flavor of food becomes aversive after one illness, after which the sights and sounds of the prey may still elicit attack but the aversive flavor inhibits feeding. Phase two occurs when the auditory, visual, and olfactory cues from the prey become associated with the now aversive flavor, thus subsequent attacks are inhibited and perhaps a second treatment is unnecessary. In some cases emesis may forge an association between vomited gustatory cues and odors of the vomitus which is sufficient for the second phase of conditioning.

For suppressing sheep predation, we could scatter baits that smell like sheep, taste like sheep, and contain a nonlethal emetic toxin. We could also perfuse carcasses of lambs and sheep with lithium. The predator could then be expected to subject himself to repeated trials until the flavor and the spoor of sheep becomes aversive. Subsequently, when foraging it would turn away before it sights sheep. Thus in open range, the aversive effect may be much more durable than our extinction data indicate. Our coyotes had no other food and few other activity options in the small enclosure. The lambs persisted in following the coyotes, and occasionally a rabbit literally leaped into a coyote's jaws.

In addition, the feeding habits of the mother coyote averted to sheep might be transmitted to her pups, via flavor which her diet imparts to her milk, and by their early experience with the prey she brings to the den. Similar mechanisms have been demonstrated in the rat (*6*). This method should be effective against other predators, such as large cat species and eagles. Studies (*7*) indicate that birds form aversions to the visual as well as gustatory aspects of food, so the infused lamb may be the method of choice for eagles. Finally, since it is known that flavors are enhanced when beneficial effects follow ingestion (*8*), this method could also be used to change the food preferences of some species that are endangered because their naturally preferred food is diminishing owing to ecological change.

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4. To establish maximal learning in one or two trials and thus minimize attack testing, we employed the combination of (i) LiCl (6.0 g) treated food in case the animal vomited and reingested the vomitus and (ii) intraperitoneal injection to ensure an effective absorbed dose. Since 0.12*M* LiCl is similar in flavor to physiological saline, lithium treatment does not radically alter the flavor of the prey.
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Sugar Sweetness and Pleasantness: Evidence for Different Psychological Laws

Abstract. *Sweetness and the pleasantness of sweetness of sucrose solutions and sweetened food conform to different functions. Sweetness rises with concentration, whereas pleasantness first rises and then decreases. The breakpoint appears to occur at a constant sweetness (that is, constant sensory) level.*

The "sweet tooth" is a widespread phenomenon of animal behavior, and the exceptions, according to Pfaffmann (*1*), are ". . . remarkable largely for their divergence from what otherwise appears to be a general rule . . . . Gustatory stimuli, therefore, appear to be biologically determined as the instigator of consummatory . . . responses." From studies of animal behavior it is relatively difficult to distinguish between the discriminative function of sweetness as information and the reinforcing property of sweetness, although direct methods have been used with some success in specific experimental paradigms (*2*). Electrophysiological evidence from the recordings of chorda tympani suggest that the hedonic and intensity aspects of taste conform to quite different laws (*1*), but relatively little attention has been paid to man, whose capacity for language can allow him to evaluate, simultaneously, the intensity and hedonic aspects of taste stimuli.

Investigations of sweetness and the pleasantness of sweetness through human psychophysical scaling raise the possibility that two quite different growth laws may be obtained, by instructing the observer to attend to these two separate aspects of taste impressions. When an observer matches numbers to sweetness so that ratios of these numbers reflect ratios among perceived sweetness, then rated sweetness appears to increase systematically according to a power function of concentration: $S = kC^n$ (*3*), where S is sweetness; C, concentration; and k and exponent n are constants. The pleasantness of the same sweet taste does not, however, rise continuously with concentration (*4*) but either flattens out or may even decrease at very high concentrations. Human psychophysical scaling of taste intensity and taste pleasantness rely upon short-term exposures to sugar solutions (a model system), so that the scientific study of taste hedonics is based upon stimuli that do not resemble actual foods. This study concerns functional relations for both the model system and real foods, and thus bridges the gap between stimuli that are usually not consumed and foods that are. As a result, one can determine whether functions obtained in simple systems have applicability to the world in which behavior takes place and whether the parameters determined in the former domain apply to the latter.

In a previous study by Moskowitz (*4*) the sweetness-pleasantness relation was reported for sugar plus water. The method of magnitude estimation was used in order to obtain ratio-scale values for both sweetness and pleasantness. For the same set of concentrations of sugars, rated sweetness grew more rapidly than rated pleasantness, and up to the sweetness of 1.0*M* glucose, pleas-

Table 1. Parameters of the sweetness and pleasantness functions.

	Sucrose solutions	Beverage	Pudding	Cake
		Sweetness		
Category scale				
k_1	7.68* (.4)†	6.98 (.3)	5.65 (.4)	5.71 (.4)
k_2	3.64 (1.1)	4.94 (.9)	4.81 (1.2)	4.61 (.9)
r^2‡	.77 .98	.76 .99	.61 .96	.55 .99
Magnitude estimation				
k_3	1.06 (.1)	1.22 (.1)	1.06 (.1)	0.77 (.1)
k_4	1.21 (.3)	1.16 (.3)	1.14 (.2)	1.15 (.2)
r^2	.52 .99	.51 .99	.63 .99	.30 .99
		Pleasantness		
Category scale				
k_5	−7.59 (2.0)	−11.03 (2.4)	−22.20 (2.1)	−12.36 (4.5)
k_6	−4.32 (.7)	−0.42 (.8)	−3.92 (.7)	0.6 (.9)
k_7	4.85 (1.3)	6.33 (1.3)	6.81 (1.3)	6.80 (1.1)
r^2	.23 .99	.24 .98	.48 .89	.12 .97
Magnitude estimation				
k_8	−2.02 (.8)	−1.06 (.5)	−3.83 (.5)	−2.05 (.5)
k_9	−0.60 (.3)	0.42 (.12)	−0.16 (.2)	0.22 (.1)
k_{10}	0.99 (.3)	1.18 (.3)	1.26 (.3)	1.2 (.2)
r^2	.14 .94	.41 .98	.08 .93	.29 .99

* Numbers in parentheses (for parameters k_1, k_3, k_5, k_6, k_8, and k_9) represent the standard error of the coefficient (group data). † Numbers in parentheses (for parameters k_2, k_4, k_7, and k_{10}) represent the standard error of the regression. ‡ First number pertains to group data, second number to mean data (averaged across 30 individuals).

antness increased monotonically with concentration. At sweetness levels higher than that of 1.0*M* glucose, pleasantness decreased with subsequent increments of concentrations (and thus of sweetness).

Do diverging sweetness-pleasantness functions characterize actual foods as well as sugar solutions? More fundamentally, do psychophysical functions generated for model systems apply to real foods as well? In order to answer this question 30 observers (ages 24 to 65; 21 males, 9 females) judged both the sweetness and the pleasantness of that sweetness of four foods (*5*). Each food (sucrose solution, cherry-flavored beverage, vanilla pudding, and yellow cake) was prepared with five concentrations of sucrose, including that required by the recipe. Each observer participated in two sessions. In one session the observer judged all 20 foods and provided estimates both of sweetness and of pleasantness of sweetness for the same sample (total of 40 judgments) by the method of magnitude estimation. In another session the observer again judged the same foods, but by the method of category scaling (interval scaling). In all sessions the observer tasted the food, expectorated it without swallowing, and made his ratings. For scaling sweetness the observer was instructed to call category 1 "no sweetness" and category 9 "extreme sweetness." For category scaling of pleasantness the observer used the nine-point Hedonic Scale (*6*), which comprises nine ordered categories (1, dislike extremely; 5, neutral; and 9, like extremely). The order of scaling sessions and the order of foods within a session, as well as the order of sucrose concentrations within a single food, were all counterbalanced to reduce possible biases due to order.

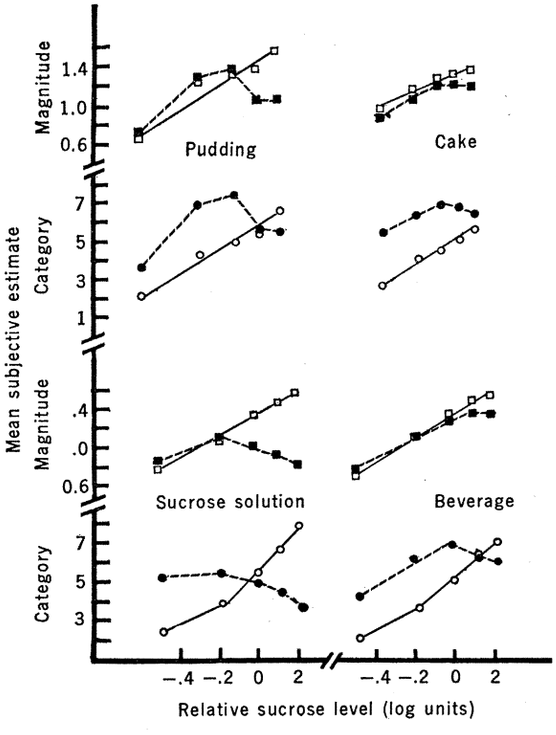

Fig. 1. Relation between sucrose concentration and mean estimate of sweetness or pleasantness, respectively, by the methods of category scaling and magnitude estimation. The mean subjective estimates for a single scaling procedure and for a single attribute (sweetness or pleasantness) are comparable across foods. Symbols: ○, sweetness; ●, pleasantness; □, magnitude estimation; and ■, category estimation.

Least-squares fits of logarithmic functions for category scaling and power functions for magnitude estimates provided the following equations:

Sweetness (category)
$$S = k_1(\log C) + k_2 \quad (1)$$

Sweetness (magnitude)
$$\log S = k_3(\log C) + k_4 \quad (2)$$

Pleasantness (category)
$$P = k_5(\log C)^2 + k_6(\log C) + k_7 \quad (3)$$

Pleasantness (magnitude)
$$\log P = k_8(\log C)^2 + k_9(\log C) + k_{10} \quad (4)$$

The squared terms (Eqs. 3 and 4) are needed in order to represent the significant nonlinearities of the pleasantness functions.

The relation between sucrose concentration and both sweetness and the pleasantness of sweetness are shown in Fig. 1, and the parameters of the functions are provided by Table 1. The following occur for these scales of sweetness and pleasantness:

1) At low levels, the pleasantness of taste grows either more slowly than or as rapidly as the sweetness intensity and, except for pudding, never more rapidly than sweetness intensity. Judgments of pudding sweetness and pleasantness are anomalous here, suggesting that possible additional factors besides sweetness enter into the sweetness-pleasantness relation.

2) At high sweetness levels pleasantness either diminishes or levels off with increasing concentration (and thus with increasing sweetness).

3) The approximate breakpoint in the pleasantness function occurs at a constant sweetness level for the foods (approximately 4.5 to 5.0 for the category rating of sweetness and between 1.0 and 1.2 for the logarithm of the magnitude estimate of sweetness).

4) Foods have a higher sweetness level for their breakpoint than sucrose solutions do, but the form of the sweetness-pleasantness relation is similar for model systems and for these foods. The fact that foods have the higher sweetness tolerance before the breakpoint suggests partial cognitive control over the pleasantness function that interacts with the perception of sweetness.

5) The downward sloping portion of the pleasantness function is no steeper (in absolute value) than the upward sloping portion.

In light of the present results it appears possible to disentangle the sweetness (discriminative) and pleasantness (affective, hedonic) aspects of a taste impression, both in foods and in model systems, and to represent each by its own unique function. It is important that real foods, evaluated by the same procedures as model systems, conform to topographically similar functions. This similarity suggests that there may be a general system of functions to govern the relation between chemical concentration of tastants in foods, taste intensity, and taste pleasantness. Caution is warranted about extensions of the present functions to foods that are not usually sweetened, however. Unsweetened foods, when sweetened, may yield functions for "unpleasantness of taste" that differ in shape from those found here (especially with respect to the absence of a breakpoint in the unpleasantness function).

The present results and approaches to sensory and hedonic measurement bear upon two major areas. First, the existence of a breakpoint at a *fixed sweetness* (not a fixed concentration) is evidence that the pleasantness response is predicated upon sensory intensity. The critical sensory sweetness needed for the breakpoint is approximately invariant. [That is, the sweetness of 1.0*M* glucose, or 18 percent by weight and volume, and 0.21*M* sucrose (here), or 7.1 percent by weight and volume, are approximately equal by direct magnitude estimation of sensory intensity reported by Moskowitz (*4*).] Furthermore, the breakpoint, a type of yes-no phenomenon occurring at the same response level across different experiments, implies that sensory sweetness is encoded in absolute terms, not relative terms, in the sensory system. Otherwise, the sensory intensity of sweetness corresponding to the breakpoint of the pleasantness function would be expected to shift dramatically from one experiment to another, both as a function of the context and the nature of the other stimuli being judged.

Second, the existence of the breakpoint and the difference between sweetness and pleasantness functions can be used to investigate hedonic responses to taste input under varying body states (for example, hunger, satiety, obesity, and so forth). Recent studies by Cabanac (*7*) suggest that body state modifies the hedonic response to foodlike materials (such as sugar solutions). Cabanac's studies can be extended by the simultaneous use of sweetness and pleasantness scales for sucrose solutions and foods to determine whether the breakpoint continues to appear after a satiating meal, and, if it does continue to appear, whether the breakpoint occurs at the same sweetness level as before. Insofar as the present procedure yields conclusions based upon interrelations among several subjective judgments, it allows a more bias-free measurement of hedonic response than procedures that rely upon changes in the response to a single stimulus over time and treatment.

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Surface Charge, Protein Adsorption, and Thrombosis

The recent report by Mattson and Smith (*1*) appears to be derived from and leading to some misconceptions.

The reviews listed under reference 1 in (*1*), if read carefully, show that no agreement exists about primary causes of protein adsorption, platelet adhesion, and thrombosis. Friedman *et al.* (*2*) [reference 3 in (*1*)] did not state "that the free energy of the surface is responsible for its thrombogenicity" (*1*) but rather that it "depends primarily on blood flow rate, time of exposure of the surface to blood, and possible platelet activity, rather than properties of the surface (which may, however, affect sequelae to adhesion)" (*2*).

Perhaps the net charge of a surface plays a role in thrombosis under certain conditions. Unfortunately, it is a negative rather than a positive charge (on glass, collagen, and phospholipid micelles) that enhances blood clotting. Stoner and Srinivasan (*3*) [reference 5 in (*1*)] erroneously reported that, according to me (*4*), the Hageman factor —possibly the first clotting factor in the sequence leading from contact with a surface to the clotting of blood—would be activated by positively rather than negatively charged surfaces.

The material used by Mattson and Smith (*1*) was 60 percent clottable fibrinogen, in other words, 40 percent something else. Their methods are unsuited for the identification of adsorbed protein, and not very well suited for quantification. Vroman and his co-workers have found that ellipsometry allows the identification of the adsorbed protein, if used in conjunction with specific antisera to identify adsorbed matter (*5*).

Mattson and Smith seem to suggest that the behavior of their crude fibrinogen preparation bears a relationship to the behavior of fibrinogen in whole plasma. I believe that, for such a comparison, their preparation is not quite crude enough. In several publications (*5*) Vroman and his co-workers reported that fibrinogen is deposited more or less preferentially by normal plasma onto several surfaces but is, within 30 seconds, modified by the plasma itself. Elsewhere Zucker and