is chemically and isotopically heterogeneous. The dynamical difficulties (*7*) encountered in delivering meteorites from Vesta to Earth suggest that Vesta has a low probability of being the source of these meteorites. Moreover, the young rubidium-strontium and argon ages of the shergottites are difficult to understand if they come from a small object such as Vesta, because recent internal heating is unlikely and impacts create only a small volume of total melt relative to unmelted material. However, the other solutions examined also have difficulties and appear to be even more improbable, on the basis of our current state of knowledge. At present, no meteorite group has been associated unequivocally with an existing astronomical object. Nevertheless, meteorites are samples from elsewhere in the solar system delivered to Earth at no cost. In view of the chemical similarities between Earth and shergottites, and the moon and eucrites, the plausible identification of these meteorite types with an astronomical object is an important contribution to our knowledge of the distribution of chemical composition in the solar system.

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Human Taste: Response and Taste Bud Number in Fungiform Papillae

Abstract. *The number of basic taste qualities registered by single human fungiform papillae is correlated with the number of taste buds borne on these papillae. Multiple sensitivity was demonstrated both in single fungiform papillae and in single taste buds, with response to all four of the basic taste qualities occurring in a single taste bud.*

Taste depends on an interaction between stimulus ions or molecules and receptors located in taste buds. On the mammalian tongue, taste buds are found on the circumvallate, foliate, and fungiform papillae (*1*). Fungiform papillae, because they are easily located and separated from other structures on the dorsal anterior part of the tongue, have been the most convenient experimental system for both psychophysical and electrophysiological studies of taste. Some psychophysical experiments (*2*, *3*) have indicated that single fungiform papillae react to only one of the four basic taste qualities (salt, sweet, sour, and bitter), whereas others have shown that more than one taste can be identified by a single papilla (*4*-*9*). In addition, not all fungiform papillae can be stimulated (*6*-*9*). These conflicting reports have raised the questions of whether a single papilla can respond to more than one taste quality and, if so, whether the number of taste qualities recognized is related to the number of taste buds borne by that papilla, especially since taste bud numbers seem to vary more than is usually assumed (*10*).

We compared the number of taste qualities recognized with the number of taste buds present per papilla in a total of 110 fungiform papillae of 31 volunteer subjects (*11*). The volunteers ranged in age from 18 to 35 and were in good general and oral health. Before the tests began, volunteers were familiarized with the techniques involved in stimulating both a small area on the anterior part of the tongue and single papillae (*6*, *8*, *12*); they were also given preliminary tests for response to all of the taste solutions. Nine other potential volunteers were excluded during these preliminary tests because they reported taste sensations with both distilled and tap water or because they were unable to distinguish among the four taste qualities (or both).

The concentration of taste solutions was adequate to ensure a strong taste sensation without being painful. Analytical reagent 10 percent sodium chloride (1.7*M*), 2 percent citric acid (0.1*M*), 0.01 percent quinine hydrochloride (0.025*M*), and 40 percent sucrose (1.2*M*; commercial grade) solutions made in glass-distilled water and stored frozen were used as test solutions; distilled water was

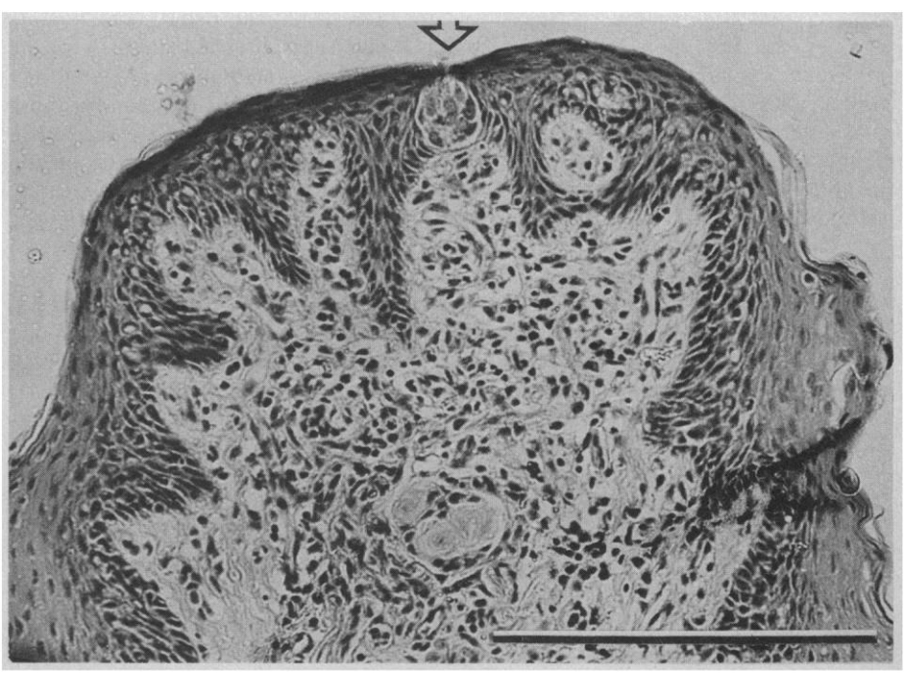

Fig. 1. Upper portion of a fungiform papilla showing a single taste bud (arrow). The bar indicates 0.25 mm.

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Table 1. Taste responses correlated with number of taste buds (*15*).

Taste response	Number of papillae with a given number of taste buds															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No taste	62*	2														
Salt			1													
Sweet			1	1†												
Sour		1	1				1									
Bitter				1												
Salt, sweet				1												
Salt, sour		1		1				1	1							
Salt, bitter						1										
Sweet, sour		3	2		1											
Sweet, bitter						1										
Sour, bitter			1	1			1									
Salt, sweet, sour						1										
Salt, sweet, bitter				1												
Salt, sour, bitter		1	1	1	2			1								
Sweet, sour, bitter			1													
Salt, sweet, sour, bitter		1	1	1	2	2	2	1		1	1		1			1
Total	62	9	9	8	5	5	4	3	1	1	1		1			1

*That is, 62 papillae without taste buds gave no taste response. †Also gave sour response for stimulation with salt.

used as a control. Test solutions were thawed, mixed thoroughly, and used at room temperature (21°C).

A total of two to six papillae, one per session, were examined in each subject with a 2- to 3-day interval between test sessions. For 2 hours before each test session the subjects did not eat, drink, or smoke. Test solutions were delivered in random order and coded by an assistant to eliminate bias. Subjects responded to solution application by pointing at a 5-choice card (salt, sweet, sour, bitter, and no taste) to indicate sensation prior to withdrawing the tongue. After each trial subjects rinsed their mouths with tap water and were then asked to describe the previous taste sensation as weak or strong. In a few cases when the taste sensation was indistinct, the test was repeated after the water rinse. After the test session the papilla was excised with a fine scalpel, fixed, and embedded in paraffin for light microscopic examination and counting of taste buds in serial sections (*10*).

A total of 195 taste buds were found in the 110 papillae examined [mean ($\bar{X}$) = 1.8, standard deviation (S.D.) = 2.8]. No taste buds were found in 62 papillae (56 percent). In the bud-bearing papillae, the number of taste buds varied from 1 to 15 ($\bar{X}$ = 4.1, S.D. = 3.0), with 26 papillae (24 percent) having between one and three and 22 papillae (20 percent) four or more taste buds, all located on the upper dorsal surface of the papillae (Fig. 1). These findings agree with other recent results (*10*).

The 62 papillae with no taste buds gave no taste response. In addition, two papillae with one morphologically typical taste bud each also gave no taste response. The number of taste qualities perceived by the 46 other bud-bearing papillae varied from one to four (Table 1). Seven papillae responded to only one of the tastes, 16 to two, 9 to three, and 14 to all four of the stimuli. Only one papilla, containing three taste buds, showed an incorrect response, salt being registered as sour. The number of papillae responding to sour was greatest (38 of the 46), which corresponds to previous findings (*6*). There was little difference between the other taste qualities: salt (29), sweet (27), and bitter (28). The intensity of the bitter taste was weak in 17 of the 28 papillae responding to quinine. This is not surprising, since quinine is a much less effective stimulus for the nerve fibers innervating the fungiform papillae (chorda tympani) than for those innervating the circumvallate and foliate papillae of the posterior third of the tongue (glossopharyngeal nerve) (*13*). The intensity of the sweet taste was strongest in three papillae bearing two, four, and ten taste buds.

A clear majority of the responsive papillae (39) thus reacted to more than one taste stimulus, corroborating the concept of multiple sensitivity in human fungiform papillae (*5, 6, 8, 9*). However, although there was no simple relationship between the number of taste qualities recognized by a fungiform papilla and the number of taste buds on that papilla, the number of taste qualities identified generally increased with taste bud number (r = .80). Of the 24 taste-responsive papillae bearing from one to three buds, ten answered to a greater number of stimuli than would be expected if a single taste bud were sensitive to only one taste quality. In fact, one papilla with only a single taste bud responded to all four taste solutions. Clearly, then, taste buds also exhibit a multiple sensitivity. This result tends to support previous microelectrode recordings from taste buds of fungiform papillae in the rat, which indicated that even a single cell may respond to more than one taste quality (*14*). If a single taste cell or taste bud can register more than one taste quality, the related phenomena of cross-adaptation, taste inhibition, and modification may be understandable by analogy with enzyme-substrate binding and competition models.

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15. The procedure for stimulation of single papillae has been described (*8*). Briefly, subjects were seated in a dental chair equipped with a head and chin rest for stability and comfortable access to the tongue. A single fungiform papilla, not too close to other such papillae, was selected on the anterior part of the tongue and ringed with methylene blue for identification. Under a ×15 stereomicroscope, the papilla was gently sucked up above the surrounding filiform papillae and dried by aspiration with a fine polyethylene suction tube. Test solutions were applied to the tip of the papilla with fine (diameter, 0.127 mm) platinum wire loops (*6*). The loops had previously been determined to deliver a droplet that was not large enough to spread beyond the surface of a single papilla. Except for a weak sensation of pain during scalpel excision of the papilla, the experiments caused no discomfort, and no aftereffects were observed.
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