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**Taste (Gustation)**

Taste, or gustation, is a sense that develops through the interaction of dissolved molecules with taste buds. Currently five sub-modalities (tastes) are recognized, including sweet, salty, bitter, sour, and umami (savory taste or the taste of protein). Umami is the most recent taste sensation described, gaining acceptance in the 1980s. Further research has the potential to discover more sub-modalities in this area, with some scientists suggesting that a taste receptor for fats is likely.

Taste is associated mainly with the tongue, although there are taste (gustatory) receptors on the palate and epiglottis as well. The surface of the tongue, along with the rest of the oral cavity, is lined by a stratified squamous epithelium. In the surface of the tongue are raised bumps, called papilla, that contain the taste buds. There are three types of papilla, based on their appearance: vallate, foliate, and fungiform.

*Structures Associated with Taste. The tongue is covered with papillae (a), which contain taste buds (b and c). Within the taste buds are specialized taste cells (d) that respond to chemical stimuli dissolved in the saliva and, in turn, activate sensory nerve fibers in the facial and glossopharyngeal nerves. This work by Cenveo is licensed under a Creative Commons Attribution 3.0 United States.*

The number of taste buds within papillae varies, with each bud containing several specialized taste cells (gustatory receptor cells) for the transduction of taste stimuli. These receptor cells release neurotransmitters when certain chemicals in ingested substances (such as food) are carried to their surface in saliva. Neurotransmitter from the gustatory cells can activate the sensory neurons in the facial and glossopharyngeal cranial nerves.

## Primary Taste Sensations

As previously mentioned, five different taste sensations are currently recognized. The first, salty, is simply the sense of Na+concentration in the saliva. As the Na+concentration becomes high outside the taste cells, a strong concentration gradient drives their diffusion into the cells. This depolarizes the cells, leading them to release neurotransmitter.

The sour taste is transduced similar to that of salty, except that it is a response to the H+concentration released from acidic substances (those with low pH), instead of a response to Na+. For example, orange juice, which contains citric acid, will taste sour because it has a pH value of about 3. Of course, it is often sweetened so that the sour taste is masked. As the concentration of the hydrogen ions increases because of ingesting acidic compounds, the depolarization of specific taste cells increases.

The other three tastes; sweet, bitter and umami are transduced through G-protein coupled cell surface receptors instead of the direct diffusion of ions like we discussed with salty and sour. The sweet taste is the sensitivity of taste cells to the presence of glucose dissolved in the saliva. Molecules that are similar in structure to glucose will have a similar effect on the sensation of sweetness. Other monosaccharides such as fructose or artificial sweeteners like aspartame (Nutrasweet™), saccharine, or sucralose (Splenda™) will activate the sweet receptors as well. The affinity for each of these molecules varies, and some will taste “sweeter” than glucose because they bind to the G-protein coupled receptor differently.

The bitter taste can be stimulated by a large number of molecules collectively known as alkaloids. Alkaloids are essentially the opposite of acids, they contain basic (in the sense of pH) nitrogen atoms within their structures. Most alkaloids originate from plant sources, with common examples being hops (in beer), tannins (in wine), tea, aspirin, and similar molecules. Coffee contains alkaloids and is slightly acidic, with the alkaloids contributing the bitter taste to coffee. When enough alkaloids are contained in a substance it can stimulate the gag reflex. This is a protective mechanism because alkaloids are often produced by plants as a toxin to deter infectious microorganisms and plant eating animals. Such molecules may be toxic to animals as well, so we tend to avoid eating bitter foods. When we do eat bitter foods, they are often combined with a sweet component to make them more palatable (cream and sugar in coffee, for example).

## Gustatory Nerve Impulses

Once the taste cells are activated by molecules liberated from the things we ingest, they release neurotransmitters onto the dendrites of sensory neurons. These neurons are part of the facial and glossopharyngeal cranial nerves, as well as a component within the vagus nerve dedicated to the gag reflex. The facial nerve connects to taste buds in the anterior third of the tongue. The glossopharyngeal nerve connects to taste buds in the posterior two thirds of the tongue. The vagus nerve connects to taste buds in the extreme posterior of the tongue, verging on the pharynx, which are more sensitive to noxious stimuli like bitterness.

Axons from the three cranial nerves carrying taste information travel to the medulla. From there much of the information is carried to the thalamus and then routed to the primary gustatory cortex, located near the inferior margin of the post-central gyrus. It is the primary gustatory cortex that is responsible for our sensations of taste. And, although this region receives significant input from taste buds, it is likely that it also receives information about the smell and texture of food, all contributing to our overall taste experience. The nuclei in the medulla also send projections to the hypothalamus and amygdalae, which are involved in autonomic reflexes such as gagging and salivation.

## Structure and Function

The neural taste pathway will undergo scrutiny from the perspective of starting within the tongue and moving away from it towards the brain. The three nerves associated with taste are the facial nerve (cranial nerve VII), which provides fibers to the anterior two-thirds of the tongue, the glossopharyngeal nerve (cranial nerve IX), which provides fibers to the posterior third of the tongue, and the vagus nerve (cranial nerve X), which provides fibers to the epiglottis region. Taste fibers categorize as special visceral afferent (SVA). The branch of the facial nerve that innervates the anterior two-thirds of the tongue is the chorda tympani nerve. Another branch of the facial nerve, called the greater petrosal nerve, supplies innervation to taste buds of the soft palate. The cell bodies of the facial nerve associated with taste occur within the geniculate ganglion. Its central processes enter the brainstem at the pontomedullary junction and travel caudally to the medulla oblongata, where they synapse at the nucleus solitarius.

The cell bodies of the glossopharyngeal nerve associated with taste are in the inferior ganglion of the glossopharyngeal nerve (petrosal ganglion). The central processes of the glossopharyngeal nerve travel through the jugular foramen, enter the brainstem at the level of the rostral medulla, and eventually synapse at the nucleus solitarius.

The cell bodies of the vagus nerve associated with taste exist in the nodose ganglion. Its central processes travel through the jugular foramen, to the medulla, and also synapse at the nucleus solitarius. At this point, fibers from all three of these nerves have synapsed at the nucleus solitarius. Specifically, the synapse occurs in the rostral part of the nucleus solitarius known as the gustatory region of the nucleus.The caudal area of the nucleus solitarius receives cardio-respiratory information, and it is known as the visceral region.

Next, the second-order fibers ascend ipsilaterally to the parvicellular division of the ventral posteromedial nucleus (VPMpc) of the thalamus, where the next synapse occurs.

The third order fibers travel ipsilaterally through the posterior limb of the internal capsule to terminate in the frontal operculum, anterior insular cortex, and in the rostral part of the Brodmann area 3B. The overall function of these third-order fibers is to provide discriminatory taste sensations. Additionally, there are secondary fibers that travel from the gustatory cortex to the posterolateral portion of the orbitofrontal cortex (OFC). This area is where the integration of taste and smell takes place, as well as the phenomenon of food reward. The description of food reward is the enjoyment of a particular food at the time in which an individual is eating it.

## Clinical Significance

The clinician can examine the integrity of the nerves associated with taste (specifically the facial nerve and glossopharyngeal nerve) with a suprathreshold taste test. Edible strips placed on specific regions of the patient’s tongue contain the five taste qualities (sweet, salty, bitter, sour, umami). The strips provide stimulation slightly above the threshold for taste. If a patient can properly identify a taste, this is considered a normal result. This test has been proven to be decidedly sensitive for analyzing taste recognition.

The electrical stimulation of the tongue through the use of a clinical electrogustometer can also be used to examine the taste threshold of patients. The examiner places electrodes on the taste buds of a patient, and the resulting action potentials are measured. However, feelings of pain have been reported by patients who have been examined by way of this method.

There are many causes for diminished or altered taste sensations in an individual, such as medications that cause dysgeusia. Examples of these medications include agents such as acetazolamide, maribavir, and cisplatin. Most often, changes in salivation as a result of taking a certain medication is the primary cause behind this adverse effect.

Relatedly, individuals who have Sjogren syndrome also report disturbances in taste. Sjogren syndrome is an autoimmune disorder in which a person’s immune system damages his or her own lacrimal glands and salivary glands (parotid gland, sublingual gland, and submandibular gland). The conclusion is that damage to the salivary glands results in a reduced outflow of saliva, which leads to the prevention of substances, like food, from reaching the taste buds.

Another cause of altered or diminished taste is due to diabetes mellitus, which is especially true in individuals who suffer from undiagnosed or untreated diabetes. Recent studies have considered the disturbances in taste to be an early indicator of the disease. Among newly diagnosed patients, one of the most common complaints within this population is the blunted taste response when eating food that they may have typically experienced to be sweet tasting in the past. When patients receive appropriate treatment for their high blood glucose, their taste disturbances can sometimes partially reverse. The specific cause for taste alteration in this population is still not fully known; though, the thinking is that progressive damage to the facial nerve, glossopharyngeal nerve, and/or vagus nerve may be the leading culprit when it comes to taste disturbances in diabetic patients.

A vestibular schwannoma (also referred to as an acoustic neuroma), which is a benign tumor that grows into the cerebellopontine angle (CPA), can cause loss of taste in the anterior two-thirds of the tongue on the ipsilateral side. In addition to the facial nerve, this tumor most commonly impinges on the trigeminal nerve (cranial nerve V) which can cause ipsilateral loss of sensation to the face, and the vestibulocochlear nerve (cranial nerve VIII), which can cause ipsilateral hearing loss. Besides an ipsilateral loss of taste sensation of the anterior two-thirds of the tongue, impingement of the facial nerve caused by this tumor can cause ipsilateral paralysis of the muscles of facial expression (leading to Bell palsy), paralysis of the stapedius muscle (leading to hyperacusis), and decreased secretions of the submandibular gland, sublingual gland, and lacrimal gland.