The Truth About Taste Buds

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Abstract
Taste perception is a complex process affected by many factors, including genetics, sex, age, and experience. Taste buds are the initial point of taste perception. Taste bud growth begins at the prenatal stage of development, and different cell types and regions of the tongue are sensitive to different flavors. For example, the greatest sensitivity to sweet is at the tip of the tongue, whereas the greatest sensitivity to sour is at the upper sides of the tongue. Eventually, babies begin to develop certain taste preferences and, as they age, genetic changes, such as allele expression, can cause individuals to be more sensitive to some flavors over others. This contributes to the differences observed in infant versus adult sensory perception. Similarly, the sex of a person can drastically vary their ability to detect certain basic traits. Aside from biological factors including age and sex, the environment also affects taste preferences and perception. This consists of race, ethnicity, culture, and location. The simple topic of taste buds is much more complex than anticipated and is important for humans to become more knowledgeable about something they use in their everyday lives.

Introduction
Sensation is a physical process, whereas perception is significantly influenced by external factors and previous experiences. Sensation describes physical input about the environment received by various sensory receptors (McKendrick 1999). Differences in sensation and perception levels cause all individuals to experience taste differently. Sensation is the first step in processing information from a food. From there, our brain must interpret these stimuli to allow us to perceive what we are tasting. The development of taste buds is entirely antenatal (prenatal), starting as early as 8 weeks of gestation. The expansion initiates with the growth of papillae, which are little bumps on the top of the tongue that help grip food while chewing(Crumbie 23) (see Figure 1). Foliate and vallate papillae are the first two of the four papillae to form, followed by fungiform papillae. By the 10th week of gestation, the filiform papillae, which resemble a thread, can be observed on the dorsal surface of the tongue. The foliate papillae are leaf-shaped structures situated at the bilateral margins of the caudal region (Reginato 2014). They are responsible for the task of detecting the five basic tastes: sweet, salty, sour, bitter, and umami (Gravina 2013). Vallate papillae are located on the caudal region of the dorsal surface. Groups of salivary serous glands, known as von Ebner glands, are located in the vallate papillae and secrete a water liquid to dissolve food particles (Ghannam 2023). The fungiform papillae may be identified on the apex of the tongue and take the shape of a mushroom. Its main function involves regulation in the sensorial system related to taste. The last type is filiform papillae. The filiform papillae, small bumps that help grip food while chewing, are widely distributed across the dorsal (top) and lateral (side) surfaces of the tongue. While they

may be mistaken as taste buds, these papillae are not involved in taste perception. All of the papillae contribute to the ability to sense the chemical, tactile, and thermal properties of food (Reginato, 2014). From there, the brain must interpret these stimuli to allow us to perceive what we are tasting.

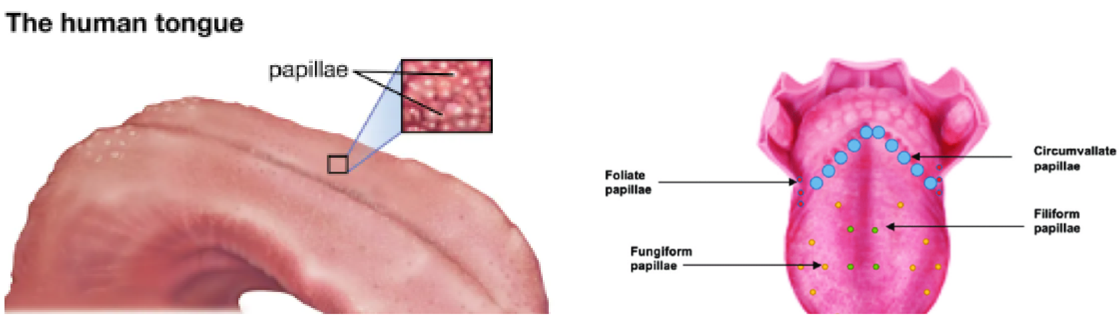

Figure 1. Diagram of papillae on the human tongue . The tongue is made up of papillae (left), with subtypes organized in a distinct manner (right). Images were obtained from Brittanica and Research Gate

Sensation differs from perception but both can be influenced by many factors including genetic differences as well as environmental and psychological aspects. This notion explains why individuals perceive stimuli in different ways. For example, the sensory perception of women is greater than that of men. A specific example of this is the olfactory bulb, located on the bottom side of the cerebral hemispheres in the brain (see Figure 2), which uses odor and taste information to the perception of flavor (Nichols 2023). Females have superior olfactory abilities, leading to better sensory perception.

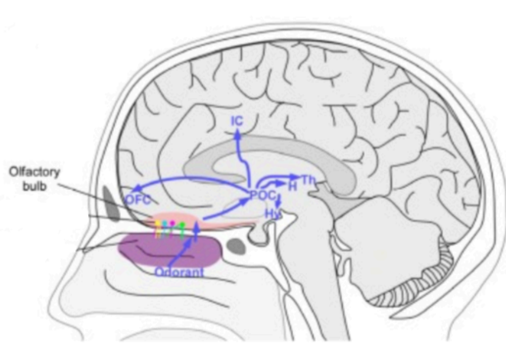

Figure 1. Visual of Olfactory Bulb. Image obtained from PubMed

The environment also plays a significant role in shaping an individual's ability to perceive taste. This idea of nature versus nurture is a controversial matter but closely relates to the idea of sensory perception. An individual's culture, race, ethnicity, and surroundings may impact perception just as much as their genetic makeup. Humans have adapted to different gastronomical palates and cuisine choices, causing some to be predisposed to perceive particular flavors and textures significantly better than others. The "nurture" aspect of nature versus nurture suggests that people with exposure to diverse foods have a more refined palate, which increases their ability to detect and differentiate between nuanced flavors. Overall, factors including genetics, sex, age, and experience largely determine an individual's ability to perceive different flavors. This study will evaluate the different roles of genetics, sex, age, and experience in the ability to perceive different flavors.

Genetics

Humans have many genetic features that contribute to taste sensitivities. Variations in taste receptor genes cause different perceptions of sweet, umami, and bitter tastes (Feeney 2012). However, the genetics behind perceiving sour and salty tastes are largely unknown, as they use different mechanisms, such as sodium ions and chloride anions, that differ from taste receptors.

Sweet, umami, and bitter tastes are perceived by the TAS1R and TAS2R taste receptor gene families (Feeney 2010). These two receptors are responsible for detecting some of the most basic tastes. The TAS1R receptors mammalian sweet and umami tastes, but the structure–function relationships of TAS1R receptors remain largely unknown (Treesukosol, 2011). Sweet and umami tastes developed as 'energetic detectors ' but bitter taste evolved as a warning against toxin ingestion. The human genome contains 29 bitter taste receptors, with T2Rs detecting numerous bitter ligands including toxic and aversive compounds. Of the T2R bitter taste receptors, TAS2R38 is one of the well-studied ones(Feeney, 2010). This gene focuses on the perception of the bitter-tasting thiourea compounds, which are found in brassica vegetables (a genus of plants in the cabbage and mustard family) and other health-beneficial foods such as green tea and soya. It also helps classify nutritional compounds from poisonous compounds (Feeney 2010). Variations in this gene are responsible for the three thiourea sensitivity groups of people: supertasters, medium tasters, and non-tasters. Compared to supertasters, tasters and non-tasters have fewer taste buds, and are less likely to consume dietary fat and to develop obesity (Duffy, 2006).

Additionally, genes are the reason why some individuals experience the taste of the same foods differently. The most common example of this is cilantro, which some people report tastes like soap. Interestingly, a 23andMe survey found that people who share OR6A2, the smell-receptor gene cluster, report a soapy taste. This is because OR6A2 picks up the scent of aldehyde chemicals, which are naturally found in cilantro leaves and used during soap making (Fink, 2021).

Age

The effects of age on taste sensation and perception can be observed throughout development and aging. Because an infant's diet consists mostly of milk, which falls under the sweet category, they prefer sweet tastes and reject sour and bitter tastes. The preference for salt appears at about 4 months after birth.

A baby's experience with flavors begins in the womb as flavors from the mother’s diet are transmitted through the amniotic fluid (Mennella 2001). After birth, babies continue to experience flavors of the mother’s diet through breast milk. A study reported that children who were only fed formula milk do not experience a wide range of flavors that breast milk can contain (Sina, 2019).

As humans age, our senses tend to weaken. Similar to how hearing abilities decline as cells within the inner ear die, taste sensation declines as a result of many different factors. As humans age, the amount of taste buds they have decreases and shrinks, causing them to become less sensitive to flavors. Until age 40, taste buds typically die off and regrow every ten days. As the number of taste buds declines, an individual becomes less sensitive to flavors; this is particularly notable after 70 years of age. This may be related to a loss of nerve endings and decreased mucus. Mucus helps odors remain in the nose, allowing them to be detected by the nerve endings and clears odorants from these nerve endings. (Brodkey 2022). The flavor of food comes from smell, so when the sense of smell is lost, the ability to experience flavor weakens.

Similarly, aging affects the salivary glands, which produce saliva and empty it into the mouth. Damage to the salivary glands can alter the quality and quantity of saliva, which makes tasting, chewing, and swallowing more difficult (Ord, 2023). Even certain central nervous system disorders such as Bell's palsy, multiple sclerosis, and epilepsy can produce deficits that inhibit tasting abilities. Age-related disorders, such as Alzheimer’s Disease and Parkinson’s Disease, can amplify these deficits. Genetic conditions like familial dysautonomia can alter the development of fungiform papillae, leading to deficits in sweet and salty perception, respectively (Kezirian 2009).

As humans age, certain tastes become more challenging to perceive than others. However, many studies focusing on changes in taste perception connected to aging have led to inconsistent results. One particular experiment consisted of two separate groups that varied in many factors, including age, that were tested for their taste perception abilities (Alia, 2021). Cotton pads soaked with sodium chloride, citric acid, sucrose, and quinine hydrochloride were applied to the tongue and each basic taste (salty, sour, sweet, and bitter) was given at 4 different concentrations (see Figure 3). Although no significant differences were found between the different age groups, the group with younger participants recognized more taste stimuli than the test group with older participants. The one exception was the sweet taste, which seemed to be perceived in the same proportion by both groups. This study concludes that younger people are more sensitive to taste stimuli, and therefore can detect it better.

Table 1

Concentrations of taste stimuli.

Stimulus	Substance	Concentration
Sweetness	Sucrose	0.05 g/mL
		0.1 g/mL
		0.2 g/mL
		0.5 g/mL
Saltiness	Sodium Chloride	0.016 g/mL
		0.04 g/mL
		0.1 g/mL
		0.25 g/mL

Table 2

Sociodemographic and Oral health related data of the studied groups. Data are expressed as Mean ± Standard Deviation.

	Control Group	Test Group	*p*-Value
Age (years)	74.6 ± 4.8	86.4 ± 7.0	<0.001
Sex (M/F)	32/26	8/24	
Height (cm)	162.9 ± 8.5	154.1 ± 9.9	<0.001
Weight (Kg)	74.9 ± 15.1	63.8 ± 11.8	<0.001
BMI (Kg/m^2)	28.1 ± 4.6	27.0 ± 5.2	NS [2]
No. of drugs	3.7 ± 2.3	8.2 ± 3.2	<0.001
Missing Teeth	5.3 ± 4.7	19.3 ± 9.1	<0.001
Occlusal Units	10.9 ± 2.5	3.6 ± 4.4	<0.001
DMFT [1]	13.3 ± 5.4	20.1 ± 8.3	<0.01
Masticatory Performance	0.43 ± 0.17	0.23 ± 0.18	<0.001

Figure 3: Images from the "The Influence of Age and Oral Health on Taste Perception in Older Adults: A Case-Control Study"

However, the particular tastes that are most difficult for elderly people to identify are still inconclusive. For example, data from the meta-analysis showed a decline in the perception of salty flavors, with an increase in the perception threshold with old age (Methven, 2012). However, a study by Drewnowski et al. reported contradictory results, suggesting that older and younger individuals had similar results in their salt perception (Drewnowski, 1996). The one taste that remained to have similar detecting thresholds for all ages is sweet. A small number of studies have inquired about sweet tastes and no clear pattern of age-related decline in sucrose was detected.

While testing, some researchers did not find any differences in tastant (a water-soluble chemical that produces a taste sensation by activating taste receptor cells) recognition between different age groups. The tastes that are more likely to undergo change caused by age are still unknown, but there is still adequate evidence to claim that age is a major factor affecting taste perception.

Sex

Males and females experience taste perceptions differently. As infants, humans have about 10,000 taste buds, but that number decreases over time as they generate less. Adult men typically have fewer taste buds than women, which may happen slowly throughout development and aging. Interestingly, about 35% of women are thiourea "supertasters", enabling them to identify bitter tastes more strongly than others, whereas the number is lower for men at 15% (ABC, 2015). It is suspected that, from an evolutionary standpoint, the tasting tools of females are more developed because of their important role in producing and protecting offspring — both during and after pregnancy, as they need to pay special attention to foods that may be harmful to the fetus' development. This may also explain why females have a stronger sense of smell than males. Women of childbearing age have stronger senses than women of pre-pubescent or post-menopausal ages. For example, human gonadotropin (hCG) is a hormone produced during pregnancy by the cells of the placenta, which circulates nutrients from the mother to the embryo (Betz, 2023). hCG is the likely culprit of dysgeusia, feelings of nausea, or loss of appetite. It may cause women to develop an aversion to the food they normally enjoy or like foods they normally dislike.

Similarly, a study was performed to discover how a menstrual cycle affects the tasting abilities of women. Gustatory (concerned with taste) and food habits were studied in 8 women between the ages of 23-37 years. Blood oestradiol (an ovarian hormone) and progesterone (steroid hormone) levels were evaluated on the 7th, 14th, and 21st day of each cycle. Recognition thresholds and cravings for sweet, salt, citric acid sulfate were tested on the 1st, 7th, 14th, and 21st day of each cycle. The types and amount of food consumed were recorded on days 1 and 2, 6-8, 13-15, and 20-22 each cycle. From this experiment, it was found that the four basic tastes were greatly influenced by hormone levels. Sensitivity to sweet taste and bitter tastes increased, whereas only a few correlations for salt tastes were discovered. No correlations were found between hormone levels and acid taste (Fidzana). This suggests that when women experience a menstrual cycle, their sensitivity to various tastes is affected differently because their hormones fluctuate. Although women's abilities as supertasters can be beneficial in the setting of pregnancy, there are also disadvantages. For example, females can be so sensitive to bitterness that they tend to be very picky eaters and dislike many foods, especially during one's menstrual cycle or pregnancy. On the other hand, the vast majority of men lack supertasting abilities, as their receptors aren't as sensitive. This could be seen as a positive because they will have less selective preferences and be more likely to eat healthier foods.

Environment

The areas where people live and their ancestral origins influence food preferences. For example, people who identify with Muslim or Jewish religious traditions may prefer Halal or Kosher foods, as that is what they are accustomed to consuming. Similarly, Singaporeans prefer to eat more unrefined carbohydrates such as oats, brown rice, and wholemeal bread. Indians consume more carbohydrates than Malays and Chinese, largely because their diets are mostly made up of rice and flour which are high-carbohydrate foods. Additionally, people living in the West tend to associate vanilla with sweeter foods, which enhances the perception of sweetness. On the contrary, in East Asia, vanilla is used more in savory dishes and therefore not used to make food taste sweeter. People's preferences for food can change largely depending on where they live and how their cultures use certain foods.

Aside from culture and ethnicity, other external factors affect what foods people prefer and how they perceive them. Taste buds may be inhibited by both high and low temperatures. Increasing the temperature of foods appears to increase responsiveness to sweetness and decrease responsiveness to saltiness and bitterness. On the other hand, decreasing the temperature of foods appears to increase responsiveness to bitterness and decrease responsiveness to sourness (Fona, 2015). Additionally, the ability to perceive tastes is reduced from one to four hours after a meal, depending on what the meal includes. A spicy meal will have a greater effect on subsequent food compared to a bland meal. During this time, flavors may not be perceived as strongly as they usually would. This may be a result of palette fatigue, which refers to the idea of the nose and taste buds being overworked, but researchers believe that the brain may also be fatigued with similar sensory information.

Interestingly, another environmental factor that influences food preferences is income. Low income is associated with poor-quality dietary intake (French, 2019). When comparing those with a higher income to those with lower income, individuals with lower incomes consume fewer fruits and vegetables, more high-sucrose beverages, and poor diet quality. The food that individuals consume is largely shaped in part by the household food purchases that create the home food environment, meaning that a family's grocery list reflects the quality of their diets. When a household begins to consume cheaper foods, and thus higher in calories, sugar, and salt, their preferences begin to conform accordingly. Their taste buds will become more sensitive to sweet and salty food, as they are constantly eating foods with those flavors. This relates to the controversial idea of nature vs nurture: although genetics, age, and sex impact food preferences, environmental factors that influence humans' lifestyles are significant.

Conclusion

Taste buds have proven to be much more complex than many previously anticipated. The formation of taste buds begins at the prenatal stage of a person's life and eventually falls into a process of reformation necessary for tasting. When activated, taste receptors sense flavors and send signals to the brain, allowing it to perceive these sensations. These ideas of sensation and perception are extremely important processes that occur and explain why humans undergo the sensory reactions they do. The ability of people to perceive tastes differently is also influenced by many factors including genetics, age, sex, and environment. The many studies cited in this paper clearly show how taste perception varies from person to person. These variations are further emphasized with concepts such as nature vs nurture. Overall, the ability of humans to taste the five different tastes isn't a simple matter, as the entire body and outside factors strongly impact taste perception.

Resources

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