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# Cooking for Geeks

Real Science, Great Cooks, and Good Food

SECOND EDITION



Jeff Potter

**Praise for the First Edition:**

“One of the most useful books on understanding cooking, kind of like a rock-and-roll version of Harold McGee’s *On Food and Cooking*.”

—Andreas Viested, *The Washington Post*

# Cooking for Geeks

**Why, exactly, do we cook the way we do?** Are you curious about the science behind what happens to food as it cooks? Are you the innovative type, used to expressing your creativity instead of just following recipes? Do you want to learn to how to become a better cook?

*Cooking for Geeks* is more than just a cookbook. Author and cooking geek Jeff Potter helps you apply curiosity, inspiration, and invention to the food you prepare. Why do we bake some things at 350°F / 175°C and others at 375°F / 190°C? Why is medium-rare steak so popular? And just how quickly does a pizza cook if you “overclock” an oven to 1,000°F / 540°C? This expanded new edition provides in-depth answers, and lets you experiment with several labs and more than 100 recipes—from the sweet (a patent-violating chocolate chip cookie) to the savory (pulled pork under pressure).

When you step into the kitchen, you’re unwittingly turned into a physicist and a chemist. This excellent and intriguing resource is for inquisitive people who want to increase their knowledge and ability to cook.

- Discover what type of cook you are and learn how to think about flavor
- Understand how protein denaturation, Maillard reactions, caramelization, and other reactions impact the foods we cook
- Gain firsthand insights from interviews with researchers, food scientists, knife experts, chefs, and writers—including science enthusiast Adam Savage, chef Jaques Pépin, and chemist Hervé This



**Jeff Potter** is curious about the science of food and loves finding answers to why ingredients and recipes work the way they do. By bringing science to food-minded people—and food to science-minded people—he educates the public about how to master the kitchen. Jeff also works with organizations and tech startups to build the technology behind their products. He’s been featured in *USA Today*, the Today Show, and is a regular guest on Science Friday.

## COOKING

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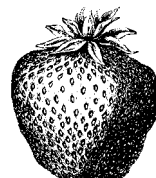
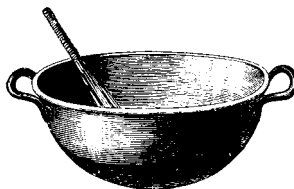
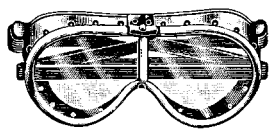
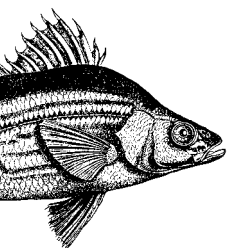
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Second Edition

# Cooking for Geeks

*Real Science, Great Cooks, and Good Food*

Jeff Potter



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## Cooking for Geeks, Second Edition

by Jeff Potter

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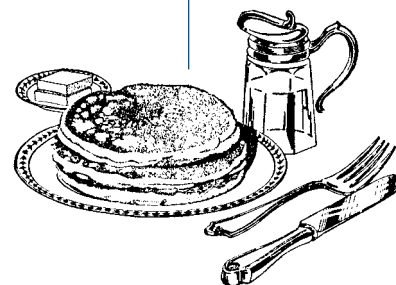
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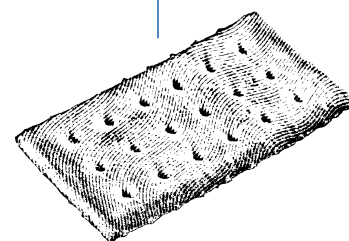
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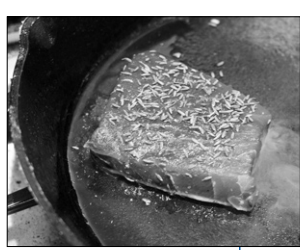
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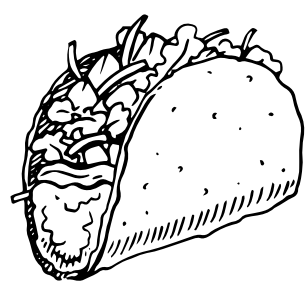


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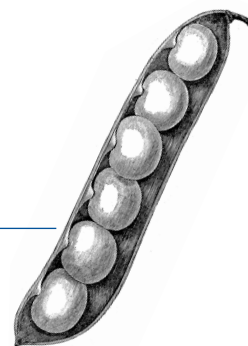
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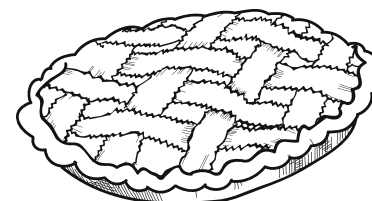
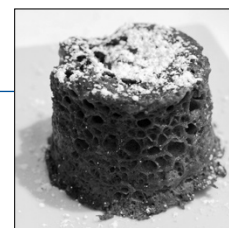


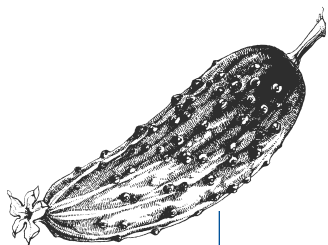
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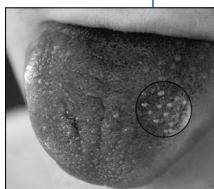
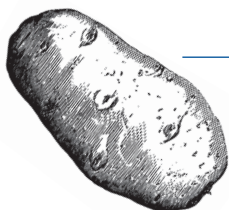


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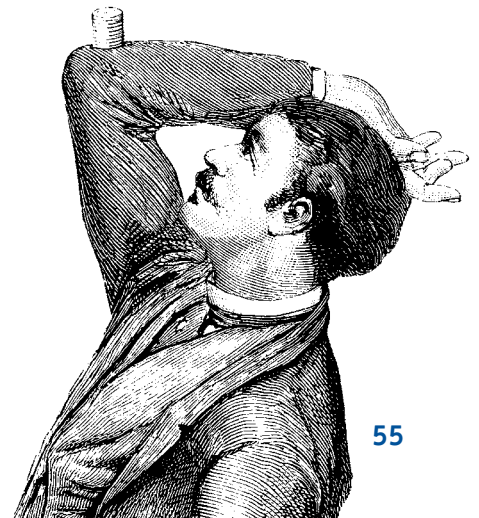
## Taste, Smell, and Flavor

### **YOU OPEN YOUR FRIDGE AND SEE PICKLES, STRAWBERRIES, AND TORTILLAS.**

What do you do? You might answer: create a pickle/strawberry burrito. Or if you're less adventurous, you might say: order pizza. But somewhere between making a gross-sounding burrito and ordering takeout is another option: figuring out the answer to one of life's deeper questions: *how do I know what goes together?*

The answer is, as with so many things, "It depends." It depends on your past experiences and what you've learned to like. It depends on your cravings as you stand there in front of the fridge pondering pickles, strawberries, and how your life has reached the point where your fridge holds only three ingredients. And it depends on how the ingredients will taste together based on how your tongue and nose sense the tastes and smells of the foods you're eating.

The best inspiration for blissful *deliciousness* is to pick good culinary inputs: ingredients that carry good flavor, generate pleasing aromas, and make your mouth water. True, you also need good technique once the ingredients land in the frying pan, but no cook can save truly bad ingredients. By understanding how flavor is created and detected, you'll be better able to answer that deeper question of culinary combinations and inspiration.



# Taste + Smell = Flavor

Experienced cooks can imagine the flavor a combination of ingredients will have without picking up a fork. For them, predicting what combinations will work well comes from remembering what worked in the past and noticing patterns in recipes. But what *is* flavor? And how can you learn to better predict what will work well together?

Flavor is based on the combination of *taste*, the gustatory sensations from your tongue, and *smell*, the sense of olfaction from olfactory receptors in your nose. Our brains also factor in a little bit of other data picked up by our mouths, such as texture and oral irritation from chemicals (think hot peppers or peppermint). There are also some minor nuances (some would say nuisances) from cues like color that can sway what we think we're tasting, but those aspects aren't as much about flavor as they are perception.

All of the senses that create the sensation of flavor are based on chemistry. Your tongue detects compounds that trigger sensory cells in a taste bud, usually with the aid of saliva. Your nose detects *volatile compounds*—chemicals that easily evaporate from their source—as they're carried by air passing through the nasal cavity. The next time you chomp down on a strawberry, keep in mind that the flavor you sense is based on some of the strawberry's compounds triggering taste receptors in your taste buds and other compounds evaporating and triggering olfactory neurons in your nose.

Our brains trick us into thinking that the sensation of flavor is a single input, but in reality our “sense of taste” is created by our brains. We usually use the word “taste” when we mean flavor, but from a technical perspective, a good strawberry only tastes sweet. That taste combines with a fruity, complex smell to create the flavor of a strawberry. For us to drill down into the science of taste and smell, it's an important clarification: taste is what your tongue does, smell is what your nose does, and flavor is the combined sensation your brain creates from fusing the signals from multiple senses. We'll spend the rest of this chapter diving into the specifics of taste, smell, and flavor, but a few key guidelines for creating amazing meals are worth pointing out here:

- **Start with good ingredients.** No amount of culinary wizardry can create all of the taste and smell molecules missing in low-quality ingredients.
- **Use proper technique.** Your tongue and nose can't detect compounds that are bound up inside food. Slicing through produce, combining ingredients, and heating foods free compounds such that you can detect them and also transform them into other compounds, changing what's available for you to sense.
- **Season with all the taste modifiers, not just salt.** Adding ingredients like salt, sugar, and lemon juice changes the detection thresholds of volatile compounds and alters unpleasant compounds. Adding a pinch of salt can “add” flavors by lowering the threshold necessary for you to detect them while also masking bitter flavors; adding lemon juice can neutralize off-smelling amino compounds.

# Lab: You Say Potato, I Say Apple

Even though they're tightly coupled, taste and smell are different senses. Try these two quick experiments with some friends to understand a few differences.

## First, grab these supplies:

### *For Test 1: Differences between taste and smell*

- Apple
- White or yellow onion
- Potato (optional)
- Turnip (optional)
- Knife and cutting board to cut foods
- Small bowl with water to soak foods

### *For Test 2: Understanding oral irritation*

- Cinnamon
- Cayenne pepper (powdered)
- 2 spoons or 2 small sample cups to hold a pinch of each spice

## Here's what to do:

### *Test 1: Differences between taste and smell*

1. Cut samples of the apple, onion, potato (optional), and turnip (optional) into thin strips, like small French fries, making sure to trim off any skins. Try to create roughly identical-looking samples, making enough of each so that every person can try a few.
2. Soak the samples in a small bowl of water for a minute or two. This will rinse off some of their juices, which is especially crucial for the onion. (These two steps can be done in advance if you're preparing for a group.)
3. Have everyone take a sample from a bowl, and while pinching your noses, bite down on

the sample. (Pinching your nose prevents the air carrying the odorants from circulating up into the nasal cavity.) Make a note of what you think you're eating—what tastes do you notice? Then, let go of your nose and note the difference. Repeat several times, until you've experienced all of the foods.

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For larger groups, try using multiple flavors of jellybean candies instead.

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### *Test 2: Understanding oral irritation*

1. Put a small pinch or dash of cinnamon on one spoon or in a sample cup and a small pinch or dash of cayenne pepper (not too much!) on a second spoon or in a sample cup.
2. Pinch your nose so that no air is flowing in or out; this will prevent your olfactory receptors from picking up any odors. Taste the cinnamon, keeping your nose plugged. What do you notice about the way it tastes and smells? Let go of your nose and breathe in and out—what do you notice?
3. Repeat with the cayenne pepper, pinching your nose, tasting, and then letting go and smelling; write down what you notice at each stage.

## Investigation time!

What did you notice about the way foods "tasted" when you pinched your nose? Both onion and cayenne pepper have strong flavors; what did you notice about the difference in the way you experienced them? Why do you think we can't "taste" much when we have a cold?

# Taste, the Gustatory Sense

Our sense of taste is an amazing accomplishment of biology and evolution, and for good reason: it steers us toward nutritious, energy-rich foods (sweet, savory) and biologically necessary building blocks (salty), and away from potentially harmful foods (sour, bitter).

The four foundational tastes of Western cuisine—salty, sweet, sour, and bitter—were first described 2,400 years ago by the Greek philosopher Leucippus (or more likely one of his grad students, Democritus). The ancient Chinese included a fifth taste, pungency/hot, and indeed spicy foods as well as cooling ingredients are detected in gustation. Another taste, savory, was described and popularized about a hundred years ago by a Japanese researcher, who identified a “meaty” taste triggered by amino acids, which he named *umami*. More recent research hints at additional taste receptors for rancid fatty acids (“oleogustus”), some metals, calcium, and possibly even water, although these are unlikely to ever be considered tastes in a culinary sense.

By itself, taste is the lesser part of flavor, accounting for somewhere around 20% of the sensation of flavor, with the other 80% or so coming from smell. As the more primitive part, though, taste is easier to understand, so we’ll start with it. The human tongue contains a few thousand taste

buds, each of which is a group of 50 to 100 receptor cells. (The little dots you see on your tongue contain some of the taste buds, but taste buds exist elsewhere, too—even on the *palate*, the roof of the mouth.) Each of these cells can interact with various types of chemicals, which are carried to them by our saliva as we chew food. It’s these receptor cells that originate the signals for various tastes. Once activated, the receptor cells transmit the signals to our brains, which assemble all the signals into a relative strength for the taste.

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The receptors for sweet, bitter, and umami compounds are known to also exist elsewhere in the human body. Sweet receptors in the gut, for example, respond to sugar and send positive signals to the brain; there’s a reason eating *and* swallowing good food is so satisfying! Other animals take this further and rely on receptors for tasting located in other parts of their bodies. Fish taste using their lips; flies can taste what they walk on through their feet.

---

The magic of taste starts with receptor cells. The standard metaphor for how they work is that of a lock and key. *Tastants*—chemical compounds that trigger a taste, such as sucrose in table sugar or sodium in table salt—act as keys, fitting into “locks” on our receptor cells. Different families of compounds fit into different locks, so a particular taste perception can be thought of as a single key matching a single lock. When you taste sugar, your brain registers “sweet” based on which taste receptor cells sugar can bind to and the subsequent neurological pathways between those cells and your brain.

Each sense of taste comes from a different type of taste receptor cell, but multiple receptors can lead to the same taste sensation. It’s estimated that there are around 40 different types of receptors on the tongue, with multiple ones for the same taste. Salt, at least in mice, is detected by two different receptors, one for low concentrations of sodium

and a second that activates with higher concentrations. Sweet tastes can also be triggered by two different receptors, called T1R2 and T1R3. Differences in compounds will also determine how quickly they fit into the “lock” of the receptor and how long they activate it, leading to different timing sensations between tastants. This lock-and-key metaphor isn’t perfect, though—the strength of one taste sensation can be moderated when another one is detected.

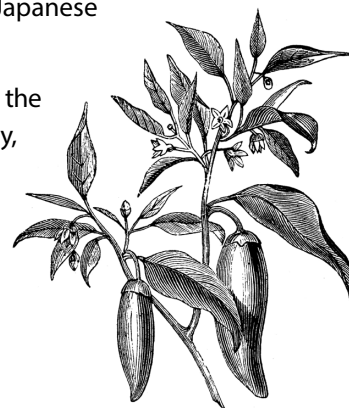
How strongly we register a taste is based on how much of a compound is present in a food we’re eating and how sensitive we are to it. Just as our other senses have thresholds for sensing (e.g., few of us can hear anything at 2 dB, while almost all of us can hear something louder than 15 dB), taste and smell have minimum absolute thresholds. Take a look at this chart showing reported values for sensitivity thresholds of common taste reference compounds, expressed in parts per million (i.e., for us to taste these compounds, they have to be present at or above these concentrations, called *suprathreshold*; take these numbers with a grain of salt, though, as they’ll change based on many factors).

<b>Sweet</b>	Sucrose	5,000 ppm
<b>Salty</b>	Sodium chloride	2,000 ppm
<b>Savory</b>	Glutamate	200 ppm
<b>Sour</b>	Citric acid	40 ppm
<b>Bitter</b>	Quinine	2 ppm
<b>Hot</b>	Capsaicin	0.3 ppm

Our sensitivity to different common compounds reveals a lot about their importance. A quick glance shows that we’re much more sensitive to sour, bitter, and irritating compounds. These generally denote unsafe food, like spoiled foods that have turned sour, or poisonous items, which generally register as sour or bitter. Evolutionarily speaking, this is no surprise; any organism that avoids chowing down on something dangerous has a better chance of passing along its genes!

You’ll notice capsaicin in the list. Capsaicin is the compound that makes hot peppers hot, and it’s an example of *chemesthesis*—the sensation of chemicals. Our taste buds, like much of our skin, can detect irritation brought on by chemicals such as ethyl alcohol and capsaicin. Other chemicals, like menthol, activate cooling sensations. These types of compounds tickle other aspects of our taste buds and influence flavor, and are why it’s incorrect to think of the tongue as only sensing four or five tastes. Different cultures place different emphasis on these sensations in their culinary traditions—many Indian dishes and southeast Asian cuisines put an emphasis on pungent, hot tastes, while the Japanese base much of their cuisine around savory/umami tastes.

Regardless of which types of cuisine you enjoy, the approach to cooking them is the same: try to balance the various tastes to a level that’s desirable (e.g., not too salty, not too sweet). There are a number of practical challenges in creating balanced tastes, and understanding them can elevate your cooking game significantly. How you prefer tastes to be balanced depends in large part on how your brain is wired and trained to respond to basic tastes. Here are a number of different aspects of taste to be aware of when cooking, both for yourself and for others.





**Remember to season!** Knowing all the science of taste won't make a dish taste any better if you don't pay attention to your senses. Learn to *really* taste things. See if you can notice changes in tastes and smells as food finishes cooking, and take time to taste a dish and ask yourself what would make it better. Adjusting the seasonings at the end may seem obvious, but it's a common step people forget. A pinch of salt or squirt of lemon juice can do wonders to balance tastes.

**Your cultural upbringing will affect where you find balance in tastes.** What one culture finds ideally balanced won't necessarily be the same for another culture. Americans generally prefer foods to taste sweeter than Europeans. Savory is a key taste in Japanese cuisine but has historically been given less formal consideration in the European tradition (although this is starting to change). Flavor preferences begin to develop *before birth*—mothers eating foods like garlic during pregnancy will impact the child's food preferences, and fetal facial reactions can be seen in the third trimester in response to pleasurable and adverse-tasting foods. This is all to say that, when cooking for others, what you find just right might be different than someone else's idea of perfection, no matter if it's one shared meal or a lifetime of shared meals with a partner.

**What you just ate can influence what you taste next.** When you're serving different dishes, the tastes from one dish can linger and impact the experience of others—an effect called *taste adaptation*. Most of our senses adapt to a signal after a while, so that we're able to pick up on other changes. A sweetened yogurt, for example, will become less sweet as you

continue eating it, and that adaptation can carry over to the next thing you taste. The next time you brush your teeth, try sipping some orange juice afterward and notice how much more bitter it is. (Sodium lauryl sulfate in toothpaste sticks around for a little while, knocking out your ability to sense sweet.) Carbonated beverages like effervescent mineral water are traditional palate cleansers, although studies suggest crackers are more effective. That bread basket on the table isn't just about filling you up: eating bread also clears out tastes when you're switching between foods!

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*Taste adaptation* occurs when your perception of taste is altered by prior sensations, sort of like a visual afterimage, while *taste perversion* happens when a compound changes how your sense of taste registers things. See page 71 for more on taste perversion.

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**Environmental factors affect how you taste things.** Drier conditions change the amount of saliva in the mouth, resulting in a decrease of taste sensitivity. Airline food suffers for this reason; salty tomato juice and pretzels are commonly served at altitude, as they have strong tastes. Our sense of taste changes with the weather!

Temperature also impacts taste sensation: foods served warmer (by some accounts, above 86°F / 30°C) will be detected as stronger by the taste buds than colder dishes, due to the heat sensitivity of some of the taste receptor cells. There's a fun quirk of biology here: foods

served below body temperature don't register as warm, so a dish served slightly below body temperature won't seem warm but will still convey stronger tastes. Colder foods, on the other hand, result in tastes with lower perceived strength, especially for sugars. There's a reason why warm soda is gross: it tastes sweeter (cloyingly so) than when it's cold. When you're in the kitchen, keep the impact of temperature on your sense of taste in mind when making dishes that will be served cold. You'll find the frozen versions of things like ice cream and sorbet to be weaker-tasting and -smelling than their warmer, liquid versions, so adjust the mixtures accordingly.

**Genetic differences can change how you taste things.** What you and I taste isn't necessarily the same. The most researched area of genetic taste differences uses the bitter-tasting compounds propylthiouracil (PROP) and phenylthiocarbamide (PTC) for understanding how we interact with foods. Some of us can't taste these compounds—myself included—while others taste them as bitter. It's not a binary “can or can't” taste but appears to be correlated with two genes, along with a few other genetic aspects. Based on one's genetic makeup, the bitter sensation can be unbearably revolting. I had one friend almost reflexively punch me upon tasting a PTC test paper—clearly an extraordinary taster. (See page 82 to learn how to test taste differences; for an interview with Linda Bartoshuk, who has extensively researched this area, see page 86.)

Being able to taste PROP or PTC isn't necessarily good or bad; it's just different. Those who taste them will experience some foods—especially dark-green leafy vegetables such as kale, cabbage, broccoli, and Brussels sprouts—as more bitter because of phenylthiourea-like compounds that their tongues can sense. PROP/PTC tasters generally also have a higher number of taste buds on their tongues, resulting in a larger number of cells that can experience oral irritation. This quirk causes them to taste astringent, acidic, and spicy foods as stronger as well. Caffeine tastes more bitter to PROP/PTC tasters, which explains why researchers find these tasters are more likely to add milk or sugar to coffee and tea, which cancels out some of the bitterness.

As you can see, a small difference in the ability to taste one family of bitter compounds can cascade through a bunch of other tastes, changing the balance of tastes that someone may want. There's some evidence for genetic differences in the ability to taste savory compounds like glutamate; who knows what other differences exist.

**Physiological issues can also impact taste capabilities—notably, age, stress, and disease.** As we age, our taste preferences shift. A kid's sweet tooth comes from a biological drive for high-calorie foods; older seniors also have shifts in smell capabilities and become less sensitive to salt and some mildly bitter tastes. (It appears that tastants like sodium and sucrose have slight odors associated with them, so there's some impact on taste thresholds from decreased smell.) For the elderly, loss of taste sensations can be a real issue—it's hard to eat bland food. Stress also impacts taste by leading to an increase in the hormone

cortisol, which, among other things, dampens the stimuli strength of taste buds. And finally, there are a broad range of diseases that can affect our sense of taste, most of which are rarely diagnosed in the nonelderly population (how would you know you have *specific aguesia*—taste blindness—when you can't tell what somebody else experiences?). While understanding the physiological issues won't change what someone tastes, it can explain the behavior you see in the way people around you eat.

From this short list of the ways that taste is impacted, you can see that taste is not as simple as the four basic sensations of salty, sweet, sour, and bitter described by the ancient Greeks. We'll examine the various aspects of taste, along with recipes and experiments, over the first part of this chapter.

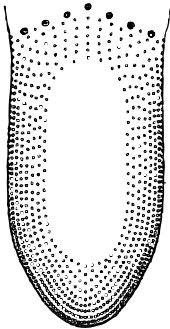


Fig. 2.

The erroneous idea that primary tastes come from different parts of the tongue started with a mistranslated paper. All regions of the top surface of the human tongue can detect primary tastes. There are small differences in sensitivity per region, which is why different parts of the tongue sense different tastes more acutely. The back of the tongue is more sensitive to bitter than the front, while the front is more sensitive to sweet than the back, so a weakly bittersweet liquid will seemingly change taste on different parts of the tongue.

## Greek-Style Marinade

*Marinades, at least by common definition, are acidic, sour liquids in which foods are soaked before being cooked. It's a bit of a misnomer, though—the word marinade is derived from the Spanish *marinar*, meaning “to pickle in brine.” Most marinades flavor only the surface of the meat, so choose thin cuts for marinating.*

In a bowl, mix:

- ½ cup (120g) yogurt**
- 2 tablespoons (30 mL) lemon juice (about a lemon's worth)**
- 2 teaspoons (4g) oregano**
- 1 teaspoon (6g) salt**
- Zest of 1 lemon, minced finely**

## Japanese-Style Brine

*Brines are always based on salt—in this case soy sauce, which is about 5–6% salt. Salt breaks down parts of the muscle tissue, leading to tenderer cooked meats. Adding other taste modifiers, like honey, balances out the saltiness.*

In a bowl, mix:

- ½ cup (120 mL) soy sauce**
- 4 tablespoons (24g) minced ginger**
- 6 tablespoons (40g) minced scallions (also known as green onions), about 4 stalks**
- 4 tablespoons (60 mL) honey**

## Tasty Ingredients by Culture

*Different cultures use different ingredients for modifying the basic tastes in cooking. Try using some of these common ingredients for adjusting tastes the next time you're cooking. (For a list of ingredients by culture that bring smells and aromas, see page 111.)*

*Note that these are broad suggestions; don't take this list as an anthology of regional cuisine. North India is more arid and cooler than South India, and uses entirely different techniques and ingredients. Many of these ingredients also bring smells, which is why each culture's foods have certain flavor principles.*

	Bitter	Salty	Sour	Sweet	Umami	Hot
<b>Caribbean</b>	Bitter melon	Salt cod (ackee and saltfish)	Lime	Molasses; brown sugar	Tomato	Hot peppers
<b>Chinese</b>	Chinese broccoli; bitter melon	Soy sauce; oyster sauce	Rice vinegar; plum sauce (sweet and sour)	Plum sauce (sweet and sour); hoisin sauce	Dried mushrooms; oyster sauce	Mustard; Szechuan peppers; ginger root
<b>French</b>	Frisée; radish; endive	Olives; capers	Red wine vinegar; lemon juice	Sugar	Tomato; mushrooms	Dijon mustard; black, white, and green peppercorns
<b>Greek</b>	Dandelion greens; broccoli rabe	Feta cheese	Lemon	Honey	Tomato	Black pepper; garlic
<b>Indian</b>	Asafetida; fenugreek; bitter melon	Kala namak (black salt, which is NaCl and Na <sub>2</sub> S)	Lemon; lime; amchur (ground dried green mangos); tamarind	Sugar; jaggery (unrefined palm sugar)	Tomato	Black pepper; chilies; black mustard seed; garlic; ginger; cloves
<b>Italian</b>	Broccoli rabe; olives; artichoke; radicchio	Cheese (Pecorino or Parmesan); capers or anchovies (commonly packed in salt)	Balsamic vinegar; lemon	Sugar; caramelized veggies; raisins and dried fruits	Tomato; Parmesan cheese	Garlic; black pepper; Italian hot long chilies; cherry peppers
<b>Japanese</b>	Tea	Soy sauce; miso; seaweed	Rice vinegar	Mirin	Mushrooms; miso; dashi	Wasabi; chiles
<b>North African</b>	Tea	Preserved lemons	Preserved lemons	Dates	Harissa, sumbala (West African)	Harissa
<b>Latin American</b>	Chocolate (unsweetened); beer	Cheeses; olives	Tamarind; lime	Sugar cane	Tomato	Jalapeño and other hot peppers
<b>Southeast Asian</b>	Tangerine peel; pomelo (citrus fruit)	Fish sauce; dried shrimp paste	Tamarind; kaffir limes	Coconut milk	Fermented bean paste	Thai chili in sauces and pastes
<b>Spanish</b>	Olives	Anchovies	Vinegar	Fruit (raisins, figs, quince); sugar	Smoked paprika	Peppers
<b>Turkish</b>	Coffee	Za'atar (mixture of thyme, salt, sesame seeds, and sumac)	Yogurt	Honey	Tomato	Red pepper flakes

## Salty

We taste foods as salty through a relatively simple biological mechanism: sodium ions from salt activate salty-taste-specific receptors by way of *ion channels*—essentially a gated passageway into a cell—which then complete an electrical circuit that sends the brain the message “salty!”

Of all the primary taste sensations, our mechanism for sensing salty tastes is unique in its detection of a specific compound, sodium. Almost nothing else triggers the taste of saltiness; ion channels are very selective about what they bind with. Sodium is a biological necessity regulated by the kidneys and used to control blood pressure, enable cellular communication, balance water levels, and manage a whole lot of other things. Our lives

depend on us eating enough of it. Given its biological importance, our ability to specifically taste salt and crave it makes sense. As with sweetness, our cravings for salty tastes are related to what our bodies need at any given moment.

The word *salty* describes the taste, while *salt* defines a chemical compound. *Table salt* refers to sodium chloride specifically; and unless you’re talking chemistry, this is the type of salt meant when the word *salt* is used. From a chemistry perspective, there are other types of salts besides

sodium chloride. One salt, potassium chloride, does taste salty but also has a bitter taste. If you look at the ingredient labels for salt substitutes, you’ll see other compounds added to moderate that bitterness. Other salts you might know of, such as Epsom salt (magnesium sulfate), also taste bitter. Salts that contain lithium instead of sodium taste salty because lithium ions ( $\text{Li}^+$ ) can permeate the salty taste cells’ ion channels. I feel sorry for the chemist who discovered this, though—lithium is toxic in large doses! (For culinary uses of these other types of salts, see page 382.) In almost all cases, salty tastes are brought about by sodium ions from table salt, so you can assume if you’re tasting salt, it’s because of sodium chloride.

It’s the sodium ion ( $\text{Na}^+$ ) in sodium chloride that tastes salty; the chloride ion ( $\text{Cl}^-$ ) merely stabilizes the sodium in solid form. For the taste of salty to register, the sodium ion has to complete the ion channel’s circuit. This is a subtle but important point for eaters needing to regulate their salt intake: how salty a food tastes cannot be used to detect how much salt is present! Sodium ions, being extremely small, easily permeate into the foods they’re cooked

with, and once constrained, won’t come into contact with the salty taste receptors. A large amount of salt added early on in the cooking process can be absorbed into a food’s interior, meaning you won’t taste it *but* you will still digest it, leading to an increased sodium intake. Be aware of this if you’re cooking for people on low-sodium diets!

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Iodized salt has the element iodine added as a nutritional fortification against diseases like goiter, which is why it’s no longer an issue in countries like the United States. Controlled experiments show no taste difference between iodized and noniodized salt when used in foods at normal concentrations.

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Very, very weak solutions of salt will taste sweet! Sodium ions appear to activate the sweet receptor, but the exact mechanism isn’t yet known.

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Adding salt can change the way other tastes register and alter the way we sense smells. Taste receptors aren't perfect, one-to-one detectors for the various compounds. Salty and sour tastes can mask each other because sodium can slightly interfere with our sour taste receptors. Adding a pinch of salt to baked goods doesn't necessarily make the food taste salty, but it will reduce sourness, which in turn increases the perception of sweetness! The addition of a small quantity of salt (not too much!) enhances other foods, bringing a "fullness" to foods that might otherwise have what is described as a "flat" taste. This is why so many sweet dishes—cookies, chocolate cake, even hot chocolate—call for a pinch of salt. How much salt is in a pinch? Enough that it amps up the food's flavor, but not so much that it becomes a distinct flavor in itself.

In larger quantities, salt acts as an ingredient as much as a taste enhancer. Mussels liberally seasoned with salt, bagels topped with coarse salt, salty lassi (an Indian yogurt drink), and even chocolate ice cream or brownies sprinkled with sea salt all taste inherently different without the salt. When using salt as a topping, use a coarse, flaky variety (look for sea salt), not rock/kosher salt or table salt—you'll need less salt for the same salty sensation this way.

### DIY Sea Salt

Making your own salt is easy—if you live near the sea and don't mind slopping some buckets of water home. Fill a few 2-quart (2-liter) containers with pleasant-smelling seawater and return home. Pour the water into a large pan, straining it through a clean cloth or coffee filter to remove any sand and particulates. Boil the water down to about a fifth or sixth of its original volume, pour it into a shallow glass pan, and allow it to dry as it evaporates over a day or two. Expect to get about ¼ cup (65g) salt per 2-quart container.

Making salt via evaporation removes the water instead of extracting the salt. This means anything else in the water, from subtle flavorings and trace minerals (good) to toxic mercury (bad), will be present in the salt. Using it once isn't an issue, but I'd avoid a life-long habit of using DIY sea salt.



- Tips**
- Avoid "hidden salt" by using only the amount needed in the early stages of cooking to trigger chemical and physical changes, and then adjust salt levels for taste at the very end of cooking.
  - A pinch of salt isn't an exact measurement. Traditionally, it's the amount of salt you can pinch between your thumb and index finger, but if you need to start somewhere, try using ¼ teaspoon (~1g).
  - Because of genetic differences in the way people taste some bitter compounds, different eaters will desire different amounts of salt to mask bitterness in foods like broccoli, Brussels sprouts, and kale. Leave a salt shaker on the table to allow eaters to balance tastes!
  - The amount of salt you prefer is in part based on your last few months of eating patterns—your body will learn to prefer less or more salt over time.

### To make something taste saltier

- Add salt (duh) or add savory-based ingredients (increasing the savory/umami sensation amplifies salt perception; for savory ingredient suggestions, see page 63).

### If a dish is too salty

- If it's only slightly oversalted, increase the sweetness or sourness to mask.
- Dilute the salt by adding more ingredients to the dish. (The old trick of adding a potato to oversalted soup does little to decrease the sensation of saltiness but does dilute the concentration of salt.)

## Roasted Poblano and Cheddar Cheese Stuffed Pork Chops

Brining—*soaking food in salty water*—adds a delicious salty flavor to meats like pork chops, as this recipe shows. This dish is both tasty and easy, making it a great date-night meal.

In a container, mix **4 tablespoons (70g) salt** with **4 cups (~1 liter) lukewarm water**. Stir to dissolve salt. Place **2–4 boneless pork chops, at least 1" / 2.5 cm thick**, in the brine and let them rest for an hour. (Longer brine times will lead to saltier meat; if you're ever brining for longer than 2 hours, use cold water and keep the meats in the fridge.)

While the pork chops are resting in the brine, create a filling by mixing together in a bowl:

- ¼ cup (40g) poblano pepper, roasted and then diced, about 1 pepper (see notes for how to roast them)**
- ¼ cup (40g) cheddar or Monterey Jack cheese, cut into small cubes**
- ½ teaspoon (3g) salt**
- ½ teaspoon (1g) ground black pepper**

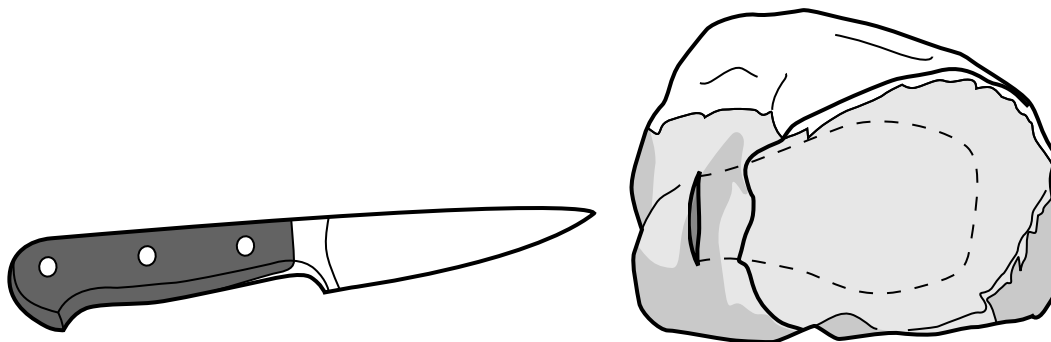
After the pork chops have brined, remove them from the water and pat them dry with paper towels. Prepare the pork chops for stuffing: using a small paring knife, make a small incision in

the side of the pork chop, then push the blade into the center of the pork chop. Create a center cavity, sweeping the blade inside the pork chop, while keeping the “mouth” of the cavity—where you pushed the knife into the side of the meat—as small as possible.

Stuff about a tablespoon of the filling into each pork chop. Rub the outside of the pork chops with **oil** and season them with a pinch of **salt**. (You'll have leftover filling. It's better to make too much than risk running out. Save the extra stuffing for scrambled eggs.)

Heat a cast iron pan over medium heat until it is hot (about 400°F / 200°C, the point at which water dropped on the surface sizzles and steams). Place the pork chops in the pan, searing each side until the outside is medium brown, about 5–7 minutes per side. Check the internal temperature, cooking until your thermometer registers 145°F / 62.8°C. Then remove the pork chops from the pan and let them rest on a cutting board for at least 3 minutes.

To serve, slice the pork chops in half to reveal the center. Serve them on top of rosemary mashed potatoes (see page 212).



## Notes

- *How do you roast a poblano pepper? If you have a gas stovetop, you can place the pepper directly on top of the burner, using a pair of tongs to rotate it as the skin burns off (expect the skin to char and turn black; this is what you're going for). If you don't have a gas stovetop, place the pepper under a broiler (gas or electric) set to high, rotating it as necessary. Once the skin is burnt on most sides of the pepper, remove the pepper from the heat and let it rest on a cutting board until it's cool enough to handle.*



*Using a cloth or paper towel, wipe off the burnt skin and discard it. Dice the pepper (discarding the seeds, ribbing, and top) and place it into a bowl.*

- *Try other fillings, such as pesto sauce or a mixture of sage, dried fruits (cranberries, cherries, apricots), and nuts (pecans, walnuts).*

- *In the United States, cooking guidelines used to call for cooking pork to 165°F / 74°C to eliminate the risk of trichinosis. Trichinosis has been eradicated from the animal population, however, and in 2011 the USDA's cooking guidelines were lowered to 145°F for whole cuts of meat (let the pork rest for 3 minutes before carving or eating it). If you live elsewhere, guidelines may still say to cook to 160°F / 71°C, based on trichinosis prevalence.*
- *As an experiment, try doing a brined versus unbrined pork chop cook-off: does brining change the weight loss during cooking? Using a gram scale, weigh a pork chop pre-brining, post-brining, and after cooking, and compare the percentage weight loss to that of a "control" pork chop that is cooked without having been brined. You may also want to test how brining changes the flavor. If you're cooking for others, enlist them as tasters. Cook both brined and unbrined pork chops, serve a portion of each to everyone, and see what preferences your tasters have.*

## Pan-Seared Mussels with Butter and Shallots

Mussels, sprinkled with copious amounts of sea salt and dipped in butter, taste amazing. Heat a cast iron pan until it's screaming hot; while it's heating, rinse about **1 pound (~500g) mussels**, discarding any broken or open ones. Drop the mussels in the hot pan. Three minutes later, they'll have opened up and cooked; sprinkle them with a **generous spoonful of coarse sea salt** and **one diced shallot**; if you like spicy food, try adding a diced serrano pepper as well. Briefly toss the ingredients to mix and then remove them from the heat. Serve the mussels directly in the pan, using forks and your fingers. Set out a small

bowl of **melted butter** for dipping and a larger bowl for discarding the shells as you eat.





## Sweet

As with salt, we're hardwired to like sweet foods. Sweet tastes signal quickly digestible calories and thus fast energy, which would have been more important in the days when picking up the groceries also involved picking up a spear. Just as the taste of saltiness tempts us to eat biologically necessary salt, the taste of sweetness entices us to eat life-sustaining, energy-rich foods. Our desire for sweetness changes over our lifespan, decreasing as we mature. A child's

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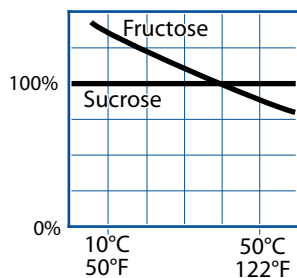
Cats can't taste sugar! Different animals have evolved to have different taste receptors based on their diets. Most pure carnivores—cats included—don't ingest carbs as part of their natural diets and appear to have no sweet detectors.

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preference for sweet things is biologically related to the physical process of bone growth. (Quick, kids, run and tell your parents that your sweet tooth is because of *biology!*)

The taste cell receptors that trigger "sweet" messages are more complicated than their salty counterparts—not surprising given the difference in complexity between a single sodium ion and the compounds that our bodies can pull apart for energy. For a

compound to register as sweet, it has to be able to latch onto two external points on the taste receptor cells that measure sweetness. To do this, the compound has to be shaped such that it can connect to both points *and* it has to have the right chemical structure to chemically bind at those two points. It's a remarkably specific "lock" that matches only a few dozen common natural "keys"—almost always various types of sugars.



*Compared to sucrose, fructose becomes less sweet as it gets warmer—using it makes sense in cold beverages!*

Subtle differences in how well compounds fit into the receptor cell's "lock" influence how sweet various compounds taste. Common table sugar (sucrose) fits relatively well, while the sugars in milk (lactose) aren't as adept and thus register as less sweet. The sugar fructose, common in fruits, tastes even sweeter than sucrose at room temperature, but as an excellent example of how complicated chemistry and biology can be, the sweetness of fructose decreases with temperature. The shape of a fructose molecule changes as it heats up, altering its ability to bind to sweet receptors. (For the chemistry geeks: fructose has a few heat-related *tautomers*—structural variations where a hydrogen atom moves over a spot, swapping the order of adjacent single and double bonds—and the tautomers that occur at warmer temperatures don't trigger the receptor cells in the same way.)

How we perceive sweetness also depends on how easily a compound binds to the taste receptors and how long it stays bound. Common table sugar, sucrose, makes only a weak connection to the receptor, which is why its onset is slow and it takes us a second or two to register "sweet!" when we taste it. Sucrose has a pleasant lingering taste, even at very high concentrations. On the other hand, fructose binds very quickly to our sweet taste receptors, but also washes away quickly. You'll find various forms of sweeteners have different taste sensations, ramping up and lingering for different lengths of time. With tasting, it's not just how strong a sensation is, but how we perceive it over time.

Compounds other than sugar can fit into the sweet receptor's detector. Lead, in the form of lead acetate, tastes sweet, as the ancient Romans unwittingly discovered. A few proteins, such as monellin, also taste sweet, and can act as sugar substitutes because of how easily they activate our sweet receptors. Sugar substitutes—both those that are synthetically created and those that are selectively extracted from plants—are selected to bind exceedingly well to taste receptors, analogous to examining the lock and designing as perfect a key for it as possible. Stevioside, the family of compounds in the stevia plant responsible for its sweetness, triggers sweetness perception at a dilution 300 to 600 times weaker than we need to detect sucrose; aspartame, a synthetic sweetener, is slightly less potent, noticeable at a concentration 150 to 200 times weaker than sucrose.

The efficacy of sugar substitutes as a weight-control mechanism isn't as clear-cut as you might think. Recent research is finding that diet sodas lead to *more* weight gain, although why this is the case is unknown. Possibly our bodies store fat based in part on the sensation of sweetness and not just calories in, or the specific artificial sweeteners may impact our gut bacteria and change how we handle food.

Sugar substitutes can also taste bitter at larger concentrations because of slight similarities between how bitter receptors and sweet receptors work. Some of the bitter receptors accept “twisted,” nonplanar versions of the sugar substitute compounds—a key that fits one lock can potentially fit other locks! This fit issue is one reason why candies that rely on sugar (sucrose) for volume can't be made with sugar substitutes. Table sugar, as a cooking ingredient, is used for more than its sweet taste: it can bind water, cause and aid in browning reactions, ferment, and crystallize—it's remarkable how many different roles one simple molecule can fill, so it's no surprise that more complicated molecules have even more quirks!

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The politics of sugar are complicated. Have you ever noticed that nutritional labels on foods in the US give a “percent daily value” for everything except sugar? The World Health Organization says to limit free sugars to 10% of your caloric intake and suggests 5% is ideal.

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- Tips**
- In a recipe that calls for a specific type of sugar—say, corn syrup—it's often included for functional reasons, not taste. Corn syrup (100% glucose) inhibits crystal formation, which produces gritty textures, and this is why caramel candies and ice cream bases sometimes call for it.
  - Modern brown sugar is made from white sugar with molasses added in, at about a 10:1 ratio. If you're cooking and are out of brown sugar, mix in about 2 tablespoons (30 mL) molasses per cup (200g) of sugar (more for darker brown sugar).
  - When making sugar syrups for sweetening drinks like iced tea, be mindful of heat. Table sugar in water, when heated and simmered, will break down into fructose and glucose, which taste less sweet. A sugar syrup heated only briefly until the sugar is fully dissolved will taste sweeter than the same syrup heated and simmered.

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**To make something sweeter**

- Add sugar, honey, or other sweeteners (see page 63); reduce sour or bitter ingredients.

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**If a dish is too sweet**

- Increase sourness (e.g., add lemon juice or vinegar) or spiciness (e.g., add cayenne pepper).
  - For culinary experimentalists, use a sweetness inhibitor (see page 393).
-

## Simple Ginger Syrup

*Sugar is good at simultaneously promoting other flavors while masking sour and bitter tastes, as this simple ginger syrup shows. Sugar moderates ginger's strong, pungent, and slightly sour taste.*

In a pot, bring to a boil and then simmer on low heat:

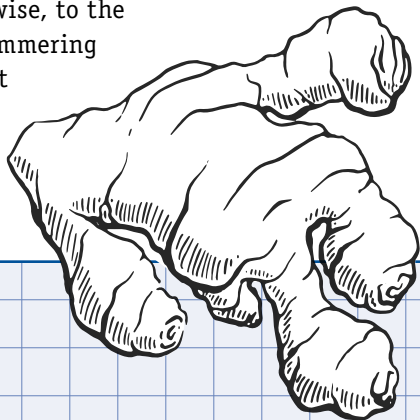
**2 cups (480 mL) water**

**½ cup (100g) sugar**

**⅔ cup (64g) raw ginger, finely chopped or minced**

Simmer mixture for 30 minutes, let it cool, and then strain it into a bottle or container, discarding the strained-out ginger pieces.

Besides adding it to carbonated water for a simple ginger soda, try using this syrup on top of pancakes or waffles. Adding a vanilla bean, split lengthwise, to the mix while simmering it will impart a richer flavor.

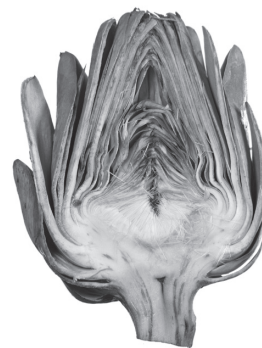


## How to Cook an Artichoke

To the uninitiated, artichokes are a culinary puzzle because they're unlike anything else we eat. (What other food do we eat that's the unbloomed bud of a flower?) They also cause taste perversion, in their case changing how sweet things taste.

One normally eats *artichoke petals* by plucking a petal off the cooked bud; dipping it in a sauce, melted butter, or infused oil (see page 401); and then scraping the flesh off the base of the petal using the front teeth. The easiest way to cook an artichoke is in the microwave: cut the stem off, slice the top inch (~2 cm) off, rinse it to get it wet, and then microwave it for 6–8 minutes (longer for larger or multiple artichokes).

*Artichoke hearts*—the centers of the flowers—are great on pizza, in salads, or simply roasted. To prepare, cut off the bottom and top of the artichoke, tear off the dark petals, trim away any remaining green parts, and scoop out the center cavity. Squirt some lemon juice on it to prevent discoloration. The heart is the white fleshy base of the bud. The first time one friend of mine tried to follow less-precise directions, he was left with nothing after trimming away everything.



## Taste Perversion with Artichokes and Miracle Berries



Our taste buds are chemical detectors full of receptor cells waiting for the right chemical to come along and trigger them, like locks waiting for the right key to open them. But what if something were able to pick those locks?

*Taste perversion* occurs when a compound temporarily changes the way your tongue tastes other foods. Artichokes, for example, have two compounds, cynarin and chlorogenic acid, that cause foods eaten shortly afterward to taste slightly sweeter. Try steaming a fresh artichoke and eating the leaves without sauce, and then sipping some water; you should notice the water tasting mildly sweet. (This is also why pairing wine with artichoke is difficult!)

There's another compound in food, miraculin, that's an even better example of taste perversion. Miraculin binds to sweet receptors and activates them when acidic compounds wander along (the effect starts in solutions with a pH of 6.5 and increases down to a pH of 4.8), thus causing foods that would normally taste sour (due to the acidic pH) to taste sweet.

The miracle fruit plant produces a small red berry, aptly named the miracle berry, that contains a large concentration of miraculin. Chewing the berry flesh for a few minutes exposes you to enough miraculin that subsequently chomping down on a lemon will yield the taste of lemonade.

The phenomenon was first observed in 1725 in Western Africa, where locals were using it to "sweeten" their experience of sour beer. In 1852, the "miraculous" berry made its first appearance

in the medical journals; more modern work has focused on potential use for diabetics. The last few decades have seen several attempts to use miraculin as a food additive, but food additives fall under different regulatory requirements (see page 376) than "plain old fruits" and miraculin has yet to clear those hurdles.

Fortunately, you can order the berries online; unfortunately, they're perishable. Dried tablets derived from the berry are also available and easier to experiment with. (For sources, see <http://cookingforgeeks.com/book/miraculin/>.) Once you have the berries or tablets in hand, invite a bunch of your friends over, munch on the miraculin, and serve up some sour foods. Plain yogurt works well, as do slices of grapefruit, lemon, and lime.

This "flavor tripping" experience isn't limited to sour foods. I've had one friend swear that the roast beef sandwich he was eating was made with a honey-glazed variety, while other friends tried Worcestershire sauce and compared it to sashimi. Try foods such as salsas, tomatoes, apple cider vinegar, radishes, parsley, stout beers, hot sauces, and cheeses. Keep in mind that miraculin makes sour foods *taste* sweet but doesn't actually alter their pH, so don't pig out on lemons, lest you give yourself a bad case of heartburn.

Miraculin, while fun to experience, ends up not being practical as a broad sugar substitute in its usual form: it'll stick around on your tongue for up to an hour, meaning other foods eaten after it will also be affected. There is some work being done to try to add proteins similar to miraculin into grain crops—imagine cereal grains that taste sweet but don't have extra sugar (see US Patent #5,326,580—*mmm, noncarbohydrate sweeteners*), but who knows where that'll go and if consumers will accept it.

## Sour

Sour, tart tastes are caused by acidic compounds in foods, and as with sweet and salty tastes, we're hardwired from birth to react to them. Similar to how we taste salt, the sensation of sourness is detected via ion channels located on sour taste receptors that interact with an acidic compound's hydrogen ions. Quite literally, your sour taste receptors are primitive chemical acidity detectors. Hydrogen ions trigger sour taste receptors; the more taste buds that are firing, the more sour a food will taste.

Humans are unique in our enjoyment of sour foods. Like bitter tastes, sour tastes are an indicator of potentially dangerous foods; in this case the aversion prevents us from consuming spoiled items. How we came to enjoy sour tastes is a small biological mystery. Somewhere in our past we lost the ability to synthesize vitamin C, likely from regular consumption of fruits high in it; one theory for our learned desire to eat sour foods centers on ensuring that we ingest enough vitamin C to avoid diseases like scurvy.

Regardless of why, we learn to enjoy sour tastes as we mature. Some items—mostly fruits—are naturally sour due to their chemistry. Ascorbic and citric acids in citrus fruits like lemons make them unbearably tart, a reasonable defense against any herbivore that doesn't know how to cook. Malic acid, common in apples, gives them a delicious tartness. Other foods become sour from spoilage: yogurt, vinegar, fermented pickles, kimchi, and sourdough bread all rely on fermentation, which generates deliciously spoiled food along with sour-tasting acids like lactic acid and acetic acid.

Of course, there are exceptions and complications to the "acids taste sour" rule. Acids are compounds that can lend out a hydrogen ion, but other regions of a compound may be able to match other taste receptors. Glutamic acid tastes savory; picric acid is bitter. And how quickly we detect sourness can vary by the type of acid, similar to how some sugars are quickly detected while others take time to register. Sour-tasting items can have different onset times and linger for varying durations, based on the chemistry of the ingredients. Citric acid is very quickly detected, giving a quick burst of sour flavor; malic acid, however, has a slow onset and lingers. Food manufacturers use this to clever effect, combining multiple acids to generate a sour taste profile that has the desired intensity over time.

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**Tips** • Taste dishes toward the end of cooking and check the balance of both saltiness and sourness, adding an ingredient such as lemon juice or vinegar to "brighten up" the flavors.

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**To make something sourer** • Add lemon juice, vinegar, or sour-tasting ingredients (see page 63).

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**If a dish is too sour** • Increase sweetness to mask.

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## Homemade Yogurt

*Yogurt is good milk “gone bad” with good bacteria. The bacteria *Streptococcus thermophiles* and *Lactobacillus bulgaricus* turn milk into yogurt by consuming lactose sugars and creating lactic acid, giving yogurt its characteristic sour, tart taste. Of course, if you add enough sugar (e.g., honey or jam) or salt (say, for marinades—see page 74), you’ll mask the sourness. The lactic acid also lowers the pH, causing the yogurt to thicken by denaturing the milk proteins.*

In a pan (or, preferably, a double-boiler), gently heat:

**2 cups (~500mL) milk (any type other than lactose-free, as the bacteria need lactose—if you like, try goat’s or sheep’s milk, if you can get it)**

Bring the milk up to 200°F / 93.3°C using a digital thermometer. Do not boil the milk, as that will affect the yogurt’s flavor.

Transfer the milk to a thermos or insulated container, and wait until it cools to 115°F / 46°C. Add **2 tablespoons (30g) plain yogurt** and stir to combine. Make sure the yogurt you use lists “active cultures” as an ingredient; this means the yogurt has living good bacteria in it. Adding the yogurt provides the necessary bacteria, so don’t add it before the milk cools; otherwise, you’ll cook the bacteria!

Cover the container and incubate the liquid for 4–7 hours. Transfer it to a storage container and store it in the fridge.

### Notes

- *Try adding honey or jam to the hot milk before inoculation to take the tart edge off the finished product (sweet helps mask sour). Many cultures use yogurt as a savory ingredient—as a garnish on top of a soup, as a marinade, or as the base for a sauce on top of meats and fish (see page 28).*
- *This recipe sterilizes the milk (pasteurized milk can still have a low level of bacteria) and keeps the incubation period short to reduce the*

*chance of growth of foodborne illness–related bacteria. As with anything you eat, keep in mind that if it tastes bad, smells off, or looks up at you and cracks a joke, you probably shouldn’t eat it. (The inverse is, sadly, not true: just because something smells fine doesn’t mean it’s necessarily safe.) If you’re comfortable with some risk in your food, longer incubations will give you a stronger, more developed flavor. Traditional recipes simply leave the milk out, covered, overnight to ferment.*

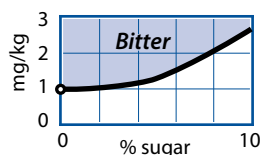
- *Traditional yogurts tend to be thin and runny, which might not be to your liking. For Greek-style thick yogurt, place the yogurt in a strainer over a bowl and let it drip-strain overnight in the fridge. Or, if you like, experiment with adding thickeners like pectin, agar, or gelatin (see page 408. For a richer yogurt, try replacing ½ cup (120 mL) of the milk with cream before heating it. For additional yogurt-making tips, see <http://cookingforgeeks.com/book/yogurt/>.*



*Make an impromptu “bain-marie” (double-boiler) by placing a metal bowl in a sauté pan and wedging a spoon under one side of the bowl to allow water to circulate underneath.*

## Bitter

Like sour, the taste of bitter evolved from a biological necessity to avoid dangerous foods, generally toxic plants. Unlike sour, bitter has much more complicated detection mechanisms. It's estimated that there are around 35 different types of receptor cells for tasting bitter compounds, with each type fitting different chemical “keys” in the lock-and-key metaphor. We detect all of these different signals as “bitter!” because the different receptor cells connect to a common nerve fiber.



*In plain water, bitter limonin can be tasted at 1 mg/kg (or higher concentrations); it takes almost three times as much when mixed into a 10% sugar solution (Guadagni, 1973).*

The taste of bitter is unusual in that we learn to enjoy it. We know bitterness is a learned preference—different cultures have different preferences for it, with Americans and the British placing less emphasis on it than other cultures—but whether we learn to like bitter flavors because of exposure effects or social conditioning is an open question. It is clear that we don't like bitter foods at the start of our lives. This “learning to like” is why bitter foods are unappealing to kids: they haven't learned to tolerate, let alone enjoy, the sensation of bitterness. Dandelion greens, rhubarb, and undercooked artichoke leaves all contain bitter-tasting compounds. Not surprisingly, I couldn't stand those things as a kid; as I've gotten older, I've come to enjoy the bitterness of something like dandelion greens in a salad.

Bitter can also be a confusing taste. A surprising number of people confuse bitter and sour tastes for each other—around one in eight English-speaking people incorrectly describe citric acid in water as tasting bitter, not sour. Coffee is commonly described as bitter, but it can also be quite acidic, giving it a sour taste in addition to its stronger bitter taste. Bitterness seems to lend itself exceedingly well to other drinks besides coffee: black tea, hops (used in making beer), and kola nuts (kola as in cola as in soft drinks) are all bitter. Like all bitter foods, they're still delicious—if you've learned to like them!

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- Tips**
- Genetic differences in bitter taste sensations change preferences for sweet items, especially in children. When serving others, remember that we don't all experience the same “taste landscape” and that differences in food upbringing change how much bitterness an eater will enjoy.
  - Salty and sweet tastes mask bitterness. Try a simple “bitter taste test” using modern tonic water, which uses quinine as a bittering agent and is easy to get at the grocery store. (Look for one free of any sweetener.) Pour tonic water into two drinking glasses. In one, add enough salt to neutralize the taste. Compare the taste of the tonic water in the two glasses.

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### To make something bitterer

- It's telling that, unlike with all the other tastes, we don't have a standard seasoning to make things more bitter! Use a bitter ingredient such as bitter greens or cocoa (see page 63).

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### If a dish is too bitter

- Increase saltiness or sweetness to mask. A pinch of salt in a salad that contains bitter items such as dandelion greens helps balance the flavor.
  - Try adding a fatty ingredient. Some studies show that moderate levels of fat reduce the sensation of bitterness without impacting other tastes.
-

## Frisée Salad with Poached Eggs and Lardons

Frisée—also called curly endive—is a bitter leafy green that's often used in a salad with poached eggs and lardons, known to the French as Salade Lyonnaise. The fat of the lardons—essentially, bacon bits—and egg yolk moderates the bitterness of the frisée. Try tasting some of the plain frisée leaves after eating the salad to notice the difference! This recipe makes two appetizer-portion salads.

Wash **1 head of frisée, about ⅓ pound (~150g)**, and cut the base off so that the leaves are separated. Either use a salad spinner or pat the leaves dry using a towel, and then transfer the leaves to a large mixing bowl. Tear any larger leaves into a few pieces.

Create the lardons using either **thick slices from pork belly** or **2–3 slices (80–120g) of thick-cut bacon**, cut into large cubes. (If using salted pork belly, you'll want to briefly boil the meat to remove some of the salt.) Place the meat into a frying pan set to medium-low heat and cook the lardons, flipping them occasionally. Once the lardons are nicely browned, turn the heat off and transfer them to the mixing bowl, leaving the rendered fat behind.

Create a vinaigrette by transferring **2 tablespoons (30 mL) rendered pork fat** from the frying pan into a small mixing bowl or measuring cup. Add **2 tablespoons (20g) diced shallot**, **1 tablespoon (15 mL) olive oil**, **1 tablespoon (15 mL) white vinegar** (use champagne vinegar or sherry vinegar, if you have it), and **1 teaspoon (5g) Dijon mustard**. Add **salt** and **pepper** to taste.

If you like, create some croutons in the pan, using the remaining rendered fat. Place **2 slices of bread** cut into  $\frac{1}{2}$ " / 1 cm cubes over medium heat, shaking the pan as necessary to jostle the bread as it toasts. Transfer the croutons to the mixing bowl when done.

Drizzle the vinaigrette over the leaves in the mixing bowl, tossing the leaves, lardons, and optional croutons.

Poach **two eggs** (see page 193 for directions). To serve, place a portion of the frisée salad on a plate and then set a poached egg on top.



## Broiled Belgian Endive

Quarter **an endive** down the center to get four identical wedges and place them on a baking sheet or oven-safe pan. Sprinkle them with a small amount of **sugar** and drizzle a small amount of **melted butter** or **olive oil** on top.



Transfer the tray to a grill or place it under a broiler for a few minutes, until the endive becomes slightly soft and the edges of the leaves begin to turn brown.

Serve with blue cheese or use the endive as a vegetable accompaniment to stronger-flavored fish.



## Savory, a.k.a. Umami

Savory tastes, sometimes called *umami*, generate lip-smacking sensations that are the hallmark of rich foods. Pizza, meats, and hard aged cheeses like Parmesan tend to be high in savory-tasting compounds, as are good broths, mushrooms, and tomatoes. While savory tastes are less discussed in Western cuisine than the four tastes described so far, they are foundational to Japanese cuisine. Savory taste receptors were only recently discovered; in 2002, researchers found a mechanism for these that has similarities to how sweet receptors work, ending any arguments that savory/umami is not a true taste.

The Japanese emphasis on savory tastes is a fascinating quirk of geography, climate, and the resulting edible plants. Japanese cuisine is the only one to make consistent, extensive use of

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Unable to conjure a memory of a savory taste? Make a simple broth by rehydrating a tablespoon of dried shiitake mushrooms in 1 cup (240 mL) of boiling water. Let the mushrooms steep for 15 minutes. Taste the liquid; it will have a high level of glutamic acid from the mushrooms. (Alternatively, you can dissolve a small amount of MSG in a glass of water, but it'll also taste salty from the sodium.)

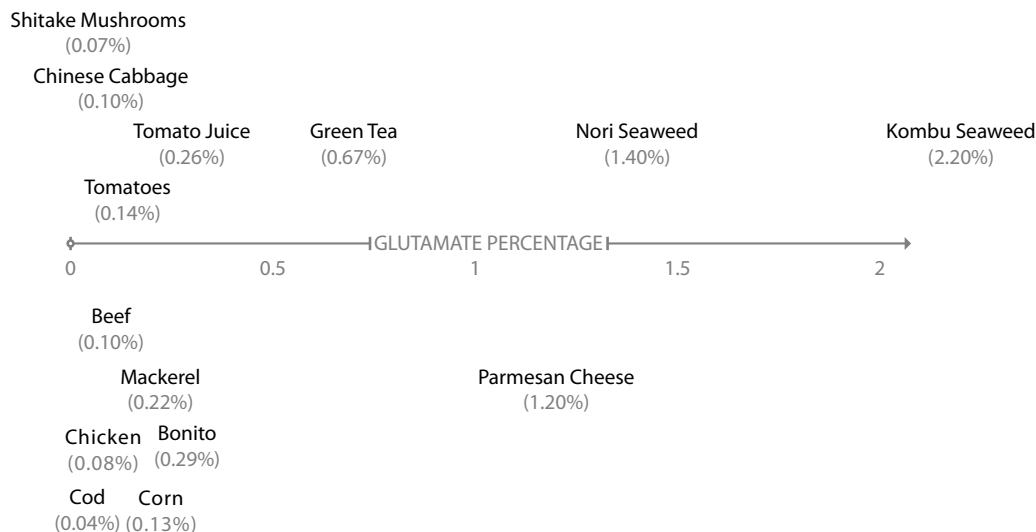
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seaweed, and seaweed happens to be very high in the chemical compound glutamate. It's this compound, in the form of glutamic acid, that was first identified by a Japanese chemist, Kikunae Ikeda, in 1908. He initially used the Japanese word for delicious, *umai*, to describe how it increases the sensation of other tastes, suggesting *umami* and then "glutamic taste" as a name for the sensation. While others had described the taste sensation before—the French foodie Jean Anthelme Brillat-Savarin mused about it almost a century earlier when he wrote about *osmazome*—it was Ikeda who successfully isolated and commercialized it.

To an average Western palate, savory tastes are subtler than the four primary Western tastes. This isn't surprising, because only a few of the everyday ingredients used in Western cooking have tastants that trigger the savory sensation. Sauces like ketchup and fish sauce (used by the ancient Romans) are typical sources for savory flavors; adopted items like soy sauce are also common. (Modern ketchup is a taste miracle: sweet, salty, savory, and even a little sour, but not bitter—no wonder kids love it!)

From a biological perspective, savory receptors on the tongue sense nucleotides and amino acids such as glutamate. Glutamate—the same glutamate in monosodium glutamate (MSG)—is the most common compound that triggers savory taste. While Ikeda initially described the taste sensation as being glutamate-sensing, it's actually a broader phenomenon. Inosinate, guanylate, and aspartate are also naturally common in ingredients. Pragmatically speaking, though, the easiest way to add a savory taste is to use ingredients high in free glutamate. (Free glutamate can dissolve away from the food in order to bind with the receptors on your tongue; bound glutamate isn't easily detected.)

Why do we sense compounds like glutamate? Unlike with other tastes, we don't have a biological predisposition for savory sensations, although we do gravitate toward them. Presumably there was an evolutionary advantage to ensuring we ate protein-rich foods,



*Free glutamate content of common ingredients.*

as they provide necessary amino acids to build and repair muscle tissue. The very first thing many of us taste in life—human breast milk—is surprisingly high in glutamate. Just as sweetness and saltiness are associated with positive attributes of food (quick energy in the case of sweet and an element essential for regulating blood pressure in the case of saltiness), our craving for savory tastes ensures we ingest enough amino acids. Regardless, the savory taste is worth understanding for its hedonistic value.

There are plenty of natural sources of glutamate. The British and Australian fondness for vegemite is due to its savory kick. Many traditional Japanese dishes call for *dashi*, a stock made from ingredients high in natural glutamate, such as kombu seaweed (2.2% glutamate by weight). Making dashi is easy: in a pot, place 3 cups (720 mL) cold water and a 6" / 15 cm strip of kombu (dried kelp), and let the mixture rest for 10 minutes. Bring it to a boil slowly on low heat. Remove the kombu just before the water begins to boil and add 10g of bonito flakes (flakes of dried and smoked bonito fish). Bring the water to a boil, remove it from the heat, and strain out the bonito flakes. This liquid is dashi. To make miso soup, add miso paste, diced tofu, and (optionally) sliced green onions, nori, or *wakame* (an edible seaweed).

Glutamate occurs naturally in many other foods—for example, beef (0.1%) and cabbage (0.1%). And if you're like most geeks and pizza makes your mouth water, it might be because of the glutamate in the ingredients: Parmesan cheese (1.2%), tomatoes (0.14%), and mushrooms (0.07%). Besides using ingredients naturally high in glutamate compounds, you can add glutamate directly to food by using MSG. MSG is to savoriness as sugar is to sweetness: as a chemical, it's mostly odorless (still full of taste!), but it triggers the receptors on the tongue.

Increasing the sensation of savoriness has an ancillary benefit: it amplifies our other senses of taste. Savoriness increases the sensation of salty and sweet compounds, meaning that you can cut the amount of salt in a dish by adding savory-tasting ingredients or using MSG. (If using MSG, you should reduce salt regardless because it dissolves and disassociates into a sodium ion and glutamate, with the sodium ion increasing the salty taste.)

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Sensitivity to monosodium glutamate, called *MSG symptom complex* by the medical community, has been found to temporarily affect around 1 to 2% of people. Intolerant individuals, given 3 grams of MSG without any other food, may experience short-term symptoms like headaches, numbness, or flushing about an hour later. Amounts of MSG added to foods don't generally exceed 0.5 grams, and double-blind controlled studies with placebos cast plenty of doubt on individuals who claim sensitivity.

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- Tips**
- For vegetable dishes and vegetarian cooking, add ingredients high in glutamate to improve overall flavor.

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- To make something more savory**
- Use savory ingredients such as corn, peas, tomatoes, Parmesan cheese, or soy sauce.
  - Use cooking techniques that increase savory compounds (e.g., curing and fermenting foods like bacon, soy sauce, and fish sauce increases their glutamate levels).
  - Add MSG, depending on how you feel about it. (The “Chinese restaurant syndrome” of MSG causing an allergic reaction is entirely placebo—no controlled study has ever replicated it—but placebo effects can be strong!)

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- If a dish is too savory**
- No good counteraction; try dilution.
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## Edamame

Japanese for “beans on branches,” *edamame*—young soybeans that have been steamed and sometimes lightly salted—is a great savory appetizer before a meal. Popping the seeds out of the pods is an enjoyable slow start to dinner. Edamame are traditionally sold still on the vine (look for them that way in an Asian food market), but for most of us they're more easily found in the freezer section at well-stocked grocery stores.

To prepare them, either drop the **edamame** into **salted boiling water** and cook for 2–5 minutes, or steam them in a microwave, using a covered container with **¼ cup (~60 mL) water**, for 2–5 minutes. Sprinkle them with **salt** before serving. Try sautéing the shelled beans in **olive oil** with **crushed garlic and soy sauce**.

## Spicy/Hot, Cooling, and Other Taste Sensations

In addition to the primary sensations of taste, our taste buds also register a set of sensations related to the chemical properties of some foods that with exposure we learn to enjoy. In culinary applications, *chemesthesis*—sensations caused by chemical compounds—contributes to the taste of everything from hot peppers to pungent garlic to cooling menthol candies.

Spicy hot sensations are the most common form of culinary chemesthesis. Compounds such as capsaicin in hot peppers both irritate cells and trigger the same mechanism used to detect hot temperatures, using a neurotransmitter called *substance P* (*P* is for *pain*; go figure). In one of nature's quirkier moves, substance P is slowly depleted as it is used and takes time—many days, possibly weeks—to replenish. This means that if you eat hot foods often enough, you will build up a tolerance for hotter and hotter foods as your ability to detect the presence of compounds like capsaicin decreases. Because of this, asking someone else if a dish is spicy won't always tell you if it's safe to jump in; he or she may be a regular eater of spicy foods. Also, as you expose yourself to spicy food, you'll need more and more of the ingredients that bring the heat to get the same level of sensation.

Spicy pungent sensations can be triggered without tripping the hot temperature mechanism. Garlic, wasabi, and mustard can all cause a smarting, mind-searing reaction, as do some stinky French cheeses that have sharp, caustic qualities. Szechuan (also known as Sichuan) peppers, used in Asian cooking, and Melegueta peppers, used in Africa, cause a mild pungent as well as a numbing sensation.

Chemesthesis includes a number of other sensations besides spicy hot and pungent. Peppermint candies get their cooling effect from the chemical menthol, which occurs naturally in mint oils from plants such as peppermint. Menthol activates the same nerve pathways that cold temperatures do, which is why chewing mint gum or eating mint candies can cause a tingling cold reaction.

Our mouths capture data for other aspects of oral irritation, too. *Astringency*, a drying, puckering reaction, occurs when certain compounds (normally polyphenols) dry the mouth out, possibly by binding to proteins in saliva that normally provide lubrication. Astringent foods include persimmon, some teas, certain unripe fruits, and lower-quality pomegranate juices (the bark and pulp are astringent). Carbonated beverages also cause cellular irritation, partly masking other taste sensations at the same time. Try sipping on some bottled seltzer water

Spilanthalol, the active ingredient in the edible flower Szechuan buttons (also known as sansho buttons, buzz buttons, or electric buttons and unrelated to Szechuan peppers), triggers receptors that cause a numbing, tingling sensation. The "buttons" are actually the flowers of the *Acmella oleracea* plant. The tingling reaction is like licking the terminals on a nine-volt battery—a curious sensation, should you be up for splurging on an online purchase.



and then “de-fizzing” it (screw the cap back on, shake the bottle, and carefully unscrew the lid to slowly vent the gas). Depending upon the brand, you may be shocked at how salty the flat water will taste. (Carbonation also interacts with an enzyme, carbonic anhydrase 4, to activate our sour taste receptors, but for now it’s unclear why it doesn’t actually taste sour to us.) Sour foods can also trigger oral irritation, although much less noticeably so than many of the other taste sensations involved in chemesthesis.

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Most European cultures don’t consider spicy/hot to be a primary taste; other cultures, like the Thai, do, and Ayurvedic medicinal practices on the Indian subcontinent define “warm” as part of basic food prescriptions. Why the difference? One theory suggests genetic differences in taste receptors between Europeans and natives of other regions. (More taste receptor cells = more cells that can be irritated.)

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- Tips**
- Spicy foods decrease the perception of sweetness and saltiness; they can increase the ability to detect some odors while decreasing others.

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**To make something spicier**

- Use hot ingredients such as cayenne pepper (capsaicin) or black pepper (slightly pungent due to the compound piperine).

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**If a dish is too spicy**

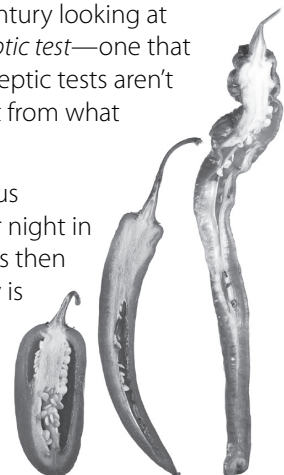
- Capsaicin is a nonpolar molecule (see page 59), which is why sugary and fatty ingredients are better able to partly neutralize it while drinking water does little to reduce the burning sensation. Dairy works well, for multiple reasons: casein proteins bind to capsaicin and lactose sugars help dissolve capsaicin into solution. If a dish is too hot, ideally add dairy; otherwise, add something with sugars or fats to reduce the heat.
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## DIY Scoville Scale

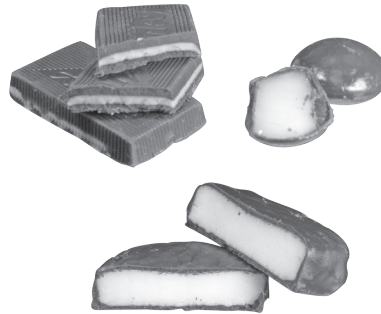
Wilber Scoville, an American pharmacist, spent a lot of time at the turn of the 20th century looking at how to extract compounds from plants. His most famous contribution is an *organoleptic test*—one that relies on the senses—for measuring the amount of capsaicin in hot peppers. Organoleptic tests aren’t particularly accurate (what one person senses will be different over time and different from what others sense), but they do have the advantage that you can do them at home.

Scoville’s method, first published in 1911, is easy, relying on dried powders from various peppers (a.k.a. capsicum): “One grain [64.8 mg] of ground capsicum is macerated over night in 100 cc. of alcohol [78.9g], and after thorough shaking, filtered. This alcoholic solution is then added to sweetened water in definite proportions until a distinct but weak pungency is perceptible on the tongue.” He doesn’t specify how much sugar to use in “sweetened water,” but 10% sugar to water is a reasonable start, should you wish to try it; for alcohol, use a neutral grain alcohol like vodka. To determine the Scoville score for a pepper, calculate how diluted the ground capsicum is in the just detectably hot solution. Use a few varieties of hot peppers so you can do relative comparisons!



## Peppermint Chocolate Mints

*Junior Mints, Peppermint Patties, Andes, After Eight—the abundance of candies that are sugar and menthol coated in chocolate is proof enough of the popularity of the cooling sensation of menthol. Try making your own, using high-quality chocolate.*



In a mixing bowl, measure out and mix until the ingredients become a consistent, thick paste:

- 1 cup (120g) powdered sugar**
- 1 tablespoon (15g) room-temperature butter**
- 2 teaspoons (10 mL) milk or corn syrup (use corn syrup if you want a more syrupy, less brittle center)**
- 2 teaspoons (10 mL) peppermint extract**
- 1 teaspoon (5g) granulated sugar**

Next, form the paste into whatever shapes you'd like your mints to take. There are a number of ways to do this. The easiest is to roll them into small balls (like Junior Mint candies); you can also form a log with the paste and slice off round discs. Once you have the shapes, let them rest on the counter for an hour or two to partly dry, or store them in the freezer for 30 minutes to firm up.

In a second bowl, melt **4–8 ounces (110–220g) dark, bittersweet chocolate**, following the directions for tempering (see page 157). If you don't mind cheating, use chocolate candy coating instead, which has different fats instead of cocoa fat and doesn't need to be tempered.

Using a fork (a plastic one with the center tines snapped off works well), dip the peppermint into the chocolate, flipping each candy to coat it, and then lightly tap the fork up and down on the edge of the bowl to thin the coating. Transfer the candies to a plate or cookie sheet lined with parchment or wax paper and allow them to set at room temperature. (Setting them in the fridge or freezer won't correctly temper the chocolate!)

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Commercial manufacturers use a bunch of tricks to make candies. Take an After Eight mint, with its liquid center: the makers create the filling by mixing an enzyme, invertase, in with the sugar. Over a few days, that enzyme breaks down sugar (sucrose) into simpler sugars (fructose and glucose), which happen to be somewhat syrupy. (See page 432 for more about enzymes.) Don't expect to be able to perfectly replicate your favorite chocolate mint candy!

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## Lab: Genetic Taste Differences

What's to say you and I taste and smell everything the same way? Imagine you're cooking dinner with family or friends and get into a heated argument about the greens needing more salt. (I know, every parent's dream.) For one person it's not salty enough, while to another it's already way too salty. Or maybe you tried a chicken recipe that has cilantro (see page 28), and it tasted awful. What's going on here?

Just like genetic variations lead to different colors of eyes, there are variations in our taste buds and smell receptors. Here are three different taste experiments that you can do to see how some of your genes for taste and smell stack up. The order of these tests doesn't matter, but I suggest doing the peppermint candy one last as a way of finishing with a pleasant taste.

### First, grab these supplies:

<i>Test 1</i>	A few leaves of cilantro	
<i>Test 2</i>	<i>Either:</i> PTC/PROP test strips (search online for "supertaster test paper" or see <a href="http://cookingforgeeks.com/book/supertaster/">http://cookingforgeeks.com/book/supertaster/</a> )	<i>Or:</i> A bottle of blue food coloring, A cotton swab or spoon, A sheet of paper punched for a three-ring binder (or other tongue-safe thing with a $\frac{5}{16}$ " / 8 mm–diameter hole), torn so that you have a small square of paper with one hole punched in it, A mirror, or a partner willing to look at your tongue
<i>Test 3</i>	A peppermint candy (e.g., Altoids or Pep-O-Mint Life Savers)—they lose potency over time, so get fresh ones!, A cup of water or mild beverage to rinse your mouth out	

### Here's what to do:

#### *Test 1: Smell of cilantro*

1. Pinch your nose, and then chew on the cilantro. Notice what your reaction is.
2. Let go of your nose, and take a breath. Take note of what odors you smell.

#### *Test 2: PTC/PROP version*

1. Place the test strip on your tongue and let it rest there for a few seconds.
2. Note what taste sensations you have. Is it strong, mild, or the pleasant sensation of wet paper?

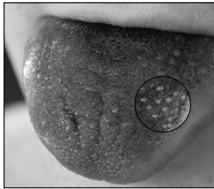
#### *Test 2: Blue food coloring version*

If you don't have test strips, you can stick your tongue out (all in the name of science, of course).

1. Place one drop of the blue food coloring on the cotton swab or spoon.
2. Stain your tongue with it. Take a sip of water to rinse some dye away.
3. Look for spots on your tongue—you should see pinkish spots surrounded by dark blue. (Those pink spots are *fungiform papillae*—little projections on the top of tongue that have taste buds—and are not stained by food coloring; it's possible to not count any.)

## Lab: Genetic Taste Differences

4. Choose the area that is densest with spots, usually the front portion of the tongue. Place the piece of paper so that you can see that spot through the hole.
5. Either using a mirror or with a partner's help, count the number of pink dots visible.



*This is what you're looking for when counting the dots on your tongue. There are about 12 dots in this example.*

### Test 3: Trigeminal sensitivity

1. Pop the fresh peppermint candy in your mouth and clamp down (no open mouths and no chewing!).
2. Wait about half a minute, giving your saliva a chance to soften up and break down the candy.
3. Chomp down on the candy *without opening your mouth*. What do you notice? Is it a strong sensation, or a mild one?
4. Take a breath through your mouth and see how the flavor changes.

### Investigation time!

What did you notice about the three tests? Any surprises? How do you think differences in taste change the way people eat? How would increased sensitivity to bitter foods change how much or the way someone seasons something?

Here are some things to keep in mind:

- About 1 in 10 people will smell cilantro differently.
- For the blue food coloring test, if you counted more than 30 papillae, you're probably a supertaster. Normal tasters tend to have between 15 and 30 papillae, while nontasters have fewer than 15, on average. About 25% of people are nontasters, 50% are normal tasters, and 25% are supertasters.
- The peppermint candy test will give you a rough sense of how sensitive you are to trigeminal stimulation. If the cooling sensation you have produces a "whoop, that's strong!" reaction, then you're likely to be very trigeminally sensitive. If you hardly notice anything, then you are likely to be mildly sensitive. Most people, however, find that the cooling effect lies between these two extremes.

### Extra credit:

Our senses can differ for reasons besides genetics: diseases can damage your senses, either temporarily or permanently. One of the quickest tests you can do for nerve damage related to taste is to wet a finger and dip it into instant coffee, preferably a really bitter espresso. Lick your finger and then swallow, paying attention to the sensations you notice. Do you sense a bitter sensation on your

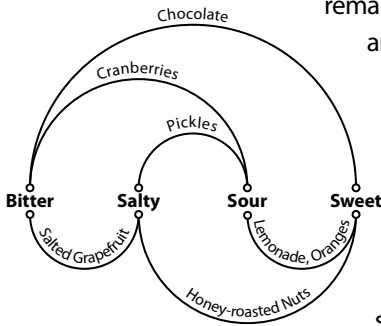
tongue, or is there a big jump in sensation as you swallow? If so, the nerve that carries signals from the front of your tongue (your chorda tympani nerve) is likely damaged, while the nerve that carries signals from the back of your tongue (your glossopharyngeal nerve) is functioning.



# Inspiration by Taste Combinations

Combinations of ingredients can change the flavors of what we eat in surprising ways. A pinch of salt can change the flavor of a dish by reducing bitterness, which in turn increases the perception of sweetness. This type of interaction is why adding an ingredient that brings taste to a dish can also bring balance and boost the sensation of desirable flavors.

Most combinations of tastes—salty + sweet, bitter + sweet—also change flavors. This is a remarkable thing! Changes in tastes, things that your tongue detects, can change aromas detected by your nose. The gustatory and olfaction systems are generally thought of as being separate, but there is overlap. Even at undetectable levels, small quantities of cayenne pepper can increase our ability to detect the aromas of seemingly unrelated items, like grape in grape jelly. Our senses are a complicated system, with the thresholds and intensities at which we register and detect a compound being changed by other compounds.



When cooking, taste the dish you're working on and ask yourself what sensations are too strong or too weak. Sometimes the fix is simple: fresh fruit that's slightly dull can be sprinkled with sugar (try this on strawberries), lightly salted (on grapefruit), or wetted with lime juice (papaya, watermelon, peaches with honey). More inspiring solutions combine ingredients with different primary tastes (sweet watermelon and salty feta cheese). Try using nontraditional taste combinations: Strawberries and black pepper? Mango salad with jalapeños and cilantro? Mixing up the basic taste combinations can be great inspiration.

Taste combinations extend beyond the classic definitions of tastes. Try experimenting with spicy/hot ingredients, pairing them with other basic tastes. Spicy + sweet? Buffalo wings! Mixing in fats can shift tastes as well, as compounds like capsaicin are fat soluble. Experiment with avocado and sriracha sauce, commonly known as *rooster sauce* for the drawing on the bottle of one popular brand. Sriracha sauce, it has been claimed, can improve any dorm food, but be forewarned: it can hit you like a freight train if you use too much!

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Adding a pinch of salt or sugar, or ¼ teaspoon (0.5g) of cayenne pepper, may not cause you to taste the food as saltier, sweeter, or hotter, but it can change the flavor! You may not notice the change when cooking, though. If you're sampling food and focused on one aspect, you will very likely miss changes to other aspects. The field of *sensory analysis*—measuring perceptions of the human senses—is fascinating and complex.

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Many foods are combinations of three or more primary tastes. Ketchup, for example, is surprisingly complex, with tastes of umami (tomatoes), sourness (vinegar), sweetness (sugar, tomatoes), and saltiness (salt). If combining tastes in a dish becomes too challenging, serve two separate components side by side, pairing one dish with a second on the basis that the two will complement each other.

## Summer Watermelon and Feta Cheese Salad

When watermelon season comes around, try this salad to experience the combination of the saltiness of feta cheese and the sweetness of watermelon.

In a bowl, toss to coat:

- 2 cups (300g) watermelon, cubed or scooped**
- ½ cup (75g) feta cheese, cut into small pieces**
- ¼ cup (40g) red onion, sliced super thin, soaked in water for a few minutes and then drained**
- 1 tablespoon (15 mL) olive oil (extra virgin because it imparts flavor)**
- ½ teaspoon (2.5 mL) balsamic vinegar**

### Note

- Try using a teaspoonful or two of lime juice, instead of vinegar, as the source of acidity. Alternatively, play with the tastes by adding black olives (salty), mint leaves (cooling), or red pepper flakes (hot), thinking about how each variation pushes the tastes in different directions.



The fast way to make watermelon cubes: use a knife to make a series of parallel slices in one direction, and then repeat for the other two axes.

Combination	Single-ingredient example	Combination example
Salty + sour	Pickles Preserved lemon peel	Salad dressings
Salty + sweet	Seaweed (slightly sweet via mannitol)	Watermelon and feta cheese Banana with sharp cheddar cheese Cantaloupe and prosciutto Chocolate-covered pretzels
Sour + sweet	Oranges	Lemon juice and sugar (e.g., lemonade) Grilled corn with lime juice
Bitter + sour	Cranberries Grapefruit (sour via citric acid; bitter via naringin)	Negroni (cocktail with gin, vermouth, Campari)
Bitter + sweet	Bitter parsley Granny Smith apples	Bittersweet chocolate Coffee/tea with sugar/honey
Bitter + salty	(N/A)	Sautéed kale with salt Mustard greens with bacon Fried bitter melon

## Linda Bartoshuk on Taste and Pleasure



Linda Bartoshuk is an American psychologist who has extensively studied how genetic differences and diseases can impact the senses of smell and taste. She is best known for her discoveries on supertasters.

### How did you find yourself studying smell and taste?

I was studying philosophy and fascinated with epistemology—how do we learn what we know? I became interested in comparing taste sensations from one person to another, which is a really interesting philosophical question. If you think about it, you and I cannot share experiences. How can I know what you experience when you taste something, or feel pain, or any kind of sensation?

### I think of indicator scales—on a scale of 1 to 10—or discrimination tests where you're given a bunch of samples and asked to rank them.

Ranking procedures give you some information, but they don't tell you what someone else is experiencing. Let me give you an example with pain. If

you're in the hospital, a nurse is going to ask you what your pain is from 1 to 10. It's a reasonable scale to find out if your pain gets better if you're given an analgesic. But does your pain relate to the person in the bed next to you? No, because you don't know what 10 is to that person. Solving that problem led to discoveries like that there are supertasters, people who taste things more intensely than others do.

### How do you compare taste differences between people, especially with something like supertasting where there are various degrees?

We ask them to compare taste to something that isn't related to taste at all. I'll give you an example. We get a bunch of people together and we look at their tongues. We can see one structure of the tongue called *fungiform papillae*; they're the larger bumps you can see on your tongue and a structure that houses taste buds. So we pick a group of people who have lots of fungiform papillae and we pick another group that have fewer. Then we put earphones on our subjects and have them match the sweetness of a soft drink to the loudness of a sound. We give them a knob to make the sound louder or softer. The people with lots of taste buds will crank that knob up to 90 decibels; the subjects with fewer taste buds will drop it down to 80 decibels. A 10-decibel difference means a doubling of loudness, so we've shown that the people with lots of fungiform papillae, and thus lots of taste buds, match the sweetness of a soft drink to a sound twice as loud. Now you might

say, "Maybe their hearing is different." Well, we don't have any reason to think that hearing is related to taste, and if we are right, on average those with the most taste buds experience twice the sweetness. To be safe, we use loudness as well as many other standards.

We know a lot about supertasters. If you're a supertaster and you taste table sugar, it'll be two to three times as sweet to you as it is to me because I am not a supertaster. I'm all the way at the other end. The metaphor I used is vision: I taste pastel and supertasters taste neon.

### Does that mean you don't enjoy food as much as supertasters?

Well, liking food is a lot more than biology. Most of it has to do with previous experience and we tend to like what we previously experienced. I don't wish I were a supertaster because I actually like the world I live in.

I love chocolate chip cookies. I can't imagine that I'd love them any more if I were a supertaster, but of course I can't tell because I can't share that experience. However, we can use our new methods to compare the pleasure people get from things. Chocolate chip cookies probably do give supertasters a little more pleasure than they give me if we're measuring it on a pleasure scale. In general, supertasters get more pleasure from their favorite foods than non-supertasters do.

### Where does pleasure associated from food come from?

We think it has to be learned. The most common belief in the field now is that

all odor affect is learned. Sometimes odor is paired with what we consider a primary affect, what we call “hardwired.” You’re born loving sugar, so you can make an odor really liked by pairing it with sugar. You can also take something like an odor of meat, the odors of things that are primarily associated with fats. The brain wants you to eat fat because you need the calories. The brain notices that the fat that it detects in the stomach came in with a particular odor. And it wants you to eat fat, so it makes you like that odor better, because that odor was paired with something it wants: fat. And that is the mechanism of a conditioned preference. This is why experimental psychology has so much to say about why we like certain foods. It’s worked out the system; there are rules to it.

### **If you wanted to have someone take greater pleasure in a food, how would you do that?**

Evaluative conditioning studies the transfer of affect from one stimulus to another. Olfaction is particularly interesting since we get so much transfer of affect with smell. You want to make somebody like a new dish? Pair the odor of that food with a really pleasant situation, like eating with somebody they really like. Later on, they’ll like the new dish more because they first had it with somebody that they liked.

This was an exam question I used to use when I was teaching a food behavior course. I’d ask the students, “You are a chemist and you’ve just invented a new odor that’s never been on the earth before.” And that’s possible. “Now, you want your new odor to be picked by the president of the company for promotion. How do

you make the president like your odor?” The answers get very creative. “Have his girlfriend wear it as a perfume.” “He likes baseball games; spray the odor on his seat when he goes to a game.” “Put it in the food he likes best.” All of these are cases of transfer of affect. You associate something neutral with something that is already liked, and that neutral stimulus becomes liked.

### **Is this why we like certain combinations of flavors?**

You can look at it from the pleasure point of view. For example, if you take duck and add orange to it, that’s a wonderful combination. Raspberry with chocolate is another pair that we tend to like. On the other hand, what if you added chocolate to duck—that doesn’t sound terribly interesting—or raspberry to orange? If you think about the pleasure of olfaction and how it is acquired, I believe there’s a structure to it that we don’t necessarily pay attention to. For example, orange is initially pleasurable because it’s paired with sweet. Duck is initially pleasurable because it’s paired with fat. Orange odor is not innately liked; you learn to like it by pairing it with sweet. And duck odor is not innately liked; you learn to like it paired with fat. Pairing odors that acquired their affect in different ways may produce more intense affect.

### **How does this tie in with combinations of tastes—tastes as in the gustatory sense?**

We know the rules of taste mixture. We know what happens if you combine sweet, salty, sour, bitter. When you add two things together that have a common taste, they add. Like sweet from saccharin and sweet from sugar; they’re going to add. But if you add

two different tastes, like sweet from sugar and bitter from quinine, they’re going to suppress each other. So the rule is whenever you add two different qualities in taste, they will mutually suppress each other. If you think about it, this may be a very nice mechanism. Think about a really complex Chinese sauce where you might use vinegar and soy sauce, put a little sugar in, and of course ginger for a nice flavor. If they added linearly, it would blow the top of your head off.

In taste, you get quite powerful mixture suppression, which keeps taste in a reasonable range. Otherwise, every time you had a complex taste, it would be much, much more intense, and that probably wouldn’t be useful since it’s more important in the world to identify different objects based on their taste. You don’t really want them to add linearly. In olfaction, it’s even worse. Think about all the different odors you can put together in a mixture. If they added up linearly, every complicated mixture would be incredibly intense and every simple smell would be weak. That isn’t how it works. In olfaction, you get suppression among the components, even more powerfully so than in taste.

### **How we perceive and react to food sounds very, very broad. There’s so much more than smell and taste in food, which makes it that much more complex.**

The love of food is an incredibly powerful force in our lives. We know a great deal about what makes people like food or dislike it. Biology plays a relatively small role because most of it is experience.

## Shopping for Flavor

Good flavor starts with quality ingredients. A perfect peach, sliced and served on a plate, can delight, but if a peach has no real smell and feels like it would be better suited for a game of baseball, there's little chance that it will be particularly appealing. Here are a few tips for shopping for flavor.

**Use all your senses.** When it comes to detecting quality, your nose, eyes, and hands are great tools. Fruits should smell fragrant, fish should have little or no smell, and meats should smell mild and perhaps a little gamey, but never bad. Melons should smell sweet, but not *too* sweet (overripe!). Color and texture are important, too; pay attention to surfaces. The way fruits like peaches and pears yield when given a firm, gentle squeeze can tell you if they're premature, ready, or goners.

**Know your ingredients.** Your senses won't always guide you. Some fruits will continue to ripen after they're picked based on the presence of ethylene gas (see page 119 for a list), which is why greenish bananas can be a fine purchase. But ripening isn't the same thing as flavor—a ripe fruit has a desired texture and sugar-to-starch ratio, but flavor compounds may still be scarce, as tomato aficionados know.

**Stagger purchases.** Smart shopping and storage can determine when fruit will be ripe. Instead of snagging one bunch of bananas, pick half a bunch that's riper and another half that's greener so as to stagger when they ripen. With ethylene-ripening fruits like bananas and peaches, you can also store some of them in a paper bag to trap ethylene gas and speed up their ripening.

**Substitute instead of compromising.** You're better off substituting something that holds the promise of packing a wallop of flavor than using a low-quality version of a specified ingredient.

**Understand seasonality.** Grocery stores have existed for about a century, and only in the past few decades has a wide variety of fresh fruit and veggies been available year-round. But different produce has different growing seasons, and off-peak produce just won't be as good. If the pile of red things labeled "tomatoes" at your grocery store were picked before they were mature, the flavor compounds won't be the delicious ones created upon maturation and the tomatoes won't have an enjoyable flavor profile. If you can't get great fresh tomatoes, you're better off with good canned ones, picked and packed at the height of tomato season—plus, canned and frozen ingredients are less likely to go to waste.

**Beware of marketing.** We like to think we're masters of our destiny, but marketers will tell you otherwise. Packages with lots of green coloring seem healthier, but unless you're eating the label, the food won't necessarily taste any different. Companies pay for prime shelf placement, so look toward upper and lower shelves for alternative products that aren't spending as much of their budget on marketing. And beware of impulse buys on the journey to the back of the store—there's a reason the dairy section is there! Almost everyone has a dairy item on their grocery list, and stores know placing that section in the back creates lots of less-than-ideal impulse buys along the way. Use a grocery list and leave the kids at home. (Fun fact: ever notice that the layout of most stores has you travel counterclockwise? This leaves your right hand free to grab items as you push the cart with your left hand.)

## Smell, the Olfactory Sense

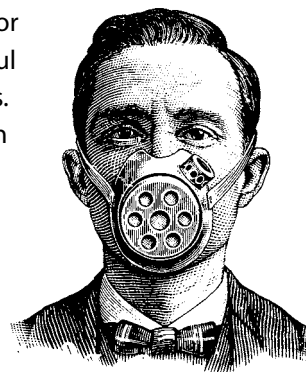
Smell is simple in the abstract and complicated in the details. In the abstract, smells lead us toward the desirable and steer us away from the unsafe. But smell does this in a much broader context than food. Choosing whom to mate with? Helping infants identify their mothers? Helping me figure out if that worn-once shirt can be safely worn again? All of these things rely on our sense of smell, formally called *olfaction*, and the complication in olfaction is the number of roles that it has evolved to play.

While the sensation of taste is limited to a handful of attributes, smell is a cornucopia of data. We're wired to detect around 360 distinct attributes and are able to discern and remember over 10,000 aromas. Add in intensity aspects, and we can discriminate between a trillion different possibilities. Our sensitivity is incredible, too. The human nose can detect some compounds below the order of one part per trillion. To put that in perspective, it'd be like being able to spot a single grain of rice while viewing all of Manhattan from space. Without smell, the flavors of foods would be limited to a handful of basic tastes and life at the dinner table would be a lot more boring.

How we sense smell is a fascinating topic, and one that's only relatively recently understood. The Nobel Prize in Physiology or Medicine was awarded in 2004 to two researchers, Richard Axel and Linda Buck, for their work in discovering the mechanism by which we sense smells. Like our sense of taste, our sense of smell is based on receptor cells being activated by chemical compounds. In smell, these compounds are called *odorants*, and they activate chemoreceptor cells in our noses. But there are many more details to the story of smell.

At first glance, smell and taste receptor cells work in similar ways. As in taste, odor receptor cells are built to detect exactly one attribute, and each receptor cell is encoded by exactly one odorant receptor gene. Just as "sweet!" taste receptors can be triggered by different compounds—sucrose, fructose, saccharine—different compounds can trigger any given smell receptor. In the case of olfaction, the receptor cells are located in the nasal cavity and respond to *volatile compounds*—chemicals that evaporate and can be suspended in air such that they pass through the nasal cavity, where the odor receptor cells have a chance to detect them.


Where things get more complicated in smell is in the variety of odor receptor cells and how they activate in groups. Unlike taste, where there are a handful of easily named sensations, smell has many, many more possible sensations. We use words like *musty*, *floral*, or *lemony* to describe categories of common sensations, but these sensations don't come from any one odor receptor. Smell is complicated for this one remarkable fact: a single compound activates multiple odor receptors, and the combination of odor receptors that are triggered is what we register as a smell. Layer on a second critical fact—that aromas, from flowers to coffee, are based on mixtures of compounds—and you can see why smell is so complex.



From a biological point of view, a tastant is like a single note being played on a piano and an odorant is like a neurological chord. In taste, we register a sensation based on one taste receptor cell firing off; in smell, we register an odorant based on the combination of olfactory receptor cells that fire off. A compound like vanillin, the molecule that gives vanilla most of its aroma, will trigger multiple olfactory receptor cells, and our brain registers that combination as “vanilla-like.” Regular vanilla, in its full glory, is based on a handful of odorants from the vanilla bean, and we detect all of those in one pass, like many different chords being played at the same time, for a symphony that registers “vanilla!”

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Your brain fills in missing details to match up with your historical experiences, which is why you should identify this drawing as an incomplete triangle.



This also explains what happens if you’ve ever experienced a partial whiff of an odor and misidentified it. When some of the “notes” are missing, your brain’s pattern-matching machinery goes to work and finds its best guess. Recently I was walking out of my apartment with a stuffed-up nose, which decreased my ability to smell. When stepping into the hallway, I smelled apricots, but as I walked down the hallway and more odorants hit my olfactory system, the smell suddenly switched to that of drying paint. How could I have “mis smelled” something that different? Only some of the neurons in my stuffed-up nose had fired off at first, and the chord they were striking was similar enough to apricots that my brain autocompleted it to the nearest thing it could find. (Why apricots? I have no idea.)

Not all compounds can be smelled. For one, compounds have to be *volatile*—having the ability to turn into a vapor through evaporating or boiling. For us to smell something, it has to be “in the air.” When you unwrap a bar of chocolate and smell it, that’s due to compounds in the bar of chocolate evaporating and drifting through your nasal cavity. Chocolate is loaded with volatile compounds, while your stainless steel spoon has very few, which is why you can smell one but not the other. A compound’s volatility also changes with temperature. We have a harder time smelling cold foods because temperature partially determines a substance’s volatility. (Incidentally, the evaporation of the volatile compounds makes the bar of chocolate infinitesimally lighter as time goes on, in case you need an excuse to eat that bar of chocolate *right now*.)

While some foods have naturally strong smells, most raw ingredients keep their odors to themselves until disturbed. An unpeeled banana, a head of lettuce, and fresh fish don’t have much of an aroma until they’re worked. Cooking adds many odorants by either freeing volatile compounds or breaking down nonvolatile compounds into new ones. Even chopping up leafy greens and vegetables releases smells, as anyone who’s cut an onion knows. Think about the difference in smell before and after you mow a lawn—the “green” grassy smell is from compounds that were trapped inside the blades of grass before they were cut.

It's not enough for a compound to be volatile and "freed" for us to detect it. Size, shape, and something called *chirality* all determine whether a molecule is smellable and how. Our sense of smell is on par with modern lab equipment, on the hunt for specific types of things. We're capable of distinguishing the difference a few atoms makes—we can smell both octane and nonane, only two hydrogen atoms and a single carbon atom apart; the primary odorants of pear and banana also differ by only two hydrogens and one carbon.

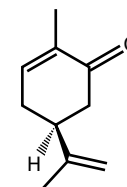


Octane



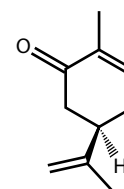
Nonane

A real surprise with smell is the impact of chirality, which has to do with whether a molecule and its mirror version (the pair are known as *enantiomers*) are identical. Your left and right hands, for instance, are chiral because they are not identical, even though they have the same fundamental shape. Carvone is a classic example in chemistry: the compound D-carvone smells of caraway, while its mirror version, R-carvone, smells of spearmint. That's how specific the collection of odor receptor cells that activate can be!



D-carvone

There are general rules of thumb for odors and volatile compounds, understandable to chemistry geeks. The families of compounds that contain certain chemical structures generally end up smelling similar. One category of compounds, called esters, are classically thought of as having fruity aromas. Another category, amines, smell stinky and rotting, like week-old raw fish, with cadaverine and putrescine being two of the better-known odors. And another group, aldehydes, tend to smell green or plantlike. This commonality supports the theory that part of smell detection stems from receptors that activate based on parts of a volatile compound's chemical structure.



R-carvone

While smelling a single compound won't bring the entire aroma of something like cut grass, some compounds are similar enough that flavor chemists can use a handful of them (in the case of grass, hexenal, hexenyl acetate, and methanol) to trick our brains into thinking we're smelling the real thing. Artificial scents—used in products from laundry detergent to candies—often cost less, can be more stable chemically than the original scents, and can even be safer ("natural" can have natural toxins). Artificial vanilla extract, for example, generally contains just vanillin, which happens to be the most common chemical in vanilla. Although the artificial stuff is missing all the other compounds from vanilla, we still register it as vanilla and generally find it to be enjoyable.

As you can see, the chemistry aspects of smell are complicated in their details, and we haven't even touched on individual differences in how we detect odors! Here are a few differences in smell that you might want to consider, especially when cooking for others:

**Genetic differences.** Just as there are genetic differences in taste, there are genetic differences in smell. The simplest example is cilantro: to some, it registers as dish soap and is disgusting; to others, it's a pleasant addition to a meal. If you're a cilantro hater, you're in good company: Julia Child hated it too. We know cilantro aversion is due to a slight genetic variation (search for rs72921001 online); about 1 in 10 of us has it, and that number is slightly higher for those of European ancestry and slightly lower for those of Asian ancestry.



**Threshold differences.** Other physiological differences are known to exist. Females have about 50% more neuronal connections in the olfactory bulb than males, increasing their ability to detect odors. Some people are much more sensitive to smells than others, presumably for genetic reasons. These differences mean that there are variations in the minimum thresholds necessary for various odorants to register. Because aromas are combinations of odorants, and different aromas have overlaps, if I'm capable of detecting all the odorants in the aroma but you only smell a subset, I might smell floral lilies and you might smell something almost fecal-like.

**Age-related changes.** Like eyesight and hearing, our sense of smell begins to deteriorate sometime in our thirties and starts to fall off faster once we reach our sixties. It's a slow decline, and unlike hearing and eyesight, is hard to notice as it changes, but the loss does impact our enjoyment of food to some degree.

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Just like we hear in stereo, it appears that we smell in stereo: we use our left and right nostrils independently. Researchers at the University of California, Berkeley, have found that with one nostril plugged up, we have a much harder time tracking scents, due to lack of "internostril communication."

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**Crossover.** The senses of taste and smell aren't completely isolated from each other. Odorants can change how we perceive the basic tastes. Vanilla aroma, for example, will increase how sweet something tastes. Fruits like blueberries are "sweeter" than strawberries, in the sense that blueberries have more sugar, but the odors in strawberries cause us to perceive them as sweeter instead. Experiments have shown that smelling sweet foods like caramel and then sipping water causes us to taste it as sweet.

**Olfactory fatigue.** Be grateful for olfactory fatigue; without it, you'd constantly smell whatever background smells exist in your home or while you're out and about. Smells begin to fade into the background after a few minutes, presumably as the brain tunes them out. Coffee beans at the perfume counter are supposedly used to reset fatigue, but research doesn't back this up as being effective—well, at least not for resetting the nose (but perhaps your wallet?).

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### What's the difference between artificial and natural vanilla extract?

In the United States, natural vanilla extract must be made from vanilla beans (~10.5% by weight) in a base that's at least 35% ethyl alcohol, while artificial vanilla extract is based on synthesizing the chemical compound vanillin, which is responsible for vanilla's primary aroma.

Depending upon manufacturing, artificial and natural extracts can be chemically indistinguishable, although what you see in the store usually has some differences. Artificial vanilla extract can have other compounds (e.g., acetovanillone) that change the extract's odor. Some of these other compounds are described as "more vanilla than vanilla"—they register as stronger odors—so artificial extract can seem stronger than a vanilla bean-derived one.

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## Describing Smells

Unlike with tastes, where everyday language makes it easy to describe a sensation such as “salty,” describing smells can be a challenge. We don’t have common language to describe strawberries other than “strawberry-like”—which is great if you’ve had strawberries, but how would you describe a durian fruit? Coffee roasters, winemakers, and cheesemongers all have their industry-specific odor descriptions, but it’s the flavor chemists who really know how to talk about smell.

Descriptive taxonomies apply labels to odors as a way of classifying and grouping foods. The simplest descriptive taxonomy, from the 1950s by J. E. Amoore, proposes just seven primary odors: camphoric (like mothballs), ethereal (like cleaning fluid), floral (like roses), musky (like aftershave), pepperminty, pungent (like acetic acid in vinegar), and putrid (like rotten eggs). Small taxonomies like this suffer from disagreement—what do the definitions mean? If I were to smell chocolate, I’d have no idea how to categorize it.

More modern descriptive taxonomies use larger vocabularies and are used by trained assessors. One of the more common ones is the American Society for Testing and Materials’s *Atlas of Odor Character Profiles – DS61*, by Andrew Dravnieks. While not all of the terms included are pleasant or even related to food, it’s certainly a diverse set, which is useful in thinking about smells. The full atlas includes hundreds of volatile compounds associated with the various terms. And, with 146 terms, Dravnieks’s list provides enough granularity to begin to form a meaningful model for odors.

Another label-based classification system, Allured’s *Perfumer’s Compendium*, is used by the perfume industry, the fine folks responsible for the smells of products from laundry detergent to toothpaste. Think that new car smell is accidental? Trained employees smell the materials that go into the interior of a new car to make sure that it smells just right. (To quote *The Matrix*: “You think that’s air you’re breathing now?”) Allured’s taxonomy uses more descriptive and narrow scents—familiar items such as banana, peach, and pear—but also specific items like hyacinth, patchouli, and muguet (lily of the valley), making it less useful to the layperson.

Descriptive taxonomies are by no means perfect. For example, both lemon and orange are classified as “fruity/citrus” in Dravnieks’s list. Descriptive taxonomies allow for some comparison of odors, but they’re not a chemical analysis, where the presence and quantities of various compounds are measured. Still, they’re fun to peruse and give you a real sense of how much better we could talk about smell if we shared a common vocabulary. Even with such a list, describing smells is more of a literary exercise than a scientific one. One sommelier friend, tired of being asked to describe wine to customers, finally flipped out and said, “If kittens could fart rainbows, it would smell like this.”

## Atlas of Odor Character Profiles

These 146 odor terms, categorized by common source, are from an American Society for Testing and Materials standards document by Andrew Dravnieks. The list provides a broad framework for thinking about odors. If you're heading out on a date and want to impress, this list is a pretty good starting point for describing aromas (this cheese...it smells like dirty linen!).

Wondering why "sweet" appears as an odor term? A sweet smell isn't the same thing as a sweet taste; it's a matter of linguistics. Sweet odors are related to alcohol-based odorants released in sweet fruit.

<b>Common</b>	Sweet, fragrant, perfumy, floral, cologne, aromatic, musky, incense, bitter, stale, sweaty, light, heavy, cool/cooling, warm
<b>Foul</b>	Fermented/rotten fruit, sickening, rancid, putrid/foul/decayed, dead animal, mouselike
<b>General foods</b>	Buttery (fresh), caramel, chocolate, molasses, honey, peanut butter, soupy, beer, cheesy, eggs (fresh), raisins, popcorn, fried chicken, bakery/fresh bread, coffee
<b>Meats</b>	Meat seasoning, animal, fish, kippery/smoked fish, blood/raw meat, meat/cooked good, oily/fatty
<b>Fruits</b>	Cherry/berry, strawberry, peach, pear, pineapple, grapefruit, grape juice, apple, cantaloupe, orange, lemon, banana, coconut, fruity/citrus, fruity/other
<b>Vegetables</b>	Fresh vegetables, garlic/onion, mushroom, raw cucumber, raw potato, bean, green pepper, sauerkraut, celery, cooked vegetables
<b>Spices</b>	Almond, cinnamon, vanilla, anise/licorice, clove, maple syrup, dill, caraway, minty/peppermint, nut/walnut, eucalyptus, malt, yeast, black pepper, tea leaves, spicy
<b>Body</b>	Dirty linen, sour milk, sewer, fecal/manure, urine, cat urine, seminal/like sperm
<b>Materials</b>	Dry/powdery, chalky, cork, cardboard, wet paper, wet wool/wet dog, rubbery/new, tar, leather, rope, metallic, burnt/smoky, burnt paper, burnt candle, burnt rubber, burnt milk, creosote, sooty, fresh tobacco smoke, stale tobacco smoke
<b>Chemicals</b>	Sharp/pungent/acid, sour/acid/vinegar, ammonia, camphor, gasoline/solvent, alcohol, kerosene, household gas, chemical, turpentine/pine oil, varnish, paint, sulfidic, soapy, medicinal, disinfectant/carbolic, ether/anesthetic, cleaning fluid/Carbona, mothballs, nail polish remover
<b>Outdoors</b>	Hay, grainy, herbal/cut grass, crushed weed, crushed grass, woody/resinous, bark/birch, musty/earthy, moldy, cedarwood, oakwood/cognac, rose, geranium leaves, violets, lavender, laurel leaves

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Flavor chemists use databases of odorants with descriptive odor terms. For example, Flavornet (<http://www.flavornet.org>), created by two researchers at Cornell (Terry Acree and Heinrich Arn), describes some 700+ chemical odorants detectable by the human nose. Listing compounds such as *citronellyl valerate* (smells like honey or rose; used in drinks, candies, and ice cream), the database is useful for generating certain flavors artificially—what compounds smell like X?

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## How Does Flying Impact Taste and Smell?

*Because our sense of smell is based on volatile compounds wafting through our nasal cavity, it follows that changes in air pressure will change our sense of smell. At lower pressure, two things happen: volatile compounds evaporate more easily (meaning more compounds are available for detection), and the amount of air in a given volume decreases (so we have less opportunity to detect those compounds).*

*To find out what happens, who better to ask than the folks preparing airline food? I called up Stephen Parkerson, a chef at Flying Food Group, one company that prepares meals for many of the major United States airlines. Here's what he says about how the taste of food at altitude changes.*

When you're up in the air, the lack of humidity, which is right around what you would have in a desert, affects your mucus and taste buds. At altitude, you lose about 30% of your taste when it comes to sweet and salty. Something that you might have on the ground that you would think would be perfectly seasoned basically tastes bland when you get at 30,000 feet. The exception to this is umami [savory taste], which really comes through with altitude.

We try to compensate for lack of flavor at altitude. If we're making something like green beans, like blanched *haricots verts*, we double the amount of salt in the water when blanching them. We don't necessarily have a ratio or an equation that we use. It's like working at a restaurant, seasoning a dish, knowing the line to take it to. We know that line for the airline as well. An airline dish that you might taste down here on the ground is going to be salty or almost to the point of too much flavor, but then when you get in the air, it tastes just like you'd be eating at your dinner table.

*The next time you fly, try tasting some food on the flight and then tasting the same thing when you're back down on the ground. You may be surprised at the difference in intensity of flavors!*

## Mock Apple Pie

*If you've never made it, mock apple pie is one of those surprises that can fool an unsuspecting eater. Made with crackers instead of apples, it has a similar texture to the real thing, and the sugar and spices are convincing enough—adding the sweetness, sourness, and flavors associated with apple pie—that you can hoodwink someone who's familiar with the real thing into thinking that's what they're eating. It's a great example of how the sensation from a combination of odors, combined with expectation, can trick the brain.*

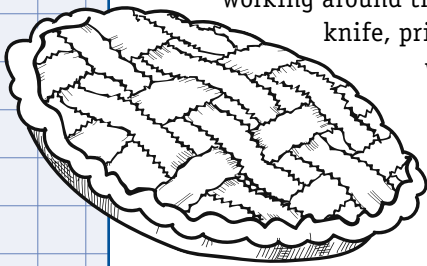
Line a pie pan with **pie dough**—see page 259 for a double-crust recipe, or cheat and buy a commercially prepared one, making sure to get a double crust (one that has a second part for the top of the pie).

In a saucepan, add **1½ cups (360 mL) water**, **2 cups (400g) sugar**, and **2 teaspoons (6g) cream of tartar**. Bring the mixture to a boil and then reduce the heat to medium, letting the syrup simmer until it is slightly thick, around 235–240°F / 110–115°C. Remove the pan from the heat and allow it to cool for a few minutes.

To the pan, add **30 (100g) buttery crackers** (Ritz brand is the most commonly used, but saltine or soda crackers work too), **1 teaspoon (3g) cinnamon**, **1 teaspoon (2.5 mL) vanilla**, **¼ teaspoon (0.5g) nutmeg**, **2½ tablespoons (38 mL) lemon juice**, and the **zest from 1 lemon**. Gently stir to mix the ingredients together, but don't overmix—the crackers need to remain in large pieces.

Pour the mixture onto the pie dough. Cut up **2 tablespoons (30g) butter** into small cubes and sprinkle them over the filling. Dust the mixture with a few pinches of cinnamon.

Place the top crust on the pie and pinch the edges of it into the bottom crust, working around the entire circumference. Using either a fork or a sharp knife, prick or slice the top crust a dozen times in a regular pattern, which will give steam a place to vent while the pie cooks.



Bake the pie in a preheated oven at 425°F / 220°C for about 30 minutes, until the crust is golden brown. Serve it warm (reheat in the microwave as necessary), ideally *à la mode* with a scoop of vanilla ice cream.

### What is cream of tartar?

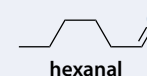
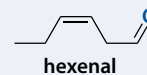
It's mostly potassium bitartrate, originally a byproduct of making wine. It also has a sour taste, and adds to mock apple pie a lot of the acidic bite that normally comes from things like malic acid in real apples. Cream of tartar doesn't smell like apple—none of the odorants are present—but the taste of sourness is about right to fool you.

## Chemicals of Common Aromas

Here are a few examples of compounds that naturally give foods their aromas. Notice that some aromas are defined by only one compound, while other aromas are complex combinations. Many herbs and spices are composed of just a few key volatiles, whereas fruit aromas usually involve hundreds of compounds.

An artificial aroma created with exactly the same compounds at the same concentrations would be no different from a “natural” one. Artificial extracts often take shortcuts, though. For example, an artificial strawberry flavoring created using only three or four of the most common odorants present in strawberries leaves out enough of the volatiles that it smells different. If you grew up with artificial strawberry flavors, though, you might prefer the synthetic version!

Flavored jellybeans and scratch-and-sniff stickers are just a few products that rely on these compounds. Try popping open a package of jellybeans and seeing if you can identify some of the odors with the compounds listed here.



Hexenal and hexanal differ by only two hydrogen atoms. They both exist in nature and smell the same (“green”), and illustrate that similar compounds can have no difference in odor.

Food compound	Comment
Almond: <ul style="list-style-type: none"> <li>Benzaldehyde</li> </ul>	Primary component of bitter almond oil. The next time you’re at the grocery store, look at the ingredients label on artificial almond extract! Incidentally, artificial almond extract is sometimes perceived as better by tasters; plus, the natural stuff has trace amounts of cyanide.
Banana: <ul style="list-style-type: none"> <li>Isoamyl acetate</li> </ul>	Creating artificial banana extract is one of the classic chemistry lab projects, to the annoyance of teachers in adjoining rooms. Isoamyl acetate is also the pheromone that honeybees use to signal an attack, so don’t eat overly ripe bananas outdoors during the height of bee season!
Black truffle: <ul style="list-style-type: none"> <li>2,4-dithiapentane</li> </ul>	Black truffle oils commonly use this instead of oil from real truffles. Some chefs hate it, presumably because too much begins to smell unpleasant.
Butterlike: <ul style="list-style-type: none"> <li>Diacetyl</li> </ul>	Used in microwave popcorn and Jelly Belly’s “Buttered Popcorn” flavor, in large doses this causes a lung disease called “popcorn lung.”
Generic “fruity” flavor: <ul style="list-style-type: none"> <li>Hexyl acetate</li> </ul>	Used in pink bubble gum and Jelly Belly’s “Tutti Frutti” flavor. It’s also present in apple varieties like Golden Delicious.
Generic “green” flavor: <ul style="list-style-type: none"> <li>Hexanal</li> </ul>	Described as like fresh-cut grass, this is used in fruity flavors like apple and strawberry.
Grapefruit: <ul style="list-style-type: none"> <li>1-<i>p</i>-menthene-8-thiol</li> <li>nootkatone</li> </ul>	Grapefruit has at least 126 volatile compounds, but these two seem to be the primary ones. Jelly Belly’s “Grapefruit” flavor likely includes these compounds.
Strawberry-like: <ul style="list-style-type: none"> <li>Diacetyl (buttery)</li> <li>Ethyl butanoate (fruity)</li> <li>Ethyl hexanoate (fruity)</li> <li>Furanone (caramel-like, sweet)</li> <li>Hexenal (green)</li> </ul>	Strawberry has roughly 150 different odorants; only 4 to 6 of them dominate the aroma. Good artificial strawberry flavors include more of them; less convincing ones will use only a few. This is why artificial fruit flavors are generally not very convincing—it’s not that they can’t be made to be so, but that economically, the cost of all the compounds doesn’t justify it (versus something like artificial almond extract that depends on only one compound).

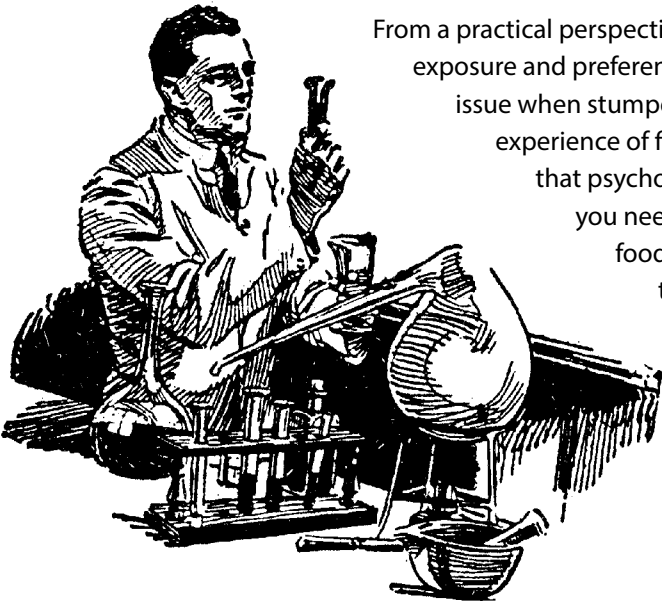
## What Is Flavor?

Flavor is a Jedi trick of the mind, a combination of the gustatory sense of taste and the olfactory sense of smell that your brain fuses into a new sensation. To give you an idea of just how clever your brain is about flavor, consider this: your brain detects odors differently based on whether you are breathing in or out. This is crazy! It's like saying swiping your hand left to right on a cold countertop causes you to feel temperatures differently than swiping right to left. Our brains are wired to process smell signals in two different ways; flavor uses the second way.

Some definitions will make this easier to discuss. *Orthonasal olfaction* is defined as what your nose detects from sniffing something that exists in the world. Sniffing a rose, unless you're also chewing it, uses the orthonasal route for smell. *Retronasal olfaction* is what your nose detects in the foods you eat when air is taken in from the mouth and circulated up to your nasal cavity. Even if you don't notice it happening, it is! Try chewing food with your nose pinched: cut off the airflow, and poof, the flavor sensation's gone.

To unravel this trick of the brain, a researcher, Paul Rozin, gave subjects unfamiliar fruit juices and soups via the orthonasal route—"Here, sniff this; remember this odor"—and then gave the foods to the subjects again via the retronasal route (through a plastic tube), asking them to identify the previously remembered odor. They did horribly. Same compound, same sensory apparatus, completely different experience. As I promised, smell is simple in the abstract but complicated in the details, so it follows that flavor is no different.

From a practical perspective, which flavors you'll like or dislike is a matter of exposure and preference. Rozin started studying the orthonasal and retronasal issue when stumped by stinky cheeses—how is it that we have a different experience of flavor for something that smells disgusting? There's a lot that psychologists and physiologists are still exploring. Fortunately, you needn't be one to cook a good meal. When working with food, keep in mind that flavor is a specific combination of the two senses of taste and smell, but not a straightforward summation of the two. Taste the food to adjust its flavor before serving it! Smelling alone isn't enough. Here are some tips for great flavor when cooking:



**Chew!** Admittedly an odd suggestion for good flavor, chewing food crushes, mixes, and kicks up a bunch of compounds for your olfactory system to detect, adding smells that fold into flavor sensation. Remember, for a compound to activate an odor receptor, it has to be present at the point of detection. This raises the question: does chewing food with your mouth open lead to a different flavor experience? (If animals always chew with their mouths open...)

**Use fresh herbs.** Most dried herbs have weaker flavor because the volatile oils that are responsible for the aromas oxidize and break down, meaning that the dry herbs are a pale substitute. Dried herbs have their place, though; it makes sense to use them in the dead of winter when annual plants like basil aren't in season. Store dry herbs in a cool, dark place (not above the stove!) to limit their exposure to heat and light, which contribute to the breakdown of organic compounds in spices.

**Grind your own spices.** Don't use preground black pepper; it loses much of its flavor over time as many of the volatile compounds change. Fresh-grated nutmeg is also much stronger than preground nutmeg. The aromatics in a preground spice will have had time to either hydrate or oxidize and disperse, resulting in flavor changes. Most dried spices also benefit from being *bloomed*—cooked in oil or a dry skillet under moderate but not scorching heat—as a way of releasing their volatile chemicals without breaking them down.

**Don't discount frozen ingredients.** Commercially frozen vegetables and fruits are convenient and work fine in some dishes. Freezing produce right when it is harvested has advantages: nutritional breakdown is halted, and the frozen item is from the peak of the season with maximal flavor (whereas the fresh version in your store may have been harvested early or late). Frozen produce is especially useful if you're cooking for just yourself: you can pull out a single portion as needed. Want to freeze your own crop or a surplus from a CSA (community-supported agriculture) food share? See page 365 for how to use dry ice. (Freezing in your home freezer takes too long and leads to mushy veggies.)

**Use alcohol in cooking.** My favorite restaurant in San Francisco uses kirschwasser in its fruit soufflés, and adding a splash of wine in sauces or to deglaze a pan to make a quick sauce is standard practice. Using alcohol changes flavors because of its chemistry: it takes the place of water molecules normally attached to compounds, resulting in lighter molecules that are more likely to evaporate, and with higher evaporation rates there are more volatiles for your nose to detect.



## Taste Aversions

My friend Dawn hates the taste of eggs. As a little kid, she ate eggs that had been cooked in burnt butter. Her brain linked the revolting acrid taste of the burnt butter with the taste of eggs, and to this day that link is stuck in the basal parts of her brain to the point that she can't eat eggs. A *taste aversion*—a strong dislike for a food, but not one based on an innate biological preference—typically stems from prior bad experiences with food, often occurring in childhood like Dawn's burnt-butter eggs experience. A foodborne illness is a common cause.

Taste aversions are fascinating because they're entirely learned associations. The food that triggers the illness is correctly identified only part of the time. Typically, the blame is pinned on the most unfamiliar thing in a meal, known as *sauce Béarnaise syndrome*. Sometimes the illness isn't even food-related, but a negative association is still learned and becomes tied to the suspected culprit. This type of conditioned taste aversion is known as the *Garcia effect*, named for psychologist John Garcia, who determined that he could create taste aversions in rats by invoking nausea when they were exposed to sweetened water. As further proof that we're at the mercy of our subconscious, consider this: even when we know we've misidentified the cause of an illness ("It couldn't be Joanna's mayonnaise salad—everyone else had it and they're fine!"), an incorrectly associated food aversion will still stick.

Sometimes only a single exposure that results in foodborne illness is all it takes for your brain to create the negative association. One of the cleverest examinations of taste aversion was done by Carl Gustavson as a grad student stuck at the ABD (all but dissertation) point of his PhD. Reasoning that taste aversion could be artificially induced, he trained free-ranging coyotes to avoid sheep by leaving (nonlethally) poisoned chunks of lamb around for the coyotes to eat. They quickly learned that the meat made them ill, and thus "learned" to avoid the sheep. As tempting as it may be, I don't recommend this method for kicking a junk food habit, but it does hold an odd appeal.

What can you do to overcome a taste aversion? To start with, you have to be willing and open. You may feel that eggs are disgusting, and if you're unwilling to unwire that association, your chances of eating an omelet are rather low. Repeated exposures to small quantities of the offending item, in situations where you feel comfortable, will eventually remove the association between the food item and negative memory (called *extinction*). Remember, start with small quantities and use consistent repeated exposures in a supported environment. If it's too much at first, try changing some aspects of the food, such as its texture or the cooking technique, so that the flavor association isn't as strong.

# Brian Wansink on Expectations, Flavor, and Eating



Brian Wansink is a professor at Cornell University, where he studies the way we interact with food. He is also the author of two books, *Mindless Eating* (Bantam, 2007) and *Slim by Design* (William Morrow, 2014), that examine how we make our choices about what we eat.

## What things change our perceptions of what we think we're smelling and tasting?

The French have an expression that says that there's no accounting for taste. It's certainly not true, other than at the very extremes of taste range. People are tremendously subjective, to the point where our taste buds end up being engineered by our expectations. If somebody says, "Taste this; it's bitter," we're going to say, "It's bitter!" But if someone says, "Hey, this is sort of bland" with the same food, we're gonna go, "Yeah, it's bland." We find this over and over again: the easiest way to change people's taste interpretation is to change their taste expectation beforehand.

## Where are people getting their taste expectations from?

Your visual perception of food will bias your taste. We find that if we change the color of lemon Jell-O with red food

coloring and call it cherry, people go, "Oh, that's good cherry Jell-O." We find that changing the way food is plated matters. If we put a brownie on a nicer china plate instead of a paper plate, people are willing to pay almost twice as much for it. We even find putting a silly piece of garnish on a plate really boosts how much people are willing to pay.

Another aspect is how much effort we think was put into the food. If we think that not very much effort was put into the food, we rate it as much lower. We also find that if you give something a name like "succulent Italian seafood filet," people go, "This is good," but if you just call it "seafood filet," people like it less.

## It sounds like expectations are incredibly important. There must be a challenge in not setting expectations too high?

No, not at all. We have never found that it backfires. Let's say I serve you a steak, and go, "Here's some steak." You try it and go, "That was pretty good, I'd give it a 6." Then I serve a second identical steak but say, "I'm going to give you the most amazing, incredible steak in the world. It was hand-massaged by midgets for years, blah blah blah." Where are expectations set? They are set high. Then you eat that steak and say, "It's kind of tough and a little bit dry. It wasn't really that good. It's only about a 6.5." What's going on here is anchoring. Even when you really overreach expectations, it doesn't make people say, "It sucks." They still rate it above what they would rate it if you'd given them no expectation at all.

We brought in sales execs who, on average, spent over \$25,000 a year on expense accounts on food. These people should know fine dining. We gave them Chef Boyardee. We put it on a plate, and read them the back of the can, something like, "This comes from a generations-old recipe from Italy; it's been made more times than can be counted." They rated it better when not told it's Chef Boyardee, at least for people who are on huge expense accounts. If you grew up never having branded products because they cost too much, the Chef Boyardee brand might give the food a halo.

## How does that halo play into our expectations?

Brands have a great halo when you like the original brand. If you like KC Masterpiece Barbecue, and there is a cobranded frozen "KC Masterpiece Barbecue burgers," you're going to go, "Oh, that's gonna be good," more so than if the package just said "Barbecue burgers."

This halo can backfire. We looked at how a person's perception of soy being in a food contributes to them thinking it's terrible. We gave people energy bars. The energy bars had 10 grams of vegetable protein; it wasn't soy. We changed the label so it said either "Contains 10 grams of protein" or "Contains 10 grams of soy protein." By planting that first suggestion in people's minds, they'd say, "This is great. It's chocolate-y. It's got a nice texture." For the soy protein label, they'd say, "Doesn't taste like chocolate. I can't get the taste out of my mouth." It's the exact same thing. People were tasting what they thought they were going to taste.

### **Is there a health halo, where things that are perceived as being healthy end up ranking lower in taste studies?**

In one of our cafeteria studies with kids, we had a vegetable and pasta dish that we either labeled as healthy, as fresh, or nothing. Simply by labeling something healthy made people rate it worse than if it was labeled either as fresh or as just zucchini pasta. Most people's perception of healthy is that healthy is something that they have to do. No one says, "I had this incredibly healthy dessert."

These perceptions of health can almost poison your view. I've got three little girls at home. We never used the word "healthy" when we'd give them things, and now they like healthy things.

### **I take it that's an issue for nutrition policy, with perception around health of foods?**

Yeah, mainly because people in nutrition policy aren't trained as behaviorists.

### **Well, then, what's the behaviorist's approach for changing the way people eat?**

First, you make it more convenient to eat. Second, you make it more attractive. Third, you make it more normal to eat. Under those three things, there are legions of changes.

Say I want my kids to eat vegetables. Do I tell them, "Eat them—they're healthy for you"? No. What I do is this: the first thing we bring out at dinnertime is salad and vegetables. Everybody gets them, and we sit there until we're done eating them. Only then does the pasta and chicken come out. This makes it a whole lot more convenient to eat better.

For attractiveness, say we have zucchini as part of dinner. I'll say, "What are we having tonight, honey?" My wife would

describe it and say, "Zucchini. Do you guys know what zucchini is? Do you know what it tastes like? Does it taste like a cantaloupe?" Just a little bit of discussion raises curiosity. It's going to be an adventure to try.

You can also make things more normal to try. When my kids wouldn't eat something, I'd say, "Well, if you're not going to eat it, can I?" They go, "Yeah." So I take a bite. I say, "That's good. That's really good, honey. I like it!" The kid is smugly thinking, "Oh, I fooled him." A few minutes later, I'll reach over and take another bite and go, "Yeah, this is good. Thanks, honey! You'll have to make more of it." So all of a sudden, the kid is seeing, "Wait a minute. You're taking my stuff!" Kids feel the endowment effect just as much as adults do. After a few times of doing that, it's like, "Stop taking my stuff, dad."

### **What about things like plate size and plate color—how do those things impact eating?**

The color thing is really neat. Most people want a simple thing, but it's one step removed from being simple. We find that color doesn't matter; it's the color *contrast* between what you're serving and the color of your plate that matters.

We had an alumni reunion here at Cornell where they got either red or white pasta and either red or white plates. We found that if you're serving red-on-red or white-on-white, you're going to serve 19% more pasta than if you're serving white-on-red or red-on-white. If the contrast is there when you're serving, you go, "Whoa. That's enough." If the contrast isn't there, you tend to serve until you go, "Whoops, a little too much."

This happens every day and it doesn't matter if it's healthy or unhealthy food. The greater the contrast between what you

serve and the plate color: 19%. We find it when we have people serve peas that are either on a green plate or on a yellow plate. You want people to eat more peas, right? They're going to serve more peas on a green plate than they are on a yellow plate because of the contrast. We have people serve pudding. They serve more chocolate pudding on a dark plate than on a yellow plate. They serve more banana pudding on a yellow plate than a dark plate.

What are you most in danger of overeating? For most people, it's white foods. So you don't have to have 50 colored plates, just have darker plates.

### **Anything else that home cooks should know about to make their meals more enjoyable?**

Turn down the lighting. We find that when we turn down lighting, people eat slower, and they rate the food as better. We did this cool study in a fast-food restaurant that was doing a reconstruction. We were able to break it in half so that one half was fine-dining style and the other half was typical bright lights and loud music. We found that simply turning down the lighting led people to eat about a third longer, eat about 18% less, and rate the food as being a lot better.

### **How much of this is based on a feeling of it being a fine-dining experience? I know that fine dining, culturally for Americans, is supposed to be dim light.**

I think it might be that, but I think it might also be priming anxiousness and activity and distraction. We had a little bit of a disappointment with something at home the other day, and we had to try to resurrect the night and make it special. We said, "We're gonna eat by candlelight, but only candlelight." The girls just loved it.

# Inspiration by Exploration

Unlike our innate preferences with primary tastes, we don't have innate likings or dislikings for most odors. The flavors we enjoy are flavors we've learned to enjoy, which is why other cultures' foods can be literally foreign to us. This is also why cultural culinary exploration is a fantastic way to learn new flavors! Some of my favorite meals are based on familiar ingredients cooked in new combinations, often based in other cuisines. The first time I had chicken tagine, a North African dish of stewed chicken, it was both familiar (chicken legs, tomatoes, onions) and exotic. (Tagines, by the way, are named for the dish they're cooked in, the combination of ingredients being whatever you have on hand.) The trick to this type of flavor inspiration is to learn about flavors and the ingredients that provide them. But how do you get that knowledge? Here are a few ways to explore with flavors, geographical and otherwise.

**Ask about ingredients in foods you're eating.** Take time to notice the aromas in the foods you are eating, taking note of smells that you don't recognize. Next time you're eating out, order a dish you're not familiar with and try to guess its ingredients. If you're stumped, don't be shy about asking the staff. I remember being served a roasted red pepper soup and being completely stumped as to what provided the richness and body (thickness) of the soup. Five minutes later, I found myself sitting across from the chef (it was a slow night), who had brought me the kitchen's working copy of the recipe and told me its real secret, Armenian sweet red pepper paste. I learned not just about a new type of flavor that day, but also about a new technique (toasted French bread puréed into the soup—an old, old trick to thicken soups) and the location of a great Armenian grocery store in the neighboring town.

**Play “culinary mystery ingredient.”** Next time you're at the grocery store, buy one thing you like to eat but have never cooked with before. For “intermediate players,” pick up something you're familiar with but have no idea how to cook. And if you've progressed to the “advanced” level, choose something that you don't recognize at all. You'd be surprised at how many foods can be unfamiliar in their ingredient form, but once cooked into a meal are familiar, or maybe even downright commonplace. Yucca roots? Try making yucca fries. Lemongrass and kaffir lime leaves? Try making tom yum soup. With tens of thousands of items available in the average grocery store, you should be able to find something new to inspire you.

**Mimic flavorings from another dish.** If you're just now learning your way around the kitchen and aren't yet familiar with that many recipes, think about the ingredients that go into foods you like. Even a simple peanut

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What people from one culture enjoy can be unpleasant to those from another culture. *Gourmet Magazine* ran a great article (August 2005) about three acclaimed Sichuanese chefs from China eating at one of the top restaurants in the United States. The flavors didn't strike chords in the ranges for which the chefs had formed much appreciation. Invariably there will be some differences between your tastes and those of your guests—hopefully you're not cooking for acclaimed Sichuanese chefs!—so don't be surprised if a combination of flavors that you love is merely okay to others.

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butter and jelly sandwich can inspire: imagine a grilled chicken skewer coated with a sweet jelly and sprinkled with chopped toasted peanuts. Maybe you like your pizza topped with onions, tomatoes, and basil. Experiment by using those toppings in a pasta dish or as toppings on bread as an appetizer (bruschetta!).

**Search online with a list of ingredients already in play.** If you're improvising a North African tagine or a stew using tomatoes, onions, and lamb but aren't sure what foods and spices might round out the flavors, run an online search for those ingredients along with

the word "recipe" and see what the Internet says. Just scanning the titles of pages listed in the search results can be enough—in this case, coriander, potatoes, and chili powder are a good bet.

**Use similarity as a good gauge of compatibility.** If a recipe calls for A, but B is extremely similar, try using B instead and see if it works. Kale and chard are both hearty green leaves that can be substituted for each other in many dishes. Likewise, provolone and mozzarella cheese both have mild flavor and share similar melting properties, so using one in place of the other in foods like omelets makes sense. Similar foods aren't always interchangeable. They each have their distinct flavors, and if you attempt to recreate a traditional dish with substitutions, you won't faithfully reproduce the original. But if your goal is to make an enjoyable dish, experimenting with similar ingredients is a great way to see where things line up and where they diverge.

**Remember to adjust quantities to create great flavor.** One of the most important levers for flavor isn't new ingredients, but adjusting quantities of existing ones. Lean in and smell the dish. Then take a taste. What flavors are out of balance? Does it need more of the seasoning ingredients? More salt? If it's dull or flat, would adding more of a sour ingredient (lemon juice or vinegar) add some brightness?

## The French Mother Sauces

*Sauces*—derived from the Latin “to salt” and originally meaning to add seasoning to food—bring flavors to meals by conveying a large amount of flavorings in a small amount of liquid. Western culture has been using them for at least two millennia, and they appear in almost all cuisines. Almost all cultures have their sauces, with techniques and ingredients varying by cuisine. Roast meats are topped with demi-glace; mac ‘n’ cheese relies on a cheese sauce. Mole sauce uses cocoa and peppers; pesto is a simple purée of basil and pine nuts with garlic and olive oil. Sauces appear in desserts, too: crème anglaise (see page 192) can be used as a sweet, rich dairy sauce, and fruit purées can add color and intense flavor (strain them to remove the seeds, and you’ve got *coulis*).

French cuisine is legendary in its use of sauces, so we’ll look there for inspiration. The French *mother sauces* are commonly attributed to Chef Auguste Escoffier—“the king of chefs and chef of kings”—who was one of the most important chefs in Western cuisine because of his work in streamlining the commercial kitchen, creating sanitation standards, and focusing on simplicity in food (“Above all, keep it simple!”). Escoffier’s 1903 seminal work, *Le Guide Culinaire*, defines five basic sauces in its first chapter. While Escoffier deserves credit for popularizing them, most of these sauces are built upon the work of another famous French chef, Marie-Antoine Carême, who had defined four of them roughly 50 years earlier (Carême didn’t include hollandaise).

## Béchamel Sauce, a.k.a. White Sauce

If you learn only one of these sauces, it should be Béchamel sauce. It's useful in everything from quick holiday gravies to dessert bases. Adding a flavoring ingredient such as cheese or mustard turns it into a fantastic sauce.

In a pan, melt **1 tablespoon (15g) butter** over medium heat. Stir in **1 tablespoon (9g) flour** and continue stirring, making sure to combine the flour and butter thoroughly, cooking for several minutes until the mixture begins to turn a blond to light brown color (this butter-flour combination is called a *roux*). Add **1 cup (240 mL) milk**, increase the heat to medium-high, and stir continuously until the mixture has thickened.

Traditional additions include **salt, pepper,** and **nutmeg**. Try adding **dried thyme**, or preheating the milk with **bay leaves**. If you're anti-butter, you can use a half-butter/half-oil mixture.

Like all mother sauces, this recipe can be modified to make "daughter" sauces. After making the roux and adding the milk, try the following variations.

### Mornay sauce (a.k.a. cheese sauce)

This is Béchamel sauce with equal parts of Gruyère and Parmesan melted in. Use 1 cup (~100g) of grated cheese for every cup of milk, adding the cheese in a third at a time to melt. If you're not a stickler for tradition, almost any cheese that melts well will work.

### Bayou sauce

Sauté a large diced onion in the butter, then add a few diced garlic cloves and Creole seasoning (roughly equal parts of onion powder, garlic powder, oregano, basil, thyme, cayenne pepper, paprika, salt, and black pepper). Add the flour and cook the roux until it reaches a dark brown color. This is commonly used in Louisiana-style Cajun cooking.

### Mustard sauce

This is Béchamel sauce with mustard seed or a spoonful of mustard added (try one with whole seeds in it). Mustard sauce can be made into a nice cheddar cheese sauce with the addition of cheddar cheese and Worcestershire sauce. Or try sautéing some diced onions in the butter while making the roux and adding mustard at the end for a mustard-onion sauce.

## Mac 'n' Cheese

The French mother sauces show up all over the place—even mac 'n' cheese is based on a daughter of Béchamel sauce.

Start with a **double batch of Béchamel sauce**. Add and slowly stir until melted:

- 1 cup (100g) grated mozzarella**
- 1 cup (100g) grated cheddar cheese**

In a separate pot, bring lightly salted water to a rolling boil and cook **2 cups / 250g pasta**. Use a small pasta, such as elbow, fusilli, or penne—something that the sauce can cling to. Test for doneness by tasting a piece of the pasta. When the pasta is ready, strain it and transfer it to the pan with the cheese sauce. Stir to combine.

You can stop here for a basic mac 'n' cheese, or spruce it up by mixing in:

- ¼ cup (60g) sautéed onions**
- 2 slices (15g) bacon, cooked and chopped into pieces**
- A pinch of cayenne pepper**

Transfer the mac 'n' cheese to a baking pan or individual bowls, sprinkle it with **breadcrumbs and cheese**, and broil it under medium heat for 2–3 minutes, until the bread and cheese begin to brown.

### Notes

- You can add more milk to the cheese sauce to make it thinner.*
- To make your own breadcrumbs, you can drop a slice of day-old or toasted bread into a food processor or blender and pulse it. Or use a knife and chop it up into small pieces.*

## Velouté Sauce

*Velouté sauce is the basis for many sauces used on top of more mild-flavored fish and meats. If you're looking to make chicken pot pie, start with a double-crust pie dough (see page 259), and then fill it with a combination of diced cooked chicken meat, peas, pearl white onions, and carrots tossed in velouté sauce.*

Start like you're making Béchamel: create a blond roux by melting **1 tablespoon (15g) butter** in a pan over low heat. Stir in **1 tablespoon (9g) flour** and wait for the flour to cook, but not so much that it browns (hence the term *blond roux*). Add **1 cup (240 mL) chicken stock** or other light stock (one that uses raw bones instead of roasted bones, such as fish stock or vegetable broth), and cook the mixture until it's thickened.

You can make derivative sauces by adding various ingredients. Here are a few suggestions. Note the absence of specific measurements; use this as an opportunity to take a guess and adjust the flavors to suit what you like.

<b>Albufera sauce</b>	Lemon juice, egg yolk, cream (try on chicken or asparagus)
<b>Bercy sauce</b>	Shallots, white wine, lemon juice, parsley (try on fish)
<b>Poulette sauce</b>	Mushrooms, parsley, lemon juice (try on chicken)
<b>Aurora sauce</b>	Tomato purée; roughly 1 part tomato to 4 parts velouté, plus butter to taste (try on ravioli)
<b>Hungarian sauce</b>	Onion (diced and sautéed), paprika, white wine (try on meats)
<b>Venetian sauce</b>	Tarragon, shallots, chervil (try on mild fishes)

## Minestrone Soup

*Sauces can also be the base for a soup, as this quick minestrone soup shows. Treat the ingredients as suggestions—really, any good vegetables and whatever starches you have on hand will work.*

Make a **double batch of Aurora sauce** (see under Velouté sauce, above). Keeping the liquid at a simmer, add in **½ cup (70g) small pasta**, such as macaroni or elbow pasta. Toss in some **diced carrots** and **celery**, along with herbs such as **dried oregano** or **basil**. Cook the soup until the pasta is tender. Season it with **salt** and **pepper** to taste.

## Sauce Tomate

Sauce tomate, French for “tomato sauce,” is similar to but not the same as the simple tomato sauces we think of today (those would be Italian tomato sauces). Escoffier’s original recipe calls for salted pork breast; I’m using American bacon (a.k.a. pork belly), as it’s easier to find. You can skip the bacon and butter and use something like olive oil instead if you prefer.

In a saucepan, render **2 slices (~60g) bacon** along with **1 tablespoon (15g) butter**. Once the fat has melted, add **1/3 cup (50g) diced carrots**, **1/3 cup (50g) diced onions (half a small onion)**, and **1 bay leaf** or **1 sprig of thyme**. Cook to soften and lightly brown, about 5 minutes, and then add **2**

**tablespoons (18g) flour** and continue cooking the mixture until it’s light brown.

Add **2 pounds (900g) of mashed tomatoes** and **2 cups (480 mL) of white sauce**. Bring the sauce to a boil, then reduce it to low heat. Add a **crushed garlic clove**, **1 teaspoon (4g) sugar**, and **1/2 teaspoon (3g) salt**. Cover the pan and let the sauce simmer for an hour or so. (If using an oven-safe pan, you can also transfer the pan to a 350°F / 180°C oven and bake it, covered.) Run the sauce through a strainer to remove the vegetable matter and bacon remains, or run it through a blender. Add **freshly ground black pepper** and **additional salt** to taste.

<b>Chunky tomato sauce</b>	Instead of straining or blending the cooked sauce, start with finely diced bacon and vegetables, cut small enough that they can stay in the finished sauce.
<b>Italian tomato sauce</b>	For a more familiar sauce, make the Italian version by leaving out the pork, flour, and white sauce. Cook it slightly longer to thicken it. (Escoffier called this sauce a purée of tomatoes.)
<b>Ketchup</b>	Skip adding the white sauce. Cook the sauce down to thicken it, and add more sugar to taste. For more flavor, add spices like cayenne pepper, chili powder, cinnamon, or paprika.
<b>Vodka sauce</b>	Toward the end of cooking, add 1/2 cup (120 mL) cream and 1/2 cup (120 mL) vodka to the sauce, and simmer it for a few minutes.

## Penne alla Vodka

*Making pasta sauce doesn’t have to be a long, drawn-out affair. You can start with a commercial version of a French mother sauce and then extend it into a derivative sauce, like starting with tomato sauce and adding the cream and vodka yourself to create vodka sauce. “Dressing up” existing commercial products can be a great way to experiment with flavors. I know one person who first learned to cook by adding simple ingredients like bacon or capers to spaghetti sauce!*

Start with **2 cups (480 mL) tomato sauce** from either a batch of *sauce tomate* (above) or a commercially prepared pasta sauce. Optionally add a small spoonful of dried **oregano**. Add **1/2 cup (120 mL) of light cream** and **4 tablespoons (60 mL) vodka**. Toss the sauce with **1 pound (~500g) cooked penne pasta** and top with **freshly grated Parmesan cheese**.



## Hollandaise Sauce

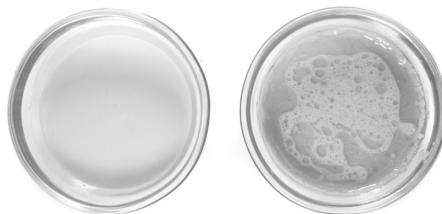
*Hollandaise sauce is the most familiar name of the bunch, typically being served on top of asparagus or poached eggs (see page 193). It's also the most science-y of the bunch: an emulsion of water and fat, like its derivative sauce, mayonnaise (we'll cover emulsions later; see page 429). If you're not a traditionalist, try making the daughter sauces using mayo instead of hollandaise.*

Slice **8 tablespoons (120g) butter** into eight pieces and set aside.

In a saucepan, whisk together **2 large (40g) egg yolks**, the **juice of 1 large lemon (2 tablespoons / 30 mL)**, and a **pinch of salt**. Set the heat to low and whisk the mixture continuously until it just begins to thicken, where the sauce is set enough that you can see a trail left behind from the whisk on the bottom of the pan. Take care not to overheat it, briefly removing the pan from the heat while continuing to whisk as necessary. Add **one tablespoon (15g) of the butter** at a time into the mixture, whisking continuously until it's completely melted and incorporated before adding each of the remaining pats, one by one.

Optionally add a few dashes of **cayenne pepper** and freshly ground **white pepper**. If you find the lemon flavor too strong—not a problem on top of asparagus but perhaps an issue with eggs Benedict—replace one tablespoon (15 mL) of the lemon juice with a tablespoon of water.

<b>Béarnaise sauce</b>	Simmer 2 tablespoons (10g) diced fresh tarragon and 2 finely diced shallots (2 tablespoons / 20g) in 2 tablespoons (30 mL) champagne vinegar or white wine vinegar; add the mixture to the sauce before incorporating the butter. Use mint instead of tarragon to make <i>Paloise sauce</i> .
<b>Dijon sauce</b>	After cooking the hollandaise, add mustard to taste; this sauce is traditionally made with Dijon mustard, which includes white wine instead of vinegar.
<b>Maltaise sauce</b>	After cooking the hollandaise, whisk in grated orange zest and a tablespoon (15 mL) of orange juice, traditionally using a blood orange.
<b>Noisette sauce</b>	Use browned butter (see page 156) instead of regular butter when making the sauce.



*Sauces like hollandaise are based on emulsions that can “break” if the fat and water components separate out. Be careful to not overheat the ingredients when making hollandaise sauce!*

## Espagnole Sauce, a.k.a. Brown Sauce

Also called *brown sauce*, *espagnole sauce* is commonly used to make *demi-glace* for use on meats. *Espagnole sauce* is considered too strong of a flavor to use on its own. It's also much more of a project to make than the other mother sauces, but well worth it to understand how restaurants pull off some of their culinary magic.

In a large saucepan, melt **4 tablespoons (60g) butter**. (Optionally, substitute a slice of bacon for half the butter.)

Add **1/3 cup (50g) diced carrots**, **1/3 cup (50g) diced onions (half a small onion)**, and **1/3 cup (50g) diced celery**. Sauté the vegetables until they're medium brown. Add **4 tablespoons (36g) flour** and cook the mixture until the flour turns light brown. Add **1/4 cup (60g) tomato purée** and **2 quarts (2 liters) basic brown stock** (for the recipe, see the note on page 350 [[Basic White Stock; ChemChapter]]). Brown stock for *espagnole sauce* was traditionally made with roasted veal bones but is now commonly made with chicken bones. (Using canned stock will work but is not as good; canned stock is actually broth and doesn't gelatinize, so it won't have the same mouthfeel. One clever trick to address this is to add a packet of unflavored gelatin into the broth before using it.)

Add a **bay leaf** and a **few sprigs of thyme**. Simmer the sauce for 2 hours, reducing it down by half to about 1 quart (1 liter). As it simmers, periodically skim any foam off the top as needed. Remove the sauce from the heat and allow it to cool, and then filter it through a strainer. (Run it through a second time using a lining of cheesecloth to separate out smaller particles.)

<b>Sauce Robert</b>	Add white wine, onion, and mustard. One of the earliest sauces, this was popular in the 1600s but has since been relegated to the historical archives.
<b>Bordelaise sauce</b>	Add red wine, shallots, and aromatic herbs. This is traditionally served with red meat like filet mignon.
<b>Diabole sauce</b>	Add cayenne pepper, shallots, and white wine. <i>Diabole</i> is French for "devil," which tells you how some feel about cayenne pepper.
<b>Piquante sauce</b>	Add capers, gherkins, vinegar, and white wine. Try serving this on chicken.
<b>Poivrade sauce (a.k.a. pepper sauce)</b>	Add vinegar and a large spoonful of crushed black peppercorns at the end of cooking, simmering the sauce for a few minutes. Take care to not overcook the sauce, as the peppercorns will develop a bitter flavor if cooked too long.

# Lydia Walshin on Unfamiliar Ingredients

PHOTO USED BY PERMISSION OF LYDIA WALSHIN



Lydia Walshin is a professional food writer who also teaches adults how to cook. I spoke with her about how she approaches new ingredients. She can be found online at <http://www.theperfectpantry.com>.

## How do you go about learning what to do with unfamiliar ingredients?

The best way to learn how to use something new is to substitute it in something familiar. So, for instance, I have a great butternut squash soup that I make in the fall and winter. When I get a new spice that I think might have similar characteristics to something in that soup, I start by making a substitution. First, I'll substitute part of the ingredient for part of another ingredient, and I'll see how that tastes. And then maybe I'll substitute that ingredient entirely.

Using the butternut squash soup as an example, my recipe uses curry powder, which in itself is a blend of many ingredients. Recently I discovered an ingredient called *vadouvan*, a French curry powder. How do I learn the way *vadouvan* behaves? I put it into something I already know, and I say, if I take half the curry powder and substitute it for *vadouvan*, how does that change the taste? And then the next time I make it, I substitute *vadouvan* for all of the curry powder, and how does that affect the taste?

Once I understand the difference between something that's familiar and something that's unfamiliar, then I can take that into other kinds of recipes. But if I start with a recipe that I don't necessarily know, and it uses an ingredient I don't know, then I don't know what the ingredient has done in the recipe, because I can't isolate that ingredient from the recipe as a whole.

**You speak of isolating ingredients almost like how a programmer would isolate one variable at a time to see how the system changes. I think a lot of us forget to apply that same methodological approach to food.**

Except that the outcome might not be as quantifiable or predictable when you're cooking, but that's the nonscientific part of me saying that cooking, to me, is both an art and a science. You need to know some fundamentals. It only takes one time making tomato sauce in a cast iron pan to realize that it's not a good idea from a science point of view and from a taste point of view—it's pretty darn awful to watch your sauce turn green and bubbly. So you need to understand the basic fundamentals of science in order to cook, but you don't need to be a scientist in order to cook, and you need to accept the fact that your outcome might be a bit more random than if you were sitting in a computer lab.



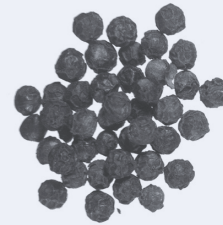
*Vadouvan* is a French-inspired spice blend with dried onions and shallots. Try making your own! See <http://cookingforgeeks.com/book/vadouvan/> for a recipe. For Lydia's *Vadouvan Butternut Squash Soup* recipe, see <http://cookingforgeeks.com/book/squashsoup/>.

## Flavorful Ingredients by Culture

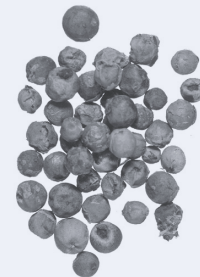
Just as different cultures use different ingredients to adjust the basic taste sensations in food (see page 58), the ingredients used to add smells and aromas also differ. Different flavoring ingredients are available in different parts of the world, based on growing climate, geographic differences in plants, and varying preferences for aromas. Some of these flavorings also change basic tastes, but as you can see, they're all very aromatic. The next time you're planning a meal or making a sauce, try consulting this table for inspiration!

<b>Caribbean</b>	Allspice, coconut, cilantro, hot and sweet peppers, jerk seasoning (primarily allspice and scotch bonnet peppers), lime, molasses, tomatoes
<b>Chinese</b>	Bean sprouts, chilies, garlic, green onions, ginger, hoisin sauce, mushrooms, sesame oil, soy, star anise, szechuan pepper
<b>French</b>	Bay leaves, butter, butter, and more butter, chives, garlic, parsley, shallots, tarragon, vadouvan
<b>Greek</b>	Cucumber, dill, garlic, lemon, mint, olives, oregano, parsley, pine nuts, yogurt
<b>Indian</b>	Cardamom seed, cayenne, coriander, cumin, ghee, ginger, mustard seed, turmeric, yogurt
<b>Italian</b>	Anchovies, balsamic vinegar, basil, citrus zest, fennel, garlic, lemon juice, mint, oregano, red pepper flakes, rosemary
<b>Japanese</b>	Ginger, mirin, mushrooms, scallions, soy
<b>Latin American</b>	Chilies, cilantro, garlic, salsas (varying by region), sofrito (onions fried with produce and herbs), tomatoes
<b>North African</b>	Almonds, aniseed, cilantro, cinnamon, cumin, dates, ginger, harissa, paprika, preserved lemons, saffron, sesame seeds, turmeric
<b>Southeast Asian</b>	Cayenne, coconut, fish sauce, kaffir lime leaves, lemon grass, lime, Thai pepper
<b>Spanish</b>	Garlic, paprika, sweet and hot peppers, sherry, saffron
<b>Turkish</b>	Allspice, cumin, honey, mint, nuts, oregano, parsley, paprika, red pepper, thyme

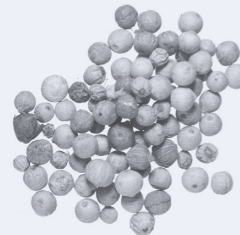
Black pepper, the fruit of a vine originally grown in South India, has a long, storied history and is used by almost all cultures. How the fruit is processed leads to different flavors.



*Black peppercorns are made by briefly boiling and then drying partly-ripe fruit.*



*Dried Green Peppercorns are a preserved version of the unripe fruit and are slightly milder in flavor.*



*White Peppercorns are the fully ripened fruit that has been brined to remove the black, outer shell, which removes much of the spicy kick.*

# Inspiration by Seasonality

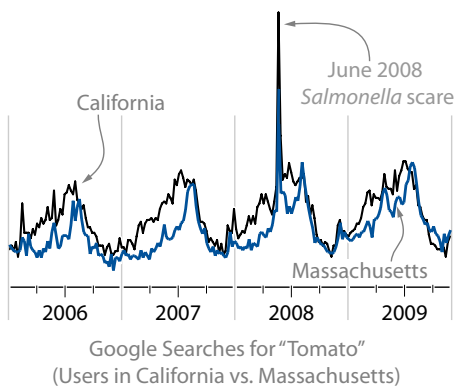
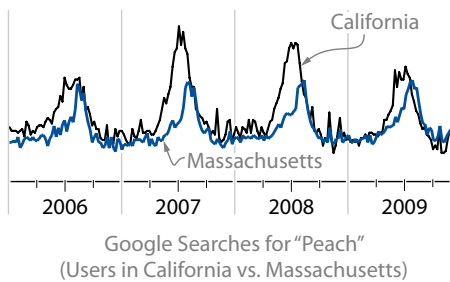
There's something magical about late spring strawberries and fresh summertime corn: flavor! It's no secret that cooking with fresh ingredients brings great flavors to foods. Limiting your shopping list to in-season items is a fun way to challenge yourself, and because in-season ingredients tend to pack more of a flavor punch, it's easier to make your cooking taste amazing. There's another perk of using in-season ingredients: they're generally priced lower, based on the laws of supply and demand. Grocery stores have to figure out how to sell all those zucchinis when they come up for harvest!

Next time you're at the grocery store, take note of what new fruits and vegetables have arrived and what is in dwindling supply. Corn on the cob is one of the most seasonal items where I live, nearly impossible to get out of season. Other produce, like peaches, is available in my local store almost year-round, but rarely delights and usually disappoints. Try this cooking challenge for inspiration: treat any food that's outside its growing season as off-

limits. Peach pie in April? Out. Even if you can get a peach in April, it won't have the same flavor as a mid-summer peach, so your pie will invariably taste bland.

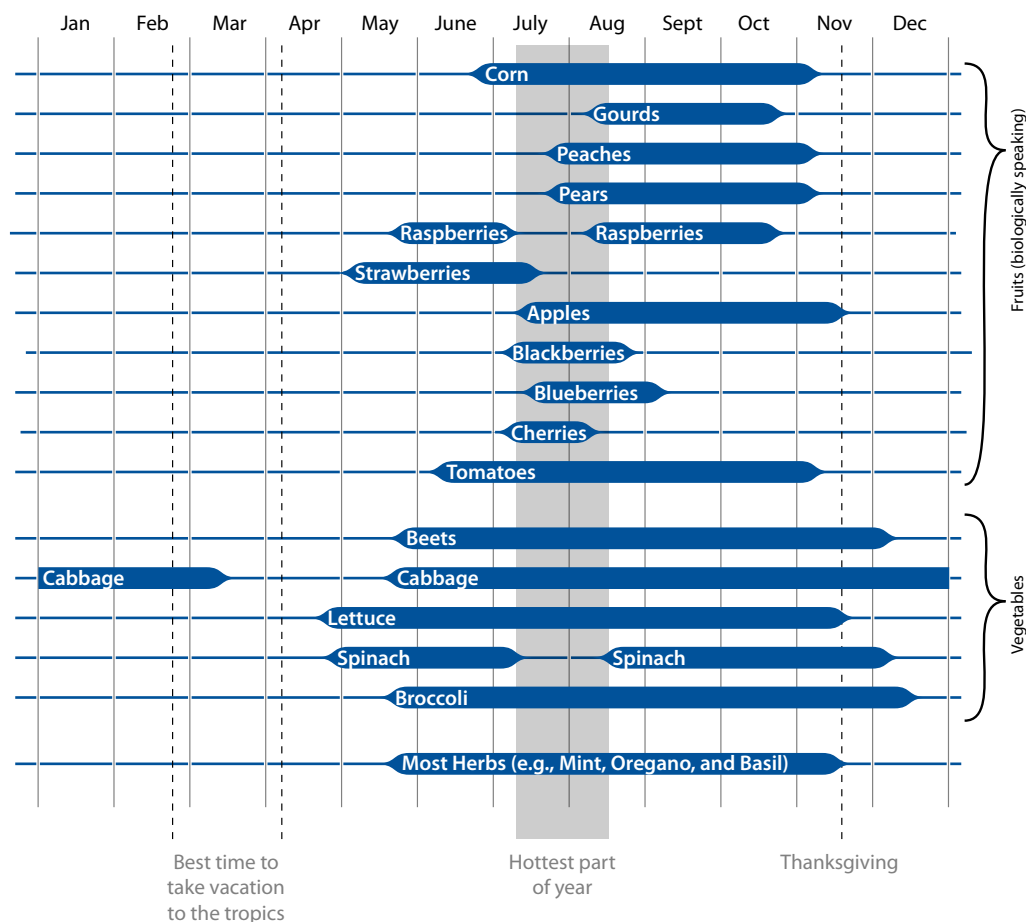
Of course, not every item is a seasonal one. Cellar onions, storage apples, and pantry goods such as rice, flour, and beans are year-round staples. If it's the dead of winter and there's a foot of snow on the ground (incidentally, *not* the best time to eat out at restaurants specializing in local, organic fare), finding fresh produce with good flavor can be a real challenge. There's a reason winter meals in cold climates lean heavily on cooking techniques to produce flavors. Classic French winter dishes like *cassoulet* (traditionally made with beans and slow-cooked meats) and *coq au vin* (stewed chicken in wine) use cellar vegetables and meats from domesticated animals. But come summertime? A quickly sautéed fish with fresh greens is amazing. I can't imagine eating a heavy, rich cassoulet in the middle of summer, yet in the dead of winter, nothing's better.

We're lucky to live in a time with an amazing food supply. Many cuisines are defined by seasonality and the history of the associated region's food environment. The 19th century French favored dishes like cassoulet and *coq au vin* based on their food supply. Cuisines in coastal parts of the Scandinavian region were constrained by the lack of a road system until only a few decades ago, so it's no surprise that modern Nordic cuisine incorporates simple cheeses and preservation methods like cured fish while shying away from complex spices.



Where people live and the time of year change what they eat: Google Trends data shows search volumes for the terms "peach" (top) and "tomato" (bottom) for California users and Massachusetts users. The growing season in Massachusetts starts later and is much shorter than in California.

On the downside, our modern food supply means we're no longer constrained by seasonal ingredients, which makes it harder to learn how to cook well. Shopping at a farmers' market can be a great source for seasonal inspiration and flavorful ingredients that will inspire. Consider the seasonal soups on pages 116–118. Buying butternut squash in July is almost impossible, and I wouldn't make gazpacho in winter. Same thing for seasonal salads. A summer salad with mozzarella, tomatoes, and basil (see page 114)? Yum. A wintertime salad with fennel? A fall harvest salad with toasted pumpkin seeds and sprouted seeds? (Guess who's hungry now, as I write this!) Understanding flavors from the perspective of the seasons can be as easy as strolling through the produce aisle and conjuring the inspiration by exploration covered in the prior section, if you keep your eyes open to the possibilities.



*Seasonality chart for fruits and vegetables in New England. Fruits have a shorter season than vegetables, and only a few vegetables survive past the first frost. Some plants can't tolerate the hottest part of the year; others do best during those times.*

## Fresh Basil, Tomato, and Mozzarella Salad

*Fresh basil and tomato are best at the peak of summertime because the compounds that give them great flavor require warm weather.*



*Try this classic combination when you're able to get good tomatoes. (And if you're adventurous, make your own mozzarella cheese; see page 433.)*

Toss in a bowl and serve:

- 1 cup (180g) sliced tomatoes, about 2 medium ones**
- 1 cup (15g) fresh basil leaves, from about 3 or 4 stems**
- ½ cup (100g) mozzarella**
- 1 tablespoon (15 mL) olive oil**
- 1 teaspoon (5 mL) balsamic vinegar (or more to taste)**
- Salt and pepper to taste**

### Notes

- *There's no wrong ratio of basil to cheese to tomato. Hold back some of each ingredient, take a look at the resulting salad, and toss in more of whatever you think will make it better. The only thing to be careful with is the salt; once there's too much in there, it's hard to fix.*
- *How to slice the tomatoes and cheese is also up to you. Try thick slices of tomato and cheese, alternating in layers on the plate. Or slice the tomato and cheese into bite-size pieces to be served in a bowl.*
- *Try making this twice, once with conventional breeds of tomatoes and a second time with heirloom tomatoes, to see the difference it makes.*

## Fennel, Portobello Mushroom, and Parmesan Salad

*Fennel bulb, also known as Florence fennel, is a cool-weather item, typically harvested in fall or early winter, before any serious winter weather. This simple salad is a great combination of flavors. Make sure to slice everything as thinly as possible and to use high-quality Parmesan cheese and balsamic vinegar.*

Toss in a bowl:

- 1 small fennel bulb (100g), sliced thinly**
- ½ medium Portobello mushroom (60g), sliced thinly**
- 2 ounces (60g) of Parmesan cheese sliced into wide, thin shavings of quality Parmesan**
- 2 tablespoons (30 mL) olive oil**

Serve by transferring a handful of the mix onto a plate. Drizzle a small amount of **balsamic vinegar** on top and optionally sprinkle with **pomegranate seeds** or **toasted pumpkin seeds**.

### Note

- *The best way to separate the seeds out of a pomegranate fruit is under water in a bowl. Slice the fruit in half, drop the halves into a large bowl full of water, and then use your fingers to break open the various compartments and separate the seeds. The fruit's white, inedible, fleshy part (called the mesocarp) will float, while the seeds will sink.*

## Environmentally Sound Food Choices

Cooking “within season” is also a great way to cook with an eye toward environmental impact, but there’s more than seasonality involved in making good, environmentally sound food choices. How do you know what to buy, though?

### Green vegetables and fruits: lowest impact.

Let’s start with the good news, with the greenest of the green: your veggies. Locally grown veggies, sold unpackaged and combined with a minimum of transportation, are about as good as you can get for the environment, and they’re about as good as you can get for yourself. That age-old advice to eat your veggies is also great advice for the environment.

**Seafood: some impact.** Whether farm-raised or wild-caught is better depends upon the species of fish, so there’s no good general rule. There are issues with both types: some methods of farm fishing generate pollutants or allow fish to escape and commingle with wild species, while eating wild-caught fish contributes to the depletion of the ocean’s stocks (and the impact of a global collapse in the fisheries from overfishing is a very real threat to the food-supply system). The biggest contribution you can make—at least on the dinner plate—is to avoid wild-caught seafood of species that are overfished. The Monterey Bay Aquarium runs a great service, Seafood Watch, that provides a list of “best,” “okay,” and “avoid” species, updated frequently and broken out by geographic region. For current recommendations, see <http://www.seafoodwatch.org>.

**Red meats: highest impact.** Red meats like corn-fed beef are environmentally expensive to produce: the cow has to eat, and if she’s fed corn (instead of grass), that corn has to be grown, harvested, and processed. All this results in a higher carbon footprint per pound of slaughtered meat than that of smaller animals like chickens.

Then there’s the fuel expended in transportation, along with the environmental impact of the packaging. By some estimates, producing a pound of red meat creates, on average, four times the greenhouse-gas emissions as a pound of poultry or fish. (See Weber and Matthews’s “Food-Miles and the Relative Climate Impacts of Food Choices in the United States” at <http://cookingforgeeks.com/book/foodmiles/>). Not all red meats are bad, though: if that meat came from a locally raised, grass-fed cow, she might actually be playing a positive role in the environment by converting the energy stored in grass into fertilizer (i.e., manure) for other organisms to use. As a general rule, though, the more legs it has, the “less good” it is for the environment. (By this logic, centipedes are pure evil...)

### *What should I do?*

Regardless of where you fall on the spectrum of local-shopping vegetarian to meat eater delighting in a bacon-wrapped slab of corn-fed beef, limiting consumption is the best method for helping the environment and is also good for your health (not to mention your wallet). Choose foods that have a lower impact on the environment and be mindful of wasted food.

When it comes to animal proteins, current data suggests the total impact on the environment of consuming fish is less than the impact of eating chicken and turkey, which likewise is more sustainable than pork, which is in turn better for the environment than corn-fed beef. One friend of mine follows the “no buy” policy: he happily eats it, but won’t buy it. I’ve heard of others following variants of the “vegetarian before dinner” diet: limiting consumption of meats during the day but pigging out at dinner.



## Springtime Lettuce Soup

*Lettuce soup was a surprise for me, especially as I've never seen it while eating out. Lettuce soup has a succulent taste similar to broccoli soup and is somewhat reminiscent of Vichyssoise, a potato, leek, and onion soup. If you've ever had a CSA share (see page 124) and ended up with 8 heads of lettuce at the beginning of spring, this soup is a great use for them.*

In a large saucepan over medium heat, melt **2 tablespoons (30g) butter** or **olive oil**. Add:

- 1 medium (100g) onion, diced**
- 1 medium (150g) potato, diced**
- ½ teaspoon (3g) salt**

Sauté the onion and potato for 5–10 minutes. Add:

- 4 cups (~1 liter) chicken or vegetable stock**
- 2 cloves (5–10g) garlic, diced**
- ½ teaspoon (1g) freshly ground black pepper**

Bring to a simmer and then add:

- 1 head (400g) lettuce, leaves torn or cut into large strips**

You can use other greens—arugula, pea shoots, spinach—based on what you have on hand. Stir the greens in, cooking a few minutes until they're tender. For a creamier soup, add **1 cup (240 mL) whole milk** or **½ cup (120 mL) cream**.

Remove the saucepan from the heat and allow it to cool for a few minutes. Purée the soup either by using an immersion blender or by transferring it to a blender and processing it in batches.

Add **salt** and **pepper** to taste, and optionally add other spices, such as **coriander** or **nutmeg**. Serve either warm (try sprinkling a cheese like **cheddar** on top) or chilled (top with a spoonful or two of **sour cream** and **fresh chives**).

## Winter White Bean and Garlic Soup

In a bowl, soak for several hours or overnight:

- 2 cups (400g) dry white beans, such as cannellini beans**

After soaking them, drain the beans, place them in a pot, and fill it with water (try adding a few **bay leaves** or a sprig of **rosemary**). Bring the water to a boil and simmer the beans for at least 15 minutes. Strain out the water and put the beans back in a pot (if using an immersion blender) or in the bowl of a food processor.

Add to the pot or bowl with the beans and then purée until blended:

- 2 cups (480 mL) chicken or vegetable stock**
- 1 medium (100g) yellow onion, diced and sautéed**
- 3 slices (50g) French bread, coated in olive oil and toasted on both sides**
- ½ head (25g) garlic, peeled, crushed, and sautéed or roasted**
- Salt and pepper, to taste**

### Notes

- *Don't skip boiling the beans. Really. One type of protein present in beans—phytohaemagglutinin—causes extreme intestinal distress. The beans need to be boiled to denature this protein; cooking them at lower temperatures (e.g., in a slow cooker) will not denature the protein and actually makes things worse. If you're in a rush, use canned white beans; they'll have already been cooked.*
- *Variations: try blending some fresh oregano into the soup. Toss some bacon chunks on top or grate on some Parmesan cheese as well. As with many soups, how chunky versus how creamy to blend the soup is a personal preference.*

## Summertime Gazpacho Soup



*Gazpacho is a Spanish treasure chest of tomatoes and raw vegetables, blended together and served cold—perfect for warm summertime meals. There’s really no wrong combination of ingredients, as long as they’re all full of flavor.*

Purée, using an immersion blender or food processor:

**2 large (500g) tomatoes, peeled, with seeds removed**

Transfer the puréed tomato to a large bowl. Add:

**1 (150g) cucumber, peeled and seeded**

**1 cob (125g) corn, grilled or broiled and cut off the cob**

**1 (100g) red bell pepper, grilled or broiled**

**½ small (30g) red onion, thinly sliced, soaked in water, and drained**

**2 tablespoons (30 mL) olive oil**

**2 cloves (5–10g) garlic, minced or pressed through a garlic press**

**1 teaspoon (5 mL) white wine vinegar or champagne vinegar**

**½ teaspoon (3g) salt**

Stir to combine. Adjust salt to taste and add **ground black pepper** as desired.

### Notes

- *The weights in this recipe are for the prepared ingredients (i.e., after removing seeds, trimming stems, or soaking).*
- *If you prefer a smooth gazpacho, purée all of the ingredients at the end. Or add a portion of the veggies, purée, and then add the remainder to achieve a partly smooth, partly chunky texture. It’s all about your preference!*

- *Gazpacho is a dish that relies on fresh ingredients that invariably have differences in flavor. There’s no mechanical or chemical reason for these quantities to be written as they are, so add more of this, less of that; whatever you like to suit your tastes. Try expanding this recipe to include other ingredients such as hot peppers or fresh herbs.*
- *Grilling or broiling the corn and bell pepper adds a smoked flavor to the soup, due to the chemical reactions that take place at higher heat, as we’ll discuss later in this book. You might find you prefer a “raw” version of this soup. Or, if you really like the smoky flavor, try adding some liquid smoke (see page 403) to amp it up.*

Whenever you see a recipe calling for a grilled vegetable, you should default to rubbing it with a light coating of olive oil before grilling it; this will prevent the vegetable from drying out while cooking.

### How to Peel a Tomato

I have a friend whose boyfriend tried to make her a surprise dinner involving tomato soup, but he didn’t know how to peel tomatoes. She came home to find her guy frantically trying to use a vegetable peeler on the tomatoes, to no avail...

To peel tomatoes, drop them in boiling water for 15–30 seconds, pull them out with tongs or a mesh spider, and then just pull the skins off. You can cut an “x” shape into the skin before blanching the tomatoes, although I find the skin on some varieties will pull back regardless, as long as the water is at a full rolling boil. Experiment to see if it makes a difference!



## Fall Butternut Squash Soup

*Fall, with its harvest and bounty of squash and gourds, is my favorite time of year for seasonal cooking. Treat this recipe as a starting template and add seasoning and other produce as garnish.*

Purée in a food processor or with an immersion blender:

**2 cups (~600g) butternut squash, peeled, cubed, and roasted (about 1 medium squash)**

**2 cups (480 mL) chicken, turkey, or vegetable stock**

**1 small (110g) yellow onion, diced and sautéed**

**½ teaspoon (3g) salt**

### Notes

- *As with the gazpacho recipe, the weights are for the prepared ingredients and only rough suggestions. So, prepare each item individually. For the squash, peel and cube it, then coat it with olive oil, sprinkle it with salt, and roast it in the oven at a temperature around 400–425°F / 200–220°C until it begins to brown. When you go to purée the ingredients, hold back some of the squash and some of the stock, taste the purée, and see which you think it needs. Want it thicker? Add more squash. Thinner? Add more stock.*
- *This soup by itself is very basic. Garnish it with whatever else you have on hand that you think might go well, such as garlic croutons and bacon. Or top it with a small dab of cream, some toasted walnuts, and dried cranberries to give it a feeling of Thanksgiving. How about a teaspoon of maple syrup, a few thin slices of beef, and some fresh oregano? Chives, sour cream, and cheddar cheese? Why not! Instead of purchasing items to follow a recipe exactly, try using leftover ingredients from other meals to complement the squash soup.*
- *If you're in a rush, you can "jump-start" the squash by microwaving it first. Peel and quarter the squash, using a spoon to scoop out the seeds. Then, cube the squash into 1–2" / 3–5 cm pieces, drop it into a glass baking pan that's both oven and microwave safe, and nuke it for 4–5 minutes to partially heat the mass. Remove the squash from the microwave, coat it with olive oil and a light sprinkling of salt, and roast it in a preheated oven until done, about 20–30 minutes. If you're not in a rush, you can skip the peeling step entirely: cut the squash in half; scoop out the seeds; add oil and salt; roast it for about an hour, cut side down, cooking it until the flesh is soft; and use a spoon to scoop it out.*



*To cut thick gourds such as squash and pumpkins, use a large chef's knife and a mallet. First, slice off a thin piece of the gourd so that it lies flat and doesn't roll, then gently tap the knife blade through the gourd.*

## Storage Tips for Fresh Produce

Keeping fresh produce tasting great depends on preserving flavor and controlling ripening. There are two main variables that you should manage: storage temperature and ethylene gas exposure.

Storage temperature is the easier variable to control. Store ripe, cold-tolerant produce in the fridge; keep unripe or cold-susceptible produce on the counter or in the pantry. “Chill injury” is the industry lingo for damage to food stored too cold and typically happens below 50°F (10°C). Tropical and subtropical fruits like bananas, citrus, cucumbers, mangos, and watermelon should be kept out of the fridge for best flavor. Lettuce and most herbs are fine in the fridge, with the exception of basil, which should be treated like fresh flowers (trim the ends off and keep it on the counter in a glass with the ends submerged in water).

The second storage variable, ethylene gas, has some quirks. Ethylene gas is naturally generated by plants, usually the fruiting part, as part of the ripening process. Storing one produce item that generates ethylene gas next to another produce item can speed up how quickly the second item ripens, but can also lead to undesirable results, as the following list shows.

Regardless of the type of produce, it should be picked mature, at a point when its flavors have fully developed. Ripening and flavor development are two different processes! If produce is picked too early, no amount of ethylene gas ripening can add good flavor.

### *Ripen in the Presence of Ethylene Gas*

*To speed up ripening, store these in a loosely folded paper bag out of direct sunlight, at room temperature. Never store unripe fruits in the fridge, as the temperature is too low for ethylene gas to further their ripening.*

**Apricots, peaches, plums.** Ripe fruits will be aromatic and will yield slightly to a gentle squeeze, at which point you can store them in the fridge. Keep unripe stone fruits at room temperature; storing them in the refrigerator causes chill injury, turning them mealy. Also avoid storing unripe stone fruits in direct sunlight or in plastic bags, which trap moisture. If you’re lucky enough to be gifted pounds and pounds of these fruits, either freeze them, make jam (see page 419), or dry them (see page 352) before they have time to go bad.

**Avocados.** Ripe fruit will be slightly firm but will yield to gentle pressure. Color alone will not tell you if the avocado is ripe. Storing cut avocados with the pit doesn’t prevent browning, which is due to both oxidation and an enzymatic reaction, but does stop browning where the pit prevents air from coming in contact with the flesh. Prevent air exposure by covering the cut edge with plastic wrap, or pouring a thin layer of olive oil on top of guacamole.

**Bananas.** Leave at room temperature until ripe. To prevent further ripening, store in the refrigerator—the peel will turn brown, but the fruit will not change.

**Blueberries.** While blueberries do ripen in the presence of ethylene, their flavor is not improved from this. See upcoming advice for blackberries, etc.

**Tomatoes.** Store at temperatures above 55°F / 13°C. Storing unripe ones in the fridge will prevent them from ripening and also affects their flavor and texture, although some folks feel fully ripened tomatoes don’t suffer much when chilled. If the ultimate destination for the tomatoes is a sauce, you can also cook them and then refrigerate or freeze the sauce.

**Potatoes.** Keep potatoes in a cool, dry place (but not the fridge; the cold will turn them sweet). Sunlight can make the skin turn green. If this occurs, you *must* peel off the skin before eating them. The green color is due to the presence of chlorophyll, which develops at the same time that the neurotoxins solanine and chaconine are produced. Since most of the nutrients in a potato are contained directly below the skin, avoid peeling them whenever possible. (You're unlikely to die from the amount of solanine present in an average potato that's gone green, about ~0.4 mg, but you can still end up with an unpleasant digestive tract experience for the better part of a day. For more, see <http://cookingforgeeks.com/book/solanine/>.)

#### Unaffected or Negatively Impacted by Ethylene Gas

*Store these separately from ethylene-producing produce.*

**Asparagus.** Store stalks, with bottoms wrapped in a damp paper towel, in the crisper section or the coldest part of the fridge. You can also put them in a glass or mug, like cut flowers (trim the ends first). Eat them as soon as possible because the flavor diminishes with time.

#### **Blackberries, raspberries, and strawberries.**

Toss out any moldy or deformed berries. Immediately eat any overripe berries. Return the other berries to the original container, or arrange them (unwashed) in a shallow pan lined with paper towels and store them in the fridge. To absorb additional moisture, place a paper towel on top of the berries. Wash them just prior to use; washing before storing them adds moisture that aids the growth of mold.

**Broccoli, cabbage, collard greens, kale, leeks, and Swiss chard.** Store in the crisper drawer of the refrigerator or in a plastic bag poked with holes to allow for any excess moisture and

ethylene to escape. Ethylene causes florets and leaves to turn yellow.

**Carrots.** Given a few weeks, ethylene can cause carrots to develop a bitter flavor. Break off green tops. Rinse carrots, place them in a plastic bag, and store them in the crisper section of the fridge. Storing carrots in the fridge will preserve their flavor, texture, and beta-carotene content.

**Citrus.** Ethylene gas helps shift the color from green to yellow (called *degreening*) and speeds up potential decay, but doesn't improve the edible part. To avoid mold in medium-term storage (6–8 weeks), store fruit in resealable bags in the produce drawer of your fridge.

**Cucumbers.** Cucumbers stored in the fridge will begin to surface pit and deteriorate after a few days. Store them on the countertop but away from fruit, as they are sensitive to ethylene.

**Garlic.** Store in a cool, dark place, but not the fridge, where odors will transfer. You can still use cloves that have sprouted, but they will not be as strong in flavor. The sprouts themselves can be cut up like scallions or chives and used in dishes.

**Lettuce and salad greens.** Check greens bought in bunches for insects. Wash the leaves, wrap the lettuce in a towel or paper towel, and then store it in the fridge in a plastic bag poked with a few holes. If you won't be using the lettuce in the next few days, wait to wash the leaves until later, as the added moisture can speed up deterioration.

**Onions.** Ethylene can lead to mold growth. Keep onions in a cool, dry space away from bright light. Onions do best in an area that allows for air circulation. Do not place onions near potatoes, because potatoes give off both moisture and ethylene, which will cause the onions to spoil more quickly. Also, don't store onions in the fridge—they'll become soft and their flavor will spread to other foods.

# Tim Wiechmann and Linda Anctil on Seasonal Inspiration



*Tim Wiechmann is the chef and owner of T.W. Food in Massachusetts.*

## **How do you go about planning a dish?**

I start with the ingredients—they all have to be in season. I came up with a dish that was made with leftover cheese from the Pyrénées. Black cherries and beets are in season, so how can I dress up a beet salad? In the Pyrénées, they have cherries with sheep's milk cheese. Most of my stuff comes from cultural things, from traveling all over and having a sound grasp on food in Europe. I study what people make from all over—they do this here, they do that there. And these things are done for thousands of years. I try to have a knowledge of these things and then I just look at my own ingredients here, and I draw them together.

My menu is actually really difficult. Everything goes through a rigorous, precise set of cooking parameters. With certain preparations, time and temperature are everything. Observation is critical, as is getting experience in knowing what looks good. If you're cooking an onion, it changes color over time. There are certain stages where you want to pull it because the bitterness increases as the caramelization increases. Onions in a tall pot will sweat differently than onions in wide pot. In a tall pot, they release their own water and cook evenly because the water doesn't disappear. We have specific pots that are good for certain things—sweat the

onions in this pot; don't use that pot—but a new cook will just grab any pot.

## **How do you know if something is going to work?**

You just try. When you start to play the piano, you don't know where the notes are. You have to have the technique, then you can think about putting the notes together. If I hit this note, then I'll get this sound; if I want onions to be sweet, I'll caramelize them. The technique follows the knowledge. I keep a log of my own recipes and times for each thing. How long to put cherries or apples in a bag and cook in the water circulator—that comes out of experience.

My big thing I always say: "Get into it and go for it." Every time you cook something—even if you burn it and it goes in the trash—it's not a failure, it's just: next time I'm not going to burn it.

*For Tim's roasted beet salad recipe, see <http://cookingforgeeks.com/book/beetsalad/>.*



*Linda Anctil is a private chef in Connecticut.*

## **How do you think about the visual experience of food?**

I approach food as a designer, but because it is food, it also has to function. Ultimately, it has to taste good. Sometimes, I'm inspired by an ingredient, a season, a shape, or a color, but inspiration can come from anywhere. I always try to include an element of surprise, whether it's visual or stimulating to other senses.

Nature is a constant source of inspiration to me. I went out to the garden to pick some sage last winter, and I had the scent of conifers from my Christmas tree on my gloves. The smells became intermingled in my mind and, suddenly, conifers became something I could use as an herb. It inspired a whole series of dishes that I put together using the flavor of conifer. I did one where I layered lots of different textures and flavors together, culminating with my video "The Winter Garden." I think it was probably my most abstract or conceptual dish that I've put together, but it really captured that whole feeling of being outside on that one day with the ice and the snow and the frost and the smell of conifers. I was the only one who ate the dish in the end. I enjoyed it a lot. It was a very personal expression to me.

## **Do you have any suggestions about how to think about presenting food?**

Keep an open mind. Pick up a piece of fruit and imagine that you were an alien on this planet who had never seen it before, and experience it through that lens. How does it look to you? What does it smell like? What does it taste like? What can you do with it? Think outside of the box and enjoy the journey! You can look at any artist or chef's food, and you'll realize it's a personal expression of who they are. It's telling a story about that person's experiences. That's a wonderful aspect of cooking.

*To watch one of Linda's videos, see <http://cookingforgeeks.com/book/winterdish/>.*

## Organic, Local, and Conventional Foods

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Seasonality of produce is only one aspect of choosing what to eat. What about organic, local, and conventional foods? There are lots of opinions and facts on these topics, and often the two get mixed together. Spoiler alert: the science doesn't back up a lot of the commonly held opinions, and there are some deep philosophical issues unrelated to the science here.

**Organic foods** are those produced following governmental regulations that restrict the use of fertilizers, pesticides, herbicides, and hormones and require humane treatment of animals. US-based food producers must be certified as following the USDA National Organic Program (NOP) regulations in order to claim organic status; likewise, businesses in the European Union must follow European Commission General Food Law regulations and pass annual audits. (As a side note, the EU and US use the same definition of organic so that the two regions can cross-ship organic foods.) Because of the current higher consumer demand for organic foods, their cost is typically higher: supply hasn't had time to catch up to demand. Organic foods also have a cost burden associated with paperwork and certification, so some smaller operations may follow the legal definition but opt to not pay for certification, and therefore can't label their food "organic."

**Local foods** have no formal legal definition, but the common lay definition is based on how many miles away a food was produced—typically, up to "a few hours' drive." *Food hubs*—sites that act as exchanges for local farms and ranches to sell product to larger-volume buyers like grocery stores—are quickly becoming common, and are strengthening local and regional food systems in fantastic ways. Eating foods produced locally has a number of benefits, including supporting the local economy, staying "within season," and connecting to the food supply on a deeper level. (Search online for the USDA's "Know Your Farmer, Know Your Food" site.) The term *local* is unrelated to *organic*, but to some consumers there is a shared ethos of sustainability, food security, and environmentalism. *Local* doesn't guarantee these things, though!

**Conventional foods** are those not certified for sale under the label *organic*. They must still be grown to acceptable government regulations, of course. Conventional food may or may not be local.

### *What's the difference in taste?*

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Organic food is viewed by some consumers as being more authentic and has a "halo of tasting better." Taste differences can certainly exist between a head of organic romaine lettuce and a conventional one at your local grocery store due to microclimate differences or how the produce is handled, but studies that have done head-to-head comparisons of identical plant varieties grown conventionally and organically have found zero difference in terms of taste. The use of organic pesticides over conventional ones does not, in and of itself, lead to taste differences.

Local produce is also often thought to taste better and has a similar “halo” effect. For some produce, flavor will deteriorate over time after harvest, so local produce may be fresher and taste better. But that’s not necessarily the case. Radishes, for example, taste better when grown in hotter climates. If you live in a comparatively cooler climate, radishes grown farther away may taste better, and their environmental impact can also be lower if locally grown ones rely on hothouses.

If this answer surprises you, consider the power of the placebo effect. If you *believe* that something is going to taste better, then it probably will. Placebo effects in taste can be incredibly, incredibly powerful, as the food marketing associations know. But the data doesn’t support the beliefs that most consumers have about any perceived taste differences.

### *What about exposure to chemicals?*

Regardless of whether you’re handling conventional or organic food, government regulations limit the levels of all types of herbicides and pesticides that are legally allowed to be present in the end products. No one should be exposed to pesticides or herbicides above certain levels, and this has been a real issue for farm workers. But is it an issue for you? The answer is complicated.

Exposure to organic pesticides and herbicides *as a category* has not been shown to be any safer than exposure to conventional ones. Some chemicals, regardless of type, are carcinogenic at sufficient concentration—dosage matters, as chemists like to say. The detectable levels of pesticides in our bodies are well below anything approaching toxic. To put some numbers to how much we’re being exposed to carcinogenic pesticides in conventional foods, consider what Dr. Belitz et al. wrote in *Food Chemistry* (Springer, 2009): “[T]he natural chemicals [in a cup of coffee] that are known carcinogens are about equal to a year’s worth of synthetic pesticide residues that are carcinogens.”

Organic products test as having lower levels of pesticides but don’t test as having better nutritional value than equivalent conventional products. Individuals who consume organic products do test as having lower levels of pesticide residues in their blood. But does having a pesticide in your bloodstream at some minimal quantity change your overall health or lifespan? The uncertainty here is why many consumers buy organic foods (especially, it turns out, new parents). There’s a lot we don’t know about long-term chemical interactions between pesticides/herbicides and our bodies. We do know that all approved pesticides are essentially safe, in the sense that they are well studied. But we don’t know, with 100% certainty, that their long-term impact is absolutely zero. It’s likely not (how could it be?), but is the impact meaningful? It may be unknowable. This is why I consider whether to buy organic or conventional products a philosophical question—how do you feel about uncertainty, when the scientific community has found very little to suggest there are risks?



### *How about no chemicals?*

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Well, food *is* chemicals, so presumably anyone asking this means added chemicals like pesticides. This may seem like an unnecessary point to make, but I've learned it's important! For example, a survey done in 1999 found that one in three respondents believed "Ordinary tomatoes don't have genes, but genetically modified ones do." Given the option, farmers would prefer to not spray any herbicides or pesticides on their crops and ranchers would rather not have to use vaccinations or drugs: they cost money and take time to use.

### *Best bang for buck?*

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Whether to shop specifically for foods that are local and/or organic is more of an ethical and moral question than a scientific one. There's a lot more to the spirit behind these choices than the nutritional value and taste sensation.

If you want to buy local produce, it's also generally cheaper: transportation costs aren't as high. Beyond the grocery store, look for a farmers' market. Farmers' markets are a great way to really understand where your food is coming from and to think about cooking and eating seasonally. Plus, your local farmer will thank you. If you want to "level up," see if you can find a nearby CSA (community-supported agriculture) share; these are fractional shares where you pay a few hundred dollars at the beginning of the growing season and then receive some fraction of the farm's yield and share in the risk (hopefully, not a drought year). They're as close as you can get to your produce without growing it yourself, and a great way to challenge yourself in cooking. (What the heck do you do with 10 heads of lettuce? Try lettuce soup: see page 116.)

If you want to buy organic but are on a tight budget, here are some general rules of thumb for where the biggest differences are in produce. For fruits, if you're going to eat the skin, buy organic. If you're going to peel them, buying organic appears to offer comparatively little difference. For veggies, organic bell pepper, celery, kale, and lettuce test as having lower levels of pesticides than their conventional counterparts. For animal products high in fat like butter and fatty meats, buy organic; a number of pesticides are fat soluble so remain in the end product.

My personal take? Being engaged in where your food comes from and taking time to cook for yourself and others is more important than whether your food is organic or conventional by the legal definitions.

*"Below legally allowed levels" doesn't mean "100% guaranteed," regardless of whether you're buying organic or conventional. In the US, the FDA inspects less than 1% of imports (as of 2012), and excess pesticide residues have been found in some foods imported from abroad when tested by independent researchers. Enforcement (and funding for it) needs to be stepped up.*

# Computational Flavor Inspiration

*Computer, what goes well with Tea, Earl Grey, Hot?*

Technology isn't that far away from being able to answer questions like this, and it's exciting! Imagine opening your fridge door, seeing a few leftover ingredients from a prior night's meal, and tapping a button on a device and saying, "Show recipes that use chicken, cilantro, and lemons." My current high-tech watch already lets me do this!

What about more inspirational possibilities? Finding recipes that use a handful of ingredients is one thing, but what if we could computationally predict new recipes, creating combinations that had never been tried before yet delight with flavor? Thanks to a better understanding of how flavors work and having enough combined data to comb through, it's now possible.

There are two main approaches to computational flavor inspiration: co-occurrence of ingredients and chemical similarity between ingredients. Both have their advantages and disadvantages; more recent research that combines the methods is beginning to bear fruit. Computers are really good at comparing lots of numbers, and these methods definitely benefit from that. (They're also really good at doing *exactly* what they're programmed to do, not what we necessarily *meant* them to do.)

First, a disclaimer: picking pleasing flavors—or at least ones that invoke an emotional response or trigger a memory—is somewhere between an art and a science. No scientific equation can capture the entire picture, and what you're craving at any given moment will also vary. Still, understanding how "flavor compatibility algorithms" work can provide you with a way of organizing your thoughts on food, and the results can be useful for the more inquisitive, off-recipe type of cook.

## Co-Occurrence of Ingredients

If items A, B, and C go together in one dish; and another dish uses B, C, and D; then there's a decent chance that A might work in the second dish as well. These sorts of transitive relationships aren't guaranteed to work, but they are useful enough that most good cooks use them intuitively. Say you like guacamole and know that it commonly contains avocado, garlic, onion, lime juice, and cilantro. When tossing together a salad that has similar ingredients—say, tomato, avocado slices, and onion—it's reasonable to guess that some coarsely chopped cilantro will work well in it, and maybe even some crushed garlic in a vinegar/oil dressing.

What if we took this idea a step further by computationally examining thousands of recipes and their ingredients? A few projects and notable books have already done this, but it's still a fun exercise. Snag a few thousand recipes (easy enough for a computer science major like myself), run them through something to clean up the data, and *voilà!* You'll have a co-occurrence matrix that shows the relative probability that an ingredient shows up with

another. With a few tweaks (normalizing the weights to be 0 to 1; dropping salt, which links everything together), the results become almost human readable. (See <http://cookingforgeeks.com/book/cooccurrence/> for a .csv file.)



*Ingredients commonly paired with chocolate based on co-occurrence in recipes—it's commonly used with almonds, bananas, butter, cinnamon, coconut, hot peppers, milk, walnuts, and vanilla.*

For chocolate, the most common ingredient it's paired with is vanilla (giving it a weight of 1 in the normalized co-occurrence matrix). The second most common ingredient (in my dataset) is milk (0.320). Walnuts (0.243), oil (0.166), cream (0.128), and pecans (0.121) are the next four. Hearing this list yields no surprises; chocolate is common with vanilla, dairy, and nuts. For other ingredients, it can be a boon. What spices are typically used with beef? (Black pepper, parsley, thyme, bay leaf, oregano, chili.) Or chicken? (Parsley, thyme, basil, paprika, cayenne pepper, ginger.) You could extend this by collecting different collections of recipes—how does ingredient co-occurrence change between cultures? (“Computer, adjust recipe to be Tex-Mex style.”) Or over time? Imagine the possibilities.

Data is only as useful as the ability to see and act upon it, so unless you're a spreadsheet junkie, something more is needed to visualize the data. I've hacked together a simple interface for clicking through the various ingredients (see <http://cookingforgeeks.com/book/foodgraph/>). With time, it'll become unusable

(or go offline). There's an expression in software, “code rot,” that describes how software becomes more buggy and less usable as the systems we use are updated and no longer 100% backward compatible. See the example image for chocolate to understand what the software looks like if you're unable to load it.

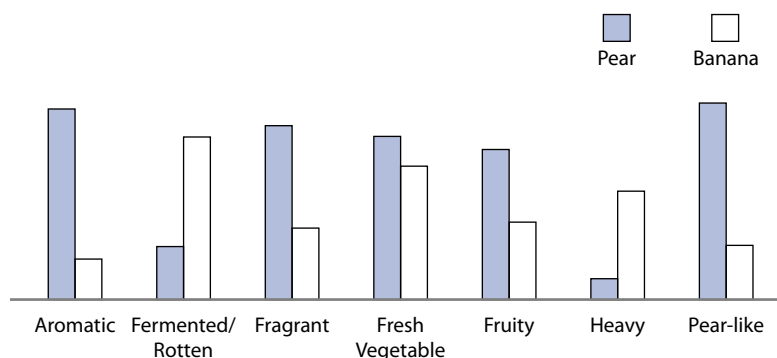
## Chemical Similarity

Many of the compounds that give ingredients their flavors can be measured and quantified—assuming you have access to lab equipment that does stuff like chromatography! Drop a sample in, separate out the compounds, and compare the results to those of known compounds. Okay, okay; this is a gross oversimplification. Maybe some day in the distant future my watch could do it, but for now it's not easy; and even the best lab equipment is not sensitive enough to detect all the odorants our noses can smell. For this reason, I'm going to describe the concept of chemical similarity using odor descriptions instead; we'll use our noses as the chemical detectors. It's only one step removed from measuring the odorants directly.

One way to determine similarity is by measuring a number of different variables—say, quantities of potential compounds or odors—and then comparing items based on those different variables. It’s a two-step process: first, figure out a bunch of numbers that describe an individual item; and second, compare those numbers between different items.

This is more easily described with an example. Imagine a flavor profile for a food item, where the profile is how much the food item smells like the terms in Andrew Dravnieks’s 146-odor list (see page 94). For every term in the list, take an item of food and score it on a scale from 1 to 5, where a score of 1 indicates “doesn’t smell like it at all” and 5 is “the very definition of the word!” Given a pear, how much does it smell like a “heavy” odor? 1. Fruity? Maybe a 3? Or how about fragrant? Say it’s a ripe pear, so 4. (The full odor atlas that Dravnieks created does something similar using a collection of known chemical compounds.) This first ranking step is not asking if the food item and odor description are compatible, just if the odor label accurately describes the smell and quantifying it with a number.

The second step to similarity matching compares the values for different ingredients, based on the theory that ingredients with similar scores can be combined or substituted for each other. Given the scores for the odors you sense in a pear, and those you sense in a banana, how much overlap would there be? You can plot a graph (almost like a histogram) for the two, showing how similar they smell. Do this for a bunch of ingredients, and it’s easy to show that pear and banana have more similar odors than, say, salmon and pear.



*Results from asking a few thousand untrained users online to vote how much they thought various odor terms described bananas and pears (taller bars indicate a larger degree of agreement between food and odor).*

Unlike ingredient co-occurrence, the chemical similarity method can find overlapping flavors that wouldn’t historically exist. You can imagine a graph with all the ingredients for a dish, showing all the “frequencies” present in the smells of each ingredient. Think of it like the various instruments that contribute to a piece of music: each has its own set of frequencies, and the combination of all the instruments makes up the overall song’s frequency distribution. When in tune, the frequencies line up: different ingredients hit the same odor terms, and not too many odor terms are struck. And as in music, when a dish is out of tune, the combination will be jarringly dissonant, even if each item is fine individually.

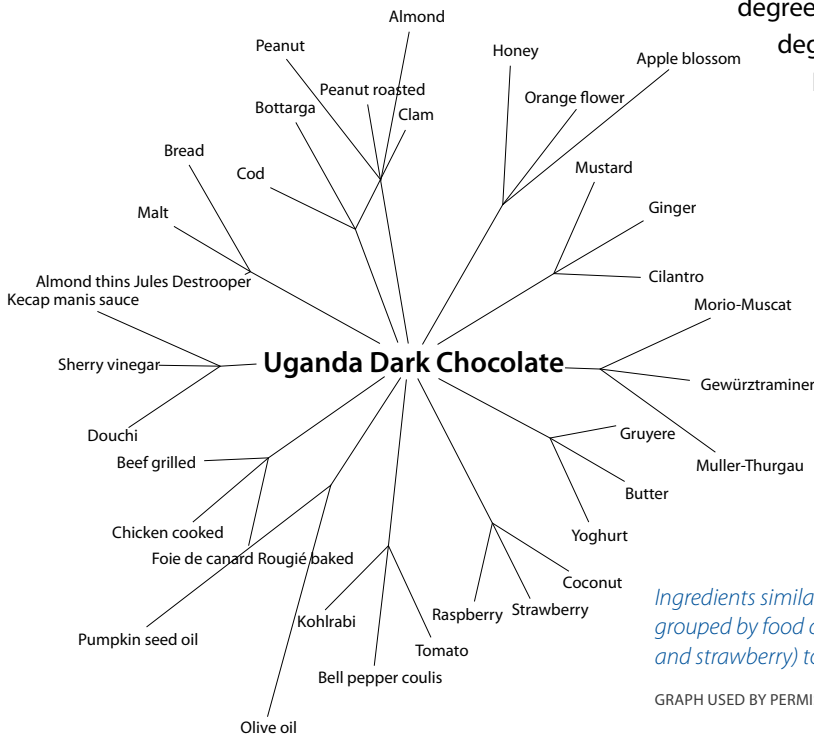
Of course, this music analogy isn't a perfect fit for thinking about flavors: chemical changes brought about by cooking or by reactions between compounds in the foods change the histogram. The music analogy also doesn't cover other variables in foods, such as texture, weight, or mouthfeel. This method works best with ingredients whose primary purpose is conveying odor. Soups, ice creams, even soufflés: all are methods of transporting the flavors and aromas of ingredients without carrying the texture or volume of the original ingredient.

Heston Blumenthal, the UK-based chef best known for his restaurant The Fat Duck, has used a number of novel flavor combinations: strawberry and coriander, snails and beetroot, chocolate and pink peppercorn, carrot and violet, pineapple and certain types of blue cheese, and banana and parsley. They sound crazy, but the research supports them and they've worked in his dishes.

Many chefs—often pros, but also non-pros who've been cooking for years—can imagine flavor combinations in their heads, doing something similar to this process mentally. Just as a composer imagines each voice and track in a piece of music, an experienced cook imagines the profile of the entire dish, from the appearance to texture and aromas. Good cooks think about which notes are missing or are too soft and figure out what ingredients can be added to bring up those values or bring down others.

What about achieving entirely new pairings, combinations that have no precedence in tradition? That's where this method shines. Research chefs searching for new ideas spend an inordinate amount of time working on new flavor combinations. Some top-tier restaurants run research kitchens, devoted to laboratory work and staffed by individuals holding both master's-level degrees in hard sciences like chemistry *and* degrees from top-tier culinary institutions.

For novel high-end restaurants and the packaged food industry, coming up with new flavors can be extremely lucrative. While the more unusual combinations they come up with may sound unappealing or call for uncommon ingredients—how often do you have caviar on hand?—they do work. At the very least, you might find these types of tools a fun source of inspiration to try new things. Experiment!



*Ingredients similar to chocolate based on chemical similarity, grouped by food category—from the traditional (fruits like raspberry and strawberry) to the uncommon (Gruyère, cod, tomatoes).*

GRAPH USED BY PERMISSION OF BERNARD LAHOUSSE OF FOODPAIRING.COM

## Fish Tacos with Pickle and Strawberry Relish

*I began this chapter with the conundrum of how to combine pickles, strawberries, and tortillas—a combination of ingredients that doesn't entice one to race off to the kitchen. But what if we had access to a supercomputer that could chew on the possibilities? IBM's research project, Chef Watson (<http://www.ibmchefwatson.com>), does exactly this, and has proved to be enticing enough to merit its own cookbook, *Cognitive Cooking with Chef Watson* (Sourcebooks, 2015). I take this development as proof that either computers are taking over the world or one no longer needs a pulse to land a book contract—possibly both.*

*Chef Watson is a curious creation, based on analyzing co-occurrence of ingredients in its database of recipes (currently, some 9,000 recipes from *Bon Appétit*) and chemical compound similarity between ingredients. When not constrained too much—say, starting with eggs and chocolate—the suggested recipes make sense and are just quirky enough to inspire. Making brownies with a cup of Gruyère cheese instead of butter? The cheese will provide the necessary fat, and cream cheese in brownies isn't unheard of. With more constraints—pickles, strawberries, and tortillas—the recipe suggestions go from quirky to weird. Even so, the results are still insightful; in the case of these three ingredients, most of the suggested recipes include fish and take the form of tacos. Strawberries happen to share a number of odor compounds with tomatoes, and knowing this, it's easier to see how the combination could work!*

In a small bowl, create the taco topping by mixing together:

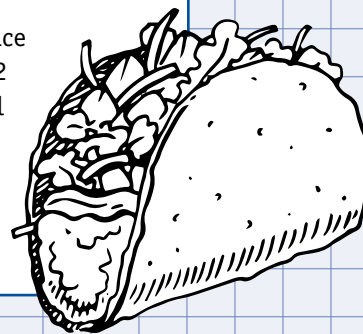
- ½ cup (90g) strawberries, hulled and diced**
- ¼ cup (40g) pickles, diced and drained**
- ¼ cup (15g) cilantro, chopped**
- 1 tablespoon (15 mL) white wine, dry vermouth, or gin**

Set the topping aside.

Prepare **½ pound (~250g) fish or seafood such as halibut, tuna, or crab** by cutting it into large chunks, 1-2" / 3-5 cm. Coat the pieces in breadcrumbs, mixing **¼ cup (~20g) panko crumbs or breadcrumbs** with **½ teaspoon (2g) sea salt** and then dredging the pieces of seafood in the crumbs.

In a frying pan over medium heat, melt **2 tablespoons (30g) butter**. Once the butter has just begun to brown, add the fish pieces. Cook for about 2 minutes and then flip the pieces, continuing to cook and flip them until the fish is cooked and the breadcrumbs are golden brown and toasted.

Serve by placing a **taco shell or tortilla** on a plate and then topping with a spoonful of the fish and a smaller spoonful of the topping. Squeeze a **slice of lime** on top.



## Lab: How Well Do You Know Your Flavors?

How well do you think you know your flavors? Here are two different group activities to challenge participants to think about what they're sensing. The first experiment uses both taste and smell and requires more advance prep work. The second experiment uses only smell and avoids potential allergy concerns, but isn't quite as rewarding.

### First, grab these supplies:

#### For Experiment #1: Flavor (both taste and smell)

10 small sample cups or an ice cube tray with at least 10 compartments (if you're going to do this in a larger group, plan on 6–10 people per setup; for a group of 36, 4 ice cube trays with folks divided into 4 groups works well)

Pen to mark cups; if you're using ice cube trays, masking tape that you can write on

Small sample spoons for each participant (if you don't mind "double dipping," one spoon per person is fine)

Paper and pencil for each participant to write down their guesses

Ingredients for tasting. (A few of these are a little obscure, but they serve as fun challenges for tasters familiar with common flavors. If your local grocery store doesn't carry all of these, snag other ingredients that you feel will work well based on where you live and how experienced the tasters will be.)

- White turnip, cooked and diced
- Cooked polenta, diced (some stores carry packaged cooked polenta that can be easily sliced)
- Hazelnuts ground to the size of coarse sand
- Cilantro paste (look in the frozen food section, or buy fresh cilantro and use a mortar and pestle to make a paste)
- Tamarind paste or tamarind concentrate
- Oreo cookies, ground (both chocolate cookie and cream filling; when ground in a blender or food processor they'll turn into a coarse, black powder)
- Almond butter (or any nut butter other than peanut butter)
- Caraway seeds
- Jicama root, diced
- Puréed blackberry

#### For Experiment #2: Smell only

15 plastic or waxed paper cups (one set of smell samples should be good for 30–40 people; for larger groups, multiply accordingly)

15 small pieces of gauze or cheesecloth to cover each cup; 15 rubber bands to secure gauze or cheesecloth

Paper and pencil for each participant to write down their guesses

Ingredients to smell. (If you have a hard time getting some of these, try substituting something similar, or simply drop the item.)

- Almond extract
- Baby powder
- Chocolate chips
- Coffee beans
- Cologne or perfume (spray directly into the cup or onto a tissue)
- Garlic, crushed
- Glass cleaner
- Grass, chopped up
- Lemon, sliced into wedges
- Maple syrup (real maple syrup, not that "pancake syrup" stuff)
- Orange peels
- Soy sauce
- Tea leaves
- Vanilla extract
- Wood shavings (e.g., sawdust, pencil shavings)

# Lab: How Well Do You Know Your Flavors?

## Here's what to do:

### *Experiment #1: Flavor (both taste and smell)*

#### **In advance:**

1. Number each cup from 1 to 10. If you're using ice cube trays, place a strip of masking tape down the length of the tray so that you can label each compartment, and number them 1 through 10.
2. Dice or purée the food items to remove any visual clues about their normal size and texture and transfer them to the appropriate numbered spots. Try to keep the diced items all of a consistent size, around  $\frac{1}{3}$ " / 1 cm.
3. Cover the samples; if you're preparing them more than a few hours ahead, store them in the fridge.

#### **When ready:**

1. Make sure to alert anyone who has nut allergies or uncommon allergies that they should abstain from partaking.
2. Instruct participants to sample items and record their guesses. It's best if everyone makes the first guess in silence! Ask them to list what their first thoughts are, and if they change their minds, to list additional guesses instead of crossing out earlier ideas.

### *Experiment #2: Smell only*

#### **In advance:**

1. Number each cup from 1 to 15.
2. Add the item to the cup and cover with a square of gauze or cheesecloth, securing it with a rubber band around the top.

#### **When ready:**

Pass the cups around for participants to smell. The order they smell the samples in doesn't matter, but for larger groups it's easier to pass them around in order. Ask participants to write down their guesses but not to say anything out loud.

## Investigation time!

These experiments use common items, mostly foods from your grocery store. Most of the suggested items aren't likely to be part of your day-to-day experience but should still be familiar. You might be surprised at the degree of difficulty in identifying some of them! It's surprising to discover how much "knowing" what a food item is—seeing the cilantro leaf or being told it's a hazelnut chocolate cupcake—allows us to sense the flavors we expect from it.

For each item, ask people what their guesses were. What does the group notice about everyone's guesses? Are some items easy to guess? How many people guessed correctly for Oreo cookies versus less-processed foods? Are some people much better at detecting odors than others?

If you are interested in taking a "real" smell test, researchers at the University of Pennsylvania have developed a well-validated scratch-and-sniff test called UPSIT that you can mail order. Search online for "University of Pennsylvania Smell Identification Test."



# Gail Vance Civile on Learning Flavors

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*Gail Vance Civile is a self-described “taste and smell geek” who started out working as a sensory professional at the General Foods technical center and is now president and owner of Sensory Spectrum, Inc., in New Providence, New Jersey.*

## How does somebody who is trained to think about flavor, taste, and sensation perceive these things differently than the layperson?

The big difference between a trained taster and an untrained taster is not that your nose or your palate gets better, but that your brain gets better at sorting things out. You train your brain to pay attention to the sensations that you are getting and the words that are associated with them.



## It sounds like a lot of it is about the ability to recall things that you’ve experienced before. Are there things that one can do to help get one’s brain organized?

You can go to your spice and herb cupboard and sort and smell the contents. For example, allspice will smell very much like cloves. That’s because the allspice berry has clove oil or eugenol in it. You’ll say, “Oh, wow, this allspice smells very much like clove.” So the next time you smell them, you might say, “Clove, oh but wait, it could be allspice.”

## So, in cooking, is this how an experienced chef understands how to do substitutions and to match things together?

Right. I try to encourage people to experiment and learn these things so that they know, for example, that if you run out of oregano you should substitute thyme and not basil. Oregano and thyme are chemically similar and have a similar sensory impression. You have to be around them and play with them in order to know that.

## With herbs and spices, how do you do that?

First you learn them. You take them out, you smell them, and you go, “Ah, okay, that’s rosemary.” Then you smell something else and you go, “Okay, that’s oregano,” and so on. Next you close your eyes and put your hand out, pick up a bottle, and smell it and see if you can name what it is. Another exercise to do is to see if you can sort these different things into piles of like things. You will sort the oregano with the thyme and, believe it or not, the

sage with the rosemary, because they both have eucalyptol in them, which is the same chemical and, therefore, they have some of the same flavor profile.

## What about lining up spices and foods—for example, apples and cinnamon?

You put cinnamon with an apple because the apple has a woody component, a woody part of the flavor like the stem and the seeds. And the cinnamon has a wood component, and that woody component of the cinnamon sits over the not-so-pleasant woodiness of the apple, and gives it a sweet cinnamon character. That’s what shows. Similarly, in tomatoes you add garlic or onion to cover over the skunkiness of the tomatoes, and in the same way basil and oregano sit on top of the part of the tomato that’s kind of musty and viney. Together they create something that shows you the best part of the tomato and hides some of the less lovely parts of the tomato. That’s why chefs put certain things together. They go, they blend, they merge and meld, and actually create something that’s unique and different and better than the sum of the parts.

It takes a while to get at that level, because you have to really feel confident both as a cook and getting off the recipe. Please, get off the recipe. Let’s get people off these recipes and into thinking about what tastes good. Taste it and go, “Oh, I see what’s missing. There’s something missing here in the whole structure of the food. Let me think about how I’m going to add that.” I can cook something and think to myself, there’s something missing in the middle, I

have some top notes and I have maybe beef and it's browned and it has really heavy bottom notes. I think of flavor like a triangle. Well, then I need to add oregano or something like that. I don't need lemon, which is another top note, and I don't need brown caramelized anything else because that's in the bottom. You taste it, and you think about how you are going to add that.

**How does somebody tasting something answer the question, “Hey, if I wanted to do this at home, what should I do?”**

I can sit in some of the best restaurants in the world, and not have a clue what's in there. I can't taste them apart, it's so tight. So it's not just a matter of experience; it's also a matter of the experience of the chef. If you have a classically trained French or Italian chef, they can create something where I will be scratching my head, going “Beats me, I can't tell what's in here,” because it's so tight, it's so blended, that I can't see the pieces. I only see the whole.

Now this does not happen with a lot of Asian foods, because they are designed to be spiky and pop. That's why Chinese food doesn't taste like French and Italian food. Did you ever notice that? Asian foods have green onions, garlic, soy, and ginger, and they're supposed to pop, pop, pop. But the next day they're all blending together and this isn't quite so interesting.

**This almost suggests that if one is starting out with cooking, one approach is to go out and eat Asian food and try to identify the flavors?**

Oh, definitely. That's a very good place to start, and Chinese is a better place to start than most. I've had some Asian people in classes that I've taught get very insulted

when I talk about this, and I'm like, no, no, no, that's the way it's *supposed* to be. That's the way Asian food is; it's spiky and interesting and popping, and that's not the way classic European food, especially southern European food, is.

**In the case of classic European dishes, let's say you're out eating eggplant Parmesan, and it's just fantastic. How do you go about trying to figure out how to make that?**

I would start identifying what I am capable of identifying. So you say, “Okay, I get tomato, and I get the eggplant, but the eggplant seems like it's fried in something interesting, and not exactly just peanut oil or olive oil. I wonder what that is?” Then I would ask the waiter, “This is very interesting. It's different from the way I normally see eggplant Parmesan. Is there something special about the oil or the way that the sous chef fries the eggplant that makes this so special?” If you ask something specific, you are more likely to get an answer from the kitchen than if you say, “Can you give me the recipe?” That is not likely to get you an answer.

**When thinking about the description of smells, it seems like the vocabulary around how we describe the taste is almost as important.**

It's the way that we communicate our experience. If you said “fresh” or “it tasted homemade,” you could mean many things. These are more nebulous terms than, say, “You could taste the fried eggplant coming through all of the sauce and all of the cheese.” This is very, very specific, and in fact, “fresh” in this case is freshly fried eggplant. I once had a similar situation with ratatouille in a restaurant. I asked the waiter, “Could you tell me please if this ratatouille was

just made?” The waiter said, “Yes, he makes it just ahead and he doesn't put all the pieces together until just before we serve dinner.” When people say “homemade,” they usually mean that it tastes not sophisticated and refined, but that it tastes like it had been made by a good home cook, so it's more rustic, but very, very well put together.

**Is there a certain advantage that the home chef has because he is assembling the ingredients so close to the time that the meal is being eaten?**

Oh, there's no question that depending upon the nature of the food itself, there are some things that actually benefit from sitting long in the pot. Most home chefs, either intuitively or cognitively, have a good understanding of what goes with what, and how long you have to wait for it to reach its peak.

**You said a few minutes ago, “We need to get off the recipe.” Can you elaborate?**

When I cook, I will look at seven or so different recipes. The first time I made sauerbraten, I made it from at least five recipes. You pick things from each based on what you think looks good, and what the flavor might be like. I think the idea of experimenting in the classic sense of experimenting is fine. Geeks should be all about experimenting. What's the worst thing that's going to happen? It won't taste so great. It won't be poison, and it won't be yucky; it just may not be perfect, but that's okay. I think when you do that, it gives you a lot more freedom to make many more things because you're not tied to the ingredient list. The recipe is, as far as I'm concerned, a place to start but not the be all, end all.

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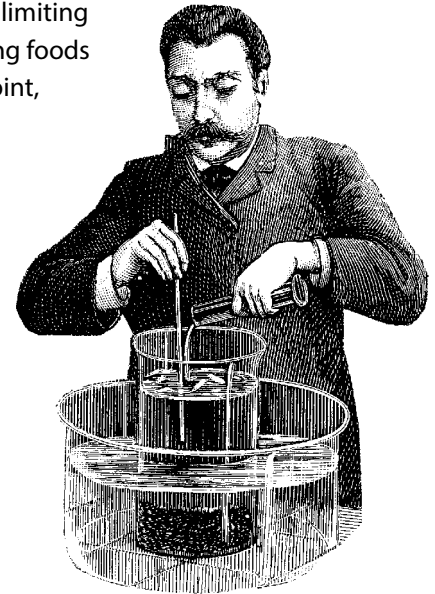
## Time and Temperature

### **EVER SINCE CAVEMEN DISCOVERED FIRE AND STARTED ROASTING THEIR DINNER, MANKIND HAS ENJOYED A WHOLE NEW SET OF FLAVORS IN FOOD.**

Heat transforms food by triggering physical and chemical reactions in the proteins, fats, and carbohydrates present in animal and plant tissues. These reactions change the flavor, texture, and appearance of food in incredibly satisfying and delicious ways.

The temperatures we cook at are only a proxy for heat-related reactions. Regardless of the temperature of your oven, it's the temperature of the food itself that determines what changes will occur. Both boiling and steaming depend on water for heat, limiting the food's temperature to the boiling point of water and in turn preventing foods from browning. Sautéing and roasting aren't limited by water's boiling point, allowing for higher temperatures and additional reactions.

Controlling the flow of heat into your ingredients and learning the temperatures at which various reactions begin to occur are your best weapons in the quest to conquer the kitchen. Different heating methods change how quickly foods cook, and understanding the key variables of time and temperature will provide the answer to that famous question: *is it done yet?*



## Cooked = Time \* Temperature

Cooking involves heat, but what *is* heat? Why can't you double the heat and cook things twice as fast? And just what exactly happens to a ball of chocolate chip cookie dough as you bake it?

When you step into the kitchen, you're unwittingly turned into a physicist and a chemist. As chocolate chip cookie dough heats up in the oven, proteins in the eggs denature (chemistry), water from the eggs and butter evaporates (physics), starches in the flour melt (more physics), and the outside of the cookie turns brown from the Maillard reaction and caramelization (more chemistry). And then you have a cookie!

Water turning into steam and starches melting are changes that physicists call *phase transitions*: a substance changing from one phase of matter (solid, liquid, gas) into another. These changes are reversible. Steam can turn back into water; fats can resolidify. The caramelization and Maillard reactions that turn cookies brown are *chemical reactions*: changes in substances that create different sets of molecules. Sometimes reactions are reversible, but usually they're not. You can't unburn something! How quickly a reaction happens (it's never instantaneous) is called the *rate of reaction*. More formally, the rate is how much of a reaction occurs in a given amount of time.

Here's the most important concept in this chapter: increasing the temperature increases the rate of reaction. This is basic kinetics, a Law of the Universe. A reaction that happens slowly at one temperature will occur more quickly at a higher temperature, assuming enzymes and any reactants stay unchanged. Because higher temperatures speed up rates of reactions, we get the rule of thumb *cooked = time \* temperature*. The answer to "Is it done yet?" depends on whether enough of the necessary reactions have occurred, and those are based on time and temperature.

### Cooked = Time \* Temperature

The question "Is it done yet?" does have a theoretical answer based on time and heat added. The below dynamic mathematical model includes factors for meat's thermal conductivity as well as denaturation rates for proteins like actin and myosin. For more, see <http://cookingforgeeks.com/book/meatmath/>. Remember to cook until medium-rare!

$$\left\{ \begin{array}{l} t_{i(j+1)} = (q_i \cdot \tau dh + 1 \cdot m_c \cdot d\tau \cdot (t_{i(j-1)} + t_{i(j+1)}) + m_c \cdot c_m \cdot h_{ij}) / 2 \cdot 1_m \cdot F d\tau + m_c \cdot c_m \cdot dh \\ K_{1i} = 0.00836 - 0.001402 \text{ pH} + 5.5 \cdot 10^{-7} \cdot t^2 \\ K_{2i} = -0.278 + 7.325 \cdot 10^{-2} \text{ pH} - 3.482 \cdot 10^{-5} \cdot t^2 \\ K_{3i} = 2.537 \cdot 10^{-3} - 1.493 \cdot 10^{-4} \cdot t_i + 2.198 \cdot 10^{-5} \cdot t_i^2 \\ K_{4i} = 2.537 \cdot 10^{-2} - 9.172 \cdot 10^{-3} \text{ pH} + 3.157 \cdot 10^{-5} \cdot t_i^2 \\ m_{1t,i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K_{1i}t} \\ m_{2t,i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K_{2i}t} \\ m_{3t,i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K_{3i}t} \\ m_{4t,i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K_{4i}t} \end{array} \right.$$

SOURCE: M. A. BELYAeva (2003), "CHANGE OF MEAT PROTEINS DURING THERMAL TREATMENT," CHEMISTRY OF NATURAL COMPOUNDS 39 (4).

If you sprinkle sugar onto a hot cookie sheet and bake it in an oven at 320°F / 160°C for an hour, some percentage of it will react—it'll caramelize—but slowly. Sprinkle the same amount of sugar onto a hotter cookie sheet and bake it at 340°F / 170°C, and the reaction will happen roughly twice as fast, meaning it'll take only half an hour to reach the same amount of caramelization. This assumes the sugar jumps to those temperatures instantly! A more complete model of cooking includes the time that cold foods take to heat up when put into a hot oven.

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Smell, touch, sight, sound, taste: learn to use all of your senses in cooking. Meat cooked to medium-rare will feel firmer and visibly shrink; cooked beyond medium-rare, it'll shrink further as other types of proteins denature. The bubbling of a sauce as it's boiled will sound different once the water is mostly evaporated. Bread crust that has had enough browning reactions will smell wonderful, and you'll see the color shift toward mahogany-brown.

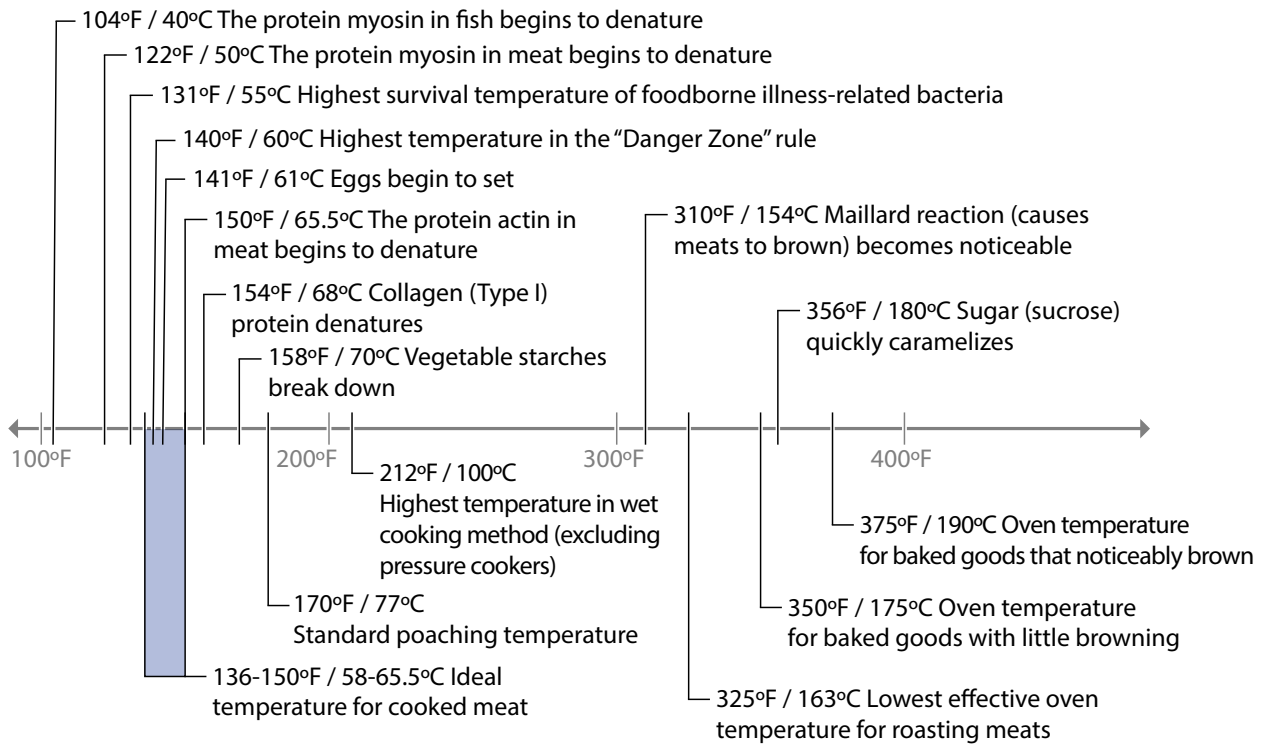
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If hotter temperatures speed up reaction times, why not dial the temperature way up and cut cooking times way down? Because other reactions will speed up too, *but not at the same ratios*. The chocolate chip cookie is a great example: we have water in the interior and browning on the surface. If you increase the temperature too much, the outside of the cookie is going to be fully browned before the center is set. Other reactions will also start to happen; for example, reactions related to burning start to speed up at around 390°F / 200°C. On the other hand, if you set the temperature too low, the cookie will dry out before the outside is done and has the rich flavors you want. Time and temperature are a thermal and chemical balancing act, as we'll see throughout this chapter.

There are two major *aha!* points here:

- The most important variable in cooking is the temperature of the food itself, not the temperature of the environment in which it's being cooked. When you're roasting a chicken, the temperature of the oven doesn't determine the rate at which reactions will happen, although it does determine the rate at which the chicken will heat up. Ultimately, it's the temperature of the chicken itself that matters.
- The temperature of the food determines the rate of reactions, but different reactions occur at different rates, even at the same temperature. Changing the temperature changes the *ratio* of chemical reactants that are produced. Heat takes time to transfer through foods, and that complicates this process further.

Many interesting changes happen to food when it's heated, most of which occur in the fats, proteins, and carbohydrates of the food. This chapter is organized around the reactions listed in this chart. It's useful to see the big picture of temperatures of reactions and temperatures of various cooking techniques—this is one of my favorite charts!



*Cooking temperatures, and temperatures at which different reactions occur.*

## Native Proteins and Denatured Proteins

Proteins as they naturally occur—in plant or animal tissues—are said to be *native* when they're in their normal, natural state. A protein is built by a bunch of amino acids linking together and then folding in upon themselves into a specific shape. Think of a protein as a long metal chain, all tangled up. When it's created, the rings of the chain are linked together, and then the chain is twisted and folded up in a specific way, giving it a 3D shape (called its *molecular conformation*).

Heating a protein changes its 3D shape, undoing the twists and folds and changing how the protein functions in a process called *denaturation*. (This is why heat kills bacteria!) Once bent out of shape (groan), the protein may not be able to attach to whatever it was holding on to (making food textures less tough). Or, given the new conformation, it might now be able to attach to other molecules (making food textures tougher). It's not just heat that can denature proteins in cooking; acid, alcohol, and even mechanical whipping or freezing can trigger denaturation.

## Heat Transfer

We've briefly looked at what happens to a chocolate chip cookie as it bakes—proteins denaturing, water evaporating, the outside browning—but how does a cookie actually heat up? Before digging into the heat-related reactions in cooking, we should look at how heat gets transferred into foods in the first place. Cookies are really complicated, so I'm going to talk about cooking steak here, but the concepts are universal.

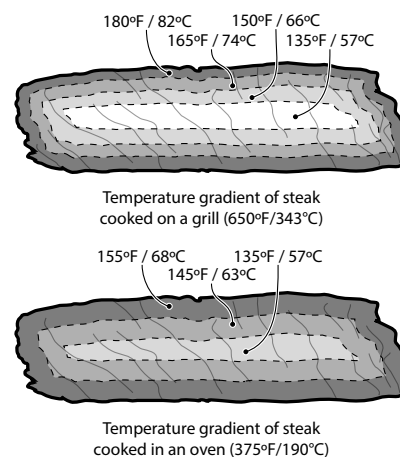
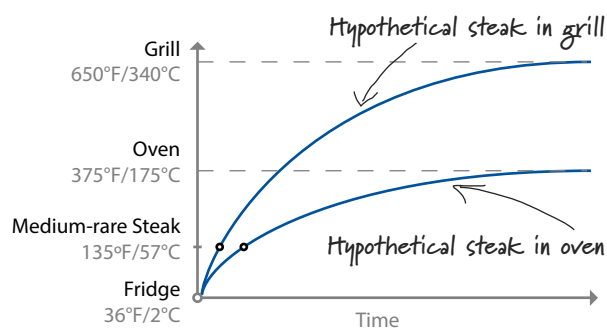
The idea that you can just cook something like a steak any way you like until its center reaches the desired temperature sounds too easy—there must be a catch. There are a few, actually.

For one, how you get the heat into a piece of food matters. A lot. The center of a steak will reach medium-rare faster when the steak is placed on a hot grill than when it's roasted in a warm oven. The laws of thermodynamics dictate this: any time there is a difference in temperature between two systems, heat will transfer from the hotter system (the grill) to the colder one (the steak). And the bigger the difference in temperatures between two systems is, the faster the heat will transfer (see chart).

This chart is an oversimplification, of course. It shows only the temperature at the center of the steak and ignores aspects like temperature stalls from evaporative cooling. (We're also considering a spherical cow here, of course, but notably *not* in a vacuum.) If we took a cross-section of the two steaks right as their centers reached 135°F / 57°C, we'd see some pretty big differences between the grilled and oven-cooked versions.

This difference in temperature from the center to the outer edges is referred to as a *temperature gradient*. These two steaks have quite different gradients because the hotter grill transfers heat faster—the bigger difference in temperature results in a steeper “gradient of doneness,” and in this case, an overcooked grilled steak.

If the steak is overcooked, then what's the appeal of cooking on a grill? It depends on how you like your meats cooked. A nicely cooked steak has an aromatic, browned sizzling surface—say, 310°F / 154°C—and an interior that's somewhere between rare and well done. If you like your steak cooked rare (125°F / 52°C), you need a steeper gradient of doneness, so use a hotter environment and cook it briefly; if you like steaks cooked until well done (160°F / 71°C), cook them at lower temperatures for a longer time. Most of us like steak cooked to medium-rare (135°F / 57°C) because this produces a texture that has the right amount of tenderness and moisture to be most satisfying.





## Pan-Seared Steak

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*Carryover refers to the phenomenon of food continuing to cook after being removed from the source of heat. While this seems to violate a whole bunch of laws of thermodynamics, it's actually straightforward: the outer portion of the just-cooked food is hotter than the center portion, so the outer portion will transfer some of its heat into the center. The amount of carryover depends upon the shape of the food and the temperature gradient, but as a general rule, I find it is typically about 5°F / 3°C.*

*Cooking steak is a great way to see carryover in action. Follow these directions, and during the rest period, continue watching the probe thermometer. You should see the core temperature peak 5°F / 3°C higher 3 minutes into the rest period. With experience, you'll learn when a steak is done cooking by sense of sight and touch, but at first, use a digital probe thermometer.*

Get a cast iron pan good and hot over high heat. Prepare a **1" / 2.5 cm-thick sirloin steak** by scoring any fat on the sides with cuts every inch or so (this will prevent the steak from warping when it shrinks during cooking) and patting the steak dry (too much surface moisture will change the steak's outside texture).

Drop the steak onto the hot cast iron pan and let it cook for 2 minutes. Don't poke it! Just let it sear. After 2 minutes, flip the steak and let it cook for another 2 minutes. Flip it again, reduce the heat to between medium-low and medium-high, and cook it for 5–7 minutes, flipping halfway though. For medium-rare steak, cook at medium-high heat until the center reads 130°F / 54°C; for medium steak, cook at slightly lower heat until the center of the steak reads 140°F / 60°C. Carryover heat will add a few degrees; these numbers are adjusted for that!

Rest the steak on a cutting board for 5 minutes. If you like, sprinkle it with salt and freshly ground pepper after cooking. (Don't salt right before cooking. The salt will pull moisture out of the interior and make the surface wetter. If you do want to salt in advance, do so an hour or so ahead of time and thoroughly blot the surface to dry it before cooking. Adding pepper before can lead to a bitter burnt taste, as the pepper will burn.)

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See page 180 for a chart of cooking temperatures for common foods, including steaks cooked to other levels of doneness.

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### Why do some recipes start at high heat and then switch to medium heat?

Dropping a cold steak onto a hot pan causes a very fast drop in the pan's temperature as heat is transferred from it into the cold steak. *Recovery time* is how long it takes for the pan to return to temperature, and is based on how fast the burner is heating it. Different burners transfer heat at different rates, and the thermal mass of your pan will matter, too. Starting at higher heat factors in the temperature drop, in essence accounting for recovery time right away.

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This temperature rule—higher heat, steeper temperature gradient—is why matching the right cooking temperature for your desired outcome matters. A recipe’s cooking time and temperature need to be chosen to heat the different regions of the food to the right levels. I know, in theory that sounds so simple, but how do you know what to set your oven to? As the saying goes: *in theory, there’s no difference between theory and practice; in practice, there is.* In practice, it’s best to make an educated guess on time and temperature and take note of whether the insides and outsides of the food are correctly cooked. If the outside is done before the inside—evidenced by a burnt outside or undercooked center—lower the temperature and cook the food longer next time. For baked goods like muffins, try dropping the temperature 25°F / ~15°C and increasing the baking time by 10%; for meats and vegetables, try a 50°F / ~25°C drop and adjust accordingly. For the opposite problem, increase the temperatures by these amounts and check what happens.

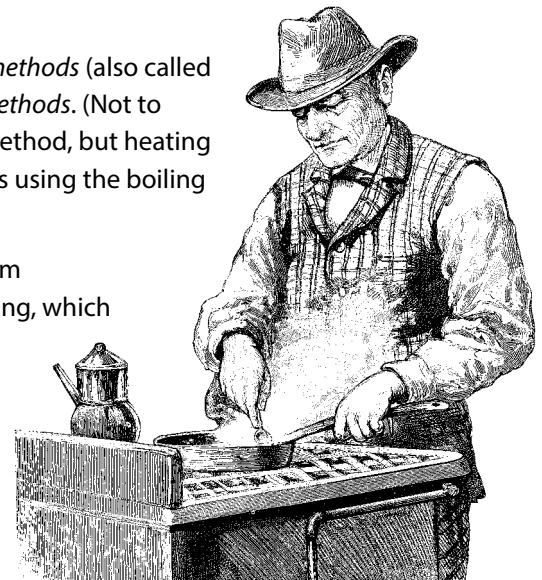
## Cooking Methods

I’ve written a lot about temperature differences and temperature gradients, but cooking is really about *heat transfer*. Formally speaking, *heat* is the transfer of energy between two systems and happens because of differences in their temperatures. I know, that sounds confusing—*what’s temperature, then?!*—but a quick example makes this simple to understand.

A pot of boiling water has a temperature of 212°F / 100°C. Heating the pot is a transfer of kinetic energy from the burner to the pot, and then from the pot to the water. Adding heat—more kinetic energy—to the boiling water does *not* change its temperature! The water remains at 212°F / 100°C, even though it’s being heated. The heat turns the water to steam, and that’s where all that kinetic energy is transferred, even though the steam and boiling water are at the same temperature.

Cooking methods that transfer heat using water are called *wet heat methods* (also called *moist heat methods*). All other cooking methods are called *dry heat methods*. (Not to confuse you, but heating the pot of water on a burner is a dry heat method, but heating something inside that water would be a wet heat method because it’s using the boiling water.)

Wet cooking methods don’t involve enough heat to create flavors from caramelization or Maillard reactions. (One exception is pressure cooking, which can set up the necessary conditions while keeping the food moist—see page 308.) You should choose wet cooking methods when you want to avoid those flavors. Steamed vegetables won’t turn brown while cooking, giving you food with less of a flavor change, which is nice for things like broccoli. Sometimes, though, the flavors from browning help a dish. Brussels sprouts are commonly boiled and



widely hated. Next time you cook them, quarter them, coat them with something like olive oil and sprinkle them with salt, and then bake them until lightly browned using a broiler set to medium. Cooked this way, they won't be so widely disliked!

Wet and dry cooking methods can be grouped into three categories based on how they transfer heat: conduction, convection, and radiation.

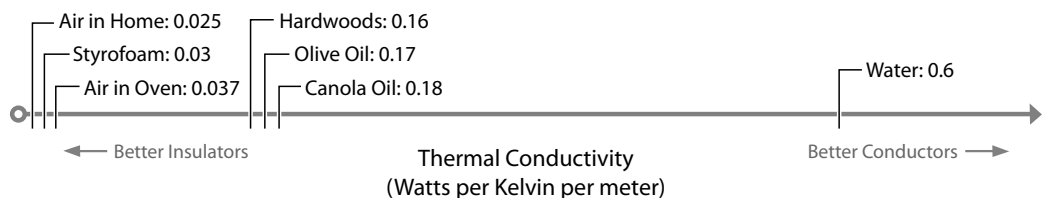
## Conduction

Conduction is the simplest type of heat transfer to understand: it's what you experience whenever you touch a cold countertop or hold a warm cup of coffee. In cooking, methods that transfer heat through direct contact between food and a hot material, such as the hot metal of a skillet, are conduction methods.

Dropping a steak onto a hot cast iron pan causes thermal energy from the pan to be transferred to the colder steak as the neighboring molecules distribute kinetic energy to equalize the difference in temperature. As the part of the steak that's touching the pan heats up, that part conducts heat up through the meat to colder regions—again, basic thermal equilibrium.

Different materials transfer heat at different rates—called *thermal conductivity*—which is why a piece of wood at room temperature doesn't feel as cold to you as a piece of room-temperature metal. Different pans will conduct heat at very different rates based on the metals they're made with (see page 46 for more on metals in pans).

The choice of cooking medium also changes conduction rate: hot water will transfer heat roughly 23 times faster than hot air at the same temperature, and 3.5 times faster than oil—that's a huge difference! This is why hard-cooked eggs cook faster in boiling water or steam than in a hotter dry oven. This is also why humidity can change cooking and baking times—water vapor is still water! Higher humidity means more moisture in air, and more moisture means more heat transfer. (Helium happens to be a decent conductor of heat—about the same as olive oil—just in case you happen to have a tank around. Hydrogen is, too, but I don't recommend that.)



*Oil transfers heat faster than air but slower than water, but it can be heated up way higher than water! This makes it a fast cooking method with the benefit of being hot enough to trigger caramelization and Maillard reactions. (Mmm, doughnuts!)*

## Convection

Convection methods of transferring heat—baking, roasting, boiling, steaming—all work by circulating a hot material against a cold one, causing the two materials to transfer heat by conduction. Technically, convection is a type of conduction cooking, but only indirectly; it's the recirculation of a material that transfers heat into foods.

In dry cooking methods, hot air, oil, or bare metal transfers heat.

Cooking fries in a deep fat fryer relies on convection of oil to heat the cold potato; cookies in an oven are baked primarily by the circulation of hot air heating the cold dough. Convection ovens, which have a blower inside to move air around more quickly, heat up foods about a quarter faster and remove cold spots in the oven. (Technically, all ovens are convection ovens, in the sense that heat is transferred by the movement of hot air. Adding a fan just moves the air faster.)

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Foods themselves can transfer heat from one region to another via convection. Cake batters, before they're set, will slowly flow, with the warmer outer regions rising and curling in toward the center.

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In wet cooking methods, such as boiling and steaming, water transfers heat. Poached eggs and steamed buns are cooked by water or water vapor raising the temperature of the food's surface. (All wet cooking methods are considered convection because water and water vapor are always moving.) It's easy to overcook foods with wet methods because of the higher rate of heat transfer. For lean, tender cuts of meat and fish, take care that the food doesn't get too hot when cooking in liquid! Keep your liquids at a gentle simmer, between 160°F / 71°C and 180°F / 82°C.

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### What's the difference between steam and water vapor?

Oh, language, how tricky you can be. *Water vapor* is easy: it's water in its gaseous form, invisible to the naked eye. *Steam*, though, can mean either water vapor or condensed water droplets suspended in air, the stuff you see "steaming" above a pot of boiling water.

There's a huge thermal difference between water vapor and the billowing cloud of steam that you see when boiling water. Water as a gas packs a *huge* thermal punch: it gives off 540 calories of energy per gram of water when it condenses. I would much rather lean my face over a steaming pot of boiling water, where the water has already condensed in the air, than lean into an airstream of water vapor, which would burn my skin as it condenses and transfers its kinetic energy.

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## Radiation

Radiant methods of heating work by the transfer of electromagnetic energy, typically microwaves or infrared radiation. The warmth you feel when sunlight hits your skin is radiant heat. In cooking, radiant heat methods are the only ones in which the energy being applied to the food can be either reflected or absorbed by the food. Different foods will absorb or reflect radiant heat based on how the energy interacts with the molecules of the food. Microwaves, for example, are absorbed very well by polar molecules like water, but very poorly by nonpolar molecules like oil (for more on molecular polarity, see page 398).

Radiant energy travels in straight lines: from the broiler straight to the food, or possibly reflecting off the walls of an oven or the surface of a reflective cookie sheet. You can use this reflective property to change how something cooks. One technique for baking pie shells uses aluminum foil around the outer edge as a reflector to prevent overcooking the outer ring of crust. If you see one part of a dish cooking too fast and the heat source is radiant, a small sheet of aluminum foil can serve as a heat reflector: a clever “thinking like a geek” hack.

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Darker colors absorb more radiant heat, which is why winter jackets are black and summertime outfits are lighter colored. Darker cookie sheets will absorb more radiant heat and then conduct that energy through the material to the underside of the cookies, causing them to bake faster on the bottom. If the bottoms of your cookies are coming out overcooked, drop your oven temperature by 25°F / ~15°C.

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Gas ovens rely on circulating hot air that heats up the oven walls; those hot oven walls then radiate heat. If you have an electric oven, the heating element gives off a lot of radiant heat directly—straight from the bottom of the oven. This isn’t good for recipes that expect the heating to be done primarily by air convection—the undersides of the foods will heat too quickly! This is why I strongly recommend you always leave a pizza or baking stone on the bottom rack of an oven: it will absorb the radiant heat and diffuse it, giving your oven a much better heat profile. (See page 35 for notes on calibrating your oven.)

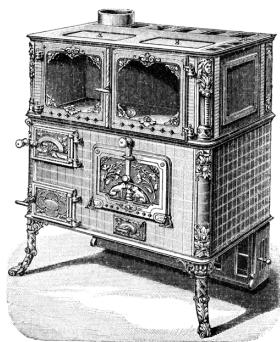
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### What’s the difference between gas and electric ovens?

Well, other than the source of heat, they bake things slightly differently, for a subtle reason: they handle humidity differently. Gas ovens usually (not always) vent the combustion byproducts—carbon dioxide, water vapor—through the oven chamber. This means they’re injecting a constant stream of moisture around the food being cooked. They’re also constantly venting the air from the oven chamber to the outside—the gas coming in has to displace something!

Electric ovens, on the other hand, start out much drier—there’s no gas being combusted and generating water vapor—but many models won’t vent air out as foods bake and give off moisture, so they end up getting more and more humid as the water in foods evaporates during cooking.

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Cooking methods listed by type of heat transfer.			
	Conduction	Convection	Radiation
Description	Heat passes by direct contact between two materials	Heat passes via movement of a heated material against a colder material	Heat is transferred via electromagnetic radiation
Example	Steak touching pan; pan touching electric burner	Hot water, hot air, or oil moving along outside of food	Infrared radiation from charcoal
Uses	Sautéing Searing	<p><i>Dry heat methods:</i></p> <ul style="list-style-type: none"> <li>• Baking/roasting</li> <li>• Deep-fat frying*</li> </ul> <p><i>Wet heat methods:</i></p> <ul style="list-style-type: none"> <li>• Boiling</li> <li>• Braising/water bath</li> <li>• Pressure cooking</li> <li>• Simmering/poaching</li> <li>• Steaming</li> </ul>	Microwaving Broiling Grilling

\*Frying is a dry-heat method because oil, while a liquid, isn't wet—there's no water in it.

## Combined methods of heat transfer

Cooking techniques invariably combine multiple methods of heat transfer. A cookie in an oven bakes because of hot air (convection), the pan heating up and cooking the underside (conduction), and some amount of radiant heat from the hot oven walls.

Some foods, like cookies, turn out better when heat is transferred into them from certain directions at certain rates. Sometimes it's obvious. You can avoid cookies burning on the bottom by reducing how much heat is transferred to them from below: either use a different cookie sheet that doesn't transfer heat as quickly (lighter color, different metal) or line the cookie sheet with parchment paper. Other dishes aren't always so easy to figure out. Pies and custards, for example, do better when heat is transferred into them from the bottom up; this prevents the top from setting and then cracking from the bottom's subsequent expansion. Setting them in a hot water bath or directly on top of a baking stone will help.

Here are some thoughts for choosing cooking techniques:

### *Use multiple cooking techniques.*

My favorite lasagna starts out being baked (convection) to heat the center and melt the cheese, and then finishes with broiling (radiant) to give a delicious browned top. If you're cooking by intuition, use cooking techniques that heat the various regions of the foods to the right target temperatures, mixing and matching as needed.

### Match the cooking technique to the shape of the food.

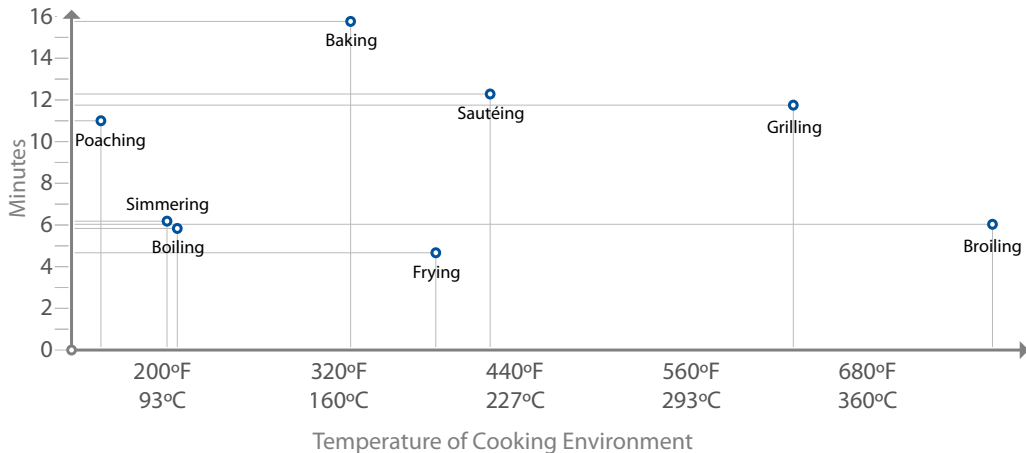
In roasting and baking, heat comes from all directions, which is great for roasting whole chickens. In searing and sautéing, however, heat is transferred from only one side, which is well suited for flat fillets of fish or chicken breasts. This is why we flip pancakes (stovetop; heat from below) but not cakes (oven; heat from all directions).

### Substitute similar cooking techniques for ones you can't do.

If you don't have a grill (radiant; heat from below), try using a broiler (radiant; heat from above) because it's the closest comparable technique (flip the food over, too—the direction the heat enters a chicken from will change things!). If you don't have a pressure cooker, use a pot full of liquid—both are wet cooking methods.

### Experiment by switching up techniques.

Pancake batter, when deep-fat fried, produces something a lot like a funnel cake. Eggs cook just fine on top of rice in a rice cooker—add the egg on top just after the rice is done cooking. Chocolate chip cookie dough *can* be cooked in a waffle iron. And pears poached in a dishwasher? Why not? (See page 326.) It might be unconventional, but heat doesn't have to come from a traditional cooking appliance!



*Frying is fastest; baking is slowest. This plot shows the amount of time it took to heat the centers of uniformly sized pieces of tofu from 36°F / 2°C to 140°F / 60°C for each cooking method. Cooking pan material (cast iron, stainless steel, aluminum) and baking pan material (glass, ceramic) had only minor impact on total time for this experiment with tofu, but for other foods like cookies it will make a difference.*

## Salt-Roasted Fish with Lemon and Herbs

*Salt can also be used as a “heat shield” on food during cooking. Packing foods such as fish, meats, or potatoes in a mound of salt protects the outer surface of the food; the salt ends up taking the brunt of any radiant heat and also cuts down on evaporation, keeping the food moister. If a whole fresh fish isn’t easy to get, try this with other foods, such as pork loin (add spices—black pepper, cinnamon, cayenne pepper—to the salt mixture) or even entire standing rib roasts.*

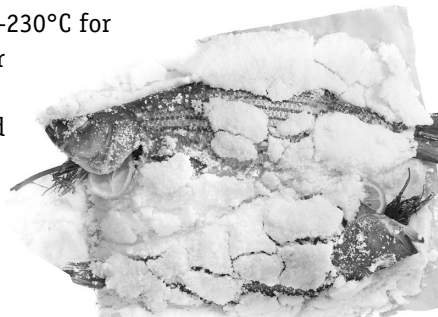
Snag a **whole fish, such as striped bass or trout**, in the range of 2 to 5 pounds / 1 to 2 kilos. Clean and gut the fish, rinse it thoroughly, and add **lemon slices** and **herbs** (try fresh dill or fresh oregano) in the center cavity. Leave the skin on; it’ll prevent the fish from getting too salty.

Prepare a salt mixture by adding just enough **water** to a **few cups of kosher salt** so that it forms a workable paste. You can use **egg white** instead of water—useful if you’re covering something with a more complicated shape than fish.

Line a baking pan or cookie sheet with parchment paper (this’ll make cleanup easier), and add a thin layer of the salt mixture. Place the fish on top of the salt, and then pack the rest of the salt around the sides and top of the fish. You don’t need to bury the fish too deeply. Go for about  $\frac{1}{2}$ " / 1 cm of salt on all sides—enough to take the brunt of the surface temperature, but not so much that the center of the fish takes too long to actually reach temperature.



Bake the fish in an oven set to 400–450°F / 200–230°C for about 20–30 minutes, using a probe thermometer to check that the internal temperature reaches 125°F / 52°C. Remove the fish from the oven and let it rest 5–10 minutes (during which carryover will bring the temp up to 130°F / 54°C). Crack open the salt crust, brush off any salt sticking to the surface of the fish, and serve.



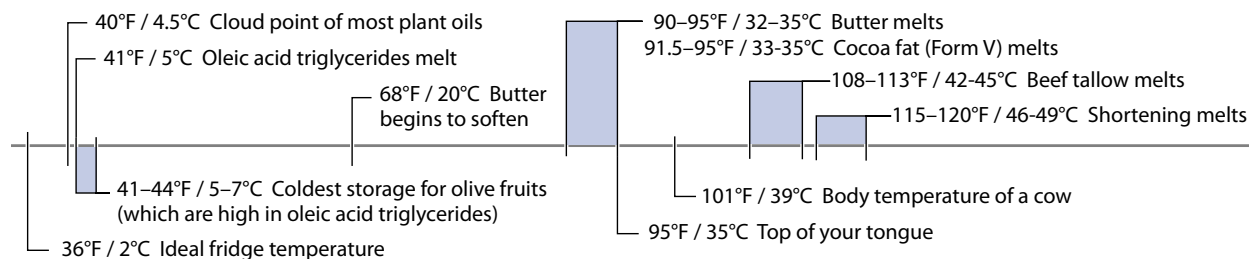


# 85°F / 30°C: Average Melting Point of Fats

*All generalizations are false, including this one.*

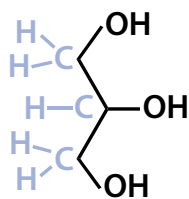
—Mark Twain

Here we are, at the first temperature range of the chapter. There's one housekeeping detail I need to take care of first: the temperature 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.



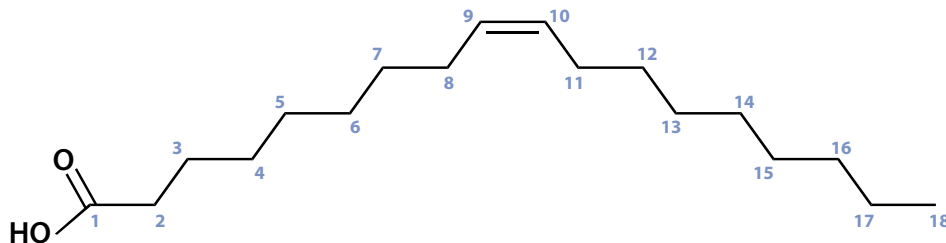
*A molecule of glycerol with all the atoms drawn.*

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!)

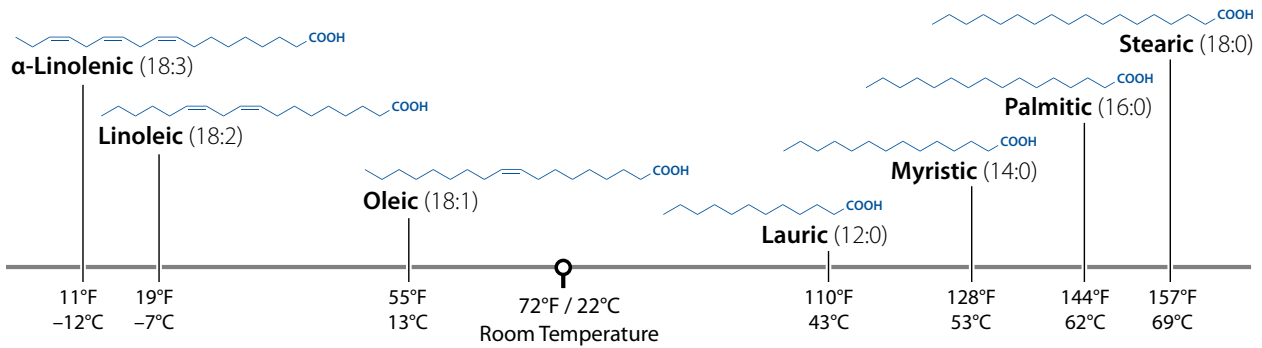
### Then what's a trans fat?

*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 *crystalized cottonseed 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!*



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  $-11^{\circ}\text{F} / -24^{\circ}\text{C}$  and  $164^{\circ}\text{F} / 73^{\circ}\text{C}$ ; based on the normal composition, butter softens around  $68^{\circ}\text{F} / 20^{\circ}\text{C}$  and melts at about  $95^{\circ}\text{F} / 35^{\circ}\text{C}$ .

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

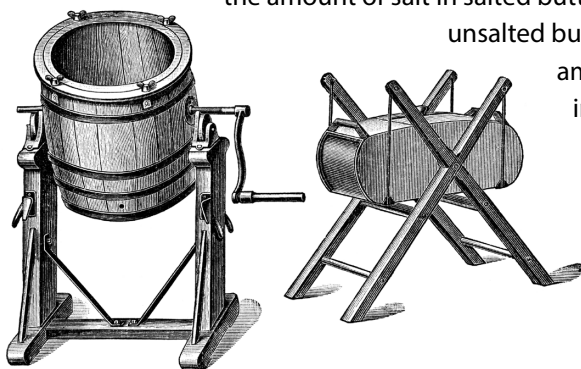
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Making great butter is a lot more complicated than merely separating the fats from the cream by churning. Changes in the size of the fat globules in the butter, based on how quickly the cream is cooled during pasteurization, will change

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.

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### **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.

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## 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,  $\frac{3}{4}$  **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  $\frac{1}{2}$  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.

## Chocolate, Cocoa Fats, and Tempering

*Mmm*, chocolate. Sweet, bitter; sometimes nutty, fruity, or spicy. It brings joy, pleasure, and for some, relief from negative moods. Any way you describe it, it's delicious. No, really, scientifically, it's delicious. Every single culture that's ever been introduced to chocolate has accepted and desired it, a feat perhaps envied by bacon.

Part of what makes chocolate great is its texture and the way it snaps. That texture comes from how the sugar and fats in chocolate are mixed together (*conched*) and how cocoa fats are melted, cooled, and *tempered*—controlling the specific crystalline structure of the cocoa fats as they set during cooling. Tempered chocolate is used on the outside of chocolate truffles, for dipping fruits like dried apricots or fresh strawberries, and for covering baked goods and confections. It's amazing that changing one thing—the way that triglycerides are stacked together—can change so much!

To understand tempering, we need to look at what chocolate itself is. Chocolate, at its simplest, is made up of cocoa butter and cocoa solids, both derived from the seeds of the *Theobroma cacao* plant. Sugar is added to sweeten it; sometimes other ingredients like milk and vanilla are also added for flavoring. *Cocoa butter*—really, cocoa fat—consists of triglycerides from the plant's seeds, mostly made up of myristic, oleic, and palmitic acid (which is very close to butter's composition, hence the similarity in melting points!). *Cocoa solids* are what's left over after the fat is removed; ground up and processed, they become *cocoa powder*, a rich dark powder that brings almost all of the flavor to chocolate. *Dutched cocoa powder* is processed to improve solubility (it'll mix better—it's more hydrophilic) and alter the flavor. (The Dutching process raises the pH of cocoa powder, which is why Dutched cocoa powder shouldn't be substituted for regular cocoa powder in baked goods that rely on it to react with baking soda; see page 277 for more).

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M&Ms were developed in 1940 by Frank C. Mars and his son, Forrest Mars, Sr. During the Spanish Civil War (1936–1939), Forrest saw Spanish soldiers eating chocolate that had been covered in sugar as a way of “packaging” the chocolate to prevent it from making a mess.

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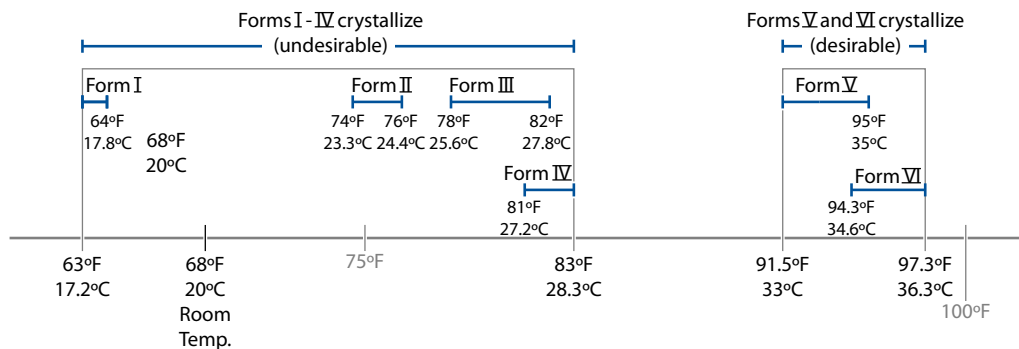
*Cacao* versus *cocoa* is a bit of an etymological mystery. In Spanish, it's always *cacao*, but somewhere along the way the metathesis *cocoa* entered the English language—perhaps in 1755 through dictionary maker Samuel Johnson, who had an entry for *cocoa* (and a note, “more properly written *cacao*”).

These days, in English, *cacao* is usually used to describe the plant and any unprocessed parts from it, and *cocoa* is used to describe products derived from the dried and fermented seeds. As an ingredient, *cocoa* can also refer to *cocoa powder* under US definitions, to the great frustration of Spanish translators.

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When chocolate is melted and tempered, it's the cocoa fats that actually melt. Cocoa solids don't melt, so it's not technically accurate to say "melting chocolate." You temper chocolate by melting and then selectively solidifying the fats in cocoa fat. It can be an intimidating and finicky process. The traditional method is to heat the chocolate above 110°F / 43°C, then cool it to around 82°F / 28°C, and then reheat it to between 89°F / 31.5°C and 91°F / 32.5°C. Once it's at this temperature, you must perform a thermal balancing act: too warm, you lose the temper; too cold, it hardens. Making great chocolate requires a great understanding of temperature, whether you use a good thermometer or careful observation (~90°F / 32°C happens to be just about the temperature of your lips).

But where do these temperatures come from? Cocoa fat can solidify into a crystalline structure in six possible different forms, based on how the fatty acids in the triglycerides are arranged, and each one of those forms melts at a slightly different temperature. The key to tempering is in changing how the fats crystallize; once melted, they can recrystallize into any of the six forms. It's for this reason that tempering works at all. Tempering coerces the fats to solidify into the desired structure; in a properly tempered chocolate 3–8% of its mass consists of "good" cocoa fat crystals.



*Melting points of the six polymorphs of cocoa fat.*

Good cocoa fat crystals come in two forms, called Form V and Form VI. (The standard classification comes from a 1966 research paper; other researchers call these two forms beta<sub>2</sub> and beta<sub>1</sub> crystals.) These two versions can crystallize into a tighter grid, creating a firmer structure that gives chocolate a pleasing smoothness and firm snap when broken. (This has to do with the shape of the triglycerides of Forms V and VI, which can pack together more tightly than the other forms.) The other four crystalline structures, Forms I–IV, lead to a softer, chewier texture.

Chocolate can go bad (the horrors!) if exposed to extreme temperature swings, which will slowly convert the good cocoa fat crystals to Forms I–IV. Such chocolate is described as having *bloomed*, having a splotchy appearance and a gritty texture. Blooming happens because about a quarter of the cocoa fat is still liquid at room temperature, and with subtle changes

in temperature over time those liquid fats can migrate to the surface, recrystallizing the good fats in the process. (If the entire bar just crumbles up like chalk, then the sugar has bloomed from moisture. Melt the whole bar and retemper it, and store it in a drier place next time.)

Like most natural fats, the fats in cocoa butters are a mix of different types of triglycerides (mostly made up of stearic, oleic, and palmitic acids). Plus, the *T. cacao* plants don't all grow exactly the same. Chocolate from beans grown at lower elevations, for example, will have a mixture of fats with a slightly higher melting point than chocolate from beans grown at higher, cooler elevations. Still, the temperature variances are relatively narrow, so the ranges used here will generally work for dark chocolates. Milk chocolates require temperatures about 2°F / 1°C cooler; the additional ingredients affect the melting points of the different crystalline forms. When looking at chocolate for tempering, make sure it does not have other fats or lecithin added because these ingredients will also affect the melting point—more than about 0.5% lecithin will greatly slow down the tempering rate.

Luckily for chocolate lovers worldwide, chocolate has two quirks that make it so enjoyable. For one, the undesirable forms of fat all melt below 90°F / 32°C, while the desirable forms noticeably melt around 94°F / 34.4°C. If you heat the chocolate to a temperature between these two points, the undesirable forms melt and then solidify into the desirable form. The second happy quirk is a matter of simple biology: the temperature of the inside of your mouth is in the range of 95–98.6°F / 35–37°C, just above the melting point of tempered chocolate, while the surface temperature of your hand is below this point.

Traditional tempering works by melting all forms of fat in the chocolate, cooling it to a low enough temperature to trigger nucleation formation (i.e., causing some of the fat to crystallize into seed crystals, including some of the undesirable forms), and then raising it to a temperature high enough to melt Form I–IV crystals but cool enough for Forms V–VI to crystallize. This three-temperature process requires a watchful eye and, during the second and third steps, stirring to encourage the crystals to form while keeping them small.

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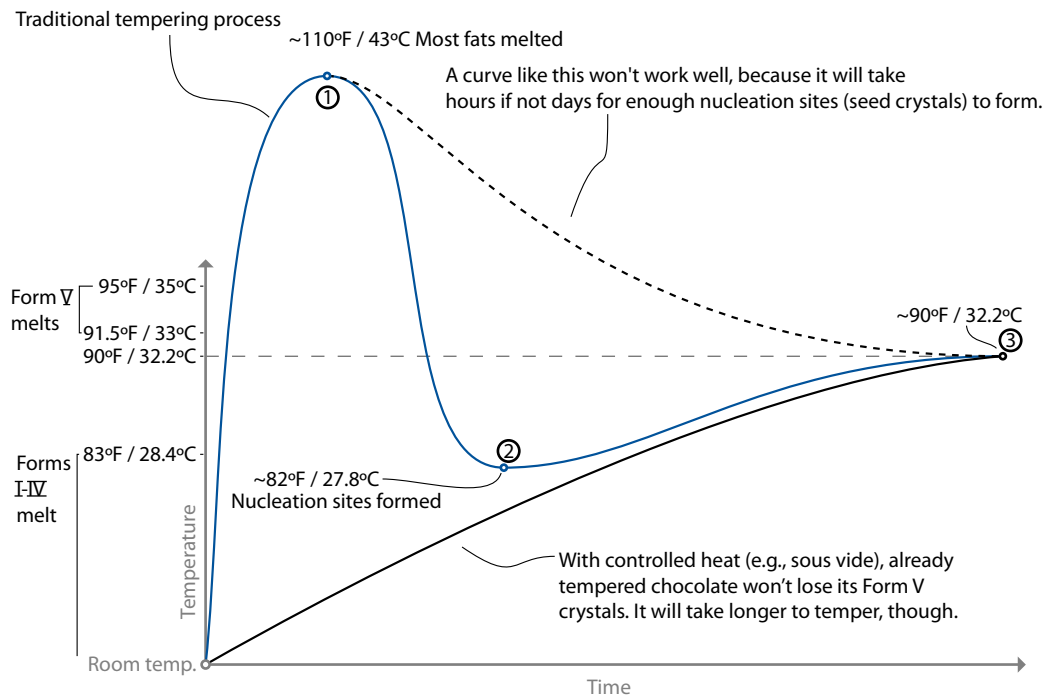
### What causes seized chocolate?

Assume you haven't been caught smuggling chocolate between countries, *seized chocolate* is what happens when a small amount of moisture gets mixed into the cocoa solids and fats. Think of what happens when a few drops of water are mixed into dry sand: it clumps up. It's exactly the same with chocolate. The cocoa solids are like the sand, but instead of being surrounded by air, they're surrounded by fat. Try pinching some cocoa powder between two dry fingers and rubbing; it'll be smooth. Add a tiny amount of water and it seizes up; add a bit more water, and it's back to being smooth. If you get water in your chocolate, you'll have to mix in more liquid—about 20–40% by weight depending upon the amount of cocoa solids present—for the mixture to be able to flow again. You'll be stuck with chocolate that won't solidify, but it's great for making ganache (see page 281)!

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Some tempering methods call for adding chopped-up chocolate at the second temperature point to rapidly seed the chocolate; this also accelerates cooling, which can be useful. It's also possible to temper small amounts of already-tempered chocolate (bars, not chocolate chips, which won't be tempered—that's why they're cheaper!) by bringing it directly up to  $\sim 90^{\circ}\text{F} / 32^{\circ}\text{C}$ , either with careful control in a microwave (nuke for 10-second intervals, stirring each time, and make sure that temperature doesn't exceed  $92^{\circ}\text{F} / 33.3^{\circ}\text{C}$ ) or in a water bath (see page 339).

To make tempering easier, use *couverture* chocolate (*couverture* is French for "cover"); this is chocolate used for covering other foods like fruits or cakes that is easier to temper due to a higher percentage of cocoa fats. In the EU, *couverture* chocolate must be at least 31% cocoa fat (not cocoa solids!); the US has no legal definition. With more cocoa fats in the mix, it's easier to get a sufficient quantity to correctly crystallize and give the right metastructure. If you can't find it, or you enjoy the experimentation process, buy cocoa fat and add 10% by weight to your chocolate as it melts. Make sure you buy cocoa fat and not white chocolate, which is only  $\sim 20\text{--}25\%$  cocoa fat!



## DIY Bittersweet Chocolate Bar

*A bar of bittersweet chocolate is typically 54–80% cocoa. Both EU food law and the US FDA's definition merely lump bittersweet bars in with semisweet chocolate (“not less than 35 percent by weight”), but as a guideline, they're roughly 30% cocoa fat, 40% cocoa powder, and 30% sugar. When you see a bar of chocolate that says 70% bittersweet chocolate, that's the amount of cocoa fat and cocoa powder. One manufacturer's 70% might be 30 / 40% fat/powder; another's could be 35 / 35%. Because cocoa powder is bitter—cocoa fat tastes something like shortening—a bar made with less cocoa powder and more cocoa butter will taste sweeter, even though both bars are 70%.*

*Cocoa powder, cocoa fats, and sugar are mixed together in a process called conching. Rodolphe Lindt, a Swiss entrepreneur, developed the conching process based on equipment he'd purchased from a spice mill back in 1879. The mixture is kept warm while being rolled between grindstones for anywhere from 6 to 72 hours, with longer times producing smoother textures by breaking up the sugar crystals and cocoa solids. To see what chocolate was like before Lindt's improvements, try making your own small sample of unconched chocolate.*

In a small bowl, melt **1 tablespoon (9g) of cocoa butter**—assuming small pellets—either in a pan of simmering water or the microwave.

Remove the butter from the heat or the microwave and add **2 teaspoons (10g) of sugar** and **2 tablespoons (12g) of cocoa powder**. Using a spoon, mix thoroughly, stirring for 1–2 minutes.

Unsweetened chocolate is generally not conched (a few premium brands do conche theirs, as the cocoa solids still benefit). If you can't find cocoa butter, try using **7 parts unsweetened chocolate** to **3 parts sugar** instead.

If you like, temper the chocolate following the temperature guidelines described in this section. Transfer it to a flexible mold or parchment-paper-lined container and allow it to cool in the fridge.

You'll notice when tasting this chocolate that the initial flavor is astringent and bitter, followed by a sweeter, possibly floral taste as the sugar dissolves in your mouth. Using superfine sugar instead will give a smoother texture, but the chocolate won't have the same mouthfeel as a conched bar.

Try experimenting by adding other ingredients—**roasted nuts, cinnamon, chili flakes, ginger, cocoa nibs, sea salt, ground coffee beans, mint leaves, bacon**. All the flavored bars of chocolate you see at the stores are simple to make!



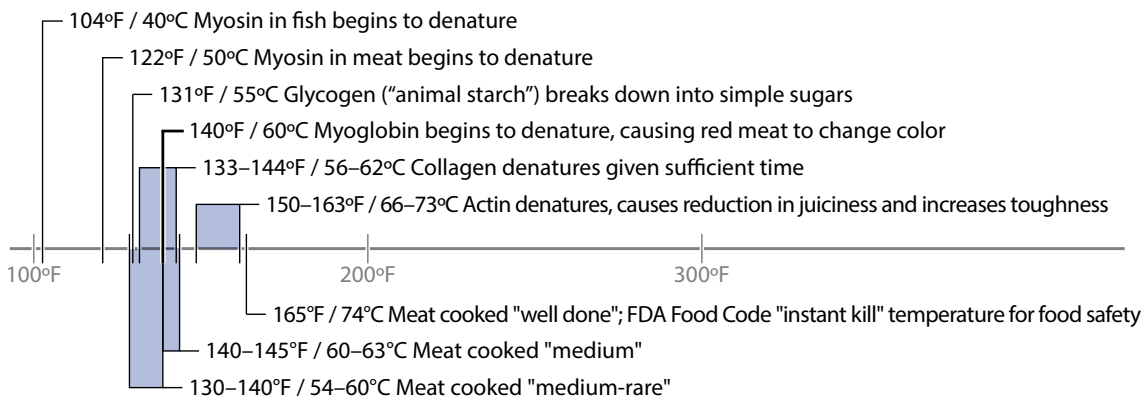
*A close-up view of the difference between commercially conched chocolate (top) and this DIY unconched chocolate (bottom).*

## 104–122°F / 40–50°C: Fish and Meat Proteins Start to Denature

Fish and meat, properly cooked, can be the centerpieces of the most amazing meals of a lifetime. Not to sound too much like a carnivore, but some of my fondest food memories involve things like my dad's holiday turkey or discovering duck confit for the first time. What makes a turkey or duck leg delicious is a combination of six variables: appearance, aroma, flavor, juiciness, tenderness, and texture. As a cook, you steer these last two factors through time and temperature, and proper cooking can lead to amazing tenderness and texture. But to understand how to get there, we have to look at what meat itself is.

Chances are, you haven't given much thought to the chemical reactions that happen in animal tissues when the animal is slaughtered. The most important change is, quite literally, that the circulatory system is no longer supplying muscle tissues with glycogen from the liver or oxygen-carrying blood. Without oxygen, cells in the tissues die, and preexisting glycogen in the muscle tissue dissipates. The thick and thin myofilaments in the muscle begin to consume the freed glycogen, resulting in the state called *rigor mortis*—Latin for "stiff death"—the stiffness created by the myofilaments binding together.

Somewhere around 8 to 48 hours later, the glycogen supply begins to taper off and enzymes naturally present in the meat begin to break down the bonds created during rigor mortis (*postmortem proteolysis*). Butchering before this process has run its course will affect the texture of the meat, as will the levels of glycogen present in the animal at slaughter. Long-term stress on the animal decreases the amount of glycogen in the muscle tissue at slaughter, causing pH changes post-slaughter that lead to faster-spoiling meat. Short-term stress spikes right before death (*antemortem*) increase glycogen in the blood, accelerating the rigor mortis phase and leading to pale, soft meat or fish that degrades. How a fish is killed will change its texture!



Denaturation temperatures of various types of proteins (top portion) and standard doneness levels (bottom portion).

Differences caused by butchering processes and how animals are handled are quite noticeable. Sensory panels have found that chicken breasts cut off the carcass before rigor mortis was complete have a tougher texture than meat left on the bone longer. (I *knew* there was a reason why roasted whole birds taste better!)

Other than shopping wisely, you have little control over how your fish and meats are handled before they end up at the store. Extremely cheap cuts of meats injected with brines, or poorly frozen fish, will provide nutrition but won't have as good a texture. If your dishes are turning out subpar, check the quality of your ingredients and avoid labels that say "marinated" or "flavored." If you are able to, find a fishmonger or butcher who can source properly handled fish and meats.

The challenge in cooking fish and meats invariably comes down to cooking them at temperatures high enough to kill pathogens but low enough to not overtighten the proteins. Fish and land animals are mostly water (65–80%), protein (16–22%), and fat (1.5–13%), with sugars such as glycogen (0.5–1.3%) and minerals (1%) contributing only a minor amount of the mass.

How much of the proteins are cooked determines a lot about the texture—tenderness versus toughness, dryness—in the cooked item. Proteins in meat can be divided into three general categories: structural, connective, and sarcoplasmic proteins. We'll ignore the sarcoplasmic ones; they don't impact cooking like the others. (If you're into pumping iron, it is these proteins that you'll be working on.) The structural and connective proteins, however, are of great importance.

## Why Is Some Meat White and Other Meat Red?

Marketing aside—"Pork. *The Other White Meat.*"—red meat is defined as meat that has more myoglobin protein than chicken. What gives meat its color isn't blood, but proteins. *Myoglobin* is purplish; when it gloms onto oxygen and becomes *oxymyoglobin*, it turns red. (Now you know why anatomy models have blue veins and red arteries!)

Chicken breast has very little myoglobin protein (0.05 mg/g), chicken thigh has about 2 mg/g, pork has 1–3 mg/g, and beef can reach up to 10 mg/g. There's less *pigment*, so to speak, in pig than cow, which is why it looks lighter, but still more than in chicken (sorry, marketing people).

Dark meats—think chicken thighs—have higher levels of myoglobin, which makes sense: the

myoglobin provides oxygen to muscle tissue, and for the parts of an animal responsible for walking or flapping wings, more oxygen is needed. The color of meat also changes based on oxygen exposure, pH levels, and storage conditions, which is why cooked meats sometimes look pink while undercooked meats can turn brown.

On a related note, if you've ever noticed ground meat go from red to brown, it's due to either myoglobin not being exposed to oxygen or oxymyoglobin no longer being able to hold on to its oxygen (one of the iron ions in its structure can lose an electron) and converting to metmyoglobin, which is brownish. Either way, it's not a sign of spoilage.



Structural proteins (*myofibrillar*) enable muscles to contract. About 70–80% of the protein in fish is structural; for land mammals, it's about 40–50%. When heated, proteins in this category set into a gel-like structure, which is why meat acts as a *binder*—an ingredient that holds foods together. There are several different types of myofibrillar proteins:

- *Myosin* makes up the majority of myofibrillar protein—about 55%—and is what actually contracts, using adenosine triphosphate (ATP) as a source of energy. Going back to rigor mortis, glycogen is converted to ATP and generates lactic acid as a byproduct. The amount of glycogen in just-slaughtered meat determines how much lactic acid will be generated as myosin burns through the remaining glycogen supply.
- *Actin* makes up about 25% of myofibrillar protein and binds with myosin; it's that binding that turns the two into a machine that can contract a muscle.
- Other myofibrillar proteins help hold together the myosin–actin machinery. Some of them—*titin*, *nebulin*, and *desmin*—are broken down over time by calpain enzymes and change the meat's texture, with notable textural differences happening starting a week after slaughter and continuing for several weeks. This is why aged steak has a more tender texture.

The third category of proteins, connective (*stromal*) proteins such as collagen, provides structure in muscle tissues like tendons. About 3% of protein in a fish is connective protein—in sharks, 10%! For a mammal, its connective proteins are about 17%. Understanding collagen in cooking is important enough that we'll cover it separately later in this chapter (see page 195); for now, just know that high-collagen cuts of meat require their own cooking techniques.

The amount of the structural proteins actin and myosin differs by animal type and region, and the actual chemical structures of the proteins differ too—myosin is a family of proteins, and mammals have evolved to have different versions of the proteins from sea creatures. Myosin in fish begins to noticeably denature at temperatures as low as 104°F / 40°C; actin denatures at around 140°F / 60°C. In land animals, which have to survive warmer environments and heat waves, myosin denatures in the range of 122–140°F / 50–60°C and actin denatures at around 150–163°F / 66–73°C.

Dry, overcooked meats aren't tough because of lack of water inside the meat; they're tough because on a microscopic level, the proteins have become so tangled together that they become chewy. Applying heat to meats changes their texture by physically altering the proteins on the microscopic scale: as the proteins denature, they loosen up and uncurl. In addition to denaturing, upon uncurling, newly exposed regions of one protein can come

into contact with regions of another protein and form a bond, allowing them to link to each other. This process is called *coagulation*, and while it typically occurs in cooking that involves protein denaturation, it is a separate phenomenon.

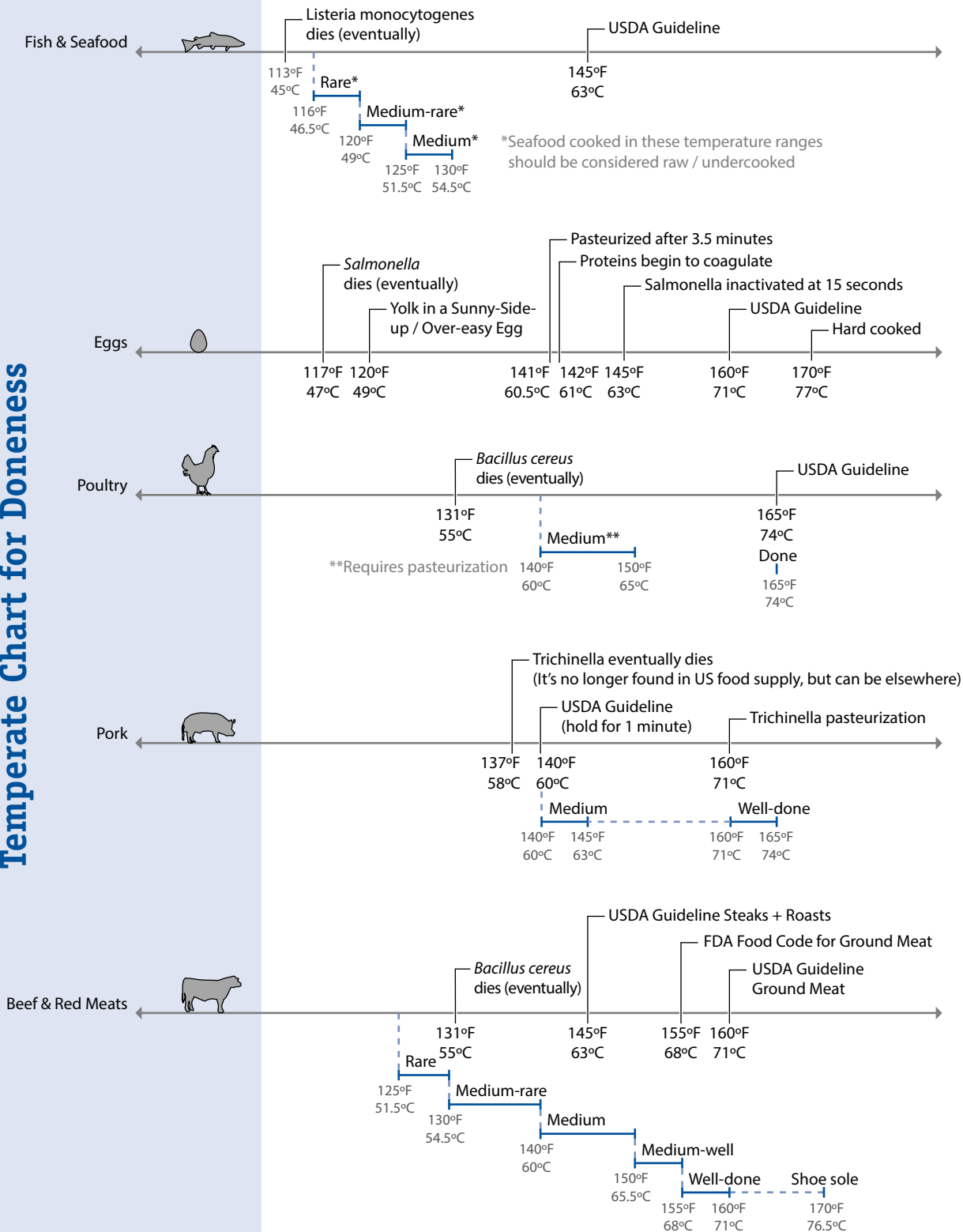
Researchers have determined through empirical data (“total chewing work” and “total texture preference” being my favorite terms) that the optimal texture of cooked meats occurs when they are cooked to 140–153°F / 60–67°C, the range that nicely lines up with temperatures at which myosin will have denatured but actin will remain in its native form. In this temperature range, fish is moist but not dry and red meat will typically have a pinkish color with juices that run dark red—although not always.

While hard to prove, the coincidence of the temperature ranges for ideal texture being above myosin’s denaturation point and below actin’s highly suggests that texture is based on the state of those two proteins. This lines up for both fish and mammalian temperatures, and extended hold periods at these temperatures eliminate the possibility that it’s merely a time-and-temperature rate-related effect. So, if you take only one thing away from this section, let it be this: denatured myosin = yummy; denatured actin = yucky. Of course, there are other proteins in play as well, and subtle changes in temperature will change the textural impact as those also denature, but with the vast majority of the muscle tissue being actin and myosin, those two proteins seem to be the key to good texture.

You can improve the texture of some cuts of meat by tenderizing them. Marinades and brines chemically tenderize the flesh, either enzymatically (relying on compounds like *bromelain*, from pineapple, which breaks down connective tissues; or *papain*, from papaya, which does more to muscle fibers) or by acting as a solvent (some proteins are soluble in salt solutions). Heat-activated chemical tenderizers are also sometimes injected into packaged meats. Dry aging steaks works by giving enzymes naturally present in the meat time to break down the structure of collagen and the myosin–actin machinery. Dry aging also changes the flavor of the meat: less-aged beef tastes more metallic and “bloodlike,” while more-aged beef tastes gamier. Which is “better” is a matter of personal taste preference. (Perhaps some of us are physiologically more sensitive to metallic tastes.) The red meat you buy at your grocer is typically five to seven days old, whereas some restaurants use red meats aged two to three weeks.

Then there are the mechanical methods for tenderizing, which aren’t actually so much tenderizing as they are cutting up the tough bits into smaller tough bits. Grinding meat for things like hamburgers slices up connective proteins and the myofibrillar structure. Thinly slicing muscle “against the grain”—perpendicular to the direction of the myofibrillar structure—also works, as is done in steak tartare (see page 174) and London broil. Some meat is microscopically sliced by very thin needles, sort of like stabbing it with a fork over and over. As we’ll see in the next section (on food safety), this has some potential issues.

# Temperate Chart for Doneness



## Buttermilk-Marinated Skirt Steak

*Most cuts of beef are from animals that are grain-finished—switched to a diet that includes grains for a few months before slaughtering—as opposed to grass-fed, which I call “grass-finished” because all cows start on grass. Grain finishing results in cuts like ribeye and strip steak having over twice as much fat as their grass-finished counterparts (around 5.2% intramuscular fat instead of 2.3%). No wonder cooking grass-finished cuts is tougher!*

*Most marinade ingredients don’t penetrate very far into meat, but enzymatic agents and acids do, given time. As a general rule of thumb, small molecules like sodium ions from salt take about 24 hours to travel an inch through cuts of meats. This is why marinade-based recipes call for long hold times—it’s not just a matter of how strong the marinade will be, but how much of the tissue will be exposed to it.*

*In theory, using the right marinade on extremely lean cuts of meat, especially grass-fed cuts, should improve their texture. Enzymatic tenderizers are used in commercial processing where they can be exposed to the meat early in the slaughtering process; home use can lead to mushy textures. Lactic acid, and potentially calcium, in buttermilk will tenderize meats and doesn’t have this issue.*

*In practice, there’s a lot of debate about marinades impacting meat texture. Visual inspection of a marinated piece of meat sliced in half only shows a change in a thin outer layer, and flavor tests seem to support this. But textural differences are not the same thing as flavor! Clearly, acids and salts do penetrate through tissues: a scallop marinated ceviche-style and sliced in half shows visible differences. Experiment and see what you think.*

Place **one ~2 pound (1 kg) flank or skirt steak** in a resealable bag and add **several cups of buttermilk**, enough to keep the meat submerged when the bag is set down. If you like, add herbs and spices to the buttermilk—try the **zest from one lemon** and a few sliced-up **garlic cloves**. Let the bag rest in the fridge for 8–24 hours. Remove the meat from the bag, discarding the marinade, and pan-sear the meat in a hot cast iron pan for 2–3 minutes per side. Slice against the grain, cutting perpendicular to the muscle fibers, for the best texture.

This marinade is good with other meats too. Try chicken, letting it marinate for at least 12 hours.

## Olive Oil Poached Salmon

*Fishes like salmon and Atlantic char become dry and lose their delicate flavors when overcooked. The trick with poaching fish is to use a low temperature and give it time to cook. Poaching is an easy way to control the rate of heat being applied, and the results are amazingly tasty.*

Place a fillet of fish, skin side down, in an oven-safe bowl just large enough for the fish to fit. Sprinkle a generous pinch of salt on top of the fish. Cover it with olive oil until the fillet is submerged. (Using a bowl that “just fits” the fish will cut down on the amount of olive oil needed.)

Place the fish into a preheated oven, set to medium heat (325–375°F / 160–190°C).

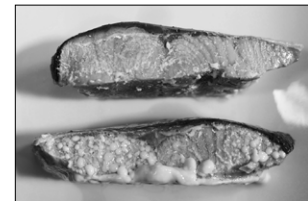
For a rare texture—amazing with good salmon—cook for about 15–20 minutes, using a probe thermometer set to beep at 115°F / 46°C. (Cooked rare, fish should be considered raw/undercooked unless pasteurized—see page 331 for more.)

For medium doneness, cook for about 20–25 minutes, until the interior reaches 130°F / 54°C.

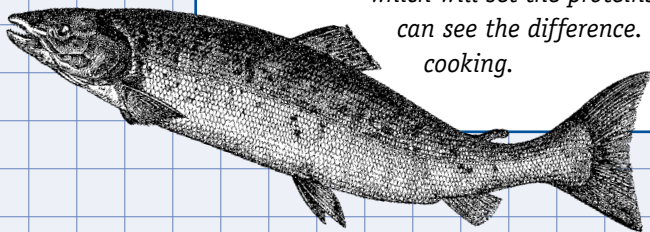
Remove the fish when the thermometer goes off, letting carryover bring the temperature up a few more degrees.

### Notes

- *Try serving the fish on top of a portion of brown or wild rice and spooning sautéed leeks, onions, and mushrooms on top. (A squirt of orange juice in the leeks is really good.) Or serve it with string beans sautéed with red pepper flakes and white rice, with a splash of soy sauce drizzled on top.*
- *Salmon contains a protein, albumin, that generates a white congealed mess on the outside of the flesh, as shown on the bottom piece in the photo. This is the same protein that leaches out of hamburgers and other meats, typically forming slightly gray “blobs” on the surface. You can avoid this by brining the fish in a 10% salt solution (by weight) for 20 minutes, which will set the proteins. The top piece in the photo was brined; you can see the difference. If you brine the fish, skip adding salt to it when cooking.*



*Salmon contains a protein, albumin, that is expressed out of the flesh and leads to an unsightly, curdlike layer forming on the surface of the fish when it's poached, as shown in the bottom piece in this photo.*



## Cumin and Salt Seared Tuna

*Pan searing is one of those truly simple cooking methods that produces a fantastic flavor and also happens to take care of bacterial surface contamination, which we'll talk about in the next section.*

*The key to getting a rich brown crust is to use either a stainless steel or cast iron pan, both of which have a higher thermal mass than other types of pans (see page 45 for how quickly different metals transfer heat). I recommend using cast iron for this recipe, as there's no worry about it warping at high temperatures. When you drop the tuna onto the pan, the outside will sear and cook quickly while leaving most of the center raw.*

You'll need **3–4 ounces (85–110 grams) of tuna** per person. Slice the tuna into roughly equal-sized portions, since you'll be cooking them one or two at a time.

On a flat plate, measure out **1 tablespoon (6g) cumin seed** and **½ teaspoon (2g) sea salt** (preferably a flaky sea salt) *per piece of tuna*. On a second plate, pour a **few tablespoons (~30 mL) of a high-heat-stable oil**, such as refined canola, sunflower, or safflower oil.

Place a cast iron pan on a burner set as hot as possible. Wait for the pan to heat up thoroughly, until it just begins to smoke.

For each serving of tuna, dredge all sides in the cumin/salt mix, and then briefly dip all sides in the oil to give the fish a thin coating.

Sear all sides of the fish. Flip to a new side once the current facedown side's cumin seeds begin to brown and toast, about 30 seconds per side.

Slice the tuna into ⅓" / 1 cm pieces and serve it as part of a salad (place the fish on top of salad greens) or main dish (try serving with rice, risotto, or Japanese udon noodles).

### Notes

- *This tuna is great for Nicoise salad. Add green beans, hard-cooked eggs, small potatoes, tomatoes, and olives on a bed of lettuce like Bibb or butterhead lettuce, dress it with a light vinaigrette, and enjoy.*
- *Keep in mind that the temperature of the pan will fall once you drop the tuna in it, so don't use a piece of fish too large for your pan. If you're unsure, cook the fish in batches.*
- *Use coarse sea salt, not rock (kosher) salt or the table salt you'd find in a salt shaker. The coarse sea salt has a large, flaky grain that won't fully dissolve on the fish and then gives a nice flavor as it dissolves on your tongue.*



*Coat all sides of the tuna in cumin seeds and salt by pressing the tuna down onto a plate that has the spice mixture evenly spread out on it.*



*Make sure the pan is really hot. Some smoke coming off the fish as it sears is okay!*



*Pan-seared tuna will have a very steep "gradient of doneness"—a thin, well-done outside and a large raw center.*

# 140°F / 60°C: The End of the Danger Zone

*The danger zone rule: don't keep food between 40°F / 4°C and 140°F / 60°C for more than 2 hours.*

While fans of music from the 1980s might want to take the “Highway to the Danger Zone,” when it comes to food, I’d suggest taking the highway in the other direction. The modern food supply is more interconnected and interdependent than ever before. As I write this, I’m eating my morning bowl of cereal, yogurt, bananas, and almonds. The muesli cereal is from Switzerland, the yogurt local to New England, the bananas from Costa Rica, and the almonds from California. The only direction from which food hasn’t come 3,000 miles is north, and that’s because not much grows at the North Pole!

While it’s a privilege to have year-round access to fresh produce and international ingredients, there is a downside: the number of people who can be affected by any given mistake has also increased. A contaminated batch of water sprayed onto a field of spinach can sicken hundreds of consumers across many state and international lines before the source of the contamination is identified.

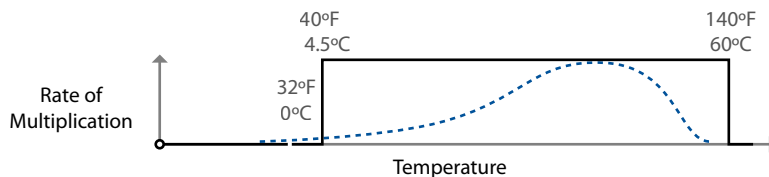
Food safety, while not a sexy topic, is an important one, and there are some interesting aspects of biology involved. (Did you know some parasites can survive even in liquid nitrogen?!) Unlike in the rest of this chapter—heck, the rest of this book—I’m going to take a brief digression away from fun “how cooking works” ideas and look at “how to not kill yourself” for the next dozen or so pages. I’ll try to keep it entertaining.

The main culprits for unsafe food are bacteria and parasites combined with poor handling. Other aspects, like viruses, mold, and contaminants, are also of concern, but these are much easier to manage. You can transmit viruses by not washing your hands or by cooking while you’re sick, both of which are easy to mitigate (wash your hands; don’t cook for others when you’re ill). If you see mold growing on something, throw it out (see page 434 for an interview on mold). The idea that mold can only be present an inch away from where you see it is wrong. Finally, contaminants and toxins are primarily issues for producers of foods, so as a consumer you’re mostly off the hook for those. (If you grow your own veggies, test your soil for contaminants.)

Back to the world of bacteria and parasites. Most critters guilty of causing foodborne illnesses reproduce at temperatures above 40°F / 4°C, with some species active all the way up to 131°F / 55°C. Throw in a margin of safety of a few degrees, and you’ll see why the “danger zone” mentioned at the start of this section is defined as being between 40°F / 4°C and 140°F / 60°C. In the fridge, bacteria and parasites remain viable but generally won’t reproduce (there are exceptions), and above 140°F / 60°C they eventually die. Somewhere in between the two temperatures, though, is party central for bad bugs.

As you'd imagine, the time range given in the danger zone rule is a vast simplification of what's really going on in the microbiological world. The rule limits the time window to two hours by assuming the worst-case scenario: food held longer than that can cause illness if contaminated with one of the more aggressive bad bugs, *Bacillus cereus*. (Who said scientists don't have a sense of humor? Try saying *B. cereus* out loud.)

The temperature ranges are also grossly simplified. Organisms reproduce at different rates at different temperatures. *Salmonella*, for example, is happiest breeding at around 100°F / 37.8°C. (No wonder we have such issues if we get sick with it!) It doesn't go from zero reproduction at 40°F / 4°C to full-on party mode at 41°F / 5°C; it's a gradual ramp-up to that ideal breeding temperature. The danger zone and cooking temperature guidelines are simplifications, and by understanding the bigger picture you can cook better-tasting and safer food.



*Multiplication rates of foodborne illness-related bacteria follow a curve with an ideal breeding range in the middle, nothing at all like what the danger zone rule implies.*

To understand the simplifications of the time and temperature ranges, we need to talk about chance. Contracting a foodborne illness is a game of probabilities. For *Listeria monocytogenes*, the bacteria that causes listeriosis and is potentially present in raw milk, you'd need to swallow somewhere around a thousand of them. While that may sound like a lot, it's not: a single sip of contaminated milk can make you sick. A single bacterium of *E. coli* isn't likely to cause a problem (not that I want to volunteer!), but given 10 to 100 of them, the odds are grim. Cooking a hamburger to medium-rare reduces their count, assuming the bacteria are present, but doesn't guarantee their elimination. What risks you should accept—do you *really* want that hamburger medium-rare?—requires knowing what the consequences are and the probabilities involved.

For most of us, the consequence of contracting most foodborne illnesses is *gastrointestinal distress*—diarrhea, vomiting, muscle spasms, and the like. However, for those who are in an *at-risk group*—anyone for whom having a foodborne illness can lead to further complications—such illnesses can be fatal. If you are cooking for someone who is elderly, extremely young, pregnant, or immunocompromised, be vigilant with food safety issues and skip dishes that have higher risks (including, alas, the medium-rare hamburger).

The odds of getting sick from food are about one in six in any given year, and about a quarter of a percent of those cases will require hospitalization, according to the United States Centers for Disease Control and Prevention (CDC). How we get sick from food is complicated. Let's look at *Salmonella* specifically, keeping in mind that the concepts apply to other pathogens as well, just with different specifics.



*Salmonella* is surprisingly prevalent, infecting tens of million of people worldwide each year. *Salmonella* reproduces in the temperature range of 44–118°F / 7–48°C and survives at an even wider range. When cooked to 160°F / 71°C, it dies instantly; that is, its *thermal death time*—how long it takes a bacteria to die at a given temperature—is zero.

The United States Department of Agriculture (USDA) publishes cooking temperature guidelines for consumers. For chicken, which is commonly tainted with *E. coli* and *Salmonella*, the USDA guidelines say to cook it to 165°F / 74°C. It's a guideline based on simplicity, not on cooking deliciously tasty chicken. Then there's the US Food and Drug Administration (FDA), which writes the actual food laws. The FDA Food Code requires commercial vendors to cook chicken to only 155°F / 68°C (section 3-401.11, for the curious).

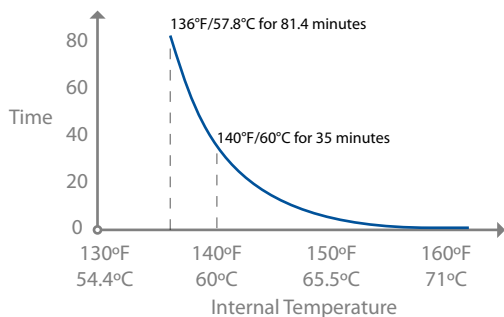
Why the difference in temperatures? In part, it's down to the craziness that is the US's food regulatory system and differences between organizations. (Seriously, who can keep track of when the USDA or FDA or CDC or NSA is supposed to be involved?) Consumer guidelines assume some amount of error, so err on the high side; commercial outfits are accountable to legal standards and assumed to have better measuring techniques and equipment.

Then there's the issue of *hold times*—how long a food needs to remain at temperature. The FDA requirement is based on a thermal death time of 15 seconds at 155°F / 68°C, meaning cooked chicken has to hit that temperature and then stay there for 15 seconds.

The rate-of-reaction discussion at the beginning of this chapter is true for bacteria and parasites too. Extending hold times increases how many of the pathogens will be killed. There's another group (and another acronym), the USDA's Food Safety and Inspection Service (FSIS), that publishes charts of hold times based on exactly this. Chicken breast cooked to 145°F / 63°C has much better texture—it's cooked yet not dry—but requires a hold time of 8.4 minutes, something that the consumer guidelines rightly assume home cooks can't safely do. (Although with sous vide cooking, it's possible—see page 320.) But

at 150°F / 66°C, the hold time is only 2.7 minutes—something that with some care you can do. Don't tell anyone, but that's how I cook my chicken. I give myself a 5°F / 3°C error, shooting for 155°F / 68°C and holding it there for 3 minutes. (*Shh!*)

Following hold times involves more than reaching a temperature (though I'd rather eat from places cooking based on simplified guidelines than none at all). The specific hold times depend not only on the organism at hand, but also the food being cooked. For chicken, with its lower fat content and smoother surface, 8.4 minutes at 145°F / 63°C is long enough to pasteurize *Salmonella*. But when you're making beef jerky,



Hold time in minutes for cooking chicken, per USDA FSIS guidelines (assuming chicken with a 12% level of fat).

*Salmonella* can survive at 145°F / 63°C for 10 hours, presumably due to the evaporative cooling of the water from the beef as it dries out and the tiny crevices in the surface that remain cooler.

If hold times seem confusing—they were to me at first—think of them like time spent in a sauna. You can survive, even enjoy, dry heat for a while, but if you're exposed to it for too long, you'll eventually die. Jump into the sauna wrapped in a cold towel and with an iced drink, and you'll last longer. The same is true for pathogens: given a long enough exposure, they will eventually die, *but not instantly*, so cooking at temperatures below the simplified guidelines requires looking up exactly what you're cooking to correctly pasteurize it.

*Pasteurization*, by the way, is merely a reduction of the typical pathogens to a safe level. Don't confuse this with *sterilization*, which would entirely eliminate pathogens. Obviously, if there are zero *Salmonella* bacteria present after cooking, the food won't spontaneously become infected unless recontaminated. With pasteurization, the levels of pathogens are dropped but not necessarily to zero, so given time at reproductive temperatures they could creep back up to dangerous levels. Sterilized foods—canned tuna fish, irradiated milk—have none of the pathogens present and when properly sealed can be kept at room temperature indefinitely.

Hold times for pasteurization depend on how quickly a pathogen dies at a particular temperature and how many of them need to be killed, based on the difference between worst possible and acceptable contamination levels. Scientists use the term *log<sub>10</sub> reductions* to talk about pasteurization, where one log<sub>10</sub> reduction cuts the pathogen count by a factor of 10. For *Salmonella*, guidelines specify a 7 log<sub>10</sub> reduction, meaning only 1 in 10 million bacteria should be able to survive.

If we can cook food to reduce the number of pathogens, why not just recook foods that are accidentally left out where the pathogens may have reproduced again? Sometimes it's not the bacteria themselves that are the issue, but the toxins they produce. While appropriate cooking might safely reduce the bacterial count, the toxins themselves, such as those produced by *B. cereus*, can be heat-stable and remain in cooked foods.

We'll take a look at the specific times and temperatures you should follow in the next section. For additional information on pathogens in food, check out the FDA's *Bad Bug Book*; see <http://cookingforgeeks.com/book/badbugbook/> for a current link.

## Steak Tartare with Poached Egg

*To some, the idea of steak tartare is a delicacy; to others, it's nauseating. Food preferences aside, carpaccio—thinly sliced raw meat—and tartare—minced raw meat—are surprisingly delicious and interesting from a science perspective. They're based on mechanical tenderization by slicing through muscle tissues, and they're a good example of managing food safety.*

*My technique here, a hot water dip treatment, removes more than 99% of any potentially present surface bacteria. As the old food science adage goes: there's no such thing as safe food, just safer food. When dipped in 183°F / 83.5°C water, E. coli is reduced by 99.4% (a 2.23 log reduction) after 10 seconds and 99.9% (a 2.98 log reduction) at 20 seconds—pretty good, but not 100%. If you wouldn't eat the poached egg—which could have Salmonella, at least in the United States—then you shouldn't eat the steak tartare. If you're game, give this a try; you might be surprised how good it is!*

For each appetizer portion, you'll need **¼ pound (~100g) beef tenderloin (fillet), top sirloin, or other lean "whole-muscle" cut**. For 4 people, snag a single 1 pound (~450g) piece. *Do not get ground meat*. Make sure that the cut of meat is not mechanically tenderized ("pinned," "jaccarded," etc.); ask your butcher. I'm lucky that mine dry-ages meats for two weeks and does the butchering in the front part of the store, so I know what I'm buying.

Set the meat in a large pot and fill it with enough water to cover the meat. Remove the meat and heat the water to approximately 183°F / 83.5°C. Dunk the meat for 10–20 seconds, then remove it and blot it with a paper towel. The meat should be grey. (Fun fact: the color will partly revert over time.)

Store the meat in the freezer on a plate for 30 minutes, giving it time to firm up so that it's easier to slice.

After the meat has firmed up in the freezer—don't actually freeze it!—use a sharp, sharp knife to cut it into *brunoise* cuts—small cubes, about ⅛" / 0.3 cm. Start by cutting the meat into thin slices, then cut the slices into strips, and finally cut the strips into cubes, pressing down to pinch-cut them if a drag-cut doesn't work. Transfer the meat to a bowl and liberally season it with **good sea salt** and **pepper**.

Tartare fans have strong opinions about how to prepare it and what should accompany it. If you'd like a starting suggestion, mix in a small amount of **lemon juice**, **mustard**, and **olive oil** to taste.

Steak tartare is almost always served with a raw egg yolk on top; I like to do it with a poached egg. The yolk is still runny, but it's a more accessible presentation to people who dislike the idea of raw egg yolk. Place an individual portion of the tartare onto a plate, shaping it into a round patty. Top it with **a poached egg** (see page 193) and serve it with **good potato chips**.



## Why Doesn't Food in the Pantry Go Bad?

Pathogens need more than the right temperature in order to multiply. Many foods are shelf-stable because they're low in available moisture (crackers, dry goods like beans and grains, oils, even jams and jellies), but there are other variables that matter too. Here's a list of the six factors that all need to be in the right ranges for microbial growth, memorable by its acronym, FAT TOM. If any one of these is out of bounds, the food won't support microbial growth.

### *F = Food*

Bacteria need proteins and carbohydrates to multiply. No food, no multiplication. They may still be present, though! Bottled water, for example, has no organic matter in it to support growth.

### *A = Acidity*

Bacteria can only survive in certain pH ranges. Too acidic or basic, and the proteins in the bacteria denature. Pickled items are shelf-stable because they're too acidic. For homemade jams, it's hard to know if the acidity is low enough unless you exactly follow a verified recipe.

### *T = Temperature*

Too cold, and bacteria effectively sleep. Too hot, and they die. Most parasites, on the other hand, are killed with proper freezing—for seafood,  $-4^{\circ}\text{F}$  /  $-20^{\circ}\text{C}$  for 7 days—and like bacteria, die when too hot.

### *T = Time*

Bacteria have to have enough time to multiply to a sufficient quantity to overwhelm our bodies. For pantry foods, temperature and time aren't limiting factors.

*Caliciviruses*—a family of viruses, norovirus being the best known—are prolific; these are typically spread by a sick individual preparing food for others. If you've spent a night "praying to the porcelain god"—diarrhea, vomiting, chills, headache—there's a 50% chance you can blame norovirus for the experience. If you have those symptoms, don't cook for others!

### *O = Oxygen*

Microorganisms will reproduce only if sufficient oxygen is present, or, for anaerobic bacteria (e.g., *Clostridium botulinum*), if no oxygen is present. Keep in mind that vacuum-packed bags are not necessarily devoid of oxygen. Foods stored in oils are completely devoid of oxygen, though, so if you make infused oils or non-acidic dressings using garlic, herbs, or chilies, store them in the fridge and use them within four days.

### *M = Moisture*

Bacteria need water to reproduce. Food scientists use a scale called *water activity*, which is a measure of the freely available water in a material (from 0 to 1). Bacteria need a water activity value of 0.85 or greater to multiply.

**Fun fact:** Botox is made from a toxin produced by *C. botulinum*, and that toxin is the most acutely toxic substance known. A dose as small as ~250 nanograms—1/120,000 the weight of a grain of rice—will do you in.

# Scallop Ceviche

*This scallop ceviche is a simple dish to prepare and refreshing on a warm summer day. It's also a good example of how acids—in this case, the lime and lemon juices—are used to make foods safe to eat.*

In a bowl, mix:

- ½ cup (120 mL) lime juice**
- ¼ cup (60 mL) lemon juice**
- 1 small (70g) red onion, sliced as thinly as possible**
- 2 tablespoons (20g or 1 bulb) shallot, thinly sliced**
- 2 tablespoons (30 mL) olive oil**
- 1 tablespoon (15 mL) ketchup**
- 1 clove (7g) garlic, chopped or run through a garlic press**
- 1 teaspoon (5 mL) balsamic vinegar**

Add and toss to coat:

- 1 pound (450g) bay scallops, rinsed and patted dry**

Store the mixture in the fridge, toss it again after 2 hours, and store it overnight to allow sufficient time for the acid to penetrate the scallops. Add **salt** and **pepper** to taste.

## Notes

- Try slicing one of the scallops in half after 2 hours. You should see a white outer ring and a translucent center. The outer ring is the portion that has had time to react with the citric acid, changing color as the proteins denature (just as they would with heat applied). Likewise, after marinating for a day or two, a sliced scallop should show a cross-section that's entirely white.
- Keep in mind that the pH of the marinade is important! At least 15% of the dish should be lime or lemon juice, assuming the remaining ingredients are not extremely basic. Lime juice is more acidic than lemon juice (pH of 2.0–2.35 versus 2.0–2.6).
- Try adding minor quantities of herbs like oregano to the marinade or adding cherry tomatoes and cilantro to the final dish (after marinating).



## How effective is lime juice at getting rid of bacteria?

For the types of bacteria that might be present in seafood, it's very effective. To quote from the literature: "In the face of an epidemic of cholera, consumption of ceviche prepared with lime juice would be one of the safest ways to avoid infection with *[Vibrio] cholerae*." (L. Mata, M. Vives, and G. Vicente (1994), "Extinction of *Vibrio cholerae* in acidic substrata: contaminated fish marinated with lime juice (ceviche)," *Revista de Biología Tropical* 42(3): 472–485.)

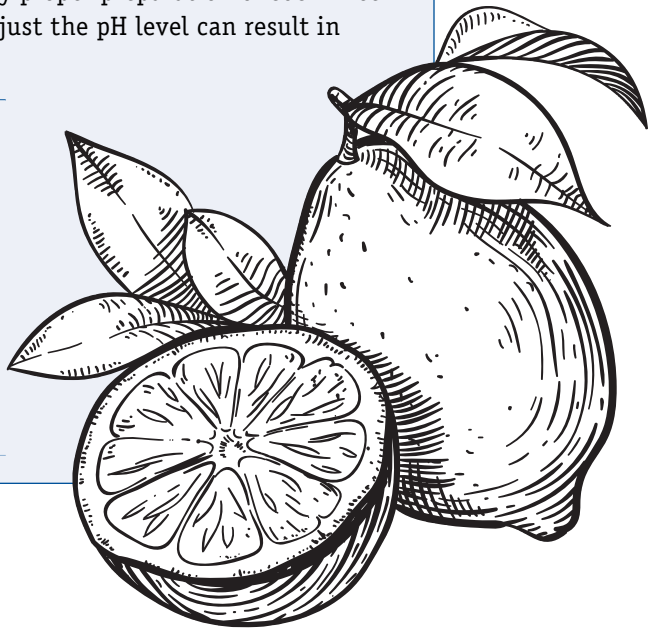
## Cooking with Acids

Heat isn't the only thing that denatures proteins and kills pathogens. A protein keeps its native shape because of the balance of forces pushing and pulling on the molecular structure. Adding an acid or base knocks these forces out of balance. The ions from an acid or base push on a protein's structure, changing the electrical charges and thus causing the protein to change its shape. For dishes like *ceviche*—citrus-marinated seafood—the acid from the lime or lemon juice causes a change on the molecular level akin to cooking with heat. This change doesn't happen only on the surface; given sufficient time, acidic and basic solutions will fully penetrate a food.

Ceviche is a classic example of using acids to kill pathogens. *V. cholerae*—a common seafood-borne pathogen—rapidly dies in environments with a pH level below 4.5, even at room temperature. Another example is cooked rice for sushi, where rice vinegar is added. Without the rice vinegar, cooked rice left sitting out at room temperature becomes a perfect breeding ground for *B. cereus*: it's moist, at an ideal temperature, and has plenty of nutrients for bacteria to munch away on. But drop the pH level of the environment down to about 4.0, and the rice falls well outside a hospitable range for bacteria to grow. This is why proper preparation of sushi rice is so critical in restaurants: failure to correctly adjust the pH level can result in sickening diners.

### Why doesn't boiling rice get rid of bacteria?

It does get rid of bacteria, but only temporarily. Some bacteria, like *B. cereus*, reproduce with spores that are heat-stable and survive boiling. Because the spores are highly prevalent in soil and water, they're nearly impossible to get rid of. Also, unless you're using a technique like canning, pathogens can be re-introduced into the food from cross-contamination after they cool down.



# Doug Powell on Food Safety

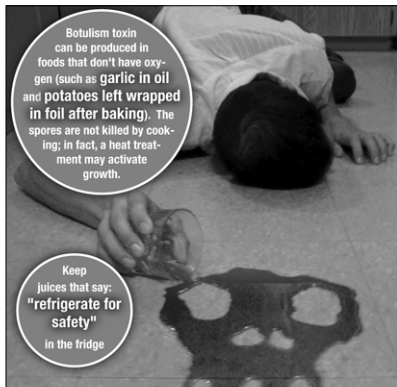
PHOTOS USED BY PERMISSION OF DOUG POWELL



Doug Powell is an associate professor at Kansas State University's Department of Diagnostic Medicine and Pathobiology. His blog, "barfblog: musings about food safety and things that make you barf," is at <http://www.barfblog.com>.

## Is there a tension between safety and quality in cooking, and if so, are there methods to achieve both?

Safety and quality are two very different things. Quality is something that people love talking about, whether it's wine, or organic food, or how it was



Botulism toxin can be produced in foods that don't have oxygen (such as garlic in oil and potatoes left wrapped in foil after baking). The spores are not killed by cooking; in fact, a heat treatment may activate growth.

Keep juices that say: "refrigerate for safety" in the fridge

grown, and people can talk themselves to death about all that. My job is to make sure they don't barf.

## For somebody cooking at home, it's easy for them to see a difference in quality. It's very hard for them to see a difference in safety until they get sick, I imagine?

There are tremendous nutritional benefits to having a year-round supply of fresh fruits and vegetables. At the same time, the diet rich in fruits and vegetables is the leading cause of foodborne illness in North America because they're fresh, and anything that touches them has the potential to contaminate. So how do you balance the potential for risk against the potential benefits? Be aware of the risks and put in place safety programs, beginning on the farm.

If you look at cancer trends in the 1920s, the most predominant cancers were stomach cancers. All everyone ate during the winter were pickles and vinegar and salt. Now that's almost completely eradicated because of fresh food. But now you have to prevent contamination from the farm to the kitchen, because more food is eaten fresh. There are trade-offs in all of these things. In preparing hamburger and chicken, there is an issue with cooking it thoroughly and validating that with a thermometer, but most of the risk is actually associated with cross-contamination. Potatoes are grown in dirt, and birds crap all over them, and bird crap is loaded with *Salmonella* and *Campylobacter*. When you bring a potato into a kitchen or a food service

operation, it's just loaded with bacteria that get all over the place.

## What's the normal time between ingestion and symptoms?

It's around one to two days for *Salmonella* and *E. coli*. For things like *Listeria*, it can be up to two months. Hepatitis A is a month. You probably can't remember what you had yesterday or the day before, so how can you remember what you ate a month ago? The fact that any outbreak actually gets tracked to the source, I find miraculous. In the past, if a hundred people went to a wedding or a funeral, they all had the same meal. They all showed up at emergency two days later, and they would have a common menu that investigators would look at to piece it together. Nowadays, through DNA fingerprinting, it's easier. If a person in Tennessee and a person in Michigan and a person in New York have gotten sick from something, they take samples and check against DNA fingerprints. There are computers working 24 / 7 along with humans looking to make these matches. And they can say these people from all across the country, they actually have the same bug, so they ate the same food.

Think of spinach contamination in 2006. There were 200 people sick, but it was all across the country. How did they put those together? Because they had the same DNA fingerprint and they were able to find the same DNA fingerprint in *E. coli* in a bag of spinach from someone's kitchen. Then they were able to find the same DNA fingerprint from a cow next to the spinach farm. It was

one of the best cases with the most conclusive evidence. Normally, you don't have that much evidence.

What to do about it isn't very clear-cut, but when you look at most outbreaks, they're usually not acts of God. They're usually such gross violations of sanitation that you wonder why people didn't get sicker earlier. With a lot of fresh produce outbreaks, the irrigation water has either human or animal waste in it, and they're using that water to grow crops. These bugs exist naturally. We can take some regulatory precautions, but what are we going to do, kill all the birds? But we can minimize the impact.

When farmers harvest crops, they can wash them in a chlorinated water system that will reduce the bacterial loads. We know that cows and pigs and other animals carry these bacteria and they're going to get contaminated during slaughter. So we take other steps to reduce the risk as much as possible, because by the time you get it home and go to make those hamburgers, we know you're going to make mistakes. I've got a PhD, and I'm going to make mistakes. I want the number of bacteria as low as possible so that I don't make my one-year-old sick.

### **Is there a particular count of bacteria that is required to overwhelm the system?**

It depends on the microorganism. With something like *Salmonella* or *Campylobacter*, we don't know the proper dose response curves. We work backward when there is an outbreak. If it's something like a frozen food, where they might have a good sample because it's in someone's freezer, we can find out more. With something like

*Salmonella* or *Campylobacter*, it looks like you need a million cells to trigger an infection. With something like *E. coli* O157, you need about five.

You have to take into account the lethality of the bug. For 10% of the victims, *E. coli* O157 is going to blow out their kidneys and some are going to die. With *Listeria*, 30% are going to die. *Salmonella* and *Campylobacter* tend not to kill, but it's not fun. So all of these things factor into it. A pregnant woman is 20 times more susceptible to *Listeria*. That's why they are warned to not eat deli meat, smoked salmon, and refrigerated, ready-to-eat foods. *Listeria* grows in the refrigerator and they're 20 times more susceptible and it can kill their babies. Most people don't know that either.

### **Are there any particular major messages that you would want to get to consumers about food safety?**

It's no different than anything else, like drunk driving or whatever other campaign: be careful. The main message about food in our culture today is dominated by food pornography. Turn on the TV and there are endless cooking shows, and all these people going on about all these foods. None of that has anything to do with safety. You go to the supermarket today, you can buy 40 different kinds of milk and 100 different kinds of vegetables grown in different ways, but none of it says it's *E. coli*-free. Retailers are very reluctant to market on food safety, because then people will think, "Oh my god, all food is dangerous!" All they have to do is read a newspaper, and they'll know that food is dangerous.

### **A lot of the guidelines I see talk about the danger zone of 40–140°F / 4–60°C.**

A lot of those guidelines are just complete nonsense. The danger zone is nice and it's important not to leave food in the danger zone, but at the same time it doesn't really get into any details. People learn by telling stories. Just telling people "Don't do this with your food" doesn't work; they say, "Yeah, okay, why?" I can tell you lots of stories of why or why not. The guidelines aren't changing what people do and that's why we do research on human behavior, how to actually get people to do what they're supposed to do. As Jon Stewart said in 2002, if you think those signs in the bathrooms ("Employees must wash hands") are keeping the piss out of your food, you're wrong! What we want to do is come up with signs that work.

### **I'm wondering what your signs look like?**

We have some good ones! Our favorite picture is the skull in the bed of lettuce. The dead person from carrot juice is pretty good, too.





## How to Reduce the Chances of Foodborne Illness

Not long ago, I overheard the fishmonger at my local grocery store tell a customer that it was okay to use the wild salmon he was selling for making sushi. However, given that the fish wasn't labeled as "previously frozen" and that it was in direct contact with other fish in the case, there was no guarantee that it was safe from harmful parasites or bacteria. What's a shopper to do in the absence of a true fishmonger?

For starters, pay attention and understand where the risks are. Not all produce shares the same types of risk. *Salmonella*, for example, tends to show up in land animals and improperly handled produce—you're actually more likely to get it from not washing your vegetables at this point! Other bacteria, such as *Vibrio vulnificus*, show up in fish that are exposed to the brackish waters of tidal estuaries, like wild salmon. Deep-water fish, such as some species of tuna, and some aquacultured fish like salmon, are of less concern. Few of us will remember such specifics—I know that I don't have a good enough memory for such details about salmon—but there are broad rules that cover cooking most foods, sushi-making ones aside.

The safest way of preventing foodborne illness—well, other than living in a plastic bubble on a diet of irradiated gruel—is avoiding cross-contamination by cooking properly. Oh, cross-contamination, what a pain you are. Cross-contamination is more of a problem than undercooked meats! Wash your hands, wash your hands, wash your hands, and don't dry those just-washed hands on a dirty towel.

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### USDA consumer guidelines:

145°F / 63°C: Fish and shellfish

145°F / 63°C: "Whole-muscle" beef and similar meats

160°F / 71°C: Ground meats

160°F / 71°C: Eggs

165°F / 74°C: Poultry and leftovers

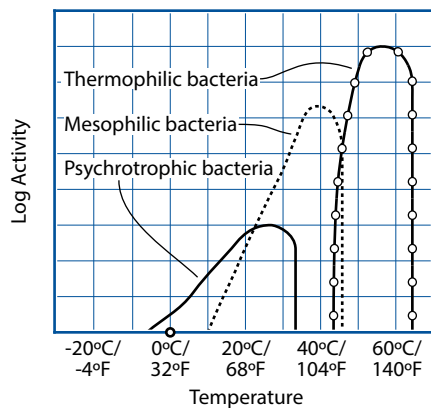
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As for cooking temperatures, the USDA recommends cooking foods based on temperatures needed to instantly kill pathogens that may be present. The USDA recommendations trade off deliciousness for safety, and when I'm retired and eating on a cruise ship or recovering in the hospital, that's what I'd want. But the rest of the time? Using the given temperatures result in overcooked foods.

Assuming you have a good digital probe thermometer, following hold time guidelines will properly pasteurize foods and at the same time avoid overcooking

them. As I've mentioned, the US FSIS publishes hold time tables; search online for *FSIS time-temperature guidelines*.

What if you're willing to "consume raw or undercooked meats," as the common menu warning goes? Depending upon the ingredients, you should still handle them wisely—avoid cross-contamination, keep foods cold—and then understand where the risks are in produce, meats, and seafood. Here's a quick summary for each of those topics.



Safe cooking temperatures depend on which pathogens might be present and their survival temperature zones. Very few bacteria that cause foodborne illness are psychrotrophic—cold growers—which is why refrigeration staves them off. (*Listeria* is the exception.) Most bad bugs are mesophilic—most active near body temperature—and luckily only a few are heat-loving thermophiles (e.g., *campylobacter*).

GRAPH BASED ON E. ANDERSEN, M. JUL, AND H. RIEMANN (1965), "INDUSTRIEL LEVNEDSMIDDEL-KONSERVING," COL. 2, KULDEKONSERVING, COPENHAGEN: TEKNISK FORLAG)

## Avoid cross-contamination

Sponges and towels are notorious—ridiculously, absolutely notorious—for cross-contamination. You wipe down a dirty countertop, rinse the sponge or towel under hot soapy water, then wring it out. An hour later, you pick it up, wipe down another countertop, and bam! You’ve just spread a beautiful thin coat of bad bugs all over the place: your tap water isn’t hot enough to kill pathogens. Or you’ve washed your hands with hot water and soap after handling raw items—but then you dry your hands on a towel you touched while dirty, and boom!

Use paper towels for drying hands and wiping down spills, and keep a stack of clean dish towels so you can toss the current one in the wash after each meal. Microwave dish sponges (rinse them and give them 2 minutes on high), boil them for 5 minutes, or run them through the dishwasher on a weekly basis.

It should go without saying: keep separate cutting boards or plates for raw and cooked foods. You can use plastic wrap over a cutting board for a quick, disposable surface—or even use the wrapper the meats came in, if you’re careful not to cut through the paper.

## Keep food cold

Have you checked what temperature your fridge is running at? It should be below 40°F / 4°C, and ideally on the chilly side (34–36°F / 1–2°C) so that foods will cool down more quickly and spoil more slowly.

While cooking food kills off most of the bacteria, there’s a chance a few will survive or make it back in via cross-contamination. There’s also the likely possibility of heat-resistant spores still kicking around. Given the right temperature range and time, they can reproduce to unsafe quantities. Stick leftovers in the fridge right away, as opposed to letting them sit around until post-meal cleanup. The exception to this is if you have a large quantity of hot food, in which case let it cool to 140°F / 60°C and then place it in an ice bath to quickly chill it even further before storing it in the fridge.

If you're going to have foods out for a while—milk on the table for a leisurely long brunch, potato salad for a picnic in the park—keep them cold. Stash containers of liquids like milk in a bowl with crushed ice and use ice packs to keep containers of foods like potato salad cold. If you know your food has been properly cooked and chilled, you can use the danger zone rule as a guideline—2 to 4 hours is an okay exposure time, but beyond that, there are risks.

## Wash produce

When's the last time you cleaned the veggie drawer in your fridge? I thought so. (I'm guilty too!) Store veggies and lettuces in plastic bags, and rinse them before eating them. You can also steam vegetables to quickly kill any pathogens. Use a container with the lid mostly closed and a small amount of water inside; the lid will keep the steam in contact with the vegetables.

Contamination of fruits and vegetables can happen before you buy them, either from contaminated water used during farming or from other sources (birds poop when flying over growing fields!). Root vegetables—carrots, potatoes, beets— and anything that harbors soil should be thoroughly washed. Wash everything thoroughly; who knows if someone sneezed on it at the store. (I know, gross, but after reading the Reddit thread on what buffet restaurant workers will never eat...well, you may not want to know.)

## Use “whole-muscle, intact” cuts of meats

The industry lingo “whole-muscle, intact” describes pieces of meat whose interior is untouched, meaning they're not ground and not *mechanically tenderized*—stabbed with a whole bunch of tiny blades to microscopically cut them up. Whole-muscle intact cuts of beef, pork, veal, and lamb are great for delicious cooking; contamination is limited to the surface, so a quick sear or dunk in boiling water and you're safe to eat the inside totally raw. Steak tartare? Perfectly fine with whole-muscle intact cuts.

But these two little words (okay, long words) “mechanically tenderized” should give you pause. About one in four retail steaks and roasts are mechanically tenderized, which does make them less tough but also shoves any surface contamination deep into the meat. Unfortunately, you can't see the microcuts, and frustratingly, food labeling laws don't require processors to label meats as mechanically tenderized. Advocacy groups have been trying for 20 years; so far, only Canada requires labeling. Short of knowing your butcher, you have no way of determining if that slab of beef is whole-muscle intact or not. Buyer beware!

## Cook ground meats to well done

Ground meats like hamburger are all outside, in the sense that surface contamination will have been ground throughout the meat. The USDA says to cook ground meats to 160°F / 71°C. Alas, this temperature is also high enough that the majority of the proteins denature

and give a tough texture. Since fats help mask dryness in meat, using ground beef that has more fat in it will lead to a juicier burger. Look for “85/15” beef—85% lean meat, 15% fat; using leaner ground beef will lead to dry burgers.

Note that change in color is not an accurate indicator of doneness. Myoglobin, oxymyoglobin, and metmyoglobin can begin to turn grey starting at 140°F / 60°C or remain pink at 160°F / 71°C when the pH is around 6.0. Use a digital probe thermometer when cooking ground meats!

It is possible to cook safe medium-rare hamburgers. If you’re up for grinding your own meat, buy whole-muscle intact and process it with the same directions given in the steak tartare recipe (see page 174). Otherwise, look for cold-pasteurized meat (a.k.a. irradiated) or cook it sous vide (see page 320) to pasteurize it yourself (roughly 30 minutes for a 1/2" inch / 15 cm–thick burger at 141°F / 61°C). If you have the equipment, the best burger I ever had was sous vide cooked, briefly fried, and liberally sprinkled with salt.

## Select fish and seafood based on how you’re going to cook it

Most parasites in seafood don’t infect humans, and cooking the seafood also cooks the worms. However, *Anisakis simplex* and tapeworms (*cestodes*) are two parasites of general concern. For cooked seafood dishes—internal temperature of 145°F / 63°C—any parasite will be dead, and while the thought of eating a worm might be unappetizing, if it’s dead there’s little to worry about other than the mental factor. Just think of it as extra protein.

Raw and undercooked seafood is another matter entirely. Cod, halibut, or salmon cooked rare? Sashimi or cold-smoked fish? All potential hosts for roundworm, tapeworms, and flukes. Fortunately, like most animals, few parasites can survive freezing. (There are exceptions: *trichomoniasis* can survive being frozen in liquid nitrogen; thankfully it’s not found in food.) Select previously frozen fish when cooking it to only low temperatures.

If you want to freeze-pasteurize fish yourself, here is the guideline—if you happen to have access to dry ice or liquid nitrogen, quick-freeze the fish first for better texture:

*US FDA 2005 Food Code, Section 3-402.11: “raw, raw-marinated, partially cooked, or marinated-partially cooked fish shall be: (1) Frozen and stored at a temperature of -20°C (-4°F) or below for a minimum of 168 hours (7 days) in a freezer; [or] (2) Frozen at -35°C (-31°F) or below until solid and stored at -35°C (-31°F) or below for a minimum of 15 hours.”*

The second concern with undercooked fish is bacteria. While freezing kills parasites, it does not kill bacteria; it just puts them “on ice.” (This is why researchers routinely store bacterial samples at -94°F / -70°C to preserve them for future study.) Luckily, most bacteria in fish exist on the surface due to improper handling, so a quick pan sear will eradicate them.



*Wash can lids before opening them—and wash the can opener, too! The blade picks up food while cutting through the lid.*

If your grocery store sells both raw and “sashimi-grade” fish, the difference between the two will be in the handling and care related to the chances of surface contamination, and in many cases the sashimi-grade fish will have been previously frozen if it’s of a species of concern. The US FDA doesn’t actually define what sashimi-grade or sushi-grade means, but it does explicitly state that fish known to harbor parasites and not intended to be completely cooked before serving must be freeze-pasteurized. Some types of tuna and farm-raised fish (those that are fed only food pellets that wouldn’t contain live parasites) are exempt from this freezing requirement, as the parasites of concern aren’t found in them.

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Parasites are to fish as bugs are to veggies: if you’ve eaten vegetables, you’ve eaten bugs; if you’ve eaten fish, you’ve eaten worms.

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Luckily for oyster lovers, the US FDA excludes molluscan shellfish from the freezing requirement. Oysters can still carry *V. vulnificus*, which is undetectable at the dinner table. The number of reported cases of *V. vulnificus* infections spikes between May and October (*V. vulnificus* does better in warmer water), so buyer beware, and if you’re in an at-risk group, skip the raw oysters. (Sorry, Mom!)

## Safe Undercooked Foods

What if you’re cooking for someone who can’t accept the risks of undercooked food, but they insist on a medium-rare hamburger or fish cooked *mi-cuit*—semicooked to a delicious texture? There are a few options for eliminating foodborne pathogens without overcooking the protein.

For fish, give frozen a chance. Look for “previously frozen” on display labels or head straight to the freezer section. Some stores sell frozen fish that’s downright gross—mushy, bland, uninspiring—but this isn’t entirely *because* the fish was frozen. (Technically speaking, freezing does cause some types of proteins to denature; adding glutamate inhibits this.) Some of the best sushi chefs in Japan use quick-frozen tuna because it’s

exceptionally good. Frozen at sea right after it’s caught (in a slurry of liquid nitrogen and dry ice), the tuna doesn’t have much time to deteriorate. Try a few different brands as quality varies; thaw overnight in the fridge for better texture.

For meats, whole-muscle intact cuts are easy to handle: sear the outside and you’re good to go. If you want to cook ground meats like hamburger to only medium-rare, look for “cold pasteurized” products; they are either irradiated (look for “treated by irradiation” on the label) or processed with electron-beam pasteurization. Several online specialty meat vendors sell cold-pasteurized meats; if you’re unable to find them in a local store, search for “irradiated” in the product search field.

## Belgian Meatballs

*Ground meats are all outside, no inside, which is why they need to be cooked to higher temperatures than whole-muscle intact cuts. There's a reason cafeterias, hospitals, and airlines don't serve medium-rare hamburgers: the potential for foodborne illness is too great. But meatballs, customarily being cooked ahead of time, are always cooked to done and delicious.*

*There's only one wrong way to make a meatball, and that's to undercook it. Otherwise, seasoning and serving style are entirely up to your tastes. Every culture has some form of meatball dish that combines various ground meats with spices. Belgian meatballs, ballekes, are made with a combination of ground beef, ground pork, onions, and breadcrumbs, which suits my tastes. Any mixture of ground meats will work; just make sure you have enough fat in whatever you use, or the meatballs will come out tough and dry. As for seasonings, that's down to personal preference. Try adding bacon, fennel, chili pepper, or whatever else inspires you.*

Set out a plate with a sheet of plastic wrap on top, for the uncooked meatballs.

In a medium to large bowl, mix:

- 1 medium (110g) onion, finely chopped**
- ½ cup (45g) breadcrumbs, about 1 slice of bread**
- 2 tablespoons (8g) dried oregano**
- 1 teaspoon (6g) salt**

Add:

- 1 large (50g) egg**
- ½ pound (~250g) ground pork**
- ½ pound (~250g) ground beef, 80–85% muscle / 15–20% fat**

Using your fingers, work the mix together, loosely pulling the ground meat apart as necessary to combine. Mixing with a spoon won't work as well; plus it'll mash up the meat more.

Form meatballs—I like mine at about a 2" / 5 cm diameter, but if you're using them in soup, go smaller—and transfer them to a plate. Wash your hands and the bowl thoroughly.

In a sauté pan over medium heat, melt **2 tablespoons (30g) of butter**. Once it's melted, use a pair of tongs to place about half the meatballs in the pan, taking care to not overly crowd the pan. Cook the meatballs, flipping them every few minutes, until the entire outside is deep brown. Wash the tongs once the outsides of the meatballs are uniformly brown.

Once the meatballs are seared, optionally add sauce to the pan—**2 cups (480 mL) pasta sauce** should about fill the pan—and simmer it over low heat. Otherwise, continue sautéing the meatballs over medium heat or finish them in a moderately hot oven.

Cook until a digital probe thermometer poked into the center of the meatballs shows a temperature of 160°F / 71°C. The model I have has a long lead cable and alarm mode, so I set it to beep at 155°F / 68°C to let me know when cooking is almost done.

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In the US, "hamburger" can have beef fat added to it; "ground beef" cannot.

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## Storage Tips for Perishable Foods

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**Seafood.** Seafood is the most perishable item you're likely to handle. Ideally, seafood should be used on the day of purchase. A day or two later is okay, but past that point enzymes and spoilage bacteria begin to break down amine compounds, resulting in that undesirable fishy odor.

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**Fun science fact:** Fish live in an environment that is roughly the same temperature as your fridge. The specific activity of some enzymes is much higher in fish than mammals at these temperatures. Putting seafood on ice buys more time by increasing the activation energy needed for these reactions. Meat is already far enough away from the ideal reaction temperatures that the few extra degrees gained by storing it on ice don't change much, which is why your fish counter has ice but the meat counter doesn't.

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**Meats.** Follow the sell-by or use-by date. The *sell-by date* is the date after which the store shouldn't consider the product safe for sale. (Not that you should push it, but it's not as if the meat will suddenly turn green and smelly at 12:01 a.m. the next day.) The *use-by date*, as you'd imagine, is the recommended deadline to cook the food. If you have a package of chicken whose use-by date is today, *cook* it today, even if you're not ready to eat it. You can store the cooked product for a few more days.

*Always* store raw meats at the bottom of your refrigerator. This reduces the likelihood of cross-contamination because any liquid runoff from the meats won't be able to drip onto other foods, like lettuce, that are eaten raw. Storing meats below other foods is required by health code in commercial establishments—that's how important this is!

If you can't cook the fish or meat you've bought on or before its use-by date, toss it in a freezer set to 0°F / -18°C or colder. Freezing will affect meat's texture, but at least the food won't go to waste. Frozen foods are indefinitely safe, but enzymes present in the meat will remain active and change its texture for the worse, noticeably so after between 3 and 12 months.

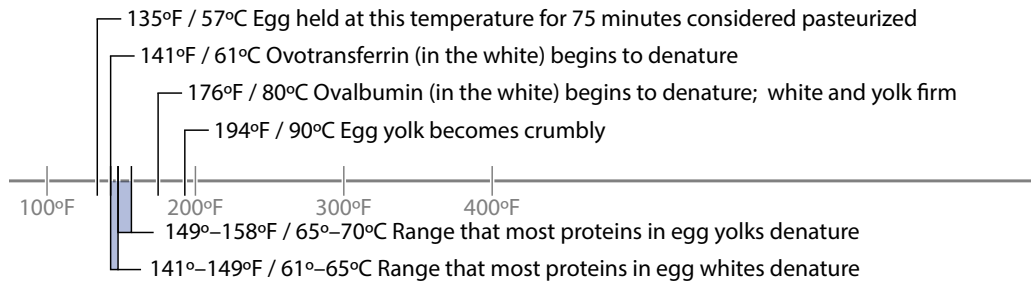
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Freezing foods does *not* kill bacteria. It takes being zapped with radiation (cold pasteurization) to render bacteria nonviable in *Salmonella*-contaminated meats—nice to know, but not very helpful unless you happen to have some cobalt-60 lying around.

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**Fruits and vegetables.** How you process and store fruits and vegetables impacts their ripeness and flavor, and can also delay the growth of mold. See page 119 for storage tips for seasonal produce.

## 141°F / 61°C: Eggs Begin to Set



*Important temperatures in chicken eggs.*

The lore of eggs is perhaps greater than that of any other ingredient. Eggs are used in both savory and sweet dishes, hot soups and frozen desserts, at breakfast and with dinner—and every culture uses them. They act as binders holding together meatloaf and stuffing; as rising agents in soufflés, certain cakes, and treats like meringues; and as emulsifiers in sauces like mayonnaise and hollandaise. Eggs provide structure to custards and body to ice creams. And all of this so far doesn't even touch on their flavor or the simple joys of a perfectly cooked fresh egg.

Eggs have a light part and a dark part, and bind the culinary world together—no wonder they're incredible! Next time you crack an egg into a frying pan, take a close look at what you see. There should be four visible parts along with the shell: the yolk, a thick white up near the yolk, a thin and watery white around the edge, and somewhere, a little white twisty thing called the *chalaza*. Each part has its own function:

- The *shell* itself is a marvel of engineering: shaped to allow a weak newborn chick an easy escape while protecting it from the outside world. (If you don't mind wasting an egg, hold one in the palm of your hand, wrap your fingers around it, and then squeeze it over a sink. It takes a strong grip to break it!) Right below the shell are two tough membranes, made mostly of collagen proteins. The shell and the membranes have to allow air in and out so a developing chick can breathe, while keeping bacteria and pathogens out. By one estimate, the shell of a chicken egg has upward of 17,000 microscopic holes in it! The color of the shell has to do with the breed of chicken and has no impact on taste or nutrition.
- The *yolk*, contrary to what I thought as a kid, is not where the animal comes from. Yolks are about half water, half nutrients; the nutrients are two-thirds lipids, one-third protein, along with lots of fat-soluble micronutrients. They get their orange color from pigmentation in the chickens' feed. Darker yolks might seem more appealing but don't actually indicate better nutritional properties compared to lighter or even cream-colored yolks. Structurally, the yolk is composed of many layers of fats deposited around a center in almost-concentric rings. The layers are



difficult to see in a hard-cooked chicken egg, but should you ever happen to hard-cook an ostrich egg—an expensive undertaking I’ve done exactly once—you can peel away the various fat layers of the cooked yolk.

- The *chalaza* is a twisted cord near the yolk that centers it in the egg, preventing the yolk from settling to the bottom of the shell. There’s really not much culinary value to the chalaza. You can fish it out with a fork, or if you’re whisking eggs into a liquid for something like a sauce or custard, strain it out.
- The *thick white* is what you see snuggled up against the yolk when frying an egg is called the outer thick white. The whites in chicken eggs are 88–90% water; the rest is protein. What makes the thick white thick is a higher concentration of one of the proteins, *ovomucin*. One measure of egg quality is based on the height of the thick white when the egg is cracked onto a flat surface, and like everything else in food, this has its own special unit: *Haugh units*, named for the inventor Raymond Haugh (not someone with a bad accent saying, “How haugh is that white?”).
- The *thin whites* are runny and exist in two places: the thin outer white, found next to the eggshell’s membranes, and the inner white, right on the outside of the yolk. It’s the thin outer white that you see as a watery puddle around the thick white when looking down into the frying pan. Like the thick white, thin whites are mostly water with some proteins mixed in. Older eggs have more thin white as the thick white breaks down over time (and thus are measurable with Haugh units).

The challenge of cooking eggs comes from how these parts of the egg change over time and the way different proteins respond to heat. An egg is a complex, dynamic system that’s constantly changing: the thick white breaks down, air flows in and out of the shell, water evaporates—they’re not perfect little time capsules, frozen in time and space!

The main change in eggs as they age is in their pH. A chicken hen deposits carbon dioxide into the egg white as it is formed, giving the white a pH of between 7.6 and 8.4. Over the course of several weeks—or a few days at room temperature—the carbon dioxide comes

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### What’s the right way to crack an egg?

Tap it on the counter, not the edge of a bowl. The shell of an egg cracked on a flat surface will have larger pieces that aren’t pushed into the egg. Eggs cracked on a sharp lip are much more likely to have little shards of shell poked into them that then end up in the bowl and have to be fetched out. (If that does happen, use half of the broken eggshell as a scoop to fetch out the shard.)



*Bad*



*Good*

out of solution and migrates away through the eggshell's pores, driving the pH of the white up between 9.1 and 9.3. Changes in pH cause the thick white to break down, increasing the volume of the thin white.

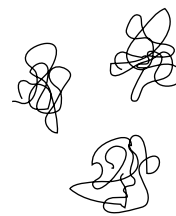
In cooking, the pH changes make older eggs easier to peel when hard-cooked; the inner membrane binds less tightly to the egg white. If you're lucky enough to have your own chickens, let the eggs rest for a few days at room temperature before hard-cooking them; steaming them also makes them far easier to peel. The change in volume of the thin white from the pH change leads to more wisps of whites floating around when you're poaching eggs; straining them is far easier than using vinegar (see page 193 for cooking tips).

Now, for the complicated and fascinating part about cooking eggs: different proteins in the different parts of the eggs respond at various rates to heat. The whites and yolk are composed of dozens of different types of proteins, each of which begins to denature at a different temperature *and* progresses at a different rate. Let's dig into some protein stuff here; it'll help you make sense of the nifty photo and chart accompanying this discussion.

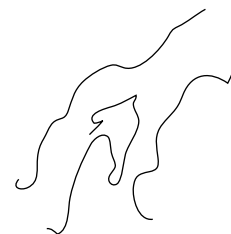
In their natural, native state, you can think of the proteins as curled-up little balls. They take this shape because portions of the molecular structure are *hydrophobic* ("water fearing"). Some of the atoms making up the protein are electromagnetically repulsed by the polar charge of water. Because of this aversion to water, those atoms cause the protein structure to fold up on itself.

As kinetic energy is added to the protein—usually from heat but also from mechanical energy (e.g., whisking egg whites)—the hydrophobic regions of the molecules start to unfold. This more open structure can then become tangled with other proteins, snagging around them and coagulating to form a linked structure. This is why cooked eggs are firm instead of flowing.

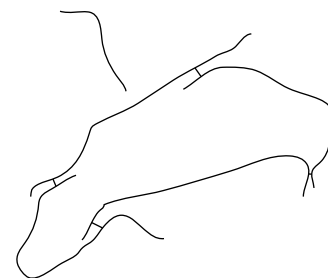
One of the most heat-sensitive proteins in chicken eggs is *ovotransferrin*, which begins to readily denature at around 141°F / 61°C and makes up 12% of the white's protein content by weight. (Other species, like ducks, lay eggs with different forms and ratios of proteins; I'm going to stick to chicken eggs from here on out.) Another protein, *ovalbumin*, accounts for a whopping 54% of the egg white protein and denatures at higher temperatures, around 176°F / 80°C. Other egg white proteins denature between these temperatures, and there are enough of them that the texture changes over the 35°F / 19°C span between ovotransferrin and ovalbumin can lead to many possible outcomes (from watery to spreadable to stiff to crumbly). It's this range that makes poaching eggs a fun challenge: not too difficult, but not trivial.



Native



Denatured



Coagulated

*Hydrophobic regions of proteins in their native state (top) remain curled up to avoid interacting with the surrounding liquid. With heat, they denature (center) and uncurl as the kinetic energy exceeds the weaker level of energy generated by water molecules and regions of the proteins that repel each other. Once denatured and opened up, the hydrophobic parts of the protein that were previously unexposed can interact and bond with other proteins (bottom).*

Egg yolk proteins have a tighter temperature span than the whites do. Runny yolks will begin to set firmer at between 149°F / 65°C and 158°F / 70°C, although some do set at lower temperatures with long holding times. (It's technically possible to cook the egg yolk firmer than the white due to differences in the slopes of the rates of reaction.)

The denaturation of egg proteins, as you'd expect, is a change based on a rate of reaction. Proteins don't denature instantaneously once they reach some magic temperature, and

their denaturation temperatures change when they're mixed with other compounds. Plus, the temperatures researchers report are usually based on isolating the proteins, not actually cooking up an egg—*caveat archimagirus!* And denaturation doesn't happen with just temperature: whisking egg whites works via denaturation as well. (We'll cover whisking later—see page 292.)

Eggs will come out with whites with a soft, custard-like texture when cooked at above 141°F / 61°C for long enough to denature some of

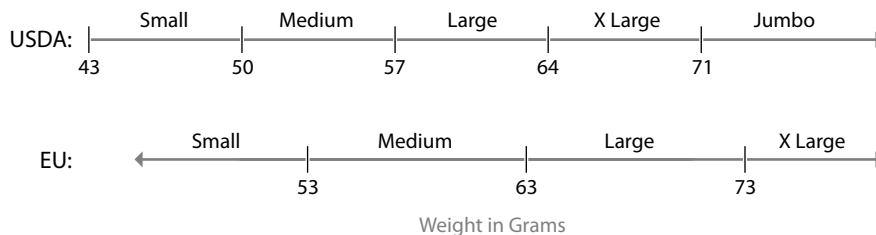
the proteins. If you heat an egg up above 156°F / 70°C for sufficient time, the white will have a firm, sliceable texture—good for sliced eggs and egg sandwiches. Above 176°F / 80°C for too long, the whites will become rubbery (presumably from ovalbumin denaturation). Proteins in the yolk will also overcook, producing a dry, unpleasant yolk. (Plus, you'll end up with a grey surface on the yolk as sulfide compounds from the white mix with iron in the yolk.) Sometimes a picture is worth a thousand words, so check out the upcoming photo of eggs cooked at different times and temperatures.

Soft-cooked and hard-cooked eggs are normally prepared in nearly boiling water or by steaming them. Cooking for 7–8 minutes will yield a soft-cooked egg and 11–12 minutes creates a nice hard-cooked one. Lower temperatures will increase the cooking time, but work

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### When a recipe calls for an egg, what size should you use?

By default, use large eggs, unless you're in the EU, in which case use medium eggs when following American recipes. The different regions use different definitions for sizing eggs (weights include the shell!).



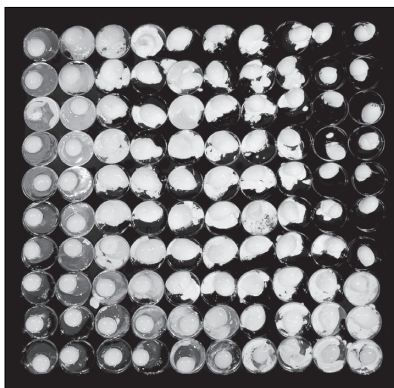
just fine—and for soft-cooked eggs are far, far better. Should you have the gear to hold an egg at a precise temperature in water, cooking for an hour or so at 144°F / 62°C will give you a runny soft-boiled egg, and 147°F / 64°C will result in something just on the edge of setting.

Time and temperature for eggs is exceedingly complicated. I've joked that an entire college course could be taught using only eggs. There are plenty of other details with eggs: how quickly the proteins denature changes their texture (faster denaturation leads to a finer gel structure of the white); egg whites are one of only two alkaline ingredients in the standard kitchen (the other being baking soda); and of course, which came first (the egg—reptiles were around long before chickens). Different species of birds have their own quirks—duck egg whites, for example, are harder to whisk up, but adding an acid like lemon juice improves them. I could go on and on about eggs, but then I'd have to change the name of this chapter...

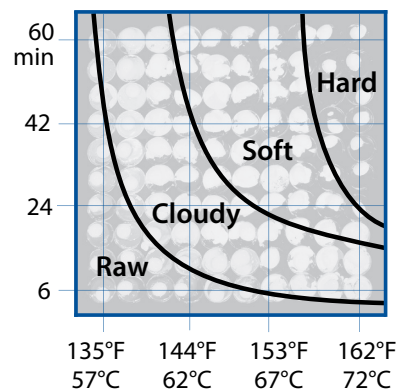
### Why do some countries refrigerate eggs but not others?

Eggs are refrigerated to prevent *Salmonella enteritidis* infection, but not because they've been washed! Yes, washing the shell of an egg does damage the cuticle to an extent that bacteria could get in, but the more likely route to *Salmonella*-infected eggs is the chicken that laid them: chickens infected with *S. enteritidis* can infect the eggs as they're formed. Refrigerating eggs prevents the bacteria from multiplying, lowering the chances that a sunny-side-up egg will land you sunny-side down.

*S. enteritidis* started popping up in eggs in the US in the 1970s, around the time that other strains of *Salmonella* that had been killing chickens were eradicated. Careful flock management and vaccination of chickens prevent infection. If the chickens in your area are known to be free of *S. enteritidis*, then storing their eggs in the fridge isn't necessary, although it will double the eggs' shelf life.



Eggs cooked at different times (y-axis) and temperatures (x-axis), from 6 minutes to 60 minutes and from 135°F / 57°C to 162°F / 72°C.



Here's a labeled chart of the time and temperature egg photo. Proteins set at different rates at different temperatures; eggs become cloudy as the most heat-sensitive proteins denature before they soft-cook or hard-cook.

## Crème Anglaise, Vanilla Custard, and Bread Pudding

Ancient Romans figured this one out a long time ago: egg yolks mixed with cream and something sweet is delicious. Crème Anglaise, custards, and bread pudding are all successive improvements on the original idea, and all rely on egg for texture and flavor.

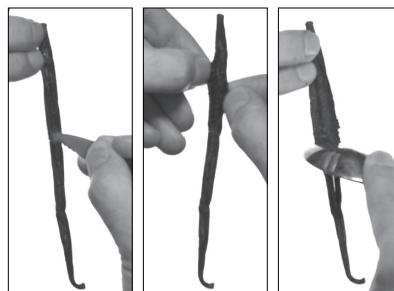
Crème Anglaise is also the base for vanilla ice cream. Freeze it in an ice cream maker, or see page 361 for more creative ways of making it. It also makes great French toast—soak thick slices of bread in the mixture for 10–15 minutes, then sauté in butter over medium-low heat for 3–5 minutes per side.

In a mixing bowl, thoroughly whisk together:

- 4 large (80g) egg yolks
- 2 cups (480 mL) half-and-half; or 1 cup (240 mL) milk and 1 cup (240 mL) cream
- 2 teaspoons (10 mL) vanilla extract; optionally add scrapings from ½ vanilla bean, sliced lengthwise
- ¼ cup (50g) sugar
- Pinch of salt

Pour the mixture through a fine-mesh strainer into a second bowl to separate out the eggs' chalazae.

**Crème Anglaise:** Heat the mixture in a saucepan over medium heat until it reaches 170°F / 77°C, the point at which it just coats the back of a



Slice the bean open with a knife and then use a spoon to scrape the vanilla seeds out.

metal spoon. Take care to not overheat it; you'll end up with egg curds.

**Custard:** To make custard, pour the mixture into small serving ramekins or oven-safe cups and place them in a baking pan. Add enough water to the baking pan to submerge the ramekins or cups halfway up and then bake them in an oven at 325°F / 160°C for 45–60 minutes.

**Bread pudding:** To make bread pudding, slice about half of a small loaf of bread (250g) into ½–1" / 1–2 cm cubes—about 4 cups' worth. Try using a cinnamon-raisin bread to add additional flavor, or add ¼ cup (40g) dried fruit and 1 tablespoon (8g) cinnamon to the mix. Transfer the cubes to a baking pan or individual serving cups, add the Crème Anglaise mix, and bake in a 325°F / 160°C oven for about 30–60 minutes, checking that the custard is set by jiggling the pan or cups and seeing that it holds its shape.

### What's half-and-half?

Half-and-half is half milk; half cream. In the United States, half-and-half must legally contain 10.5–18% milkfat. You can make your own half-and-half by mixing milk and cream. For a chart of fat levels in different types of milk and cream, see page 300.

Super-premium ice cream—the highest grade of ice cream sold in the grocery store—is 10–16% fat. If you're using Crème Anglaise for making ice cream, aim for 12–22% fat (by weight). This recipe is about 12% fat; use whole cream instead of half-and-half for a 22% fat version.

## Poached Eggs

*You can poach eggs hours in advance, which makes them great for breakfast or brunch with friends. Slightly undercook them and store them in an ice-chilled water bath; when ready to use, briefly reheat them for a minute in a pan of hot water. There are three challenges to cooking poached eggs: feathery whites, flavor, and a properly set yolk.*

- **Feathery whites**, the wispy junk on the outside of a poorly poached egg, are created from the outer thin layer of egg white mixing with hot water as the egg poaches. The outer thin layer has a lower concentration of *ovomucin*, the protein that makes egg whites thick. There's an easy solution to feathery whites: drain the egg through a small fine mesh filter or slotted spoon before poaching. (Swirling the water to create a vortex and placing the egg in the center helps too, but cooking eggs one at a time is tedious for larger numbers.)
- **Flavor**, in my book, is why salt or vinegar should be added to the water. An egg poached in plain water is unseasoned and tastes flat; adding salt (about a 1–3% salt solution) vastly, vastly improves a poached egg's flavor. Vinegar is commonly added to solve the feathery white problem, and it does help, but it also imparts a flavor that I don't care for. If you like it though, add it.
- **Properly set yolks** are created by proper time at temperature. Cook room-temperature eggs in simmering (180–190°F / 82–88°C) water



for 2–3 minutes; shorter if you like them runny, longer if you like them firm.

## Easy-to-Peel Hard-Cooked Eggs

*When I wrote the first edition of *Cooking for Geeks*, I included a clever “shock and awe” solution for creating tasty, easy-to-peel hard-cooked (hard-boiled) eggs. Shocking the eggs in boiling water for 30 seconds makes them easy to peel; then cooking them in a fresh batch of cold water brought to a near-boil finishes them with a more pleasing texture. Since then, I've discovered—well, rediscovered—that steaming eggs is far better. When the egg is steamed, the shell will crack and fall right off into two pieces.*

Make sure your eggs are a few days old—or at least that the eggs have a pH on the higher side of things. If you're lucky enough to have really fresh eggs, they can be harder to peel.

Optionally poke a hole in the bottom end of the shell, where the air pocket is. This doesn't make sense when you're cooking eggs in water—the water gets in and screws stuff up—but when you're steaming eggs, the hole will prevent the shell from cracking by giving air from the air pocket an escape route as it expands during heating.

Boil ½" / 1 cm of water in the bottom of a pan, add the eggs, cover them with a lid, and wait 12 minutes. Keep the heat on high the entire time; you need steam to be constantly hitting the eggs for them to cook.

Before peeling the eggs, let them cool down. You don't need to shock them in cold water to make them easy to peel, but dropping them in cold water—no ice necessary—will make the shape of the egg rounder (no “flat bottom”). You can peel them when they're still steaming hot, but you need a little bit of water to release the inner membrane from the outer white.



## Slow Scrambled Eggs

*Scrambling eggs is easy—if you don't overcook them. For regular scrambled eggs, use medium heat—never high!—and remove them from the burner just before you think they're done. The carryover heat in the eggs will continue to cook them.*

*The 30-minute method involves ultra-low heat, continuous stirring, and a vigilant eye. It takes time, but after many years of eating eggs, it's nice to have them cooked a new way. Cooking the eggs over very low heat while continuously stirring breaks up the curds and evaporates most of the water, giving them a flavor that can be described as cheese- or creamlike and not like regular scrambled eggs—try them unseasoned, without even salt, to appreciate their flavor.*

In a bowl, crack **two or three eggs** and whisk them thoroughly to combine the whites and yolks. Don't add any salt or other seasonings; do this with just eggs. Transfer them to a nonstick pan on a burner set to the lowest heat possible.

Stir the eggs continuously with a silicone spatula, doing a “random walk” so that your spatula hits all parts of the pan. And low heat means *really* low heat: there's no need for the pan to exceed 160°F / 71°C. If your burner is too hot, pull the pan off the stovetop for a minute to keep it from overheating. If you see any curds (lumps of scrambled eggs) forming, your pan is too hot.

Continue stirring until the eggs have set to a custard-like consistency. When I timed myself, this took about 20 minutes, but you might reach this point in as few as 15 minutes or upward of half an hour.



## Oven-Roasted Eggs

*Here's a simple way to cook eggs for a brunch or dinner for one. Improvise! Add cheese, herbs, and grains. Try adding some crushed red pepper flakes to the breakfast version or sriracha sauce to the dinner version to give it a kick. You can prepare the dish a day or two in advance and stash it in the fridge, cooking it when you're ready.*

In an individually sized oven-safe bowl (ideally, one that you can serve in), add:

### **Breakfast version:**

- 1 cup (30g) fresh chopped spinach**
- 3 tablespoons (20g) grated mozzarella cheese**
- 3 tablespoons (45 mL) heavy cream**
- 1 tablespoon (15g) butter**

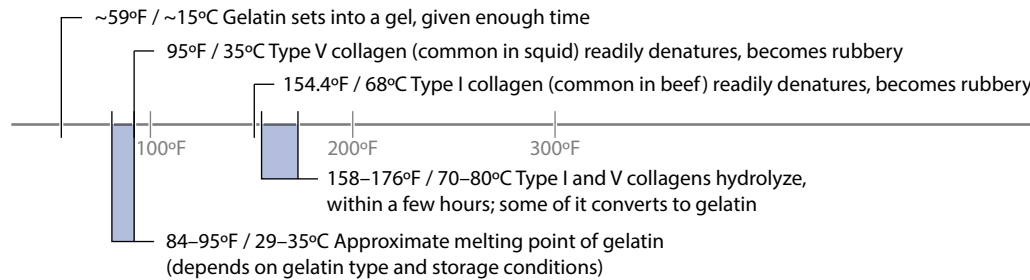
### **Dinner version:**

- ½ cup (100g) crushed tomatoes**
- ¼ cup (50g) black beans—canned is easiest**

Create a well in the center of the ingredients by pushing the food into a ring around the edges of the bowl. Crack **1 or 2 eggs** into the well, add a **pinch of salt** and some **freshly ground pepper**, cover the mixture with aluminum foil, and bake it in a preheated oven set to 350°F / 180°C until the egg is set, about 25 minutes. (I use a probe thermometer set to beep at 140°F / 60°C so I can absentmindedly wander off or chat with friends without worrying about overcooking the eggs.)

*Fun trivia: Quail eggs weigh about 9 grams on average, while duck eggs typically weigh 70 grams. I was happy to learn that ducks themselves are also about eight times heavier than quails (just in case you find yourself on Jeopardy!).*

# 154°F / 68°C: Collagen (Type I) Denatures



*Temperatures related to collagen hydrolysis and the resulting gelatin.*

When we covered animal proteins and denaturation earlier in this chapter, I mentioned that collagen was special enough that it deserved its own section. And here we are! First, a quick refresher. Animal proteins—fish and seafood included—can be grouped into three categories: structural, connective, and sarcoplasmic. Structural proteins are generally the most important ones to manage in cooking, but connective tissues become even more important for certain seafood and meats.

An animal's connective tissues provide structure and support for the muscles and organs in its body. You can think of most connective tissues—loose fascia and ligaments between muscles as well as other structures such as tendons and bones—as a bit like steel reinforcement: they don't actively contract like muscle tissue, but they provide structure against which muscles can pull and contract. (Fun fact: pound for pound, collagen is tougher than steel.)

The most common type of protein in connective tissue is collagen, and while there are several types of collagen in animals, from a culinary perspective the main chemical difference between them is the temperature at which they denature. Collagen shows up in two different ways: either as discrete chunks like tendons outside of the muscle, or as a network that runs through the muscle. Collagen is tough—it provides structure, after all—and becomes palatable only given sufficient time at sufficiently high temperatures.

Pressure cookers work wonders on collagen. Since the reaction rate for breaking down collagen is temperature dependent, raising the temperature up to 250°F / 120°C cuts cooking time by ~75%. See page 308 for more about pressure cookers.

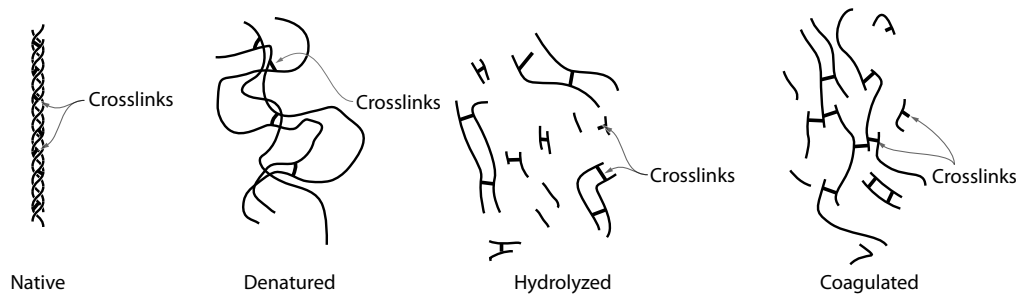
It's easy to deal with collagen that shows up as discrete pieces: get rid of it by cutting it off. For cuts of meats that have a thin layer of connective tissue on them (called *silverskin*, presumably because of its somewhat iridescent appearance), cut off as much as possible and discard it. Beef tenderloin cuts commonly have a side with this layer; trim off as much as possible before cooking. Chicken breasts also have a small but noticeable tendon connected to the chicken tenderloin. Uncooked, it's a pearly white ribbon. After



cooking, it turns into that small, white, rubber-band-like thing that you can chew on endlessly yet never get any satisfaction from. Generally, this type of collagen is easy to spot, and if you miss it, it's easy to notice while eating and can be left on the plate.

The collagen that forms a 3D network through the muscle tissue is tougher to manage (pardon the pun). For cuts of meats that are high in it, the only way to remove its tough texture is to cook it—usually with long, slow cooking methods. The rate of reaction for collagen is much, *much* slower than for other proteins in meat. To understand the cooking challenges and how to solve certain problems you might see, we need to dive into the molecular structure of collagen.

In its native form, collagen is like a rope: it's a linear molecule composed of three different strands that are twisted together. The three strands are held together by weak secondary bonds (but there are a lot of them!) and stabilized by a small number of *crosslinks*, which are stronger covalent bonds. (*Covalent bonds* are bonds where the electrons from an atom in one location are shared with another atom.)



*Collagen in its native form is a triple helix, held together in its helical structure by secondary bonds (left) and stabilized by crosslinks. Under heat, the secondary bonds break and the protein becomes denatured, but the crosslinks between the strands continue to hold the structure together (second from left). Given sufficient heat and time, the strands in the triple helix themselves break down via hydrolysis (third from left) and, upon cooling, convert to a loose network of molecules (right) that retains water (a gel).*

In addition to being crosslinked, the strands also form a helical structure because of secondary bonds between different regions of the same molecules. You can think of it like a braided rope, where each strand wraps around the other two strands. It has a “curl” to it because the internal structure finds its optimal resting place in that shape.

Under the right conditions—in cooking, exposure to enough heat or the right kinds of acids—the native form of collagen denatures, losing its linear structure and untwisting into a random mess. This happens from kinetic energy literally vibrating the structure, bouncing it around. Too much bouncing around, and the electromagnetic energy that normally holds the triple helix structure in place can't keep things together. As the energy increases, the collagen changes even more, tightening and shrinking up to about a third to a fourth of its original length. (There's only one way for a protein to be native, but many ways for it to be wrong.)

Acids can also denature the collagen protein: their chemical properties provide the necessary electromagnetic pull to disrupt the secondary bonds of the helical structure. It's only the twisting that goes away during denaturing in collagen; the crosslinks remain in place and the strands remain intact. In this form, collagen is like rubber—it actually *is* a rubber from a material science point of view—and for this reason you'll find its texture... well, rubbery.

Given even more heat or acid, though, the collagen structure undergoes *another* important transformation: the strands themselves get chopped up and lose their backbone, and at this point the collagen has no real large-scale structure left. This reaction is called *hydrolysis*—thermal hydrolysis in the case of heat, acid hydrolysis in the case of acid. Hydrolysis takes time due to the amount of energy needed to break the bonds and the stochastic processes involved.

Hydrolyzing collagen not only breaks down the rubbery texture of the denatured structure, but also converts a portion of it to gelatin. (This is where gelatin—the stuff that makes Jell-O—comes from!) When collagen hydrolyzes, it breaks into variously sized pieces, the smaller of which are able to dissolve into the surrounding liquid, creating gelatin. Gelatin gives dishes such as braised oxtail, slow-cooked short ribs, and duck confit their distinctive mouthfeel. Gelatin can also be extracted and added to other dishes, making gelatin desserts, aspics, and many other products.

Since dishes like short ribs and braised oxtail rely on gelatin to provide that wonderful texture, they need to be made with high-collagen cuts of meat. Trying to make a beef stew with lean cuts will result in tough, dry meat. The actin proteins will denature (recall that this readily occurs at temperatures of 150–163°F / 66–73°C), but the gelatin won't be present in the muscle tissue to mask the dryness and toughness brought about by the denatured actin. Don't try to “upgrade” your beef stew with a more expensive cut of meat; it won't work!

“Great,” you might be thinking, “but how does any of this tell me whether I need to slow-cook a piece of meat?” Think about the piece of meat (or fish or poultry) that you're working with and consider what part of the animal it comes from. For a land-based animal, those regions of the animal that bear weight generally have higher levels of collagen.

This should make sense. Because the weight-bearing portions have a higher load, they need more structure, so they'll have more connective tissue. This isn't a perfect rule of thumb, though, and cuts of meat generally have more than one muscle group in them.

For animals like fish, which don't have to support their weight on land, the collagen levels are much lower. Squid and octopus are notable exceptions to this weight-bearing rule. Their collagen provides support equivalent to that of bone structures for fish. The trick to

cooking them is either to give them a very brief exposure to heat, keeping the proteins native, or to give them enough time at temperature to hydrolyze. Anything in between, and you've got rubber.

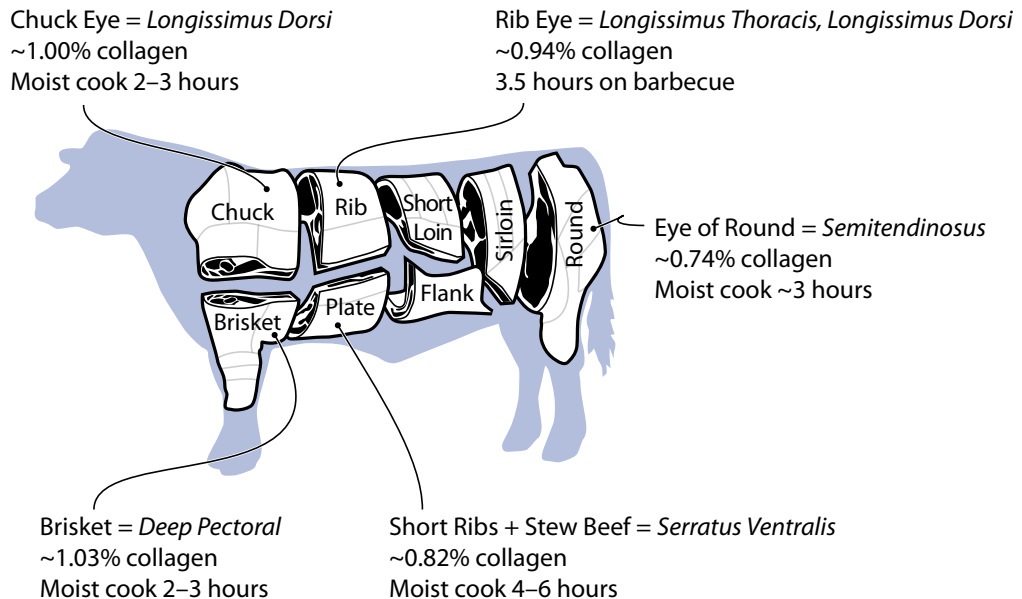
Another rule of thumb on collagen: older animals have higher levels of collagen. As animals age, the collagen structure has more time to form additional crosslinks between the strands in the collagen helix, resulting in increased toughness. This is why older chickens are traditionally cooked in long, slow roasts. (The French go so far as to use different words for old versus young chickens: *poule* instead of *poulet*.) Most animals raised for meat are young at time of slaughter, so age is as important a factor as the type or cut of meat.

The other easy rule of thumb for collagen levels is to look at the relative price of the meat: because high-collagen cuts require more work to cook and come out with a generally drier texture, people tend to favor other cuts, so the high-collagen cuts are cheaper.

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Try marinating a small cube of meat in mashed up papaya—which contains an enzyme, *papain*, that acts as a meat tenderizer by hydrolyzing collagen—and then feeling its texture.

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*Cuts of meat from a part of an animal that supports its weight will be higher in collagen and need a longer cooking time—primarily muscles in the chuck, rib, brisket, and round.*

## Tomato, Herb, and Squid Bruschetta

*Squid was a culinary mystery to me for a long time. You either cook it for a few minutes or an hour; anywhere in between, and it becomes tough, like chewing on rubber bands. (Not that I chew on rubber bands often enough to say what that's like.) Why is this?*

*The collagen in squid is enjoyable in either its native state or hydrolyzed state, but not in its denatured state. It takes a few minutes to denature, so with just a quick pan sear it remains in its native state (tossed with some fresh tomatoes and dropped on top of bruschetta, it's delicious). And hydrolysis takes hours to occur, so a slowly simmered braised octopus turns out fine. Braising it in tomatoes further helps by dropping the pH levels, which accelerates the hydrolysis process.*

To make a simple squid bruschetta, start by preparing a **loaf of French** or **Italian bread** by slicing it into ½" / 1 cm slices. You can create larger slices by cutting on a bias. (Save the triangular end piece for munching on when no one is looking.) Lightly coat both sides of the bread with **olive oil** (this is normally done with a pastry brush, but if you don't have one, you can either fold up a paper towel and "brush" with it or pour olive oil onto a plate and briefly dip the bread into it). Toast the bread. A broiler works best (the slices of bread should be 4–6" / 10–15 cm from the heat). Flip the slices as soon as they begin to turn golden brown. If you don't have a broiler, you can use an oven set to 400°F / 200°C. For small batches, a toaster also works.

Once your bread is toasted, place it on a plate and store it in the oven (with the heat off) so that it remains warm.

Slice with a knife or, better yet, cut into bite-sized pieces using kitchen shears:

**1 pound (450g) squid (either a mix of bodies and tentacles or just bodies)**

Bring a sauté pan up to medium heat. You want the pan hot enough so that the squid will quickly come to temperature. Add a small amount of **olive oil**—enough to coat the pan thinly when swirled—and drop the squid into the pan.

Use a wooden spoon or silicone spatula to stir the squid. Take note when it starts to turn white—it should become subtly less translucent—and cook it for another 30 seconds or so. Add to the pan and toss to combine:

**1 cup (250g) diced tomato (about 2 medium tomatoes, seeds removed)**

**1 tablespoon (5g) fresh herbs, such as oregano or parsley**

**¼ teaspoon (1g) sea salt**

**Ground pepper to taste**

Transfer the squid and tomato topping to a bowl and serve it with the toasted bread.



*Try using a pair of kitchen shears to snip the squid into small pieces directly into a hot pan. Add tomatoes and herbs, toss, and serve.*

## Duck Confit

*Duck confit—duck legs cooked in fat—tastes entirely different from duck cooked almost any other way. It's like bacon and pork—to quote Homer Simpson, they're from “some wonderful, magical animal.” (Apparently my magical animal is the duck...)*

*Good duck confit is succulent, flavorful, tender, mouth-watering, and perhaps a bit salty. Cooking duck “confit-style” is all about converting tough collagen proteins into gelatin.*

*I'm a pragmatic cook. Traditional recipes for duck confit prescribe a long, drawn-out affair, which is fine for a leisurely Sunday afternoon spent in the company of friends and a bottle of good wine, but doesn't line up with keeping things simple.*

*The secret to duck confit is in the time and temperature, not the actual cooking technique. The upshot? You can make duck confit in a slow cooker or in an oven set at an ultra-low temperature. The type of fat used to cook the duck doesn't matter either; some experiments have shown that duck confit cooked in water and then coated in oil is indistinguishable from traditionally cooked duck confit. Regardless, definitely skip the exotic block of duck fat; duck legs are expensive enough as it is.*

Rub salt into the outside of the **duck legs, 1 per person**, covering both the side with skin and the side with meat exposed. I use roughly **1 tablespoon (18g) of salt per duck leg**; you want enough to coat the outside thoroughly.

Place the salted duck legs in a bowl or plastic bag and store them in the fridge for several hours to brine. Salting the meat adds flavor and draws out a little bit of the moisture, but if you're in a real rush, you can skip this step and just lightly coat the duck legs with a few pinches of salt. After dry-brining the duck legs, wash off all the salt.



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Remember: store raw meats in the bottom of the fridge so if they drip, the runoff won't contaminate fresh produce or ready-to-eat foods.

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*Duck legs that have been cooked long enough fall apart easily because most of the collagen and connective tissues that normally hold muscles together are gone.*

At this point, you have a choice of heat sources:

#### *Slow-cooker method*

Arrange duck legs in the bowl of a slow cooker or in a multipurpose rice or pressure cooker. Cover them with oil (I use **canola** or **olive oil**) and set the cooker to slow-cook mode for at least 6 hours (preferably 10–12).

#### *Oven method*

Arrange duck legs in an oven-safe pan and cover them with **oil**. Place them in an oven set at 170°F / ~80°C for a minimum of 6 hours.

The duck legs will become more tender with longer cook times. I've cooked batches of 36 duck legs overnight using a large pot held at temperature in an oven. If you do cook a large batch, remember that the core temperature needs to get to about 140°F / 60°C within 2 hours. In this case, heat the oil up to ~250°F / 120°C before placing the duck legs in it. This way, the hot oil will impart a solid thermal kick to get the cold legs up to temperature faster.

After it's cooked, the duck skin will still be flabby and, frankly, gross. But the meat should be tender and yield with a bit of poking. You can either remove the skin (pan-sear it by itself for duck lardons!) or score the skin with a knife and then pan-sear the skin side of the duck legs to crisp it up.

If you are not going to use the duck legs straightaway, store them in the fridge.

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After cooking, the oil will be a blend of duck fat and your starting oil. Save it! You can also use it for sautéing greens and shallow-frying potatoes.

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#### *Notes*

- *Traditional recipes call for duck fat instead of olive oil. One advantage to the duck fat is that, upon cooling to room temperature, it solidifies, encasing and sealing the duck leg in a sterilized layer of fat, somewhat like how some jams are preserved with a wax seal. If you were living in France a century ago, this would've been a great way to preserve duck legs for a long winter, but with the invention of refrigeration and modern grocery stores, there's no need for the duck fat to store the meat safely for the few days it might last. Use olive oil. It's cheaper and healthier.*
- *If you pour off the oil and liquid into another container, a layer of gelatin will separate out on the bottom once it cools. Use that gelatin! Try tossing it into soups.*

## Duck Confit in Pasta

Prepare two duck legs, confit-style, as just described. These can be done in advance and stored in the fridge. If you're not in the mood to wait a day, check if your grocery store sells prepared duck confit, or if you have a pressure cooker, use it to rapidly cook the duck legs.

In a large pot, bring **salted water** to a boil for making pasta.

Prepare the duck meat by pulling the meat off **2 legs of duck confit**, discarding the bones and skin or saving them for stock. In a pan, lightly sauté the duck leg meat over medium heat to brown it.



*To strip the leaves, grip near the bud end of the plant...*



*...then run your fingers down toward the base of the stem.*

### Notes

- You might find it easier to transfer the duck mixture to the pasta pot and stir in there, because your frying pan might not be big enough. When serving, you can grate Parmesan cheese on top and sprinkle on more of the oregano or thyme leaves.
- The secret to this recipe is its combination of ingredients: the heat of the cayenne pepper is balanced by the fats and sugars in the cheese, the fats in the duck are cut by the acids in the tomatoes, and the aromatic volatile compounds in the fresh herbs bring a freshness to this dish that's just plain delicious. If the world were going to end tomorrow, I'd want this tonight.
- When you're separating duck meat from a cold duck leg (from the fridge), the duck fat will be whitish and slippery; the meat will be darker and more strandlike. When in doubt, if it looks yummy, it probably is. Since the meat is to be browned, don't include the dark jellylike stuff—that's gelatin—as it will melt and then burn as the water boils off.
- When pulling fresh thyme off the stem, be careful not to get the actual stem in the food. It's woody, chewy, and not enjoyable. Pinch the top of the stem with one hand and run the fingers of your other hand down the stem, against the direction the leaves grow in, to strip them off.

Add to the pan:

- 28 ounce (800g) can diced tomatoes**
- 8 ounce (225g) can tomato sauce**
- 1/4-1/2 teaspoon (0.5–1g) cayenne pepper**

Simmer the tomatoes and tomato sauce for 5 minutes or so. While the sauce is simmering, add to the pot of boiling water and cook per the directions on the package:

- 1/3 pound (150g) long pasta—ideally, pappardelle (an egg-based noodle with a wide, flat shape) or spaghetti**

Once the pasta is cooked, strain (but do not rinse) it and add it to the sauté pan. Add and stir to thoroughly combine:

- 2 tablespoons (2g, about 12 sprigs) fresh oregano or thyme leaves (dried is nowhere near as good)**
- 1/2 cup (50g) grated Parmesan cheese**
- 1/4 cup (30g) grated mozzarella cheese**

## Slow-Cooked Short Ribs

*Short ribs and other high-collagen cuts of meat aren't difficult to work with; they just require time at a temperature at which the collagen can hydrolyze. This is what slow-cooking the meat achieves. Either use a cooker with slow-cook mode, or use an oven-safe baking pan and cook for several hours—this is great in the cold months of winter!*

*(While you can do this quicker in a pressure cooker, not everyone has one, and even if you do, you can't see what's happening to the texture of the meat as it cooks.)*



*This is an intentionally easy recipe, but don't let that fool you about its taste: slow-cooked meats can be amazingly good, and if you're cooking for a dinner party, they make for easy work when you go to assemble the dinner.*

If you have a rice cooker or pressure cooker, check to see if it has a slow-cook setting. In this mode, the cooker will heat foods to a temperature typically in the range of 170–190°F / 77–88°C, which is warm enough to be safe from bacterial

contamination and cool enough to not steam-dry the meat.

If you don't have a pressure cooker, use an oven-safe baking pan and cover it with aluminum foil before baking the short ribs in an oven set to 180°F / ~80°C.

Pour a **bottle of barbecue sauce** into the cooking container. (I'm listing store-bought sauce here because it's convenient, which is part of the appeal of slow cooking; to make your own sauce, use the recipe on page 312.)

Add the **short ribs**, arranging them in a layer so that the barbecue sauce covers the meat.

Slow-cook the short ribs for at least 4 hours (longer is fine). Try starting this in the morning before going to work—the slow cooker will keep the food safe, and the extra time will help ensure that the collagen is fully dissolved.

### Notes

- *Ideally, you should pan-sear the short ribs for a minute or two before cooking. This will cause browning reactions, bringing a richness to the final product.*
- *Keep in mind the danger zone rule covered earlier. Don't load up a slow cooker with so much cold meat that the cooker will be unable to raise the temperature above 140°F / 60°C within a 2-hour period.*
- *Try adding other ingredients to the sauce, or making your own sauce if you like. I'll often pour a tablespoon or so of wine or port into the empty BBQ sauce jar to “rinse out” the thick sauce, then pour the port-sauce slurry into the slow cooker.*



# Lab: Collagen Protein Experiment

Try this experiment to see the different states of collagen protein: native, denatured, and hydrolyzed. Collagen will denature and hydrolyze (two different processes!) at different rates based on temperature and the specific type of collagen, but how long does each take?

## First, grab these supplies:

- 6 small samples of high-collagen animal tissues—try using slices of squid, either from a squid tube sliced into rings or by snagging a package of frozen raw calamari; you can also use 6 pieces of stewing beef cut into ½" / 1 cm cubes (beef will take ~3 times longer to cook)
- 1 cup / 240 mL neutral-flavored cooking oil, such as canola or vegetable oil
- An oven or slow cooker
- 2 forks and a plate
- *If you're using an oven instead of a slow cooker:* a small oven-safe container such as a glass measuring cup

## Here's what to do:

1. *If you're using an oven:* add the cooking oil to the measuring cup and place it in the oven. *If you're using a slow cooker:* add the oil to the slow cooker container.
2. Set the oven to 200°F / 95°C, or use a slow cooker on either stew or “keep warm” mode.
3. Use a fork to add all the samples to the oil and start a timer.
4. *For seafood tissues like squid:* After 20 minutes of cooking, use a fork to remove one of the samples and set it on a plate for later investigation. Repeat every 20 minutes, removing another sample. *For mammalian tissues like beef:* Remove samples every hour, instead of every 20 minutes.
5. Once all the samples are removed, you can turn off the oven or slow cooker and discard the oil after it's cooled down.

## Investigation time!

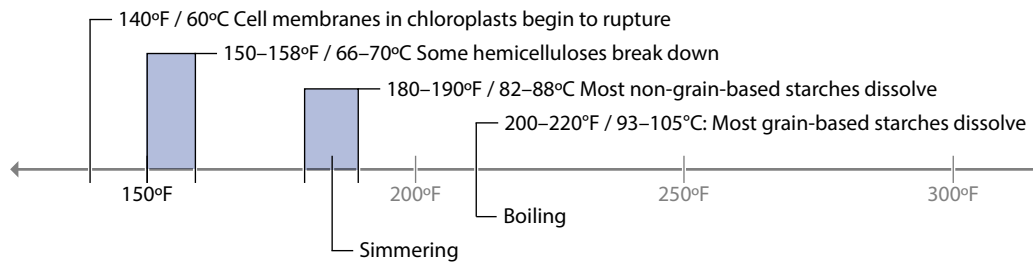
Look at the samples on the plate—what do you see? Try using the two forks, one in each hand, to pull each sample apart, recording which ones are easy to pull apart and which are tough.

## Extra credit:

Try repeating this experiment with both seafood-based and mammalian-based samples and compare the difference in times.

Another idea: try making beef stew, removing a cup of the stew after 30 minutes, a second cup after 2 hours, and a third cup after 6 hours. Chew on some of the stewed meat pieces to compare the texture differences. (Doing this with kids? Do a blind experiment to remove the placebo effect: blindfold the kids and give them two servings of the 2-hour sample and one serving of the 6-hour sample—can they figure out which one is different?)

# 158°F / 70°C: Vegetable Starches Break Down



*Temperatures related to plants and cooking.*

Whereas meat is predominantly proteins and fats, plants are composed primarily of carbohydrates. Compared to proteins in meat, which have a narrow temperature range between undercooked and shoe leather, carbohydrates are generally more forgiving, although cooking them too long will lead to mushy textures and color loss.

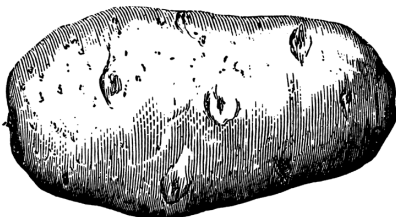
Cells in plants contain different compounds of culinary interest. As you'd expect, the different compounds have different properties. Here are five of the more common ones and how they react to heat:

- *Cellulose* gives plant cell walls their primary structure. It's completely indigestible to humans in its raw form and gelatinizes at such a high temperature, 608–626°F / 320–330°C, that we can ignore it while discussing chemical reactions in cooking. (There's evidence that pressure-cooking beans does break down some cellulose—always exceptions to the rule!)
- *Lignin* is fibrous, stringy stuff that shows up in secondary cell walls that appear in some plant cells, like those in wood. Like cellulose, lignin doesn't change much in cooking. When it does show up, it gets stuck between your teeth and feels vaguely like chewing on wood (I'm looking at you, asparagus). The base of an asparagus stalk can develop a fair amount of lignin, which is why you can (and should!) snap it off.
- *Hemicellulose*, not the same thing as cellulose, is any of a large variety of polysaccharide compounds found in cell walls that hold the cellulose and lignin together. It's easily broken down by acids, bases, and enzymes starting in the temperature range of 150–158°F / 66–70°C. In cooking tender plants, it's the hemicelluloses that we're targeting, being mindful to not break them down too much in order to avoid mushy textures. Unlike lignin and cellulose, hemicellulose is partly soluble in water. These three compounds make up the bulk of insoluble dietary fiber and help your body flush out the digestive tract.

- *Starch* is a plant's energy store and is what gives us energy when we eat plants. Starches as they natively exist are semicrystalline structures made up of two carbohydrate molecules, amylose and amylopectin. When heated and exposed to water, the semicrystalline structure *gelatinizes*—absorbs water, melts, and breaks down. Upon cooling, it continues to hold on to the absorbed water. Cooking converts that semicrystalline structure to a form that can be more easily digested; this is the basis for the theory that humans gained an advantage over other species when we first started cooking plants. There are a few temperature ranges involved in gelation—one range for amylopectin absorbing water and a higher one for the melting of the amylose structure, and then a potential third range for when the gel sets during cooling. These temperatures depend on the ratios and specific structures of amylose and amylopectin, as well as environmental factors like the acidity or alkalinity of the liquid they're exposed to. In cooking, which one we care about depends on the way starch is being held onto by the plant's cells. We care primarily about the higher temperature range where amylose dissolves, which typically happens at between 135° and 220°F / 57° and 105°C.
- *Pectin* is cellular glue that holds cell walls together, similar to how collagen holds muscle tissues together. Firmer fruits get their structure from pectin compounds; the skins and cores of apples are 10–20% pectin. These compounds begin to degrade when heated above 140°F / 60°C in acidic conditions (pH of 1.5–3). For pectin to gelatinize in jams and jellies, the recommended target temperature is 217°F / 103°C (easily reached with sugary liquids). Pectin isn't a major component in most fruits and veggies in cooking, but for jam making it's critical (see page 419).

How does all of this relate to cooking your veggies or fruits? You can determine what temperature you need to cook fruits and vegetables to based on their composition. The length of time at temperature, the amount of moisture in the tissue, and processing conditions will impact the exact temperatures needed, so treat these as guidelines:

- *Cook root vegetables* such as potatoes above 175°F / 80°C. Cooking to higher temperatures will yield additional texture changes from water steaming up (fluffier baked potatoes), but slightly lower temperatures are fine, as you can see in potato gratin. Root vegetables have a higher percentage of amylopectin as compared to grains, which means the starches from them gelatinize more easily (typically at around 135–160°F / 57–70°C). When cooking, use a temperature range a bit above this for reasonable cooking times. Root vegetables contain enough moisture that you don't need to worry about adding a liquid for the starch to absorb during gelation. Of course, if you're working with a starch extracted from a plant—arrowroot or potato starch (sometimes called potato flour, but it's actually starch)—it'll need a liquid to absorb. (See page 408 for more.)



- *Cook grains like rice* in near-boiling liquid. While the amylopectin degrades at lower temperatures, there's more amylose in the structure of grains, and that doesn't dissolve until around 200–220°F / 93–105°C. (If you're familiar with sous vide cooking—see page 320—this is why you can sous-vide-cook root vegetables but not grains.) Most grains also don't have enough water in them to gelatinize—they're seeds meant to last through the winter!—so you must use water when cooking them.
- *Cook firm fruits* like apples long enough for the pectin in the cell walls to break down. The temperature depends upon how acidic the fruit is; somewhere between 140 and 212°F / 60 and 100°C is necessary. Use firmer fruits when poaching to avoid mushy results! Likewise, the secret to great fruit pies, according to some, is to mix two varieties or even species of fruits: one that's firm and remains intact when heated combined with a second type that breaks down under cooking. Try combining a baking apple with a sauce apple, like Granny Smith with McIntosh, or mix types: baking pears like Bosc or Bartletts with sauce apples like McIntosh, Cortland, or Golden Delicious. (For more about pectin, see page 419.)
- *Cook fruits and veggies that have high amounts of water* at moderate temperatures: 150–158°F / 66–70°C is sufficient to break down the hemicelluloses. Less sturdy leafy greens, like spinach, can be quickly wilted in a pan with a small amount of water or oil; even a quick toss in hot pasta that was just strained will do the trick. Sturdier greens, like Swiss chard and kale, should have the stalks and ribs removed and cooked first, as those parts of the plant have more structure and will need more of the hemicelluloses broken down to become pleasantly soft.

There are other compounds in fruits and vegetables that change when heated. One in particular is worth pointing out: chlorophyll. When green vegetables are cooked, their color shifts from vivid green to dull brown because of this compound changing. The membranes around the chloroplasts in the cells rupture under heat, causing the chlorophyll to react and change into a different molecule (pheophytin) that has a brownish color. This conversion is pH and temperature dependent, so more acidic environments speed it up while lower heat slows it down. Adding a pinch of baking soda to cooking water will inhibit the reaction. (Too much baking soda, though, causes other reactions—we'll cover water chemistry in the next chapter.) Taking care to cook in hot but not boiling water and not overcooking is the traditional solution, and quickly transferring the cooked foods to very cold water will drop their temperatures and stop the reaction as well. Personally, I err on the side of undercooking string beans and asparagus—slightly undercooked and they're still tasty, but overcooked? Yuck.

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Sautéing something like diced veggies and want to tenderize but not brown them? Toss in a splash of water to drop the temperature if it gets too high.

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# Quick Steamed Asparagus

Microwave ovens make quick work of cooking firmer greens and high-starch vegetables. Yams, potatoes, and other root vegetables all respond well to a few minutes of cooking in a microwave. You can steam vegetables in a microwave, too!

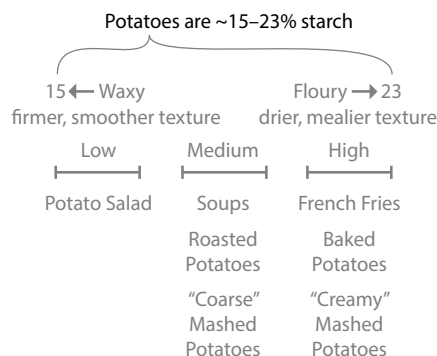
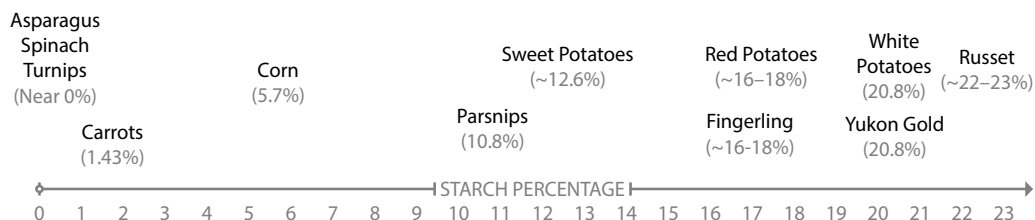


In a microwave-safe container, place **asparagus stalks** with the bottoms trimmed or snapped off, and add a thin layer of **water** to the bottom. Put the lid on, but leave it partially open so that the steam can

escape. Microwave for 2–4 minutes, checking for doneness partway through and adding more time as necessary.

## Notes

- This technique cooks the food using two methods: radiant heat (electromagnetic energy in the form of microwaves) and convection heat (from the steam generated by heating the water in the container). The steam circulates around the food, ensuring that any cold spots (areas missed by the microwave radiation) get hot enough to both cook the food and kill any surface bacteria that might be present.
- Try adding lemon juice, olive oil, or butter and sautéed crushed garlic to the asparagus.



Root vegetables with higher starch levels require more time to cook, which is why roasting carrots is faster than roasting potatoes. Higher starch levels also lead to fluffier textures, as you can see in the photograph of two cooked potatoes, one low in starch (left) and one high in starch (right).

## Sautéed Greens with Sesame Seeds

*Greens like spinach and the more tender parts of hardier-leafed plants like kale cook quickly—there's not much starch or fiber to break down. It's all about the hemicelluloses!*

In a sauté or nonstick pan preheated over medium heat, add:

**2 tablespoons (30 mL) sesame or olive oil (enough to coat the pan)**

**1 tablespoon (8g) sesame seeds**

Briefly toast the sesame seeds, then add:

**1 bunch spinach, Swiss chard, collard greens, or other leafy green; stems and thick veins removed, and sliced or torn into 1" strips**

Using tongs, quickly toss the greens to coat them with oil and seeds. Your pan should be reasonably hot so that the greens heat quickly, but not so hot that the oil burns. Continue tossing the greens while cooking so that they wilt evenly. Add **salt** and **pepper** to taste.



### Notes

- Depending upon your tastes, extend this recipe by adding one of these combinations:  
*5 cloves garlic, minced; juice from half a small lemon (about 1 teaspoon / 5 mL)  
2 teaspoons (10 mL) balsamic vinegar, and possibly a pinch of sugar  
1 teaspoon (5 mL) sherry vinegar; ¼ teaspoon (0.3g) crushed red pepper flakes; 1 15 ounce (425g) can cannellini beans; 3 cloves garlic, minced  
¼ red onion, sliced thinly and sautéed; ½ apple sliced into bite-sized pieces and cooked; handful of chopped walnuts, toasted*
- Try cooking some strips of bacon, removing the bacon, and then sautéing the greens in the rendered bacon fat, adding a teaspoon or so (~5 mL) of balsamic vinegar. Dice the bacon and combine the two, and optionally add some blue (or other) cheese. Quantity of ingredients is really down to personal preference, so experiment!
- You can strip the stem and thicker veins from hardy greens such as Swiss chard by grabbing the stalk with one hand and the green leaf portion with the other hand, and pulling the stalk out.

When wilting greens, pull them off the heat before they're done. Carryover heat will finish them.

## Poached Pears

*Poached pears are easy, tasty, and quick. Much of our enjoyment of fruit comes from not just their flavor but also their texture. Consider an apple that's lacking in crispness or a banana that's been bruised and become mushy: without their customary texture, their appeal is lost. But this isn't always the case. Poaching fruits such as pears causes similar changes in the structure of the fruit's flesh, breaking down cell walls and affecting the bonds between neighboring cells to create a softer texture that's infused with the flavor of the poaching liquid.*



In a shallow saucepan or frying pan, place:

- 2 medium (350g) pears, sliced lengthwise (longitudinally) into eighths or twelfths, and cores removed**
- 1 cup (240 mL) red wine; or 1 cup (240 mL) water, ½ cup (100g) sugar, and 1 teaspoon (5 mL) vanilla extract**
- ¼ teaspoon (0.5g) ground pepper**

Set the pan over low to medium heat, bringing the wine to a simmer and then poaching the pears for 5–10 minutes, until soft. Flip them halfway through, so that both sides of the slices spend some time facedown in the liquid. Remove the pears and discard the liquid. (You can also reduce the liquid down into a syrup.)

### Notes

- *Fun chemistry fact: the boiling point of wine is lower than that of water. The exact temperature depends upon the sugar and alcohol levels, and as the wine simmers, the ratios shift. It'll start somewhere around 194°F / 90°C. It's doubtful that this will actually help you avoid overcooking the pears, though.*
- *Pears are one of those fruits that are underripe until you look away and then go rotten before you can look back. To encourage them to ripen, you can keep underripe pears in a paper bag so the plant tissue will be exposed to the ethylene gas they give off. I find I can get away with poaching pears that are a little more underripe than I might want to eat fresh, but your pears should be at least a little soft.*
- *Try serving this dish with caramel sauce (see page 228) and vanilla ice cream. Or try poaching other fruits, like fresh figs, and using other liquids. Figs poached in port or a honey/water syrup with a small amount of lemon juice and lemon zest added after poaching are sweet and tasty.*
- *You don't need to actually measure out the ingredients. As long as the pears have enough liquid to poach in, they'll turn out great. Add freshly ground pepper to suit your tastes.*

Never use preground pepper. Preground pepper quickly loses its complex aromatic flavors—well before it makes it into your hands—leaving it with a hot spicy kick but none of the subtlety of peppercorns.

## Grilled Vegetables

*Grilling is as American as apple pie, which is to say that while it's part of our culture, its roots can be traced back to somewhere on the other side of the Atlantic Ocean. Grilling became an American tradition after World War II, when one of the owners of Weber Brothers Metal Works came up with the Weber Grill and ignited a backyard pastime.*

*Whether a propane or charcoal grill is better depends on your usage. Propane grills are easier to fire up if you just want to cook a quick burger or roast a few veggies. Charcoal grills, on the other hand, take a bit more work to get going but create a hotter cooking environment that can lead to better flavor development (more browning reactions). Regardless of what you go for, grilling is a great way to cook relatively thin items such as skirt steaks, burgers, or sliced vegetables. You can also slow-cook larger items on a grill—I've enjoyed a few summertime afternoons drinking with friends while waiting for an entire hog to cook.*

*The second major difference between propane and charcoal grills is temperature. While propane itself burns at somewhere around 3,100°F / 1,700°C, by the time the heat dissipates around the grill it cools down to about 650°F / 340°C. Using a generous but reasonable amount of wood or charcoal generates a heat source with a much higher amount of thermal radiation. When I've metered wood and charcoal grills, I've gotten temperatures around 850°F / 450°C.*

### Grilled Summer Vegetables

Grilled veggies are a fantastic treat, and easy, too. While someone might yet find a way to make lettuce kabobs work, it's easier to stick with the classics: choose sturdy vegetables low in water content (e.g., **asparagus**, **squash**, **bell peppers**, **onions**).

Slice your vegetables into large pieces and toss them into a bowl with a small quantity of **olive oil** and a few pinches of **salt**. You can get fancy with marinades and sauces, but if you're working with great produce, it seems like a shame to mask the flavor.



I generally grill my burgers or whatever meat I'm cooking first, and grill the vegetables while the meat rests. Grill the veggies for a few minutes, flipping them halfway through.

### Grilled Sweet Potato Fries

Slice a **sweet potato** into wedges. (Can't find sweet potatoes? Look for yams. Americans use the word *yam* when they really mean *Ipomoea batatas*.)

Coat the outside of the sweet potatoes with **olive oil** and sprinkle them with **coarse sea salt**. Place them on the grill for 10 minutes, flip, and grill until tender, about another 10 minutes. Serve while hot.

Instead of the olive oil/salt coating, you can make a sweet coating by brushing the wedges with a mixture of roughly equal parts of **butter** and **honey** melted together. Or try sprinkling **red pepper flakes** on the cooked wedges for a spicy version.





## Rosemary Mashed Potatoes

*This simple mashed potato recipe uses a microwave to cook the potatoes. Cooking a potato—or any other starchy root vegetable—requires gelatinizing the starches in the vegetable. For this to occur, two things need to happen: the starch granules need to get hot enough to literally melt, and they need to be exposed to water so that the granules absorb and swell up, which causes the texture of the tissue to change. Luckily, there's enough water naturally present in potatoes for this to happen without any intervention needed. Try popping a sweet potato in your microwave for 5–8 minutes to see—use a fork to poke holes in it first!*

Microwave until cooked, about 6 minutes:

**3–4 medium (600g) red potatoes**

After cooking, cut the potatoes into small pieces that can be mashed with the back of a fork. Add and mash together:

**½ cup (120 mL) sour cream**

**⅓ cup (80 mL) milk**

**4 teaspoons (20g) butter**

**2 teaspoons (2g) finely chopped fresh rosemary leaves**

**¼ teaspoon (1g) salt (2 large pinches)**

**¼ teaspoon (0.5g) ground pepper**

### Notes

- *For a tangy version, trying substituting plain yogurt for a portion of the milk.*
- *Different types of potatoes have different amounts of starch. Varieties with high starch content (e.g., russets, the brown ones with rough skin) turn out lighter and fluffier when baked and are generally better for baked or mashed potatoes. Lower-starch varieties (red or yellow potatoes, typically smaller and smooth-skinned) hold their shape better and are better suited for applications in which you want the potato to stay intact, such as potato salad. Of course, there's still a lot of room for personal preference. When it comes to mashed potatoes, I prefer a coarse texture to the creamy, perfectly smooth potatoes so often shown in movie scenes associated with Thanksgiving, so I tend to use red potatoes.*



## 310°F / 154°C: Maillard Reactions Become Noticeable

You can thank Maillard reactions for the nice golden-brown color and rich aromas of a Thanksgiving turkey, Fourth of July hamburger, and Sunday brunch toast. Coffee, cocoa, and roasted nuts all rely heavily on Maillard reaction byproducts for their flavors. If you're still not able to conjure up the tastes brought about by Maillard reactions, take two slices of bread and toast them—one until just before it begins to turn brown, the second until it has a golden-brown color—and taste the difference.

The nutty, toasted, complex flavors generated by the Maillard reaction are created when amino acids in proteins and certain forms of sugars (called *reducing sugars*) combine and then break down. Named after the French chemist Louis Camille Maillard, who first described it in the 1910s, the Maillard reaction wasn't well understood until the 1950s. During the reaction, compounds with free amino groups undergo a condensing reaction with reducing sugars. For example, meat has a reducing sugar, glucose (which is the primary sugar in muscle tissue), and also contains amino acids like lysine; with heat, these two compounds easily react with each other to form two new molecules.

The Maillard reaction is much more complicated than the other reactions we've talked about so far. One of the two new molecules generated at the start of the reaction is good ol' H<sub>2</sub>O, but the other is a complicated, unstable molecule that quickly cascades through more reactions. That cascade of reactions eventually settles down into a few hundred compounds, and it's these compounds that create the colors and flavors we want.

To complicate matters, the molecule generated by the first condensing reaction depends on *which* compounds start it all off. Any compound with a free amino group—amino acids, peptides, or proteins—can combine with any carbonyl compound (usually reducing sugars), so the initial starting molecule can take many, many forms. This is why the flavor byproducts from the Maillard reaction will be slightly different if you're grilling a hamburger or baking bread; the ratios and types of the amino acids and reducing sugars (e.g., glucose, fructose, and lactose) present in the two foods are different. In yet another wrinkle, the byproducts break down into different compounds depending on the pH of the solution they're in, shifting the flavors as well—it's complex!

Now that I've made it sound really complicated (which it is), how can you control the Maillard reaction and its aromas and colors? Fortunately, understanding the Maillard reaction from a cook's perspective is far easier than from that of a chemist. There are four ways you can control it, and understanding them requires a simple explanation of the chemistry rules around rates of reactions.

Obviously, a lack of either amino acids or reducing sugars prevents the reaction—both have to be present. There's a standard chemistry rule: increasing the concentration of reactants increases the rate of reaction. This is why some breads call for milk as an ingredient, and why brushing an egg wash on top of pastry crusts adds color. Both proteins and lactose in milk and the amines in eggs will increase the quantity of reactants and thus generate more Maillard reaction–based flavors and colors. Without them, no dice. If you want more Maillard reactions to occur, the first way is to up the concentration of ingredients that lead to it.

Temperature is the basis of another chemistry rule related to reaction rates. The *activation energy*—the amount of energy needed for a chemical reaction to occur—is based on the kinetic energy of a molecule. With higher temperatures, there's a much better chance that a molecule will bounce over the energy barrier necessary for the reaction to happen—but it's still a probability. At lower temperatures, the reaction can still happen, but much more slowly. (Depending on the type of reaction, there can be a minimum threshold.) Assuming you have plenty of reactants around, upping the temperature of the environment cooking the food is the easiest way to speed up the reactions.

The pH of the environment, which affects so many things in food, also changes how the Maillard reaction happens. The initial step of the reaction depends on free amino groups, but those get tied up under more acidic conditions. This is why adding baking soda to onions speeds up their browning and why dipping pretzel dough in a lye solution makes them browner. There are very few alkalizing ingredients in the kitchen—egg whites, baking soda—but fortunately they're mostly tasteless in small quantities. If you want to speed up browning on baked goods, try brushing an egg white wash on the surface of the dough; for foods like caramelized onions (a partial misnomer), add a pinch of baking soda to speed up the reaction.

The rate of Maillard reactions also depends on water: not too much or too little. The first step in the Maillard reaction generates a compound that's easily reversible—it can go back and forth between two states (one of those  $\rightleftharpoons$  symbols in chemistry diagrams)—and in this case it's the water molecule from that very first step that can be reabsorbed. When the water molecule is attached to the compound, it prevents the second step in the reaction

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Maillard reactions won't readily happen on wet foods. If you're about to sear meat, give it a quick pat with a paper towel to blot away surface moisture. Adding salt to a lean cut of meat right before cooking it pulls moisture toward the surface, which then takes longer to evaporate away when cooked. Either salt meats well in advance and then pat them dry before cooking, or add salt after cooking.

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from happening. If the environment is too wet, the probability of the water molecule staying attached to the compound increases, blocking the reaction from continuing. But if the environment is too dry, then the reaction doesn't begin either—the amino acid and sugar have to be mobile enough to connect. (The peak for reaction rate, with respect to water, is around 0.6 to 0.7  $a_w$ , if you're familiar with water activity; more practically, about 5% water.) It's unlikely that changing the amount of water is the fix for any Maillard reaction rate problems you see, but it does explain the difference you can see in a baking test of wetted flour and dry flour cooked on the same sheet.

Accounting for all these variables, in most culinary applications the delicious flavors and pleasing colors from the Maillard reaction still require moderately hot temperatures. The 310°F / 154°C temperature given here serves as a good guideline for when Maillard reactions will begin to occur at a noticeable rate, whether you're looking through your oven door or sautéing on the stovetop. For most cooking, 350°F / 180°C is a reasonable temperature, either in the skillet or the oven, to develop these flavors. Recipes that call for extended cooking times, like a roast kept in an oven for many hours, can be cooked at 325°F / 160°C. It's rare to see recipes call for lower oven temperatures than this because of how slowly the Maillard reaction will happen. Avoiding the Maillard reaction—it's not a flavor you always want, such as in meringue cookies like macaroons (see page 294)—is simple enough: make sure one of water, pH, or temperature is out of the necessary range. Most often this means setting the oven to a very low temperature (say, 250°F / 120°C), which is exactly what's done for meringue cookies.

We'll cover the other major browning reaction, caramelization, in the next section, but it's worth pointing out here that caramelization can deprive the Maillard reaction of the reducing sugars it needs. Searing meats in a too-hot pan will caramelize the glucose in the meat before it has a chance to react with amino acids, so when cooking meats, use a medium-high heat, but not too hot.

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Maillard reactions do happen below my 310°F / 154°C guideline—just not very rapidly. Stocks simmering at 212°F / 100°C for many, many hours and with sufficient concentration of the reactants will begin to slowly turn brown and develop the Maillard reaction flavors. (Some chefs swear by pressure cookers for making stocks; higher temperature means faster Maillard reactions!) It's even possible for Maillard reactions to happen at room temperature, given sufficient time and reagents: some aged cheeses like Manchego and Gouda have minor amounts of some of the Maillard byproducts. It happens elsewhere, too: self-tanning products happen to work via the same mechanism!

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## Skillet-Fried Potatoes

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*The humble potato, like the egg, has a dark side (the skin) and a light side (the inside), and can bind things together (the starches). But why do potatoes turn brown when fried? There are plenty of amino acids and glucose, along with some amount of water, setting up the necessary environment for the Maillard reaction. Try serving these potatoes with roast chicken (on page 218) or as part of breakfast (in which case, try adding red bell peppers, yellow onions, and small chunks of bacon).*

*This recipe uses two types of heat: first boiling, to raise the temperature of the entire potato to quickly cook the starches, and then sautéing, to raise the temperature of the outside. You can microwave the potatoes instead of boiling them, but the saltwater does a nice job of seasoning them.*

In a medium-sized pot, bring salted water to a boil and cook for 5 minutes:

**3–4 medium (700g) potatoes, diced into “forkable” bite-sized pieces**

Drain the potatoes and transfer them to a heavy cast iron or enamel pan on a burner set to medium heat. Add:

**2–4 tablespoons (30–60 mL) olive oil or other fat (leftover chicken, duck, or bacon fat tastes great)**

**1 teaspoon (6g) kosher salt**

Stir the potatoes every few minutes, flipping them so that the facedown sides have enough time to brown but not burn. Once most of the potatoes are browned on most sides, about 20 minutes, turn the heat down to low, add more oil or fat if necessary, and add:

**2 teaspoons (4g) paprika**

**2 teaspoons (2g) dried oregano**

**1 teaspoon (3g) turmeric powder**

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*Par-cooking*—partially cooking a food to speed up later cooking—isn't just about making more dirty dishes. Par-cooking can be done ahead of time so that an ingredient cooks faster when you're ready to finish it, or it can be done as a first step before you switch cooking methods. In this case, par-cooking speeds things up because the first cooking step uses hot water, which heats the potatoes faster. You can skip this step and just cook the potatoes in the pan, but they will take an extra 30 minutes or so to cook.

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## Great Garlic Bread

*Garlic with butter on toasted bread: what could be better to a garlic lover? Garlic has an amazing culinary history (search online for “four thieves vinegar”) and many known health benefits (from allicin—see the note on garlic presses).*

*Even garlic and butter can't save subpar bread, though. Supermarket bread—the fresh-baked loaves in a chain grocery store—is never as good as a true bakery's bread. If you can, start out with amazing bread.*

Mince—do not use a garlic press!—**lots of garlic**. Six cloves (4 tablespoons / 60g), or about half a garlic bulb, isn't unreasonable; true garlic lovers may want more. Transfer the garlic to a small bowl and add:

- 4 tablespoons (60g) softened or melted butter**
- 2 tablespoons (30 mL) olive oil**
- ½ teaspoon (2g) sea salt or garlic salt (omit if using salted butter)**
- 2–4 tablespoons (10–20g) chopped fresh parsley**
- 1–2 spoonfuls of red pepper flakes (optional)**

Mix ingredients to combine.

Slice a **loaf of Italian** or **French bread** in half, making a top piece and a bottom piece. Place the bread, both sides face up, on a baking sheet lined with aluminum foil. Brush or spoon the garlic mixture onto the bread. Bake the bread in a preheated oven at 350°F / 180°C for 8–10 minutes (longer if you like crispier garlic bread), and then broil until the top is golden-brown.

### Notes

- *Try adding Parmesan or mozzarella cheese on top. Or use different herbs like dried oregano instead of parsley, which is traditionally used due to the misguided belief that it'll cut down on garlic body odors. You can also slice the bread or even cube it before baking.*
- *Garlic begins to brown up and toast at around 260–280°F / 125–140°C. Too brown, and it'll taste burnt. Pay attention to the garlic bits while broiling the bread.*

### When should you mince garlic instead of using a garlic press?

I recommend garlic presses for convenience. Between a quick squirt of garlic or no garlic, I'll take the quick squirt. But some abhor the idea of using a garlic press because it changes the flavor of garlic—but only in some cases.

The flavor issue is caused by a heat-labile enzyme (one that breaks down when heated) in garlic, *alliinase*. When garlic is crushed, *alliinase* comes into contact with a compound, *alliin*, and converts it into another compound, *allicin*. *Allicin* isn't so great-smelling, which isn't surprising for a sulfur-based compound. At 6 seconds, half of the *alliin* is already converted to *allicin* (*alliinase* is the most abundant protein in garlic, so the rate of reaction is super fast). Slicing or mincing garlic doesn't mix the *alliin* with the *alliinase*, and once the garlic's heated, the *alliinase* can't react, so no *allicin*. The only way to avoid that reaction with a garlic press is to squirt the garlic straight into something like hot oil. If you're following a recipe that doesn't allow for that, slice or mince the garlic instead to avoid the off-tastes.

There's more to the story, though. While *allicin* doesn't smell so great, it's the only compound in garlic known to have health benefits. Sorry, folks, but without that off-odor of either raw garlic or pressed garlic left to sit around, there are no known health benefits!

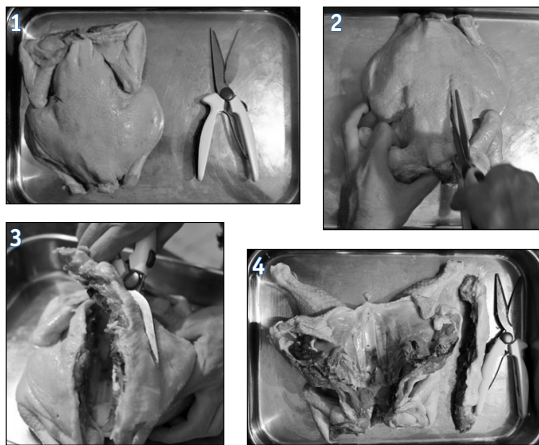
## Butterflied Roast Chicken

*You might be the type who prefers to let the butcher do the butchering, but it's worth learning how to butterfly a chicken even if you're squeamish about raw meat. Butterflying a chicken is called spatchcocking in Great Britain and crapaudine by the French—at least for small poultry that's grilled. A butterflied chicken is much easier to cook than a whole bird! It's economical, too, yielding four to six meals for not much money and a few minutes of surgery.*

*A chicken that's been cleaned and gutted is topologically a cylinder. It's basically a big, round piece of skin and fat (outer layer), meat (middle layer), and bone (inner layer). Cooking a whole bird intact is harder than cooking a butterflied bird, because invariably that cylinder is going to get heated from different directions at different rates—that is, unless you have a rotisserie grill, which heats the outside uniformly, cooks it uniformly, and makes it uniformly yummy.*

*By snipping the spine out of the chicken, you transform that cylinder into a plane of chicken—skin on top, meat in the middle, bone on the bottom. And the topology of such a surface is well suited to heat coming from a single direction (i.e., broiling or grilling), meaning it's much easier to cook to develop a nice, brown, crispy skin.*

1. Prepare your working space. I do this in a roasting pan, because it's going to get dirty anyway. Unwrap the chicken, removing the organ meats (discard them or save them for something else), and fetch a pair of heavy-duty kitchen scissors. The chicken should be dry; if it's not, pat it dry with paper towels.
2. Flip the bird around so that the neck flap is facing you. With the scissors, cut down to the right side of the spine (or left side, if you're left-handed). You shouldn't have to apply that much force. Make sure you're not cutting the spine itself, just to the side of it.
3. Once you've made the first cut, flip the bird around again—it's easier to cut on the outer side of the spine—and cut down the second side.
4. Once the spine is removed (trash it, or save it in the freezer for making stock), flip the bird over, skin side up, and using both hands—left hand on left breast, right hand on right breast—press down to break the sternum so that the chicken lies flat. You can remove the keel bone as well, but it's not necessary. (The keel bone is what connects the two halves of the butterflied chicken together.)



Now that you have a butterflied chicken, cooking it is straightforward. Because the skin is on one side and the bone on the other, you can use two different heat sources to cook the two sides to their correct level of doneness. That is, you can effectively cook the skin side until it's brown from Maillard reactions, and then flip the bird over and finish cooking it until a probe thermometer or manual inspection indicates that it is done.

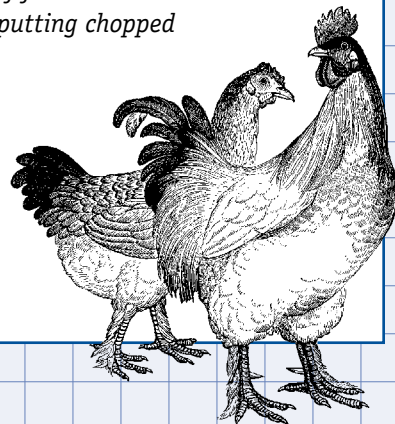
Rub the outside of the butterflied chicken with **olive oil** and sprinkle it with **salt**. (The oil will prevent the skin from drying out while cooking.) Place the bird on top of a wire roasting tray in a roasting pan, skin side up. (The wire tray raises the bird up off the pan so that it doesn't stew in the drippings that come out.) Tuck the wings up, over and under the breasts, so that they're not exposed to the broiler.

Broil the chicken at medium heat for about 10 minutes, or until the skin develops a nice level of brownness. Keep a good 6" / 15 cm between the bird and the heating element of your oven. If your broiler is particularly strong and parts of the chicken begin to burn, you can create a "mini-heat shield" with aluminum foil.

Once the skin side has browned, flip the bird over (I use folded-over paper towels instead of tongs to avoid tearing the skin). Switch the oven to bake mode, at around 350°F / 177°C. Ideally, use a probe thermometer set to beep at 160°F / 71°C (carryover will take the chicken up to 165°F / 74°C). If you don't have a probe thermometer, check for doneness after around 25 minutes by cutting off one leg and checking that the juices run clear and the flesh looks cooked. If it's not done, set the two halves back together and return it to the oven, checking periodically.

### Notes

- *Some people like to brine their chickens. It adds salt into the meat, changing the flavor. Try brining the chicken in a salt solution for an hour or so (½ cup / 150g salt, 2 quarts/ 2 liters cold tap water—but really, you can just dump salt in water until it's saturated). If you're going to brine the chicken for longer, which will result in a saltier chicken, store it in the fridge to keep it below 40°F / 4°C while it brines.*
- *Alton Brown's TV show Good Eats has an episode on butterflying a chicken. Brown creates a garlic/pepper/lemon zest paste to stuff under the skin, and roasts the chicken above a bed of cellar veggies (carrots, beets, potatoes). It's a great recipe, as the paste brings a lot of flavor to the bird and the cellar veggies pick up the chicken drippings. For another variation, try putting chopped garlic and aromatic herbs such as rosemary under the skin.*
- *For further inspiration, look at Julia Child et al.'s Mastering the Art of French Cooking, Volume 2 (Knopf, 1970), which has an excellent description of Volaille Demi-Désossée—"half-boned chicken." Child removes the breastbone (leaving the spine intact), stuffs the bird (foie gras, truffles, chicken livers, and rice), sews it back up, and roasts it. Looking at historical recipes—both recent and older—is a great way to understand food better.*





## Seared Scallops

*Scallops are one of those surprisingly easy but often-overlooked items. Look for scallops that are dry packed—not soaked in liquid—to avoid them weeping water while cooking. High-quality frozen ones work fine (make sure the ingredient list says only “scallops” to ensure they’re dry packed too); defrost them overnight in the fridge.*

Prepare the **scallops** for cooking by patting them dry with a paper towel and placing them on a plate or cutting board. If your scallops still have their bases attached, peel them off using your fingers and save them for some other purpose.

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Not sure what to do with those little side muscles attached to the main body of the scallop (scallop bases)? Pan-fry them after you cook the scallop bodies and nibble on them when no one is looking.

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Place a frying pan over medium-high heat. Once the pan is hot, melt about **1 tablespoon / 15g**

**of butter**—enough to create a thick coating—in the pan. Using a pair of tongs, place the scallops, flat side down, into the butter. They should sizzle when they hit the pan; if they don’t, turn the heat up.

Let them sear until the bottoms begin to turn golden brown, about 2 minutes. Don’t poke or prod the scallops while they’re cooking; otherwise, you’ll interfere with the heat transfer between the butter and scallop flesh. Once the first side is done cooking (you can use the tongs to pick one up and inspect its cooked side), flip the scallops to cook on the second flat side, again waiting until they’re golden brown, about 2 minutes. When you flip them, place the scallops on areas of the pan that didn’t have scallops on them before. These areas will be hotter and have more butter; you can take advantage of this to cook the scallops more readily.

Once they’re cooked, transfer the scallops to a clean plate for serving.

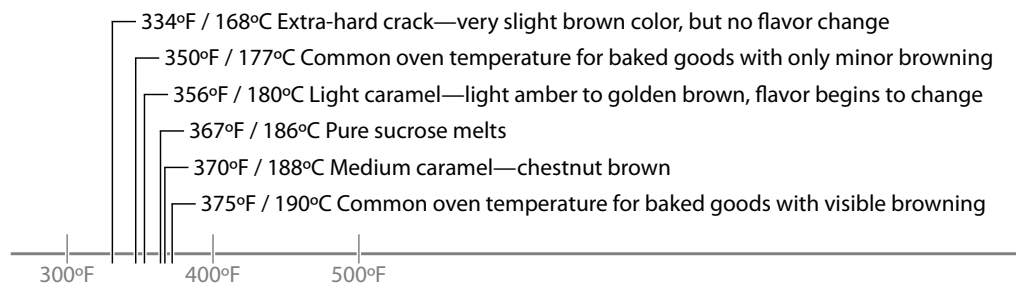
### Notes

- *Try serving these scallops on top of a small simple salad—say, some arugula/rocket tossed with a light balsamic vinegar dressing and some diced shallots and radishes.*
- *If you’re not sure if the scallops are done, transfer one to a cutting board and cut it in half. You can hide the fact that you checked for doneness by slicing all of the pieces in half and serving them this way. This lets you check that they’re all done as well.*
- *You can dredge the uncooked scallops in breadcrumbs or another light, starchy coating. If you have wasabi peas, use either a mortar and pestle or a blender to grind and transfer them to a plate for dredging the scallops.*



*Try crushing wasabi-coated peas and dredging the scallops in them before searing.*

## 356°F / 180°C: Sugar Quickly Caramelizes



*Temperatures related to sucrose and baking.*

Caramel sauce: delicious, calorie-laden, and made by the simple act of heating sugar. Unlike the Maillard reaction, which is named for the chemist who first described the reaction, caramelization is named for the end result. The word *caramelization* comes from the 17th-century French for “burnt sugar,” originally Late Latin for “cane” (*canna* or *calamus*) and “honey” (*mel*)—a good visual description of melted, browned sugar!

There are a couple of different ways to burn sugar (besides getting distracted while cooking). The simplest is with dry heat: sugar in a dry pan will *thermally decompose*—literally, breaking down under heat. In the case of sucrose, the molecular structure will break apart and go through a series of reactions that create over 4,000 different compounds. Some of those compounds are brown (the best-looking tasteless polymerization reactions you’ve ever seen!), while others smell wonderful (you can thank fragmentation reactions for these, as well as blaming them for some of the bitter tastes).

Heating sugar with water, as is done in wet-method caramel recipes, changes things slightly. When wet, sucrose will *hydrolyze*—a reaction that involves taking in water (hence “hydro”). In the case of sucrose, it hydrolyzes into glucose and fructose, called *sucrose inversion*. With heat, those molecules then rearrange their structure into another form that kicks off a water molecule and begins a chemical reaction journey. The hydrolysis of sucrose is a simple reaction. Even if you’re not up on your high school chemistry, you can see that the count of atoms on one side of the equation lines up with the count on the other side:



This is how pastry chefs make invert sugar syrup! The concentration of sugar, temperature, and pH all speed up the reaction, so if you’ve ever seen a caramel recipe call for cream of tartar, that speeds up the conversion to glucose and fructose. And, because fructose has a lower caramelization temperature (more on that in a minute), a wet caramel sauce should, in theory, caramelize at lower temperatures and have a different chemical makeup than a

dry one. The full chemistry of caramelization is still poorly understood—while researchers have been able to describe some of the reactions, the full pathway taken on the chemical reaction journey still has its mysteries.

Describing the temperatures for caramelization is also tricky because of the closeness between melting points and decomposition temperature ranges. Melting, a physical change, is not the same thing as decomposition, a chemical change. By definition, sucrose is a pure substance: it has a specific molecular structure. Pure sucrose melts at 367°F / 186°C, a state change where it goes from solid to liquid. Glucose, likewise, has a melting point of 294°F / 146°C; fructose comes in at a relatively cool 217°F / 103°C.

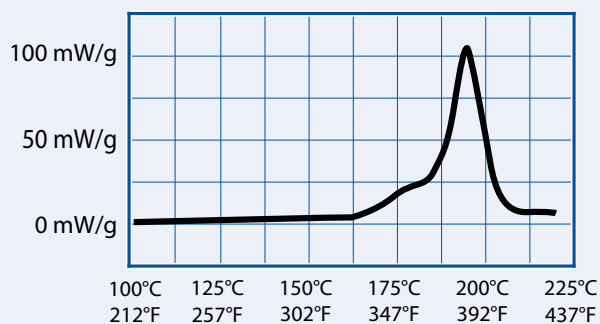
But these sugars begin to thermally decompose at temperatures lower than their melting points. The decomposition happens at a very, very slow rate at modest temperatures and begins to pick up to a noticeable rate as temperatures increase. For sucrose, that inflection point is somewhere around 338°F / 170°C—a good 30°F / 16°C below its melting point. If enough thermal decomposition happens before sucrose is heated to its melting point, granules of sugar will “apparently melt,” to use the phrase coined by the researchers. Heating a granule of table sugar—a bunch of sucrose molecules (with some impurities!) packed into a crystalline structure—to just below its melting point will cause some of the

## How Do Scientists Tell When Something Is Melting?

One common technique used is *differential scanning calorimetry* (DSC). In DSC, scientists closely monitor the temperature of a sample in a closed environment while heating it, either recording the precise amount of energy needed to raise the temperature at a constant rate, or recording the precise change in temperature while adding energy at a constant rate. DSC picks up phase changes (e.g., solid to liquid) and chemical changes (like protein denaturation or thermal decomposition) because these changes require heat energy but don't raise the temperature.

Take a look at the DSC graph. This graph shows how much energy was needed to heat a room-temperature sample to its melting point, raising the temperature at a constant rate over the course of about a minute. The graph noticeably ramps up around 338°F / 170°C and again around 356°F / 180°C, which is why caramelization is so often described as occurring at either of

those temperatures. But notice that the line does slope up well before these temperatures! Heating sucrose at a slower rate will shift these two inflection points to lower temperatures; if it's heated slowly enough, decomposition and melting will show up in two distinct peaks. Cooking sugar “low and slow” will still thermally decompose it; it'll just take longer.



DSC graph for sucrose.

sucrose molecules to convert to other compounds via thermal decomposition. The granule of sugar is no longer a pure substance! This is why a granule of sugar “apparently” melts below its true melting point when heated slowly. Sugar, like everything else that makes up our food, is fascinating and complicated stuff.

As for flavor, caramelization is like the Maillard reaction in that it generates thousands of compounds, and these new compounds result in both browning and enjoyable aromas. For some foods, these aromas, as wonderful as they might be, can overpower or interfere with the flavors brought by the ingredients. For this reason, some baked goods are cooked at 350°F / 177°C or even 325°F / 163°C so that they don’t see much caramelization, while other foods are cooked at 375°F / 191°C or higher to facilitate it. When cooking, ask yourself if what you are cooking is something that you want to have caramelized aromas, and if so, set your oven to at least 375°F / 191°C or extend the baking times out long enough for the reaction to occur. If you’re finding that your food isn’t coming out browned, it’s possible that your oven is running too cold, so adjust the temperature upward.

### Does starch caramelize?

Not directly. Starch is a complex carbohydrate; caramelization is the decomposition of simple carbohydrates, a.k.a. sugars. Given time under heat, starch will break down into dextrin, which is a bunch of glucose molecules linked together. Dextrins are commonly used as adhesives—the stuff you lick on the back of an envelope—and are made by heating starch for many hours. Additional processing converts them to things like maltodextrin (see page 416), but almost all of the browning you see in cooked food comes from sugars (caramelization) and reducing sugars with amino acids (Maillard reactions). Starch can be broken down into glucose, which will caramelize, either via enzymatic reactions or hydrolysis, so there are exceptions. To see the difference, try baking a pinch of dry cornstarch, sugar, and flour alongside slightly wetted versions of each (to see how water changes things) on a lined cookie sheet at 375°F / 190°C for 10 minutes and investigating the results.

Temperatures of common baked goods, divided into those below and above the temperature at which sucrose begins to visibly brown.	
Foods baked at 325–350°F / 163–177°C	Foods baked at 375°F / 191°C and higher
Brownies	Breads Sugar cookies
Chocolate chip cookies ( <i>chewy 12–15 minute cookies</i> )	Peanut butter cookies
Sugary breads: banana bread, pumpkin bread, zucchini bread	Chocolate chip cookies ( <i>crispy 12–15 minute cookies; higher temperature means more evaporated water</i> )
Cakes: carrot cake, chocolate cake	Flour and corn breads Muffins

## Sugar Cookies, Butter Cookies, and Cinnamon Snickerdoodles

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*What's the difference between a sugar cookie, butter cookie, and snickerdoodle? By weight, they're all ~25% sugar, ~25% butter, ~44% flour, ~5% egg, and 1% other. It's that "1% other" that makes all the difference. Butter cookies don't have any rising agent, while both sugar cookies and snickerdoodles do. Snickerdoodles also have cream of tartar, giving them a tangy flavor and chewier texture.*

*Cookies are a perfect example of both caramelization and Maillard browning reactions. Some people like their cookies barely browned; others like them nicely toasted up. Personally, I like sugar cookies tender and barely browned and butter cookies golden medium-brown.*

In a small bowl, mix **2½ cups (350g) flour** and **1 teaspoon (6g) salt**. Optionally add **½ teaspoon (2.5g) baking powder**, skipping it if you're making butter cookies. If you're making snickerdoodles, also add **2 teaspoons (6g) cream of tartar**. Use a whisk or fork to thoroughly mix the ingredients together.

In a large bowl, cream together **1 cup (230g) unsalted butter** (room temperature) with **1 cup (200g) sugar**. Add **1 large (50g) egg** and **1 teaspoon (5 mL) vanilla extract** and mix together. Optionally add flavorings, such as **¼ teaspoon (1.25 mL) almond extract** or **1 teaspoon (2g) lemon zest**.

Stir half of the dry ingredients into the large bowl, mixing to combine. Repeat with the rest of the dry ingredients. If you have time, chill the dough for several hours at this point—traditionally these doughs are firmed up so that they can be rolled out and cut into shapes.

If you like, prepare sugar to roll the dough balls in by pouring **¼ cup (50g) sugar** onto a small plate. For snickerdoodles, add **1 tablespoon (8g) cinnamon** and mix it with the sugar. For flavored sugar cookies, try adding **2 tablespoons (12g) fennel seeds** to the sugar. For crinkle cookies, set out a second plate with **¼ cup (30g) powdered sugar**.

To bake, scoop the dough into **½ ounce / 15g** portions, making small balls about **1" / 2.5 cm** in diameter, and roll them in the sugar. (You can also roll the dough out and use cookie cutters—see page 340 for how to make your own.) Place the dough balls on a parchment-lined cookie sheet and flatten them, using either a fork for a lined surface or your palm for a flatter cookie. For tender, lighter cookies, bake at **325°F / 165°C** for 10–12 minutes; for crispier, firmer cookies, bake at **375°F / 190°C** for 10–12 minutes. If you like your cookies crispy brown throughout, try baking them at **325°F / 165°C** for 25–30 minutes.

## Notes

- If sugar cookies or butter cookies aren't your thing, try adding flavoring to the mix, rolling the dough in sugar and chopped nuts, or dipping the baked cookies in chocolate. For chocolate-flavored cookies, replace  $\frac{1}{2}$  cup (70g) flour with  $\frac{1}{2}$  cup (40g) Dutched cocoa powder. For something festive, roll the dough balls in colored sugar. (To make your own colored sugar, mix a few drops of food coloring with  $\frac{1}{4}$  cup (50g) sugar in a plastic bag, seal it, and shake well.) Or get fancy and make two batches of dough—one vanilla and one chocolate, or two batches dyed different colors—and then roll the two doughs together to form a sliceable log with one dough in the center and the other wrapping it.
- Modern-day snickerdoodles are essentially chewy sugar cookies dusted in cinnamon, but that wasn't always the case. The earliest recipe I know of skips the flour, which was presumably useful for the 19th-century cook who found herself (rarely himself) out of it yet wanting to cook a treat. If you like your snickerdoodles old-fashioned-style, see <http://cookingforgeeks.com/book/snickerdoodles/> and use small eggs (modern-day eggs are larger).
- Crinkle cookies, often made with darker doughs that include cocoa powder or molasses, get their crackled appearance from being rolled in sugar. As the cookie expands, the sugar absorbs moisture, causing the surface to dry out and set before the cookie has fully expanded. For better results, roll your dough balls twice: first in granulated sugar, then in powdered sugar.



**325°F / 160°C**

**350°F / 180°C**

**375°F / 190°C**

**400°F / 200°C**

*Cookies baked at 350°F / 180°C and lower remain a lighter color because sucrose won't caramelize at these temperatures much when baked at standard baking times. Try making two batches of cookies, one with fructose sugar instead of table sugar, to see what a difference caramelization makes!*

## Lab: Tasty Rates of Reactions—Find Your Perfect Cookie












Here's an easy experiment to do, and the data is delicious! Everyone has their own idea of what makes a perfect cookie, and texture is a big part of perfection, at least for cookies. If you like your cookies gooey, they need to be baked so that some of the egg proteins remain unset. If you like your cookies crispy, they need to be baked so that most of the moisture in the dough evaporates away. But what if you want a cookie that's crispy around the edges and gooey in the middle? It's possible—with the right combination of time and temperature.

Almost all reactions in cooking are based on temperature. Different reactions occur at different temperatures, but it's not so simple as saying, "this reaction happens at  $x$  degrees." Reactions speed up with higher temperature, and many of the temperature ranges for different reactions overlap. For example, moisture in cookie dough will evaporate at the same time as the dough's egg proteins are setting.

Finding your perfect cookie requires playing around to figure out what exact time and temperature combination gives you the properties you like best. Try baking cookie dough at different times and temperatures to see how the different reactions change.

### First, grab these supplies:

- One batch of light-colored cookie dough (see page 224 for sugar cookie dough, or use store-bought dough)
- Stuff to bake the cookies: spoon, spatula, parchment paper, a cookie sheet, a timer, and an oven
- Two sheets of letter or A4 paper and something to write with

30 min						
25						
20						
15						
10						
5						
	275°F 135°C	300°F 149°C	325°F 163°C	350°F 177°C	375°F 191°C	400°F 204°C

## Lab: Tasty Rates of Reactions—Find Your Perfect Cookie

### Here's what to do:

1. Choose what time and temperature values and intervals you want to experiment with. For example, you could choose to do a range of temperatures from 300°F / 150°C to 375°F / 190°C in 25°F / 12.5°C intervals and a time range of 6 minutes to 21 minutes in 3-minute intervals.
2. Create a grid on your two sheets of paper, labeling the x-axis with each of your temperatures and the y-axis with each of your times. Leave about 2.5" / 6 cm between each label.
3. Bake!
  - a) Set your oven to the lowest temperature you choose.
  - b) Place small scoops of dough, about ½ ounce / 15g each, onto a lined baking sheet. If you're baking 6 different times for each temperature, then put 6 dough balls onto the sheet.
  - c) Set your timer to the beginning of the time range (e.g., 6 minutes) and begin baking the cookies.
  - d) When the timer goes off, remove one cookie and set it onto the grid at the correct spot.
  - e) Set the timer for the interval (e.g., 3 minutes), and remove another cookie when the time's up, repeating the process until all the cookies for the current temperature are baked.
  - f) When you're done with one temperature range, increase the oven to the next range and wait 10 minutes or so for the oven to adjust. (If you're doing this in a group, you can split up who does each temperature, but make sure to calibrate your ovens and use cookie sheets of the same material.)

### Investigation time!

There are two different browning reactions that happen in baking: the Maillard reaction and caramelization. What do you notice about how long cookies take to bake to medium-brown at one temperature versus another temperature? Do you think you could estimate how much faster a cookie bakes with a 25°F / 12.5°C increase in temperature?

Take a look at the lowest-temperature, longest-cooked cookie and compare it to the highest-temperature, shortest-cooked cookie. What do you notice about the difference between the color of the edges and the centers? What would cause this?

What do you think would happen if you changed the ingredients in the dough, like decreasing the amount of sugar, or adding an acid like lemon juice?



## Wet and Dry Caramel Sauces

*Caramel sauce is one of those components that seems complicated and mysterious until you make it, at which point you're left wondering, "Really, that's it?" Next time you're eating a bowl of ice cream, serving poached pears, or looking for a topping for brownies or cheesecake, try making your own.*

*There are two methods for making caramel sauce: wet and dry.*

**Wet method:** *This is the traditional method for making caramel sauce, and the only way to make lighter-colored caramel sauces. Adding corn syrup to the sauce prevents sucrose molecules from crystallizing into a big mess. If you don't have corn syrup, take care to not overstir; stirring speeds up crystal formation.*

### *Microwave version*

Microwaves make quick work of caramel sauce—the microwave rapidly heats the water, which then heats the sugar. In a clear microwave-safe bowl, heat **1 cup (200g) granulated sugar** and **¼ cup (60 mL)** water for 1–3 minutes, paying attention to the color of the sugar. It will bubble and remain clear for a while and then suddenly begin to turn brown—stop the microwave then! You can let it go for a few seconds longer to reach a medium brown. Remove the mixture from the microwave and very slowly add **½–1 cup (120–240 mL) heavy cream** (use more cream for a runnier sauce), stirring or whisking to combine as you pour.

### *Stovetop version*

In a saucepan, heat **1 cup (200g) granulated sugar** and **¼ cup (60 mL)** water. Optionally add **1 tablespoon (15 mL) corn syrup**. Allow the mixture to simmer for 5–10 minutes, during which time you should see most of the water bubble out and notice the sound of the bubbling change. Using a digital thermometer, heat the sugar syrup to about 350–360°F / 175–180°C, or look for it to begin to turn an amber color. You can cook it to higher temperatures for richer flavors, but for that, the dry method is easier. Remove the mixture from the heat and very slowly add **½–1 cup (120–240 mL) heavy cream** (use more cream for a runnier sauce), stirring or whisking to combine as you pour.



*Caramel sauce being made with the dry method.*

**Dry method:** *If you are making a medium-brown caramel sauce—above the melting point of sucrose—you can skip the candy thermometer, water, and corn syrup and take a shortcut by just melting the sugar by itself. Make sure the pan is dry—if there's much water in it, it'll cause the sugar to crystallize when it evaporates and the sugar won't melt as well.*

In a dry skillet or large pan over medium-high heat, heat **1 cup (200g) granulated sugar**.

Keep an eye on the sugar until it begins to melt, at which point turn your burner down to low heat. Once the outer portions have melted and begun to turn brown, use a wooden spoon to stir the unmelted and melted portions together to distribute the heat more evenly and to avoid burning the hotter portions.

Once all the sugar is melted, remove it from the heat and very slowly add **½–1 cup (120–240 mL) heavy cream** (use more cream for a runnier sauce), stirring or whisking to combine as you pour.

### Notes

- *Caramel sauce is a calorie bomb: 1,589 calories between the cup of heavy cream and cup of sugar. It's good, though!*
- *Try adding a pinch of salt, or a dash of vanilla extract or lemon juice, to the resulting caramel sauce. A tablespoon or two of bourbon is delicious too!*
- *Different temperature points in the decomposition range yield different flavor compounds. For a more complex flavor, try making two batches of caramel sauce, one in which the sugar has just barely melted and a second where the sauce is allowed to brown a bit more. The two batches will have distinctly different flavors; mixing them together (once cooled) will result in a fuller, more complex flavor.*
- *Sucrose has a high latent heat—that is, the sugar molecules are able to move and wiggle in many different directions. Because of this, sucrose gives off a large amount of energy when going through the phase transition from liquid to a solid, so it will burn you much, much worse than many other things in the kitchen at the same temperature range. There's a reason pastry chefs call this stuff "liquid Napalm."*

## What's the Difference Between Beet Sugar and Cane Sugar?

From a molecular perspective, sucrose is sucrose: it has a defined molecular structure and the sucrose molecules in your container of sugar are identical to the sucrose in my container. But the table sugar we use is only *mostly* pure sucrose. There's somewhere around 0.05% to 0.10% of trace impurities in highly refined white sugar, and those impurities can vary based on growing conditions and the source plants. There are also potential differences in the quality of the crystalline structure. A grain of sugar is a small crystal of sucrose molecules, and just like the Hope Diamond, the crystalline structure isn't 100% pure. One research paper from 2004 ran DSC analysis on two different samples of sucrose and found noticeable differences in their melting and decomposition rates due to these differences.

About half of the sugar in the United States comes from the sugar cane plant, while the other half comes from sugar beets. Sugar labels don't have to identify which plant the sugar comes from, and sugar manufacturers claim that trained sensory panels can't tell the difference. Bakers and online forums disagree, finding sugar from the sugar cane plant strongly preferable to beet sugar. A 2014 paper from the University of Illinois backs them up: aroma and flavor was noticeably different, with 62 panelists detecting differences between the two types of sugar when used in pavlova and simple syrup. They didn't detect differences, though, between the two types when they were used in sugar cookies, pudding, whipped cream, or iced tea.

## Roasted Glazed Carrots with Red Onions

*Roasting vegetables such as carrots creates a pleasant nutty, toasted flavor from both the Maillard reaction and caramelization. Adding a sugar—honey, brown sugar, maple syrup—intensifies the flavors and colors.*

Prepare about **2 pounds (1kg) of carrots** by peeling them—the skins can be extremely bitter, and peeling improves their taste—and cutting any tops off. If some carrots are much thicker than others, cut those in half. Slice **1 or 2 small (70–140g) red onions** into wedges, removing any skin and roots.

Pick an oven-safe pan large enough to hold the carrots one or two layers deep and coat it with a thin layer of **olive** or **sesame oil**. Add **1 teaspoon**

**(3g) sea salt** and any spices you like—**ground cumin, cinnamon, coriander**, and a hint of **cayenne pepper** are delicious. Add **2 tablespoons (25g) brown sugar or maple syrup** and a **tablespoon (15 mL) of lemon or orange juice** and mix. Transfer the carrots and onions to the pan, rolling them around to coat all sides.

Preheat the oven to 400–425°F / 200–220°C. Cook the carrots for 20–30 minutes, turning them occasionally, and remove them when they're brown and tender.

### Note

- *Try stirring in chopped fresh sage or other aromatic herbs after cooking.*

# Bridget Lancaster on Cooking Misconceptions

PHOTO USED BY PERMISSION OF AMERICA'S TEST KITCHEN



*Bridget Lancaster is the executive food editor for television, radio, and media at America's Test Kitchen. She is an original cast member of America's Test Kitchen and Cook's Country, both broadcast on public television. Before working at America's Test Kitchen, she cooked in restaurants in the South and Northeast regions of the United States.*

## How did you get into cooking?

I got into the hobby of cooking from my mother, who is a great cook. This was the time when convenience food started coming out, prepackaged things, foods that had “Helper” at the end of the title. My mother just refused to participate in any of that. So everything was scratch—always homemade cakes, breads...

Also, my grandfather worked in the Army for years. When he was in Korea, he would ask the men in his company for different foods that were sent in care packages. They would take those foods and create a meal, something special

that wasn't just Army sanctioned. I think he always had that interest in taking something that was so humdrum, so pedestrian, and turning it into something special. I think that's where I got interested in not settling for less, always thinking, “This could be a little bit better. This could be a little bit more.” My relationship with *Cook's [Illustrated]* is all about that.

## You once mentioned that you grew up not knowing that things like pasta sauce even came in a jar. As you learned more about cooking, what things surprised you that people buy instead of make?

Well, that was one of them because of the fact that a great pasta sauce takes 10 minutes to make, from scratch. Salisbury steak that's in the frozen aisle, with frozen mashed potatoes? It was almost as if we had all turned into astronauts, and we were looking at food as a thing to consume instead of actually being a meal.

Not to say that there aren't great ready-made things, like really good sausages and canned tomatoes. I use canned tomatoes all winter long because I don't really like buying fresh in the winter; they're red Styrofoam.

## You mentioned that you got into the hobby of cooking from your mother. What are the things that you wish you had learned from her, that you think are hard to learn unless you're doing it with somebody?

The simplest ingredient is just, it is what it is. The less you do to it, the better it is.

I think understanding the magic step was missing. Say you put brownies in the oven—it goes away and when it comes back, it looks completely different. What's happening at that point? I never asked those questions. I just accepted it at kind of face value.

## I think a lot of people do think that it's a magic box. You put the cookie dough in, and you bake it, and out comes a cookie somehow. What other magic steps happen that people don't realize are important?

Some of it happens before it even goes into the box. One is probably stirring. You think of cake batter, cookies, any kind of baked good. Before it goes into that magic box, if you stir it too much, it makes it tougher. That's now what we know as the new villain on the street, gluten. It's important for structure, but it can be easily activated more, so that there's more gluten developed. So you end up with cake that's tough instead of cake that's tender.

With steak, the magic step is salting. My mom would call it a marinade, but now we know that soy is the primary ingredient, more like a briner-ade. It's part salt brine with more flavor. She would let it sit for a good half-hour in mostly soy sauce, no real acid in there. That went on the grill, and when it came back, it was savory all the way through.

Our grandparents didn't know about connective tissue and the conversion of collagen into gelatin. But they knew that if you had really tough cuts of meat, you could literally change their structure into something very different, as different as cake batter compared to a baked cake, by putting that tough cut of meat into the oven, the longer and slower, the better. You really change the structure with only temperature and time and how long it takes for that to occur.

### **The black box of cooking vegetables: what do people miss there?**

I think if I could go back in time and get my mom to roast some vegetables, I would have been a little less picky. As children, our taste buds are very different, and we pick up on bitter first, before we pick up on other tastes.

Roasting takes away the bitter, and it converts it into sweeter and deeper flavors, but not bitter. I think that's the best thing that ever happened to vegetables. Roasted Brussels sprouts. You see them in restaurants now too! They bring out baskets of roasted Brussels sprouts, and I just laugh because I want to take a survey, go around the restaurant and ask people, "Did you eat Brussels sprouts when you were a kid? Wasn't that the worst

thing that your parents could have threatened you with when you were a child?" Now we eat them like they're popcorn.

Cauliflower is another one. I think this is partially thanks to the vegetarian, even vegan, crowd that wanted something that was thought of as a substantial main course. You now see cauliflower steaks: it's treated; it's browned. It might be high-roasted, or it might be grilled, but you're taking the same treatments that we've done for meat and other things and looking at it as a way to add more flavor and turn something that was a side dish for so long into something more special.

### **It's interesting that you tie that to vegetarian or vegan cuisine. Are there other subgroups that deal with food that've introduced the broader population to new interesting things?**

Today, we see an emphasis on different grains. Not only is it vegetarianism or veganism, but people with gluten sensitivities. They can't have barley. They can't have wheat, obviously. So you're seeing an exploration. Some are new things—breads made with new grains or a combination of grains—and we're also seeing a little bit of a celebration of things that are naturally gluten-free, like Southern cornbread. Northern cornbread tends to have both flour and cornmeal in it, but southern cornbread is just cornmeal.

A lot of these trends start in restaurants because you have somebody going in and saying, "I'm allergic to dairy." Then there are some cultures where the foods are just naturally dairy-free. Take a lot of Thai food. You don't see a lot of cheeses in Thai food. You don't see milk, dairy milk. You see coconut milk.

I think our culture is becoming more diverse, not only in its people, but in its cuisine. We're seeing more of this in cookbooks and in restaurants and in home cooking. We're trying new cuisines from around the world that just happen to be either gluten-free or dairy-free, but they weren't engineered to be that way. You see people making oatmeal porridge with coconut milk now, instead of regular milk, or smoothies with different types of dairy.

### **What are the common mistakes that you see with people who are learning to cook?**

Probably the number one mistake is they're afraid of salt. They don't know that salt added at various stages not only affects the taste, but also the texture of food. You think about adding onions to a pan that has oil or butter in it—add a little bit of salt to draw out the moisture, so you can get more caramelization and more flavor that way. The most important step, after you've turned off the stove, is to check the food. Adjust the seasonings at the end. Is it a little dull? Does salt brighten it?

Number two, people just are watching the clock instead of peeking under that chicken breast to see if it's browned to the right color. That'll tell you if it's time to turn it over, not necessarily the recipe time.

Another thing: there's a fear of the equipment. The safest thing to cook with is a very, very sharp knife. The most dangerous thing to cook with is a dull knife. And there's a fear of the stove, in a certain way. I see people only turn their stovetop up to medium. They'll wonder why, when they put food in the pan, it just steamed instead of getting

a really deep, dark crust on it. You have to crank the heat up, put some oil in the pan, and let that heat until the oil just starts to smoke. Smoke is kind of a danger sign, but it's also a great indication that you're ready to go. I understand that fear, but the heat gives the caramelization and the browning of the food.

### Where do you think this fear of the kitchen comes from?

We're definitely afraid to fail, but I think there's been a generation or two that fell away from the kitchen, and the microwave became another black box where almost no prep was necessary. People were able to eat quickly. I have succumbed to Stouffer's mac-and-cheese going into the microwave a couple times in my life. Pretty darn good.

When you have a fear of something, you're supposed to face it every day, and it goes away. I think if you're only cooking once, twice a week, you don't want to screw it up. Plus, if you buy really good food items, there's sticker shock, so you *really* don't want to mess it up.

I think there was a generation where cooking was seen as tethering. Not to get political, but we didn't want to be tied to the stovetop. A couple of generations didn't benefit from someone being in the kitchen. Think of the Italian nana, always adding something to this big magical pot and stirring it away, and you get this amazing gravy at the end of it. Not everybody had that experience. I think it's coming back. But who would have thought that there would be food TV? I'm guilty for being a part of it. But who in the world, besides Julia Child, did you ever think would be on your TV, telling you how to cook? Maybe Justin Wilson or Graham Kerr, bless his heart.

I remember reading after 9/11 there was a big uptick in people buying kitchen equipment, because there was kind of a feeling that you needed to nest. You needed security of your home. I remember reading the article and thinking, "That's one of those game-changers for some people."

### What aspects of cooking and science have surprised you? Things that should have been easy but were hard, or were hard and turned out to be easy?

I think knowing exactly what you just said: things that should be easy are the hardest. I now know that, but it was a surprise. One of the jobs that I went for as a cook, you had to make an omelet for the chef. Think about an omelet. An omelet should be really, really simple, and that was the point. But it's so hard to make because there's so little to an omelet; one minor change to a step can really change everything.

I think the biggest thing, though, is that we can always do better—as long as we don't assume anything. Think of the old kitchen lore, "Don't salt your beans." That's my favorite one because I never salted beans growing up because you were gonna just ruin the whole dish. Then we find out that actually you can salt your beans. It not only adds flavor to the dish, but it changes their structure so that they're a little bit creamier.

