Smell, the Olfactory Sense

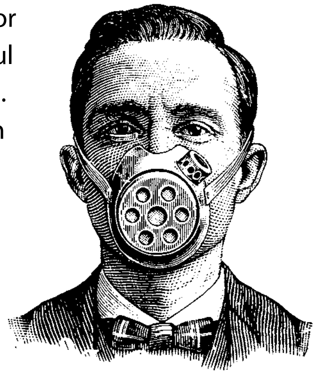
Smell is simple in the abstract and complicated in the details. In the abstract, smells lead us toward the desirable and steer us away from the unsafe. But smell does this in a much broader context than food. Choosing whom to mate with? Helping infants identify their mothers? Helping me figure out if 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.

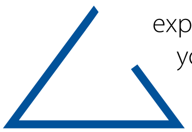
At first glance, smell and taste receptor cells work in similar ways. As in taste, odor receptor cells are built to detect exactly one attribute, and each receptor cell is encoded by exactly one odorant receptor gene. Just as "sweet!" taste receptors can be triggered by different compounds—sucrose, fructose, 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!"

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 "missmelled" 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*.)

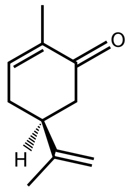
While some foods have naturally strong smells, most raw ingredients keep their odors to themselves until disturbed. An unpeeled banana, a head of lettuce, and fresh fish don't have much of an aroma until they're worked. Cooking adds many odorants by either freeing volatile compounds or breaking down 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.

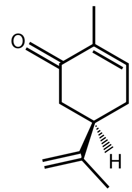
Octane

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



R-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, call 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.

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.

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."

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?).

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.

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.

Common	Sweet, fragrant, perfumy, floral, cologne, aromatic, musky, incense, bitter, stale, sweaty, light, heavy, cool/cooling, warm
Foul	Fermented/rotten fruit, sickening, rancid, putrid/foul/decayed, dead animal, mouselike
General foods	Buttery (fresh), caramel, chocolate, molasses, honey, peanut butter, soupy, beer, cheesy, eggs (fresh), raisins, popcorn, fried chicken, bakery/fresh bread, coffee
Meats	Meat seasoning, animal, fish, kippery/smoked fish, blood/raw meat, meat/cooked good, oily/fatty
Fruits	Cherry/berry, strawberry, peach, pear, pineapple, grapefruit, grape juice, apple, cantaloupe, orange, lemon, banana, coconut, fruity/citrus, fruity/other
Vegetables	Fresh vegetables, garlic/onion, mushroom, raw cucumber, raw potato, bean, green pepper, sauerkraut, celery, cooked vegetables
Spices	Almond, cinnamon, vanilla, anise/licorice, clove, maple syrup, dill, caraway, minty/peppermint, nut/walnut, eucalyptus, malt, yeast, black pepper, tea leaves, spicy
Body	Dirty linen, sour milk, sewer, fecal/manure, urine, cat urine, seminal/like sperm
Materials	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
Chemicals	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
Outdoors	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

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?

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.

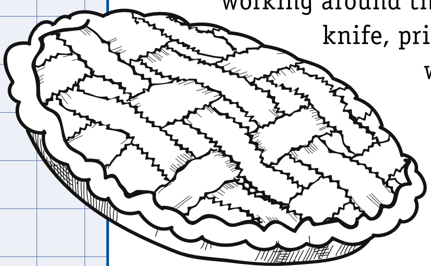
Line a pie pan with **pie dough**—see page 259 for a double-crust recipe, or cheat and buy a commercially prepared one, making sure to get a double crust (one that has a second part for the top of the pie).

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.