Basic Oral Physiology

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Preface

ORAL PHYSIOLOGY is a rather new body of knowledge that has only recently been included in the undergraduate curriculum of dental schools. When I began to teach oral physiology to undergraduates eight years ago, the only available texts were far too detailed and advanced, suitable for graduate level courses only. I therefore began to compile a set of notes that has eventually formed the basis of this book.

The physiology of the oral cavity is a particularly exciting topic, since sensory and motor systems interact to regulate such highly intricate functions as mastication, swallowing, salivation, and speaking. Yet the mouth is essentially a feeding organ, and all of these oral functions are therefore primarily concerned with food identification, intake, and processing. Thus, I have organized this book with food intake as a unifying concept, but other oral functions have not been neglected. For example, since food and inspired air meet at the larynx, the mouth must also play a primary role in preventing food from entering the airway. Another essential oral function is speech production, which involves not only the oral cavity but also structures principally designed for respiration.

The chapters are organized to cover the feeding function of the oral area. After brief introductory chapters on feeding in general, the next chapters detail the physiology of sensory input from the mouth. Subsequent chapters describe the physiology of the motor output to the salivary glands and muscles, as well as the central control functions that integrate the sensory input and motor output. The final chapters of the book cover the production of speech and a number of topics that are peripherally related to oral function.

Among the most exciting recent advances in oral physiology are neurophysiologic investigations that explore central nervous system control of orofacial function. I have therefore included much neurophysiologic data, and the reader should be familiar with basic neurobiology. I have assumed that the student has already taken a course in general physiology. For students requiring additional information, references have been added at the end of each chapter and footnotes are used to define terms that may be unfamiliar.

Many individuals have been influential in the preparation of this text, and I owe them a note of appreciation. My students have provided many helpful criticisms and comments. Drs. Arthur Storey and Ronald Dubner read an early manuscript and gave valuable suggestions. I also appreciate the help of Dr. Katarina Borer on a particular chapter, and Dr. Charlotte Mistretta's advice on many aspects of the text. The book has been typed and retyped many times, but the major effort was by Mrs. Andy Appel, Ms. Diana Stacy, and Ms. Barbara Sonntag, whose help and patience made the book possible. In addition, I must thank numerous colleagues and scientific publishers for granting permission to reproduce many of the figures. Last but not least, I am grateful for the help and understanding shown by the editorial staff of Year Book Medical Publishers.

ROBERT M. BRADLEY
ANN ARBOR, 1981

Contents

1 / Oral Factors in Feeding

OBJECTIVES

At the end of this chapter you should be able to:

1. Explain the dual roles played by oral receptors in feeding.
2. Understand the terms *preference* and *aversion*.
3. Explain how preferences and aversions are measured.
4. Describe the different preference and aversion behavior for different tastes.
5. Describe how human taste responses are measured.
6. Understand the concept of hedonic* ratings of taste.
7. Understand the behavioral manifestation of the "sweet tooth."
8. Describe the role of oropharyngeal sensation in food selection.
9. Describe the motivational role of oropharyngeal sensations in feeding behavior.
10. Understand the innate and learned aspects of taste preferences and aversions.
11. Describe the health-related consequences of motivational aspects of food preferences.
12. Describe methods to combat the ill effects of the "sweet tooth."

INTRODUCTION

MOST INDIVIDUALS would agree that the flavor of food and drink is important to them in making a choice on whether to choose or reject a particular component of a menu. While many factors are responsible for this behavior, oral receptors, including taste, smell, temperature, and touch, provide important inputs for the control of food intake. Oral sensations arising from these receptors taken together contribute to the overall sensation of flavor. Food with a

*Hedonics is the study of the property of pleasantness/unpleasantness of a sensation.

good flavor is palatable and encourages ingestion, whereas non-palatable food will be avoided or ingested in lesser amounts.

The role of oral sensation in food intake has been examined in both humans and animals. Most of the research in this area has concentrated on the taste component of flavor; the roles of smell, touch, and temperature in palatability have not been investigated extensively. Thus the information in this chapter on the role of oral sensation in the control of food intake deals almost exclusively with taste sensation. And the taste stimuli that have been used in these studies consist of pure chemicals dissolved in distilled water usually at one concentration. It is only recently that work has been reported on sensory evaluation of complex mixtures of sensations such as those found in foods.

The work using solutions of chemicals provided the basis for the later studies on foods and has effectively demonstrated that oral receptors play a dual role in feeding. They have been found to be important in the identification of nutrients and also provide incentives for feeding.

IDENTIFICATION AND CHOICE OF NUTRIENTS

Preference-Aversion Behavior

At the basis of food preferences and aversions is *choice*. Humans make choices when selecting their foods either in a raw state or as prepared in a restaurant. The choices are not absolute but are scaled, so that for a particular individual some foods are more preferred than others. To measure taste preference and aversion, experiments have been performed in which animals have to choose which food or fluid to consume. The choice is exercised on the basis of the flavor of the food or fluid—how it tastes, smells, and feels (temperature and texture). Even the color of food is important.

In one type of experiment to demonstrate the importance of taste, an animal is given a choice between two drinking bottles, one containing distilled water and the other a solution of a chemical in water. If the animal prefers the chemical solution, it will choose to drink it rather than water. On the other hand, the animal will reject the solution if it does not like the taste; that is, the animal will show an *aversion*. If the animal cannot taste the solution (for example, if the concentration or the taste is too weak), or if the animal neither likes nor dislikes the solution, it will take equal volumes from the water and solution bottles. By this simple test, the taste preferences and aversions of an animal may be examined. In the case of a strong preference, the animal will show 100% intake of the solution and for strong aversion 0% intake of the solution. The results from such an experiment, in which four tests were made with solutions that taste bitter, sour, sweet, or salty to man, are shown in Figure 1–1. Not only were the animals presented with solutions having different tastes but also the concentrations of each taste solution were altered.

As illustrated in the figure, consumption (or preference) is not the same for all of the solutions. When the concentrations of salt and sucrose presented to the animals are increased, intake increases so that, at certain concentrations, almost 100% of fluid intake is from the salt or sucrose solutions. At this peak salt or sucrose concentration, the animals are exhibiting a strong preference. Once this concentration is exceeded, intake decreases; that is, the animals begin to show aversion at very high concentrations

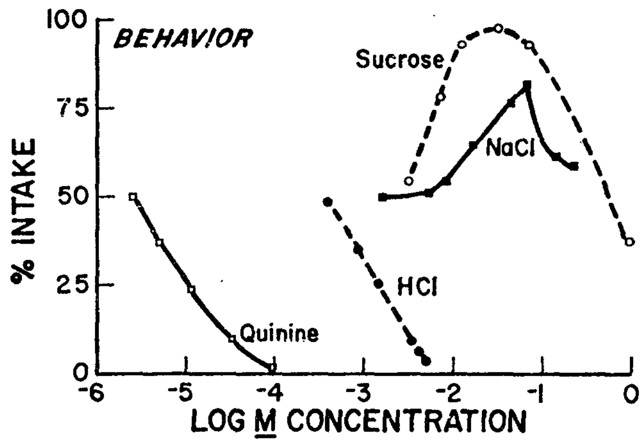

Fig 1–1.—Percentage preference or aversion for different concentrations of sucrose, NaCl, HCl, and quinine in rats. In this figure and many others in this book, concentration is expressed in Molar, or M, concentration. This is a standard method of expressing concentration. A Molar solution contains one gram molecular weight of the solute in one liter of solution. (From Pfaffmann C., *Psychol. Rev.* 67:253–268, 1960. Copyright 1960 by the American Psychological Association. Reprinted with permission.)

of salt and sucrose. On the other hand, the curves for quinine and hydrochloric acid are quite different. As soon as the solutions reach a concentration that can be tasted, the animals drink them in lesser amounts.

Measurement of Human Food Preferences and Aversions

It is not possible to use the two-bottle preference test in humans. However, it is possible to present humans with solutions of chemicals and ask them to evaluate the taste of the solutions. This type of testing, called *hedonic* testing, can be accomplished in a number of ways. One method in use is to assign numbers to various descriptions of taste sensation, ranging from "dislike extremely" to "like extremely." A typical hedonic scale is listed in Table 1–1.

Observers, therefore, have to taste a particular solution and make a decision in assigning one of the descriptions to the perceived taste. Other scales have been developed, and these often reflect the quality being investigated. For example, food manufacturers developing a new beverage may change the descriptions in order to measure a particular aspect of the taste of the drink. The result of a category scaling for the four taste qualities of salt, sweet, bitter, and sour is shown in Figure 1–2. In this experiment, humans were given various concentrations of sodium chloride, glucose, quinine sulfate, and citric acid, and, using the hedonic scale listed in Table 1–1, assigned a label from the six possible labels to the perceived taste. The assigned number then was plotted against concentration (open circles). At the same time, the intensity of the solution was also estimated (closed circles).

Both the concentration, or intensity, and the taste quality are important in determining hedonic rating. Quinine always is rated as unpleasant (at low concentration it is rated as category 3, but as concentration increases it becomes categories 2 and 1). Salt and citric acid are pleasant at a certain concentration and then become

TABLE 1–1.—CATEGORY HEDONIC SCALE

1. Dislike extremely
2. Dislike moderately
3. Dislike slightly
4. Like slightly
5. Like moderately
6. Like extremely

rapidly unpleasant. On the other hand, the glucose function increases in pleasantness with concentration, and even at high concentrations, although liking does not increase, never is rated as unpleasant. Similar relationships between hedonic rating and intensity have also been reported for sucrose. The quality of sweet, therefore, is unique among the four taste qualities in that it does not seem to taste unpleasant. However, although this is true for most individuals, there are some who do not show this characteristic hedonic curve for sweet. A certain number of humans do find that as intensity of sweetness is increased, the perceived sensation is rated as unpleasant.

It should also be noted from Figure 1-2 that the curves for in-

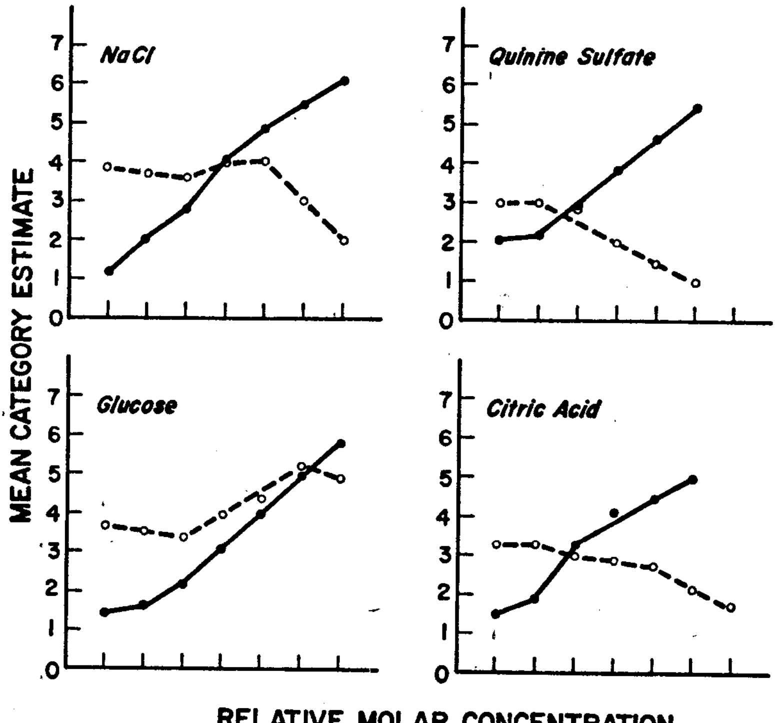

Fig 1-2.—Relationship between concentration of solutions of sodium chloride, glucose, quinine sulfate, and citric acid and intensity *(closed circles)* and hedonics *(open circles)*. (From Moskowitz H., in Weiffenbach J.M.: *Taste and Development: The Genesis of Sweet Preference*. U.S. Dept. H.E.W. DHEW Publication # [NIH] 77-1068, 1977, p. 286.)

tensity (see Chapter 3 for details of intensity scaling of taste) are not the same as the hedonic curves (except perhaps for sweet). In general, increasing concentration is rated with an increase in perceived intensity. The difference between the curves for ratings of intensity and hedonics reveals that despite the fact that only concentration of the stimulus is being changed, the behavioral response can be quite different, depending on what parameter of the stimulus sensation is being examined.

Role of Oropharyngeal Sensation in Preference-Aversion Behavior

From the preceding discussion it should be apparent that the solutions with different tastes produce different behavior patterns. A number of experiments have shown that these behaviors are mediated by oropharyngeal sensations. In preference testing experiments, the animals are not deprived of food and therefore have no nutritional need. Saccharin solutions, which have no caloric value, are preferred to water, and quinine solutions are avoided as soon as they are tasted. The amount of quinine swallowed never is large enough at any concentration to produce its aversive behavior by being ingested. In addition, the aversion to quinine takes place as soon as it is tasted, before ingestion has taken place. Most individuals tasting quinine immediately would express disgust and not only refrain from swallowing the solution but try to rinse the taste away.

Two experiments have demonstrated the need for taste in order to manifest preference-aversion behavior. In the first of these, the animals were provided with an esophageal fistula, so that the solutions taken into the oral cavity, when swallowed, were prevented from reaching the gut. The preference-aversion curves in these animals were identical to control animals, thereby demonstrating that oral sensation alone, and not postingestional factors (effects produced by digestion of the solution), was necessary to produce the behavior.

The second experimental procedure was to prevent the animals from tasting the solutions. Fluids were made to bypass the oral cavity and flow directly into the gut. These animals show no preference-aversion function. When the same animals were allowed to taste the solutions, normal preference-aversion functions were obtained (Fig 1–3).

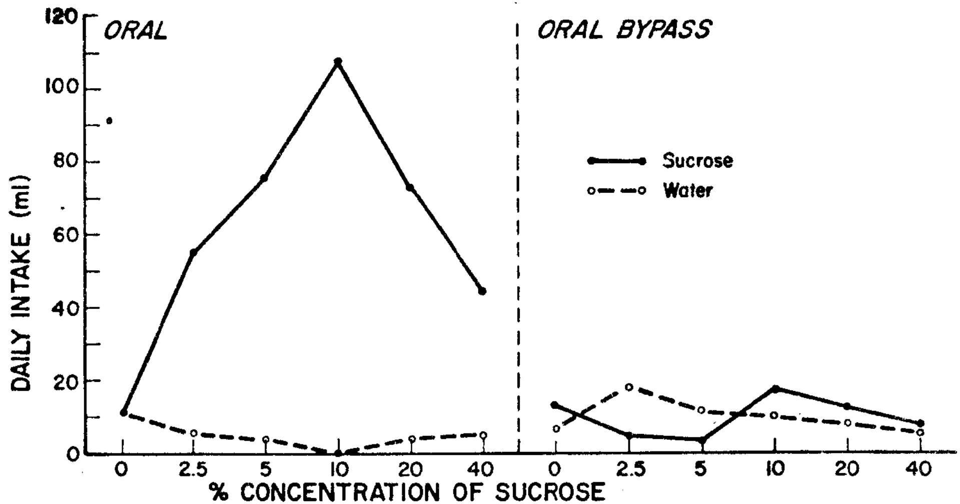

Fig 1–3.—Disappearance of the preference-aversion curve for sucrose when animals bypass the oral receptors. On the left-hand side, the animals tasted the solutions and showed typical preference-aversion behavior for sucrose. On the right of the figure, the fluids (water and sucrose) bypassed the oral cavity, and the typical preference-aversion curve disappears. (From Borer K., *J. Comp. Physiol. Psychol.* 65:213–221, 1968. Copyright 1968 by the American Psychological Association. Reprinted with permission.)