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.

> 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.

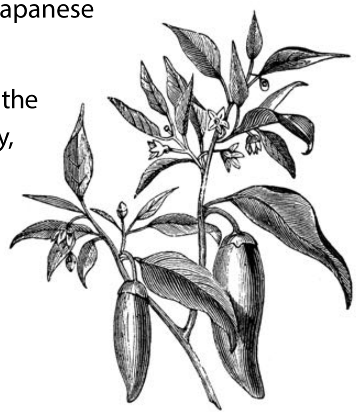
How strongly we register a taste is based on how much of a compound is present in a food we're eating and how sensitive we are to it. Just as our other senses have thresholds for sensing (e.g., few of us can hear anything at 2 dB, while almost all of us can hear something louder than 15 dB), taste and 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).

Sweet	Sucrose	5,000 ppm
Salty	Sodium chloride	2,000 ppm
Savory	Glutamate	200 ppm
Sour	Citric acid	40 ppm
Bitter	Quinine	2 ppm
Hot	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!

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.

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.

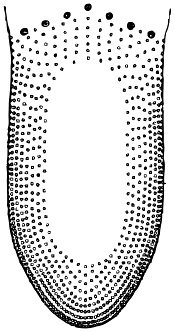


Fig. 2.

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**