

THE PHYSIOLOGY OF TASTE

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Sweet, sour, bitter and salty. That's it, pal, unless you want to count umami, the weird, nearly-indescribable sensation associated with monosodium glutamate. Which you probably don't, unless you're a chemical senses researcher or about to chow down on cheap Chinese take-out.

Every time you stick something in your maw, one or a combination of those four primary tastes alerts you to vital information about that mouthful of matter. If it's sweet, maybe it's got the nutrients your body needs to keep running for another few hours. If it's salty, perhaps you can replace some of those vital minerals you just excreted through sweat or urine. If it's sour, there's a chance it's not ripe and will give you a bad bellyache. If it's bitter, watch out -- it could be poison and your next swallow will be your last.

Of course, these are not the things you think about when sitting down to an elegant, five-course French meal or even while scarfing down a chili dog, fries and a Bud at a baseball game. Mostly, you're hungry, and you want something that tastes good. Simple as that

But deciding what tastes "good" is anything but simple. A food's flavor doesn't usually depend on data from a single sense. Rather, smell, touch, sight and even hearing often come into play, and the best methods of pleurably exciting those senses during a meal or snack occupies the days of thousands of chefs, brewers, marketing flaks, and scientists around the world.

Open your mouth and say, "Aaahh!" There's your tongue, that pink, flexible muscle marinating in saliva.

You might call the little knobs dotting the surface of your tongue taste buds, but you'd be wrong. Those are papillae, and there are four kinds of them: fungiform and filiform on the front half, foliate and vallate on the back. The actual taste buds, described variously as resembling either tiny navel oranges or onions, cluster together in packs of two to 250 within the papillae. The buds in turn consist of up to 100 cells, either receptor or basal.

When something tasty enters the mouth, its chemicals are dissolved by the saliva, and the free-floating molecules enter the taste bud through a pore in its center. If the molecule binds to the tip of a receptor cell, it will excite that cell into issuing a series of chemical and electrical signals. It used to be thought that these electrical signals would then be fired directly into the brain, but the process turns out to be more complicated than that.

For example, sweet and some bitter taste stimuli activate a chemical messenger known as gustducin, member of the old and venerable G-family of proteins and cousin to transducin, the protein in the eye which helps to translate light into vision. In ways not completely understood, the activation of gustducin initiates an electrochemical dialogue among the receptor cells, which then transmit their messages to the basal cells at the

bottom of the bud. The basal cells can also "talk" back to the receptor cells and among themselves. Once everybody has their stories straight, the data are relayed to the brain, to the gustatory cortex to be specific. "Geez, that's sweet," you think.

Salty and sour molecules don't seem to need to mess around with the receptor tips, permeating the taste cells directly through special channels in their walls. For example, the channels allow electrically charged sodium ions in and potassium ions out. As the interior of the cell grows progressively more positively charged, it sets up a small electric current that triggers more intercellular messages and, once again, word is passed to the brain that something salty, perhaps a pretzel, is about to plummet down the esophagus.

If you were paying attention in high school biology, you may remember a map of the tongue that grouped the buds detecting sweetness on the tip of the tongue. Those were flanked by the salt-detecting buds, with the sour ones running farther along the sides. The bitter buds, last defense against gag-inducing toxins, lurked across the back of the tongue.

Nice, neat, orderly. And not very accurate. There are taste buds throughout the oral cavity, even on the upper palate. Any bud is capable of detecting all the basic tastes. It's just that some are more sensitive to a particular taste than to the others.

The tongue map also neglects to take into account the impact the other senses have on taste. In a lot of cases, you pick up clues about the food you're about to eat long before any of it gets into your mouth. Like that left-over beef stroganoff that's been sitting at the back of your refrigerator for a month. Chances are, you won't even bother to dirty a fork before chucking that rank mess into the Dispos-All. Your nose knows what's up, that the last thing your body needs is a stomachful of virulent bacteria in cream sauce.

Smell, of course, doesn't simply warn against spoiled food. It also increases your enjoyment of practically everything you eat. Much of what we commonly refer to as "flavor" is actually a combination of smell and taste, with taste most often assuming the secondary position.

As a child, I read a book of scientific riddles which included the question "When does an onion taste like a strawberry?" The answer was "When you hold your nose," and the text urged me to go to Mom's larder and try the experiment myself. Loath to bite into a raw Bermuda even with my nostrils clamped shut, I gave it a pass, but the theory is still sound. With your eyes closed and your nose pinched tight, you wouldn't be able to tell the difference between, say, a chunk of apple and a chunk of turnip. Anyone who's ever suffered with hay fever or even just a bad head cold can verify that most foods taste pretty much the same when your nasal passages are clogged with excess mucus.

On the way into your mouth, foods are already giving off vapors that waft up into your nose. Once you start chewing, more vapors travel the retronasal route, up the pharynx and into the nasal cavities. At the back of each cavity, the molecules hit the olfactory membrane, a postage stamp-sized patch of yellowish gray tissue. Each membrane contains an estimated 100 million receptor cells, which sounds impressive until you realize that a German shepherd reportedly has a billion of the little suckers.

The olfactory receptor cells are actually neurons, or nerve cells, outfitted at their knobby ends with six to twelve hair-like cilia. The cilia dangle into the thin layer of mucus that coats the membrane and snag passing particles for smell analysis.

Each receptor cell is connected by a single primary olfactory neuron to one of the brain's two olfactory bulbs. The primary olfactory neurons pass through holes in the cribriform plate, a penny-thin bone at the front of the cranial cavity upon which the

olfactory bulb rests. The primary neurons come together in structures known as glomeruli and there meet secondary neurons.

Messages shoot across the synapses, the gaps separating the primary and secondary neurons. Smell nerve fibers then wend their way in complex paths throughout the rest of the brain, particularly into the most primitive portions, evolutionarily speaking. Some fibers reach the hypothalamus, the center controlling appetite, anger, fear and pleasure, while others continue into the hippocampus, which regulates memories, or descend into the depths of the brain stem, where such basic functions as remembering to breathe are regulated.

That's why odors can generate extremely powerful emotional responses. In Proust's masterwork, it probably wasn't the sweet taste of that madeleine that unleashed the remembrance of things past. Rather, it was likely to have been the buttery odor that stimulated the narrator's hippocampus and hypothalamus. See how an understanding of neuroscience adds to the enjoyment of interminable classics of French literature?

As for how you identify one particular scent from another, the answers are far from clear-cut. In the 1930s, researchers discovered that different areas of the olfactory bulbs are sensitive to different types of smells, that some receptors are stimulated by a particular odorant while others aren't. A popular theory developed by in the 1960s by Dr. John Amoore of the U.S. Department of Agriculture emphasized the shape of a molecule as a key component of its perceived smell. He proposed five primary classes of odors with specific molecular shapes: camphor-like (spherical), musky (disk-shaped), floral (kite-shaped), pepperminty (wedge-shaped) and ether-like (rod-shaped). He also suggested two other classes, pungent and putrid, whose distinguishing characteristics were not their shape, but the electric charge of their particles. All in all, Amoore believed that there at least thirty primary odors.

Like the tongue map of yore, Amoore's classifications work as gross generalizations, but they don't come close to revealing the whole picture. In 1991, researchers at Columbia University, Drs. Richard Axel and Linda Buck identified a family of genes that carry blueprints for particular odor receptor proteins. It's pretty darn large family, with as many as one thousand members. Consequently, human noses contain roughly a thousand types of receptor cells, and, because each type may be capable of recognizing more than one smell, the number of distinct odors capable of being perceived by the human nose jumps up to an estimated 10,000.

Just as many folks start out with 20-20 vision in their youth and wind up wearing tri-focals come retirement, your senses of taste and smell changes over time. The average adult reportedly has approximately 10,000 taste buds, but children have more, including some dotted along the inside of their cheeks. Infants seem to arrive hard-wired to react to bitterness and sweetness, though the ability to detect saltiness takes six months or so to develop. The childish craving for sweets typically declines during adolescence, probably as a way of limiting caloric intake.

As you journey through adulthood, your sense of taste remains at roughly the same level, although abusing your taste buds, such as by smoking or repeatedly scalding the tongue with hot beverages, obviously has a dulling effect on them. Unlike all other brain cells, the olfactory receptor cells in the nose are continually dying off and regenerating themselves, but a gradual loss of smell sensitivity is not uncommon in the elderly.

Sometimes, though, things go seriously awry, permanently in some cases. It's estimated that between two and four million Americans suffer from smell and taste disorders. The complete loss of smell is called anosmia, while a significantly reduced ability to detect odors is referred to as hyposmia.

Viral infections and head trauma are among the leading culprits. Viruses can kill off olfactory cells, which usually grow back but sometimes don't. A blow to the back of the head can send the brain careening at high speed into the front of the skull, severing the delicate connections between olfactory neurons. Exposure to toxic chemicals can rob you of your sense of smell, and benzene, chlorine, mercury and various insecticides have all been implicated in various cases. Loss of smell can also be one of the early symptoms of Alzheimer's and Parkinson's diseases, leading some researchers to theorize that the agents that cause those maladies enter the central nervous system through the olfactory nerve, damaging it in the process.

If called to sacrifice one of your senses, you might think jettisoning smell would be the way to go. But according to Dr. April Mott, Medical Director of the Connecticut Chemosensory Clinical Research Center, patients with anosmia cope with formidable obstacles to their physical and mental well-being. First of all, remember that a food's flavor accounts for about three-quarters of its flavor. Just imagine what it would be like if breakfast, lunch and dinner tasted pretty much the same every single day of your life. Also, because eating plays such a focal role in our social lives, anosmia patients sometimes feel isolated from their friends who enjoy the everyday pleasures of going out for pizza or having a cocktail after work.

Other dangers and inconveniences abound for the smell-impaired. They can't smell smoke, detect gas leaks, spot certain types of rotten food, or know immediately when Junior needs his diaper changed. Some become increasingly worried about their own body odor, taking multiple showers every day to forestall any unwitting olfactory offensiveness.

Unpleasant tastes and smells chronically plague a small percentage of patients with chemosensory disorders. Sjogren's Syndrome, a fairly common ailment among post-menopausal women, dries out the mouth and nose and can sometimes produce a foul, soapy taste. Cancer patients undergoing chemotherapy or radiation therapy occasionally report phantom tastes or odors.

There's even reason to suspect that Louis XI, a 15th Century king of France, suffered from an olfactory disorder. The perception that everything around him stank terribly no doubt contributed to his bad temper and helped earn him the sobriquet of "the terrible king."

Synesthesia, wherein one sensation involuntarily conjures up another, probably stands as the top nominee in the category of Weirdest Sensory Syndrome. The fusion of sound and color -- perceiving the musical note of high C as possessing a red hue, for example -- has been noted in the medical literature as far back as the seventeenth century. In "The Man Who Tasted Shapes," however, Richard E. Cytowic recounts the case of Michael Watson, an art teach in North Carolina, who had the singular ability to associate various tastes with a collection of three-dimensional geometric shapes.

Cytowic describes how might feel to a synesthete to grab a slice of chocolate mint pie from the 'fridge and eat it: "As you do, you feel a dozen columns before you, invisible to the eye but real to the touch. You set the fork down and run your hand up and down

their cool, smooth surfaces. As you roll the minty taste in your mouth, your outstretched hand rubs the back curve of one of the columns. What a sumptuous sensation. The surface feels cool, refreshing, even sexual in a way."

Sounds kind of scary, but Cytowic asserts that synesthesia is a normal brain function in every person but that reaches conscious awareness in only a handful. In synesthetes, parts of the brain become disconnected from each other due to a rebalancing of local metabolism following a stimulus. Cytowic traces synesthesia's ultimate origin to our old friend the hippocampus, where the perception of subjective experience is monitored.

Even for those of us not prone to synesthesia, the sense of touch provides another important facet to a food's flavor. Is it slick like an oyster? Cold like a milk shake? Full of carbonation like a Diet Coke? All of these sensations and many more are registered by the trigeminal system of nerve fibers.

The pungency of a wad of green mustard served with sushi doesn't correspond to any of the four basic tastes. Rather, the kick you get from it is a function of how much pain it inflicts on nerve fibers in your mouth. Also located in the tongue's papillae, these pain fibers are actually wrapped around the taste buds.

Chemical irritants that humans have learned to like in their food include capsaicin in chili peppers, the gingerols in ginger, piperin in black pepper and the various isothiocyanates in onions, mustard, radishes and horseradish. You consider them "hot" because they stimulate only a subset of the pain fibers in your mouth, not all of them. But that subset also includes sensors that monitor temperature, hence the burning sensation associated with even an ice-cold super-jalapeno.

Why do some folks prefer to eat foods that actually inflict pain? In a study done at the University of Pennsylvania in 1980, Dr. Paul Rozin hypothesized that eating chilis and the like releases endorphins, the euphoric, pain-killing neurochemicals responsible for the fabled "runner's high." Or maybe it's simply that, as they say, variety is the spice of life, and a bit of oral irritation now and then pleasurably broadens the spectrum of flavors.

As to the reason why some people can cheerfully withstand the ravages of irritant-packed food and others bolt for the water fountain at the first nibble on a wayward jalapeno, part of it is no doubt genetic, but there's also a phenomenon known as "transient desensitization." Keep eating chili after chili, and your mouth is going to get hotter and hotter. Take a break, though, maybe two or five minutes, and when you resume your meal, the burning sensation won't be quite so fierce. ... Desensitization can last hours, and people who make a habit of eating spicy food may be partly desensitized virtually all the time.

Wouldn't you know it, but one fine example of these different sensory sensations working in concert occurs when you drink a glass of beer?

According to Dr. Gary K. Beauchamp, Director of the Monell Chemical Senses Center in Philadelphia, one of beer's primary components, namely the alcohol, stimulates all three sensory systems. "It stimulates taste, being a little bit bitter itself. It stimulates olfaction, having a sort of sweet odor. And it stimulates the trigeminal system, giving the drink some bite. That's probably one of the reasons why it's so difficult to make an alcohol-free beer that has the same characteristics as a normal brand."

Just as beer manufacturers are continually monkeying around with their product's basic recipe to fill new marketing niches, chemosensory researchers are always on the alert for new methods of boosting flavor while removing a food's less healthy ingredients (sugar, salt, fat, etc.). So far, the search for an artificial sweetener, for example, has relied purely on serendipity, but, according to Dr. Beauchamp of Monell, that may change as scientists develop a better understanding of molecular chemistry. He says, "Once we have identified what the sweet receptor is, we'll be able design sweet molecules. Even though there are clues suggesting there will never be a salt substitute, we may be able to make a salt enhancer."

There's no telling exactly what the Brave New World of Flavor might hold. Perhaps no-fat, low-sodium, low-calorie kibble that packs the appetite-fulfilling power of a sixteen-inch deep-dish pizza with a dozen different toppings.

In the meantime, as you think about what gives your brain's gustatory cortex the biggest jolt for the money, you might do well to contemplate the words of nineteenth-century art critic John Ruskin: "Taste is the only morality. . . Tell me what you like, and I'll tell you what you are."