A MATTER OF TASTE

The Evolution of Flavor

By Benjamin Miller

In middle school most of us probably learned about the four taste groups: sweet, bitter, sour, and salty. If you had a particularly up-to-date science curriculum, you might also have learned about umami, or "savory." Today, scientists recognize that much more is at work than simply four types of taste buds sending a composite signal to the brain. The way we taste foods, in fact, originates from the kinds of foods humans have adapted to enjoy or dislike, which gives us important clues about our evolution.

Ultimately, the foods most essential to our survival tend to taste good while foods likely to be harmful tend to taste bad (1). Over time, all these genetic manipulations have influenced our preferences so that parents rarely have to convince their children to eat their pasta, although natural selection may still need work on the veggies. Simple genetic predispositions, however, cannot explain all of our vastly complex and varied food preferences, as many frustrated parents of multiple children realize. Exactly how much our palates are preconceived and how much they are environmentally influenced remains highly debated.

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The Biology of Taste

As you might remember from that middle school science class, your mouth detects flavors through a set of receptors located in clusters called taste buds. Depending on the type of receptor it contains, a taste cell can be triggered in one of two ways: direct biochemical stimulation or lock-and-key reception (2).

One directly stimulated sensation is the response to salty flavors. Just as neurons use a balance of positively charged ions to transduce signals, taste cells experience a charge gradient across their membranes in the presence of positively charged sodium ions. Embedded ion channels are activated, creating a cascade of signals to inform the brain that a salty flavor is present (3). Another directly stimulated taste cell, the sour response, is activated by protons released from acids, such as the common sour flavors of citric acid (lemon juice) and acetic acid (vinegar) (4).

Other receptors operate on a lock-and-key basis, in which the physical shape of the stimulus fits specifically into a slot, causing the release of ions or neurotransmitters. In sugars, for example, certain chemical clusters, or functional groups, hang off the main carbon rings. The functional groups snap into multiple sockets on a receptor, like the points of a key lifting the springs inside a keyhole (5). Another lock-and-key receptor is the umami receptor, which binds to the amino acid glutamate in a manner quite similar to that of sugars (5).

Perhaps the least understood and most intriguing of the major flavor groups is the bitter taste response. While the bitter response is also a lock-and-key receptor, unlike sweet and umami, there is no single configuration of molecules that triggers the signal for bitterness. There are, in fact, more than thirty different receptors, differing in size and shape, but each triggers the same bitter response (6). In the lock-and-key metaphor, it is as if three dozen different doors, each with its own particular lock and key set, leads to the exact same room. This surprising phenom-

Cat got your tongue!?

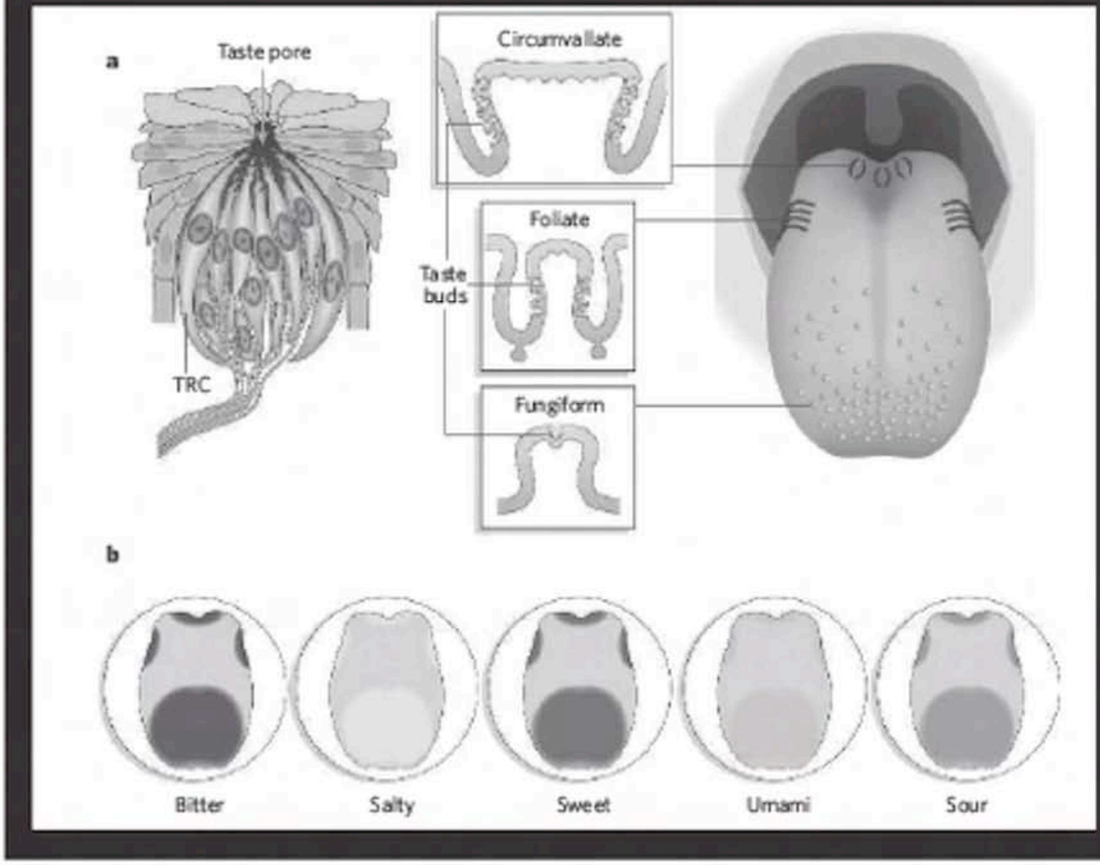


Figure 1. There are at least three different constructions of flaps and pores on the tongue which contain taste buds (4), but it is clear that none of them are specialized to receive any particular input, debunking the theory that each flavor group has its own area on the tongue (6).

credit: Chandrashekar, J., et al. "The Receptors and Cells for Mammalian Taste." Nature. 444.7117 (2006): 288-294.

enon of multiple pathways for bitter taste transduction has led many scientists to investigate not just how we taste our food but why we taste it.

Evolution of Good Nutrition

There are, of course, important and advantageous reasons why we taste our foods in particular ways. Sugars and carbohydrates, which dissolve into simpler sugars in the mouth, both activate the distinctly pleasant sweet response, and both are the basic energy sources for our bodies. In a world before agriculture and food over-production, it would have been most efficient to eat foods rich in carbohydrates and sugar. With such an advantage for consuming these food groups, natural selection led to an inherent pleasure in eating sweet foods.

Similarly, a preference for the savory and delicious flavor of umami would have enriched our ancestors' diets with the proteins and essential amino acids necessary for growth and metabolism (7). Furthermore, the sour taste, pleasurable in small amounts, is mostly commonly encountered in nature from citrus fruits and various tart berries, both of which have high concentrations of important vitamins (4). Beyond the simple distinction of pleasant versus unpleasant, chefs, who we can assume strive for the most pleasant tastes, find that no single taste on its own is as delicious as a balance of several together; quite literally, a balanced diet just tastes better. These apparent dietary adaptations give us insights into the evolution of desiring a balanced, healthy diet, albeit for a less technologically advanced society.

Evolution of Defense Against Poison

In addition to providing an impulse for good nutrition, our responses to flavors can also serve as a defense mechanism against ingesting harmful substances. The sour taste response, for example, is pleasant in small quantities but repulsive in concentrated doses, likely to warn against eating unripe fruit or spoiled foods (4). This distinction is highlighted in dairy products: spoiled milk, which can make a person sick, has an unpleasant sour flavor, while carefully cultured yogurts and sour creams are healthy and palatable, with only a pleasant tang.

Likewise, the extremely complex response to bitter taste can discourage ingestion of poisonous compounds. The

Fire and Ice: The Flavors of Hot and Cold

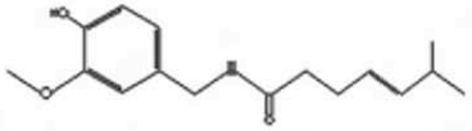
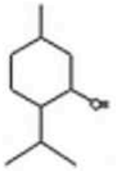


Figure 2. Similar to physical sensation of heat that capsaicin stimulates (shown left, and detailed below), menthol (right), a compound found in mint, directly stimulates the same neural response associated with cold (12). This, of course, begs the question of whether or not menthol can give you brain-freeze.



most common bitter flavors in nature belong to a class of nitrogen-containing organic chemicals called alkaloids, which generally originate from plants (8). Common alkaloids include caffeine and quinine, along with drugs such as nicotine, morphine, and cocaine, all of which are toxic in concentrated doses and trigger the bitter response. Adrenaline, another well-known alkaloid, controls the flight-or-fight response, and one often detects its bitter taste in intense or frightening situations. A few alkaloids are extremely toxic, such as the common rat poison strychnine. Among the most infamous poisins, cyanide is noted for both its extreme toxicity and its subtle taste of bitter almonds. This correlation of bitter tastes and toxins indicates that we may have evolved to avoid the most common poisonous compounds.

Disparity of Tasting

In contrast to these common nutritional aspects, individuals differ in their preferences and abilities to taste. Phenylthiocarbamide (PTC), for instance, is an organic compound that the majority of the population can detect in extremely small quantities as revoltingly bitter, but a small segment of the population cannot detect it at all, due to a single dominant allele. Similarly, supertasters represent a fairly small percentage of the population who have highly acute senses of certain taste groups, due to an overabundance of certain receptors. Without compelling evidence for an environmental basis, most scientists assume that supertasting is a genetic phenomenon. Unlike the ability to detect PTC, however, the genetic variations required for supertasting would be extremely complex, involving multiple genes, sometimes on different chromosomes (9).

Perhaps the most notable example of variation in taste thresholds is personal tolerance of spicy food. Spice, however, is an exception in the world of taste reception; rather than operating within the taste bud as the five major groups do, spice is detected directly by the same neurons that respond to painful stimuli (10). In this case, capsaicin, a chemical naturally found in chili peppers, triggers the same receptor net that responds to extreme heat and acidity (11). When you eat a jalapeño or breathe mustard gas your mouth is, according to your senses, on fire. The class of vanilloid receptors that respond to capsaicin, however, has an interesting twist: the receptors actually turn off if they are over-stimulated because they can quickly exhaust their supply of neurotransmitters (12). Furthermore, excess capsaicin can act as a cytotoxin, permanently damaging and destroying neurons, leading to an overall build-up of tolerance to its effects (13), and indicating that not all differences in how we taste can be traced back to our genetic history.

The Chef's Perspective

The added complications of such unconventional taste groups as spice and mint have fueled debates over how we perceive flavors. Some scientists maintain that several taste cells process information inside their taste bud, then relay the integrated signal to the brain (3). The presence of these other flavors which do not act within the taste bud unit has led others to think that each signal is sent to the brain independently (3). Furthermore, many questions remain regarding the importance of receptor numbers versus differences in the neural wiring itself in determining our ability to taste, as well as our taste in tastes. Ultimately, future findings will provide additional clues as to how we perceive tastes and how these various and complex sensory schemes evolved. ■

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