Psychologic Factors Regulating the Feeding Process

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Workers in the fields of psychology, physiology, nutrition and related areas have frequently assumed that the quantity of food ingested per day by an animal is a measure of some hypothetic entity called "appetite." For example, in the pioneer studies of Richter the operational definition of appetite has been "intake per day." If the daily intake of a 3 per cent sodium chloride solution increases after adrenalectomy, it is said that the appetite for sodium chloride has increased. Again, if rats depleted of vitamin B stop eating carbohydrate and ingest large quantities of fat, it is said that the appetite for carbohydrate has decreased and that the appetite for fat has increased. Independent variability of intake is the main evidence for existence of separate appetites (or specific hungers) for protein, fat, carbohydrate, water, minerals and vitamins.

This assumption, that quantity of food consumed per day is a measure of "appetite," agrees with a common sense notion that the better one likes a food the more one eats of it. The cook is flattered when all the biscuits are eaten but disappointed if they remain on the plate untouched! Yet, the view that the quantity of food consumed measures a unitary "appetite" must be abandoned for the reason that intake does not depend upon a single factor.

There are at least four kinds of factors that regulate intake: (a) affective arousals determined by excitation of the head receptors and by post-ingestion conditions; (b) feeding habits and attitudes based upon dietary experience; (c) neural organizations that facilitate or inhibit ingestion of foods; and (d) the chemical constitution of the organism as determined by the genes and by dietary history.

I wish to consider several of these factors and their interrelations and for convenience will consider them under three main headings: (1) Taste and post-ingestion regulators of intake. (2) The relation between bodily needs and feeding habits. (3) The psychologic and chemical bases for the organization of feeding habits.

At the start, however, I should say a few words about the two main types of apparatus we have used in our experiments. One type permits the rat to make a choice between two kinds of foodstuff (solids or fluids) that are presented simultaneously and briefly for choice. The other kind of apparatus records fluid intake continuously during brief exposure (5 to 20 minutes) or continuously for 24 hours or more.

**TASTE AND POST-INGESTION REGULATORS OF INTAKE**

McCleary distinguished between taste factors and post-ingestion factors in the regulation of intake. He demonstrated the importance of the internal determinants by introducing solutions through a tube directly into the stomach of the rat. He found that pre-loading the stomach with glucose or fructose solutions depressed the ingestion of glucose after the tube had been removed. McCleary believes that osmotic pressure (varying with the kind of substance and the concentration) is the important factor associated with...

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depression of intake. He found that pre-
loads of urea, sodium chloride and glucose,
when matched for osmotic pressure, produced
equivalent amounts of depression of ingestion.
Interestingly enough, pre-loads of hypotonic
saccharin solutions did not depress the sub-
sequent ingestion of glucose solutions and Mc-
Cleary suggests that the intake of saccharin
solutions is regulated by taste factors as dis-
tinct from post-ingestion factors.
Shuford studied the relation between the
head receptors and the internal regulators with
a different method but his results agree com-
pletely with those of McCleary. Shuford
arbitrarily selected for study three concentra-
tions of glucose solution, namely, 5, 15 and 35
per cent, by weight. For each of these glu-
cose solutions he determined the concentra-
tion of a sucrose solution that was equally
acceptable to his panel of 30 albino rats. In
determining equally acceptable (isohedonic)
concentrations a series of preference tests were
run in which a constant concentration of glu-
cose was compared, in turn, with several con-
centrations of sucrose solutions. From the
results of preference tests the isohedonic
values were computed.
Repeted tests have shown that when the
subject has only a brief contact with a sugar
solution or an immediate choice between two
sugar solutions the sweeter is regularly preferred to the less sweet. With sucrose solu-
tions, for example, both rats and men prefer
the higher concentration to the lower all the
way up the continuum from zero (distilled
water) to a saturated solution. The reason
why this fact is important is that if one de-
pends upon the volume of intake to determine
relative acceptability, one finds an optimal
concentration at about 8 or 9 per cent but no
such optimum exists when the subject is
limited to a brief contact with an immediate
choice. The sweeter solution is regularly preferred to the less sweet.
In Shuford’s tests each of the 30 rats was
given a 20-minute drinking test with six solu-
tions presented, one at a time. The six solu-
tions were presented according to a counter-
balanced Latin square design.
Figure 1 shows the cumulative mean intake
of the solutions. These pairs of curves demon-
strate the following points:

(1) During the first few minutes of drinking,
the equally acceptable sugar solutions were consumed at the same rate.

(2) The initial rate of ingestion is a function of the concentration or degree of sweetness. This can be seen by comparing the initial slopes of the three pairs of curves. This initial rate of acceptance follows the rule that a higher concentration of sugar solution is more acceptable (as shown by the rate of acceptance) than a lower concentration.

(3) The inhibition of ingestion is definitely related to the osmotic pressure of the substance in solution. Osmotic pressures for the equally acceptable pairs of solutions are shown in Table I.

If the curves for the 5 per cent glucose and 2 per cent sucrose solutions are compared, the similarity is remarkable. The taste factor evidently determines the shape of these curves since all rats were non-thirsty before and during the tests. The divergence of curves for the other isohedonic pairs of solutions can be attributed to the operation of a post-ingestion factor since the two kinds of sugar solution differ greatly in osmotic pressure but not in sweetness or palatability. The shape of the intake curves, then, is determined by two opposing factors: a facilitating taste factor and an inhibiting post-ingestion factor, related to osmotic pressure.

The work of McCleary and Shuford clearly demonstrates that intake is regulated by two distinct groups of factors: head receptor factors and internal organic processes. Hence we can not rely upon the total quantity of food ingested as a measure of some hypothetic entity called "appetite." The post-ingestion inhibition of intake is closely related to what we commonly call the satiation of appetite; but appetite, in this sense, is distinct from palatability.

THE RELATION BETWEEN BODILY NEEDS AND FEEDING HABITS

The early claim of J. M. Evvard that the appetite of the pig is a reliable indication of physiologic need found partial support in the self-selection feeding experiments of C. M. Davis with infants and children and in the numerous self-selection experiments of Curt Richter with rats, as well as in the work of W. F. Dove and various other investigators. In 1944, however, the Editors of Nutrition Reviews, after considering available evidence, published the following six statements about appetites as a guide to nutrition:

(1) Appetites are often fickle and unpredictable.

(2) Appetites may be trivial in origin.

(3) Nutrition based upon appetites is not universally successful.

(4) Individual animals vary in their ability to make choices that will improve their nutritional status.

(5) Factors affecting human appetites may be expected to be more numerous and more complex than those affecting the appetites of animals.

(6) From the evidence, self-selection of diets appears to be inferior to scientific evaluation of diets for the maintenance of good nutrition.

In the light of this blast from the nutritionists, and even apart from it, no one today would have the temerity to claim that the food choices of animals are an infallible guide to correct nutrition. On the other hand, there is danger that these statements will lead to an opposite extreme view: that there is no relation at all between food selections and bodily needs. The truth lies somewhere between these extreme views. The experimentalist must ask questions like these: To what extent are the food selections of animals in agreement with their metabolic needs? What are the mechanisms that regulate the selection of foods and how are these mechanisms related to bodily needs?

A dramatic example of the relation between bodily need and feeding habit appeared
Groups of rats were maintained upon a self-selected diet in large cafeteria cages. From time to time they were given brief-exposure preference tests between two of the components of their diet: sucrose and casein. A clear and consistent preference of sucrose to casein developed. Then the protein was removed from the diet, all other elements remaining the same. After 25 to 32 days of depletion there were objective signs of protein starvation: loss of weight, reduction of general food intake, development of peptic ulcers, etc. With severe protein starvation the rats continued to select sugar (which they did not need) in preference to casein (which they did need). This was a very unwise choice. Then we tested the rats with a new technic in which the test-foods were widely separated but located in familiar places. The animals had to choose between running to sugar or running to casein. Under the new testing conditions the rats quickly learned to run to casein. The preference was clear and consistent.

At the close of the experiment it was possible to put the animals on the standard preference tester and demonstrate a preference of sugar to casein. Five minutes later the same rats, on another apparatus, clearly revealed the reverse preference, a preference of casein to sugar. The second choice was a wise one agreeing completely with manifest bodily needs.

The interpretation of this result, made after a series of control experiments, is as follows: The initial preference of sugar to casein was based upon palatability relations. It is commonly known that rats like sugar and do not like casein (although they will accept it). The first preferential habit (for sugar) was persistent. This habit stabilized food selections even when the choice was inappropriate. The introduction of a different technic for testing preferences required the animals to form a new habit and this new habit developed in agreement with manifest bodily needs. The general underlying principle is this: New habits tend to form in agreement with bodily needs, but established habits tend to persist as regulators of food selection even when the food selections are out of line with bodily needs. In other words, feeding habits once formed tend to stabilize the choice of foods independently of need but habits do tend to form in agreement with needs.

The question remains as to how a need for protein led to the organization of a protein-selecting habit. It is possible that the protein starvation changed the palatability of casein so that it tasted better to the rats, but it is also possible that some organic relief from the distress that was produced by severe protein starvation was the basis of the new habit. This is a problem that requires further study.

In a well-known investigation of Harris et al. rats were depleted of thiamine. They were then given a choice between diets containing a small but sufficient quantity of thiamine and diets that lacked the vitamin. Under these conditions the animals failed to discriminate between adequate and inadequate diets. The vitamin-depleted rats were then educated. They were given only the adequate diet, marked by a particular flavor, for a few days. When they had associated relief from organic distress with a particular flavor they continued to select the diet with that flavor even after the vitamin had been withdrawn and placed in another diet. Apparently a diet must be labeled by a flavor and, further, it must be associated with relief from organic distress before the dietary habit will form.

Other work upon the organization of dietary habits has been reported. Scott and Quint published observations upon the appetites for certain vitamins. They report that rats maintained upon an adequate diet do not show any appetite for thiamine, riboflavin, or pyridoxine. But if the animals are maintained upon a diet deficient in these vitamins, they develop an appetite for them. Animals depleted of pantothenate, however, do not develop an appetite for this vitamin unless it is placed in a food that is clearly labeled with a flavor; even then some of the rats fail to select the vitamin-containing diet.

Scott and Verney believe that the appetites for thiamine, riboflavin, and pyridoxine are learned. These appetites are probably learned by vitamin-depleted rats through associating the eating of a vitamin-containing diet with
some beneficial experience that had occurred at the time of the ingestion of the adequate diet. Scott and Verney thus agree with the views expressed by Harris et al.7

In summary, it is clear that feeding habits may or may not agree with bodily needs, that such habits tend to stabilize the selection of foods quite apart from bodily needs and, most emphatically, that some food habits are organized in complete agreement with bodily needs.

THE PSYCHOLOGIC BASIS FOR THE ORGANIZATION OF FEEDING HABITS

It is important, in the light of the above evidence, to consider the basis of habit organization. Upon what do feeding habits depend? There are two kinds of answers that I should like to consider: The first is psychologic, the second is chemical.

In considering the hedonic basis for the organization of feeding habits it is necessary to distinguish between affective arousals that are dependent upon stimulation of the head receptors and affective arousals that are dependent upon internal organic conditions.

Palatability and Appetite

The term palatability refers to the hedonic value of a foodstuff that is dependent upon its taste, aroma, texture, temperature, appearance, etc., and that may be modified by its surroundings. In other words, palatability implies an affective arousal that is dependent upon excitations of the head receptors. The hedonic hypothesis states that animals learn to select and to seek foods which they like rather than foods which they need, or require nutritionally, but there is a considerable agreement between what an animal likes and what he needs. Similarly, animals avoid foods which they dislike rather than foods that are harmful but, again, animals tend to dislike foods that are injurious. The term appetite, as used in everyday life, implies a conscious desire for a specific kind of foodstuff. Appetites are built up through depletion of needed substances; they are satiated through ingestion of the needed substances.

The relation between palatability and appetite will be illustrated by a recent experiment9 upon the acceptability of different kinds of drinking water. The subjects in the illustrative experiments were 12 adult female rats. To eliminate thirst an unlimited supply of tap water was kept continuously present in the cages where they lived. The rats were taken from these cages into an adjoining room where their responses to two kinds of drinking water were immediately tested by the brief-exposure preference method. Each animal was given a series of choices between tap water and distilled water. The animals were thoroughly familiar with both kinds of water prior to the tests and with the testing procedure.

Under these conditions 5 of the 12 animals selected tap water in preference to distilled water. The choice of tap water was statistically significant at better than the one per cent level of confidence. Animals that did not meet the criterion of statistical significance still took tap water more frequently than distilled. The group as a whole selected tap water in 67 per cent of all choices whereas a chance selection would yield 50 per cent.

After the preference for tap water had been clearly established the rats were made thirsty by depriving them of water for 20 to 23 hours prior to the preference tests. As expected, the thirsty rats were much more active upon the apparatus. Minute for minute, during the 12-minute tests, the thirsty rats made more runs than the non-thirsty. But the thirsty animals were much less discriminating. No thirsty rat showed a preference for tap water and only one animal revealed any preference at all (a temporary preference for distilled water).

How can we interpret this result? The initial choice of tap water, I assume, is based upon a palatability difference. Rats and men like the taste of tap water better than the taste of distilled water. In our rats thirst raised the level of acceptability of both kinds of water. The increment in acceptability attributed to thirst obscured the relatively small difference in palatability.

The experiment, I think, demonstrates an
important relation between palatability and thirst as separate but interrelated determinants of the acceptability of different kinds of drinking water.

**Affective Arousals with an Internal Organic Basis**

It should be pointed out that affective arousal occurs after foods have been ingested. A square meal, to a healthy person, brings a feeling of comfort and well-being; and the ingestion of certain foods, e.g., green apples, produces acute gastric distress.

We know that the deprivation of oxygen or water or the accustomed maintenance food quickly produces acute distress. Further, as we know, a diet that lacks an essential element such as protein or thiamine sooner or later produces a specific deficiency. Distress produced through depletion does not necessarily imply any craving, or appetite, to remove it. The organism may suffer from a dietary deficiency and have no knowledge of the nature and cause of his distress. But if relief from discomfort can be associated with the ingestion of a particular kind of food, then the organism can learn the behavior necessary to accept and pursue a particular kind of food.

Accordingly, feelings of comfort and discomfort, based upon the eating of certain foods and also upon depletion or repletion, are clearly affective arousals. In a psychologic sense, they are affective arousals just as truly as the pleasantness from a sweet taste or the unpleasantness from a bitter taste.

In general, it is our hypothesis that feeding habits are organized on the basis of affective arousals. These arousals may be based upon the taste, smell, temperature and texture of foods, i.e., upon palatability. Or affective arousals may be associated with the after-effects of eating or of being deprived of nutritive substances. Thus the affective-arousal hypothesis extends far beyond palatability effects to take account of affective arousals produced by post ingestion conditions and through depletions of dietary substances.

**CHEMICAL REGULATORS OF FOOD PREFERENCES AND ADDICTIONS**

**Food Preferences and Body Chemistry**

Our studies with rats have shown that food preferences are learned. When given an opportunity to choose between two foods, rats learn to select one in preference to another. The increasing frequency of choice we have called a preferential trend. The preferential trend indicates that the subject is learning to discriminate preferentially between two test-foods. Preferences develop quickly or slowly. When a preference develops quickly we assume that the foods are widely separated in acceptability; when the trend moves slowly we assume that the foods are near together in acceptability. In special instances where no preference develops we assume an equality or near equality in the level of acceptability of the test-foods.

We have repeatedly found that when all the rats in a group are maintained upon a constant diet the animals in the group tend to develop one and the same pattern of food preferences. There are occasional signs of individuality in preference. For example, in one study 42 rats were given a preference test between casein and sucrose. Of these, 41 preferred sucrose and one consistently preferred casein. Why this animal differed from the rest of the group we do not know, but from time to time such individual differences have been observed. Possibly individual differences in food selection depend upon individual differences in body chemistry.

We have demonstrated that the pattern of preferences revealed by the group is dependent upon the diet. For example, if rats are fed a protein-deficient diet, the preferential rating of casein is higher than that of sucrose but with a protein-adequate diet, casein has a low rating.

My guess is that food preferences and body chemistry are very significantly related to each other. There are doubtless species' differences in food preferences that depend upon differences in the chemical constitution of organisms, but very little is known about this matter. There is great need for research in
which biochemical controls are combined with precise studies of preferential patterns.

Addictions and Body Chemistry

Hebb distinguishes between habits and addictions. Both feeding habits and addictions are learned and both have a neural basis; but the addiction, as distinct from the habit, has a biochemical basis.

Hebb pointed out that an objective science of behavior must deal with specific patterns of food-seeking behavior that are learned, or acquired. Hence the problem of specific hunger is really a problem of how specific food-seeking patterns are acquired. Addictions, such as the addiction to alcohol or morphine, are acquired gradually; they take weeks or months to develop. When an addiction has once developed there is some kind of internal chemical adaptation that makes it necessary for the organism to maintain a blood concentration of a specific substance for the maintenance of stable neural functioning. When the addiction has become established the addict is in discomfort and often in emotional distress if he is deprived of the substance to which he has become addicted. The addiction clearly has a chemical as well as a neural basis.

CONCLUSION

The total intake of a substance per day is assuredly an important measure for the science of nutrition; but in the study of behavior it is misleading to assume that intake measures a single variable called "appetite." Appetite is a genuine determinant of intake, but it is not the sole determinant. Intake depends upon the palatability of the foods, the affective arousal that follows ingestion of certain foods, or being deprived of them, the existing habits and attitudes of an organism, and the chemical state of the organism as determined by its constitution and dietary history. In addition to these factors there are complex physiologic regulators of intake which we have not considered in this paper.

It is here suggested that an appetite (specific hunger) be defined in behavioral terms as an acquired determination to seek out and select a particular nutrient. Further, it is suggested that the psychologic and chemical determinants of the feeding process be studied in relation to each other. Both a chemical and a psychologic approach are required for an adequate analysis of patterns of food preference and addictions.

Finally, it is clear that we cannot rely too strongly upon the wisdom of the body as a guide to correct nutrition. This must be supplemented by the wisdom of the nutritionist based upon years of careful research. But even the wisdom of the nutritionist is insufficient if he fails to take account of the psychologic factors that regulate the feeding process. After the nutritionist has prepared an adequate diet the animal may refuse to eat it, or he may eat excessive quantities and suffer therefrom. Hence the science and art of feeding animals and men must rest upon psychologic principles as solidly as it rests upon the principles of physiology, chemistry, and the science of nutrition.

REFERENCES


