# Scientists discover protein receptor for carbonation taste

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(PhysOrg.com) -- In 1767, chemist Joseph Priestley stood in his laboratory one day with an idea to help English mariners stay healthy on long ocean voyages. He infused water with carbon dioxide to create an effervescent liquid that mimicked the finest mineral waters consumed at European health spas. Priestley's man-made tonic, which he urged his benefactors to test aboard His Majesty's ships, never prevented a scurvy outbreak. But, as the decades passed, his carbonated water became popular in cities and towns for its enjoyable taste and later as the main ingredient of sodas, sparkling wines, and all variety of carbonated drinks.

Missing from this nearly 250-year-old story is a scientific explanation of how people taste the carbonation bubbling in their glass. In this week's issue of the journal *Science*, researchers at the National Institute of Dental and Craniofacial Research (NIDCR), part of the National Institutes of Health, and their colleagues from the Howard Hughes Medical Institute at the University of California, San Diego (UCSD) report that they have discovered the answer in mice, whose sense of taste closely resembles that of humans.

They found that the taste of carbonation is initiated by an enzyme tethered like a small flag from the surface of sour-sensing cells in taste buds. The enzyme, called carbonic anhydrase 4, interacts with the carbon dioxide in the soda, activating the sour cells in the taste bud and prompting it to send a sensory message to the brain, where carbonation is perceived as a familiar sensation.

"Of course, this raises the question of why carbonation doesn't just taste sour," says Nicholas Ryba, Ph.D., a senior author of this study and an NIDCR scientist. "We know that carbon dioxide also stimulates the mouth's somatosensory system. Therefore, what we perceive as carbonation must reflect the combination of this somatosensory information with that from taste."

A somatosensory system transmits sensory information within the body from protein receptors to nerve fibers and onward to the brain, where a sensation is perceived. Common sensory information includes taste, touch, pain, and temperature.

Ryba added that the taste of carbonation is quite deceptive. "When people drink soft drinks, they think that they are detecting the bubbles bursting on their tongue," he said. "But if you drink a carbonated drink in a pressure chamber, which prevents the bubbles from bursting, it turns out the sensation is actually the same. What people taste when they detect the fizz and tingle on their tongue is a combination of the activation of the taste receptor and the somatosensory cells. That's what gives carbonation its characteristic sensation."

Although some chefs might disagree, food does not tickle the taste buds that line the upper surface of the tongue, roof of the mouth, and upper esophagus. Rather the salt in a pretzel or the sugars in a chocolate drop bind to matching taste receptor cells clustered in our taste buds.

Scientists believe that our sense of taste generates only a limited palate of distinct qualities: the familiar sweet, sour, salty, bitter and savory tastes. Much of the flavor of food (the "tickling of taste buds") comes from a combination of this taste information with input from other senses like touch and smell.

Over the past decade, there has been tremendous progress in identifying the basis for detection of the five major taste qualities. Indeed, the laboratories of Charles Zuker, Ph.D., a senior author of this study from UCSD, and Ryba have previously teamed up to identify the receptor proteins and cells responsible for sweet, bitter, and savory taste and the receptor cells for sour detection. But can our sense of taste detect other flavors?

Recent work from a number of groups has suggested taste buds might detect other qualities, such as fat and metallic tastes. It also indicated that the gas carbon dioxide induces strong responses in taste nerves. The body senses carbon dioxide on many levels - in the somatosensory system (including touch and pain), smell, and in the brain and blood to control respiration. But how it is detected in taste was quite unclear.

This prompted Jayaram Chandrashekar, Ph.D., lead author of the study and a scientist at UCSD, to explore the taste of carbonation. Together with David Yarmolinsky and Lars von Buchholtz, Ph.D., co-authors of the paper, he discovered that the enzyme called carbonic anhydrase 4 is selectively expressed on the surface of sour taste receptor cells.

Carbonic anhydrase 4, or CA-IV, is one of a family of enzymes that catalyzes the conversion carbon dioxide to carbonic acid, which rapidly ionizes to release a proton (acid ion) and a bicarbonate ion (weak base). By so doing, carbonic anhydrases help to provide cells and tissues with a buffer that helps prevent excessive changes in pH, a measure of acidity.

The scientists found that if they eliminated CA-IV from the sour-sensing cells or inhibited the enzyme's activity, they severely reduced a mouse's sense of taste for carbon dioxide. Thus CA-IV activity provides the primary signal detected by the taste system. As CA-IV is expressed on the surface of sour cells, Chandrashekar and co-workers concluded that the enzyme is ideally poised to generate an acid stimulus for detection by these cells when presented with carbon dioxide.

Why do mammals taste carbonation? The scientists are still not sure if carbon dioxide detection itself serves an important role or is just a consequence of the presence of CA-IV on the surface of the sour cells, where it may be located to help maintain the pH balance in taste buds. As Ryba says, "That question remains very much open and is a good one to pursue in the future."

More information: The article is titled "The Taste of Carbonation." The authors are Jayaram Chandrashekar, David Yarmolinsky, Lars von Buchholtz, Martyn Goulding, William Sly, Nicholas J. P. Ryba, and Charles S. Zuker.

Source: NIH/National Institute of Dental and Craniofacial Research