retaining its shape—at room temperature. The fatty acids in butter (mostly myristic, oleic, and palmitic acids) are present in different combinations of fat molecules that melt at temperatures between –11°F / –24°C and 164°F / 73°C; based on the normal composition, butter softens around 68°F / 20°C and melts at about 95°F / 35°C.

To see a video of how butter is made, see http://cookingforgeeks.com/book/butter/.

Making great butter is a lot more complicated than merely separating the fats from the cream by churning. Changes in the size of the fat globules in the butter, based on how quickly the cream is cooled during pasteurization, will change the texture, as does the amount of water left in the churned butter. Milk fats can also vary in their fatty acid composition. If the cream has larger amounts of warmer-melting fats than normal, then the butter ends up being soft. (The ratio of the fatty acids depends on the cow's diet; cream from grass-fed cows has less saturated fat and a lower melting point.) It's worth making your own butter once to understand the process, but in practice, buying butter is far easier and more economical. But which type? And how to store it? Here are a few tips:

Salted and unsalted butter

Salted butter is great for eating—hopefully you know the joy of slathering a hearty pat of room temperature, salted butter onto a slice of freshly baked bread. Because the amount of salt in salted butter can vary (1.5–3%), though, it's better to use unsalted butter in cooking so that you can add in a known amount of salt. When you see "butter" in a recipe, including in this book, use unsalted butter by default. Salted butter has one other benefit: salt inhibits bacterial growth, making salted butter less likely to spoil when stored at room temperature.



Sweet cream versus cultured butter

Butter was traditionally made using cream from milk that had been left out to separate; by the time the cream had floated to the top, it had fermented and gone slightly sour. (Leave it out longer, and you get sour cream!) Most Americans are used to sweet cream butter that's made from cream that hasn't fermented; in Europe and elsewhere, the cream is allowed to partly ferment, thus creating cultured butter.

Storing butter

The ideal butter is firm enough to retain its granular structure but soft enough to be spreadable, having a texture technically described as waxy. This simply isn't possible with butter stored in the fridge. It's safe to store salted butter on the counter; use a container that blocks light and limits airflow, and consume it within two weeks to avoid rancidity. (Oxygen can insert itself into the fatty acid, leading to butyric acid—which gets its name from rancid butter!) Unsalted butter should be kept in the fridge and left to warm for an hour before use; this step is essential for proper mixing with sugar when you are baking.

Baking with butter

Solid butter will mix differently into doughs and batters than melted butter will. Mixing solid butter with sugar will create small air bubbles; if melted fat is creamed with sugar, it'll coat the sugar granules instead of trapping small air bubbles. Melting butter also separates out the water, allowing it to form more gluten than it would otherwise (see page 249). Also, different brands of butter can have slight differences in the amount of water present. This can impact baked goods like pies; try using higher-fat butter for buttery baked foods.

Homemade sour cream

Cultured butter starts with slightly soured cream—but what if you let it ferment even longer? You'd end up with sour cream! The flavor and creaminess is unmatched by what you can buy, and it's incredibly easy to make.

Snag **a container of heavy cream** from the store, open it, and add **a spoonful of plain unflavored yogurt** that has active bacteria in it. Close the container and briefly shake it. If you have a slow or pressure cooker with a yogurt mode, place the container in the cooker, submerged in an inch of water, and ferment it for 12 hours; otherwise, culture the cream by leaving the container on your kitchen counter for a day or so. Store the sour cream in the fridge and use it within a week.

Clarified Butter, Browned Butter, and Ghee

Making clarified butter involves heating butter to boil off all the water and then straining out the milk solids, a form of heat clarification. *Without the milk solids, clarified butter has a higher smoke point of around 450°F / 230°C.*

To make clarified butter: Melt **1 cup (230g) butter** and, if it's unsalted, **¾ teaspoon (5g) salt** in a saucepan over medium heat, or in a covered container in a microwave. You'll see the melted butter begin to froth; this is the water steaming up. After a few minutes, the water will have evaporated, leaving you with butter and a whitish substance, which is the milk solids. Remove the pan from the heat and either carefully pour off the fat, leaving behind the milk solids, or strain the liquid through a fine mesh strainer. You can use clarified butter to sauté fish and roast vegetables and to fry breadcrumbs and bread like English muffins.

With browned butter and ghee you can take the clarification process a step further by toasting the milk solids to impart an aromatic, rich flavor into the fat. Browned butter leaves the toasted milk solids in, which is great for flavoring, while ghee filters them out, allowing for a much higher smoke point—you can use ghee but not browned butter for frying.

Ghee was first used in Indian cooking and typically made from cow or buffalo milk that's sometimes cultured (fermented like yogurt). It's a simple solution to the lack of refrigeration, which is why it's common in the cuisines of warmer climates. Why make your own? The compounds created by the Maillard reaction aren't shelf-stable. Reaction products from the initial stage continue to break down over a few weeks in the ghee, increasing the amount of acetic acid (think white vinegar) and leading to flavor changes—freshly made stuff will taste different!

To make browned butter and ghee: Start with the directions for clarified butter, but continue the cooking process to lightly toast the milk solids. Keep a watchful eye and remove them from the heat once they begin to turn brown. Darker brown milk solids will give you a more aromatic flavor. If you're making ghee, allow the mixture to rest for at least 5–10 minutes and then filter; the rest time will allow flavors from the toasted milk solids to dissolve into the fat.

Try using browned butter in baked goods like pancakes, muffins, or cookies (madeleines!): for butter, substitute 85% browned butter and 15% water—roughly 7 tablespoons (100g) browned butter + 1 tablespoon (15 mL) water for each ½ cup (115g) of butter (if your recipe calls for creaming, add the water to the wet ingredients). Or try using it to make a sauce: melt the browned butter, and add a squirt of lemon juice and some fragrant herbs, such as sage.

Try using ghee anywhere you would normally use a high-heat oil, such as in frying or roasting.