Annu. Rev. Nutr. 1999. 19:41–62

DEVELOPMENT OF FOOD PREFERENCES

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KEY WORDS: children, food intake, overweight, obesity

ABSTRACT

Using a developmental systems perspective, this review focuses on how genetic predispositions interact with aspects of the eating environment to produce phenotypic food preferences. Predispositions include the unlearned, reflexive reactions to basic tastes: the preference for sweet and salty tastes, and the rejection of sour and bitter tastes. Other predispositions are (*a*) the neophobic reaction to new foods and (*b*) the ability to learn food preferences based on associations with the contexts and consequences of eating various foods. Whether genetic predispositions are manifested in food preferences that foster healthy diets depends on the eating environment, including food availability and child-feeding practices of the adults. Unfortunately, in the United States today, the ready availability of energy-dense foods, high in sugar, fat, and salt, provides an eating environment that fosters food preferences inconsistent with dietary guidelines, which can promote excess weight gain and obesity.

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0199-9885/99/0715-0041$08.00

INTRODUCTION

This review addresses the factors that shape the development of humans' food preferences during the first years of life. The term "preference" refers to the selection of one item over others. In general usage and in this review, preference connotes that liking is the basis for selection, although liking is only one of a number of motives that affect food selection (47, 53, 98, 106, 114, 117, 124). Food preferences are learned via experience with food and eating. However, the more widely accepted but erroneous view is that food preferences are unlearned, innate reflections of the body's need for nutrients. Because this view has had a pervasive influence on popular beliefs about the etiology of food preferences, research that either supports or refutes the "wisdom of the body" is briefly reviewed below. The bulk of the review addresses how early learning and experience affect the development of food preferences and, in particular, how genetic predispositions to accept or reject foods work in concert with the eating environment to shape learned food preferences. Genetic predispositions for basic tastes place constraints on food preferences. Genetic predispositions also include developing preferences for foods based on associations with the contexts and consequences of eating the foods.

In determining food selection, food preferences and "taste"[1] reign supreme (2), which emphasizes the important source of pleasure eating provides in our daily lives. The only activities of daily life rated higher than "a fine meal" were (*a*) spending time with family, (*b*) holidays, and (*c*) sex (136). Tiger (134) has argued that making essential behaviors pleasurable increases the likelihood the species will survive. However, although taking pleasure in eating may be adaptive in some circumstances, recent evidence suggests that many Americans are taking too much pleasure in food. The prevalence of overweight and obesity is high and still increasing (75, 97): Roughly half of American adults are classified as overweight (body mass index of >25), and the prevalence of overweight in children has doubled over the past 20 years (101). Although the causes of the increasing prevalence of overweight are multiple, including changing trends in energy expenditure (68, 75, 97), recent data confirm a link between adiposity

[1] In the strict sense, the term taste refers only to those sensations arising from the taste system, which includes basic tastes of sweet, salt, sour, and bitter. In common usage, it tends to be used instead of the word flavor, a more inclusive term used to denote the complex of sensory cues, including those arising from olfaction, taste, and touch systems, which have a major influence on our food preferences.

among children and their food preferences and food selection (56). American diets are still too high in total energy, too high in discretionary sugar and fat, and too low in complex carbohydrates (75). As reported by 40% of Americans, the major obstacle to consuming healthier diets is fear of having to give up preferred foods (2). Results from a recent survey of 3307 2- to 19-year-olds showed that 45% of children's total energy intake came from discretionary sugar and fat (96) and that the intake of only 1% of children met all dietary guidelines.

Much of early research conducted on food preferences and dietary self-selection was designed to investigate whether food preferences supported the selection of nutritionally adequate diets. The "wisdom of the body" theory stated that food preferences reflected innate, unlearned "special appetites" for needed nutrients, including sugar, salt, fat, protein, carbohydrate, and micronutrients. One study supporting this theory reported that when animals without nutrient deficits were allowed to self-select their diets from foods representing various nutrient sources, they grew well and showed no signs of nutrient deficit (113). Although such data have been widely cited in support of the "wisdom of the body," Galef (62) pointed out that the data, in fact, do not support it: ". . .the evidence is not consistent with the view that replete animals can reliably compose a nutritionally adequate diet. . . . General acceptance of the view that omnivores can easily self-select nutritionally adequate diets is attributed both to over reliance on theory and to lack of critical attention to data" (62, p. 218).

Research with infants and young children by Davis (40–43) has also been cited as evidence in support of this theory, although the author herself disagreed with this interpretation. In a series of longitudinal dietary self-selection studies with infants and young children conducted over periods of weeks or months, children were offered at each meal a variety of 10–12 nutritious foods, simply prepared, without added sugar and salt or other seasonings (40–43). The children chose from among the foods offered, and the nurses were instructed not to interfere with or control the children's food choices in any way. Davis reported that the children grew well, were healthy, and had no feeding problems. However, rather than interpret this as evidence for the "wisdom of the body," she emphasized that "self selection can have no value if the diet must be selected from inferior foods."

Davis' research emphasized that the food available in a child's environment was critical in determining the ability of the child to self-select adequate diets. The "trick" of the experiments was in the foods that were made available to the children—they were offered only nutritious foods, simply prepared without added flavors or salt—and Davis emphasized that whether or not children preferentially selected adequate diets from among the foods available depended on what they are offered. She also cautioned against interpreting her findings as evidence for innate, unlearned "wisdom of the body." She rejected the idea that children had innate preferences and instead favored the idea that children's preferences developed over time and were acquired via experience: As an infant's experience with foods grew, food preferences began to emerge. Davis' observations suggest an alternative to the innate preferences of the "wisdom of the body": Children were predisposed to respond to novel foods in systematic ways and to prefer some tastes to others, but they also were predisposed to learn preferences for foods made available to them. Despite Davis' interpretations and other critical evaluations of the view that food preferences support adequate food selection (62, 130), the "wisdom of the body" still persists as a theme in contemporary pediatric texts and in some popular books for parents on child feeding (76).

It is important to note that nearly all the research with humans on food preferences and food selection has been conducted among affluent, white, middle-class US and Western European populations, where inexpensive, energy-dense food is readily available (see 134a for an exception). Because food preferences and food selection are causally linked to the current prevalence of overweight and obesity, the focus on studies from affluent populations can be justified. However, priority should be given to research that compares the development of food preferences across differing food environments. Perhaps the best current example of the pervasive and clear effects food availability has on food preferences and food intake comes from the cross-national survey data linking increased gross national product to increased availability and intake of high-fat foods and the prevalence of overweight individuals (60, 110).

Food Preferences: A Developmental Systems Perspective

A developmental systems perspective is used in addressing the question of how food preferences develop. This perspective, derived from evolutionary biology, views development as a result of the interaction of genetic predispositions with environmental factors (61, 69), and it allows us to move beyond the question of whether genes or environment are more important in development. Rather than ask whether it is "nature or nurture," the question has become, "How are genes expressed in differing environmental contexts to produce particular phenotypes?" In this case, food preferences and food selection patterns are the phenotypic behaviors that result from these gene/environment interactions.

Parents provide genes and, especially during the early years of a child's life, create the child's eating environment, making it difficult to separate genetic and environmental factors (109). The parents' child-feeding practices are influenced by their own weight history, which also has a genetic component (20, 57, 58). The choices parents make, beginning with their choice of an infant-feeding method (breast or bottle), affect their subsequent child-feeding practices (59) and the infant's developing food-acceptance patterns (132). With respect to how a child's early experience affects food preferences later in life, it is possible that food preferences formed early in life persist to affect adult food selection; however, there are no longitudinal data to either support or refute this view (17, 111).

GENETIC PREDISPOSITIONS INFLUENCING THE DEVELOPMENT OF FOOD PREFERENCES

The developmental systems perspective implies that environmental factors work conjointly with genetic predispositions to produce food preferences. The genetic predispositions that initially constrain food preferences include (*a*) the predisposition to prefer foods that are sweet and salty and to reject those that are sour and bitter; (*b*) the predisposition to reject novel edibles (neophobia) and to learn preferences for the more familiar; and (*c*) the predisposition to learn preferences by associating foods with the contexts and consequences of eating them. Most of the research investigating an infant's genetic predisposition to respond preferentially to basic tastes was conducted during the 1960s and 1970s and is reviewed only briefly here (see 37 for an excellent review of this literature).

Although these predispositions are common to all normally developing members of the species, an additional research challenge is to identify genetic variability contributing to the development of individual differences in phenotypic food preferences. For recent reviews of the genetic effects on individual differences in food preferences and food selection in adults, the reader is referred to Reed et al (112) and Pérusse & Bouchard (103). These reviews tend to suggest that in humans, genetic differences account for relatively little of the variance in food preferences and that environmental factors are important. With the exception of research exploring how, in children's responsiveness to the bitter taste of 6-N-propylthiouracil (PROP), individual differences relate to food preferences (4), research has not yet been conducted to address how genetic variability in children's predispositions to respond to basic tastes interacts with their experience to shape individual differences in food preferences.

Our species-typical genetic predispositions probably evolved because they had adaptive value, promoting the ingestion of edibles that were good sources of needed nutrients. However, this evolution occurred over thousands of years, in a food environment very different from the present one. The high and increasing prevalence of overweight individuals suggests that the predispositions that were adaptive under conditions where food was scarce are not adaptive in today's environment, described as "obesigenic" (75), where inexpensive foods high in sugar, fat, total energy, and salt are readily available.

Predispositions for Basic Tastes: Sweet, Bitter, Sour, and Salt

SWEET By using a variety of measures, including ingestion and facial expressions, newborns were found to prefer sugar solutions to water (45, 46, 129), and sweeter solutions were preferred over less sweet solutions (100). Although it is not possible to know for certain what emotional responses accompany an infant's reflexive facial reactions elicited by the basic tastes, her response to the sweet taste—a combination of relaxation of the facial muscles and a retraction of the mouth angles, resembling a smile (36)—is interpreted by adults as "she likes it." Work by Blass & Fitzgerald (27) reveals that the ingestion of sweet sugars leads to endogenous opioid release, which could mediate the infant's apparent pleasure response to a sweet taste. Further corroborating evidence (28) indicates that during circumcision, the presentation of a sweet taste reduces an infant's crying and distress.

The predisposition to prefer a sweet taste is readily modified by experience with food (9, 131). To determine how the preference for sweet was altered via early feeding experience, Beauchamp & Moran (9) conducted longitudinal research examining the preferences for sweet solutions versus water of 199 infants at birth and then at 6 months of age. They reported that at birth, all infants preferred sweet solutions to water, but by 6 months of age, preference for sweetened water was linked to the infant's dietary experience. Approximately one quarter of the infants were routinely fed sweetened water by their mothers. These infants showed a greater preference for sweetened water than did infants who had not been drinking it. This effect was specific to water and did not generalize to other beverages.

Based on their experience with sweet taste in food, young children learn that some foods are appropriate contexts for sweetness whereas others are not (131). Preschool children repeatedly given tofu, either plain, salted, or sweetened, came to prefer the version that had become familiar to them. This finding suggests that, in general, sweet taste is preferred but only in familiar food contexts.

BITTER Infants show negative facial expressions to bitter tastes. In contrast to the gustofacial response to sweet taste, facial expressions of newborn infants in response to bitter tastes—depression of the mouth angles accompanied by an arching of the center portion of the upper lip—are interpreted as "dislike" or "distaste" (129). This reaction is present at birth, prior to learning. However, newborn infants do not reliably inhibit their intake of bitter-tasting fluids relative to water (44), at least when urea is used as the stimulus. It is possible that infants perceive the bitter taste but that they are not yet able to use this ability to modulate intake.

More recent research suggests there may also be developmental trends in an infant's response to bitter tastes (79). Although newborns did not reliably reject the bitter taste of urea, such rejection reactions were evident among infants 14–180 days old, which suggests that developmental shifts in perception of bitter taste, or in the ability to use the bitter taste to modulate intake, occurred during the first months of life. As with other basic tastes, as early as infancy, this species-typical response to bitter is modified by experience. Protein hydrolysate formulas taste bitter and, owing to the presence of free amino acids, are not well accepted by infants. However, they are best accepted by infants who have had early experience with these formulas (93).

In addition to species-typical responses to bitter taste, genetic differences also contribute to the variability in human reactions to bitter substances. Duffy & Bartoshuk (50) reviewed the evidence that, among adults, individual differences in sensitivity to the bitter substances PROP and phenylthiocarbamide (PTC) are due to genetic differences, with those who have the two recessive alleles being nontasters and those who have one or both dominant alleles being tasters. Gender differences also influence the distribution of tasters and nontasters, with females more likely to be tasters. In the population in general, approximately 30% of individuals are nontasters and 70% are tasters. Anatomical studies indicate that tasters have a greater number of fungiform papillae than nontasters have (50, 133).

A number of studies that have classified adults based on their status as tasters or nontasters have explored whether there are other differences in perception and preferences for basic tastes, in particular sweet tastes, between tasters and nontasters (48). These studies indicate that PROP tasters are more likely than nontasters to dislike sweet taste and to be more sensitive to the bitter taste of caffeine and quinine, and more sensitive to the burn of capsaicin, the active ingredient in chili pepper. PROP tasters also prefer mild tastes over sharp tastes and have more food dislikes (4, 49, 55, 133). In the one study conducted with children, Anliker and colleagues (4) investigated relationships between PROP-taster status and food preferences in 5- to 7-year-olds. They noted some systematic differences in PROP-taster status and the children's acceptance of milk and cheese.

SOUR Infants also show negative gustofacial reactions to sour substances (129) and reject solutions having sour tastes (citric acid) (44). No research has been conducted to determine links between perception of sour taste and food preferences or to assess how the preference for sour may change with experience during the early years of life.

SALT At birth, salt does not reliably elicit either a consistent distinctive facial expression (129) or a differential intake that would indicate that salty substances are distinguished from water or that salt is a preferred taste (8). Reports of accidental poisonings of newborns fed formulas prepared with salt instead of lactose suggest that infants either did not detect high levels of salt in formulas or were not able to inhibit their intake of concentrated salty solutions (54). A reliable preference for the salty taste appears at about 4 months postnatally (7, 8, 71). These findings are consistent with developmental shifts in salt perception and preference observed among other mammalian species (74). The relatively late appearance of the preferential response for salt has been interpreted by some as evidence that salt preference is due to experience with salt in foods, but research by Harris et al (72) revealed a preference for salted over unsalted cereal in exclusively breast-fed infants 16–25 weeks old, indicating that this preference was not dependent on experience with salted foods (human milk is relatively low in salt content).

By early childhood, children's most preferred level of salt is more concentrated than that preferred by adults (6, 10), a pattern similar to that noted for sweet solutions. Infants' and children's preference for salt is also shaped by their experience with salt in foods (6), and perinatal experience may influence salt preference later in life (39, 128). Crystal & Bernstein (39) explored the relationship between mothers' experience with morning sickness during pregnancy and infants' salt preference at 16 weeks. Based on self reports, they selected mothers who (*a*) were "moderate-to-severe vomiters" during early pregnancy or (*b*) reported no vomiting during pregnancy and then assessed their infants' reactions to 0.1 and 0.2 M salt solutions, using both infants' facial expressions and intake as measures. Results revealed that mothers who reported moderate-to-severe dehydration during early pregnancy had infants who showed higher salt preferences. This finding is similar to that for young adults reported by Crystal & Bernstein (38), who showed differences in salt preferences as classified based on retrospective reports of their mothers' experiences with pregnancy sickness.

INNATE PREDISPOSITIONS TO PREFER OR REJECT BASIC TASTES: SUMMARY AND IMPLICATIONS There are species-typical predispositions to respond preferentially to the basic tastes: At birth, sweet taste is preferred and sour and bitter are rejected; preference for salt emerges by approximately 4 months. These predispositions affect the infants' behavioral responses to these tastes, including their reflexive facial expressions and their intake. There is now substantial evidence that these predispositions to prefer sweet and salty substances and reject bitter ones are readily altered via experience with food and eating. In the predisposition to reject bitter tastes, there is evidence that genetically coded individual differences in taste perception and preferences are linked to preferences for complex food stimuli, although the evidence for these links in children is limited.

Data on infants' predispositions to respond preferentially to basic tastes can make only a limited contribution to our understanding of the development of food preferences. First, these initial predispositions are readily modified via early experience. Second, foods are complex systems that, in addition to taste, stimulate the olfactory, tactile, and visual sensory systems. Most of what we refer to as the "taste" of food is really flavor, a combination of taste and smell, as well as mouth-feel and other textural cues (50, 52). Third, responses to basic tastes have an unlearned component that may be tuned to the detection of nutrients (sugars are sweet, NaCl is salty, and many poisons are bitter). Olfaction is also critical in flavor perception and food preferences. Olfaction is organized to identify foods more holistically, rather than to identify nutrients, and to be readily influenced by learning and experience (5, 50). Unfortunately, we know even less about the development of olfactory preferences than we know about taste preferences (52, 84).

FOOD NEOPHOBIA AND LEARNING TO PREFER NEW FOODS

Food neophobia, literally "fear of the new," is manifested by omnivores, including humans, in avoidance of new foods. The neophobic predisposition to avoid new foods may seem maladaptive for species that need to consume a varied diet to obtain adequate nutrition. However, neophobia serves a protective function. We need dietary variety, but eating new foods can be a risky business: They could be toxic, causing illness or death (116). The neophobic response functions in concert with learning mechanisms that serve to reduce initial neophobic reactions: predispositions to learn preferences and aversions. With experience, learning can transform the initial neophobic rejection of a new food into a preference.

Humans are omnivores, and we are also mammals. During early infancy, we are nourished exclusively by milk, and during this period, food preferences are not an issue. However, once solid foods begin being introduced and the transition to an adult diet begins, food preferences begin to influence food intake. Although the timing of weaning and introduction of solids differs across cultures, current nutritional guidance in the United States is that by the second half of the first year, an exclusive milk diet no longer provides adequate nutrition, and solid foods should be introduced (1, 71). It is at this point in development that the predisposition to respond neophobically to new foods begins to influence food preferences and intake.

Recent research has begun to reveal how early experience and learning can reduce the neophobic response to new foods. These findings are of practical importance because they suggest interventions to promote young children's acceptance of new foods, thereby enhancing dietary variety. However, we have only a rudimentary understanding of factors that facilitate or impede the reduction of the neophobic response and promote the development of food preferences consistent with healthy diets and optimal nutrition. For example, we know that the neophobic response is reduced by repeated opportunities to consume new foods (22). When 2-year-olds were given varying numbers of opportunities to taste new fruits or cheeses, their preferences increased with frequency of exposure. Between 5 and 10 exposures to a new food were necessary to see an increased preference for it. Although repeated opportunities to taste and eat a new food reduced neophobia and enhanced acceptance, repeated opportunities to smell or look at new foods did (24). This finding is consistent with the view that neophobia is only reduced as we learn that the food is safe to eat and does not cause illness (80).

Although the neophobic rejection of new foods is species-typical, neophobia changes during development, and there are individual and gender differences in strength of neophobic response. There is also evidence for familial similarities in neophobia, which may have a genetic component; neophobia is linked to other temperament and personality characteristics (107), which are known to have genetic links. From a recent study in Sweden with a large, population-based sample ($N = 722$), Hursti & Sjödén (77) reported moderate relationships between parents' and children's neophobia. Males showed greater neophobia than did females, both among children and adults (82). The authors also confirmed that during childhood, the neophobic response to new foods decreased with age.

Familial patterns of neophobia and individual differences in neophobia may be determinants of dietary variety. Participants were asked to report whether they had served particular uncommon foods in the home. In both samples, the higher the neophobia of the mother and the children, the fewer of the listed uncommon foods had been served to the family. Mothers who were more neophobic structured their children's food environments so that new and uncommon foods were presented less frequently than in families where mothers were less neophobic, thereby providing fewer opportunities for children of neophobic mothers to try new foods and reduce their neophobia (77). In addition, neophobic mothers would probably model eating novel foods less frequently.

The strength of the neophobic response changes during development. We recently reported that among infants who are just beginning the transition to solid foods, the neophobic response appears to be minimal (21). In this research, mothers introduced 4- to 6-month-old infants to a new fruit or vegetable by feeding one new food to the infant over a series of 10 lunches. We also examined whether experience with one food affected an infant's willingness to eat other novel foods, varying in similarity to the repeatedly eaten food. Results indicated that only one feeding of a new food was sufficient to increase an infant's intake of that food dramatically, from a mean of 30 g at the first feeding to a mean of 60 g at the second feeding. In addition, this reduction in neophobia appeared to generalize to similar foods, so that if an infant had experience with one vegetable, other vegetables (but not fruits) were more readily eaten. These findings are reminiscent of those obtained with rats, which are highly neophobic but needed only a single positive experience with a new food to accept a novel food as familiar and safe (80).

These findings, showing dramatic reductions in neophobia after only one feeding, contrast with the pattern of findings obtained when toddlers, preschool children, and adults are repeatedly given opportunities to eat new foods. Beyond infancy, neophobia may be more persistent; in research with 2- to 5-year-olds, approximately 5 to 10 exposures to a new food were required to produce significant increases in children's preferences. Minimal neophobia might be adaptive during infancy, a period when access to food is controlled primarily by adults and infants are not yet mobile and able to forage for themselves (21). By early childhood, when children are increasingly mobile and independent and more able to procure food on their own, neophobia could serve a protective function. Young children may also be especially neophobic because they have not yet learned rules of cuisine that can reduce the neophobic response among adults, by making novel foods seem familiar through the use of "flavor principles" (115).

Pliner and colleagues explored age differences in neophobia among older children and adults, comparing 3- to 8-year-olds with 10- to 20-year-olds (102, 105, 107) and with adults (90). Their findings reveal that neophobia decreases from childhood through adulthood. A similar relationship has been reported by Koivisto & Sjödén (82). Taken together, the findings suggest that during development, the relationship between age and the neophobic response may be curvilinear: Neophobia is minimal in infancy, increases through early childhood, and declines from early childhood to adulthood.

The research by Pliner and colleagues on neophobia explored reasons why people are reluctant to eat novel foods, and the findings indicate that at least in such relatively "safe environments" as cafeterias, people are reluctant to eat new foods not because they believe the foods are potentially dangerous but because they anticipate that the foods will taste bad (87, 90). Providing information that new foods taste good, or providing opportunities to sample good-tasting novel foods, can reduce neophobia, for both adults and children. In contrast, providing information about the nutritional value of new foods, i.e. "It's good for you," had no effect on children's willingness to try new foods (107).

Reducing Neophobia Through Social Influence

Especially for infants and children, eating is a social event, and others can have an impact on children's food preferences and food selections. From very early in development, mothers' eating behaviors, attitudes, and child-feeding practices have a major impact on the development of children's food-acceptance patterns (19). Recent research indicates that what the mother eats during pregnancy and lactation can affect a human infant's very early flavor experience, which in turn shapes the formation of flavor preferences and ingestive behavior (93). This research has investigated the effects of perinatal experience with flavors transmitted from the mother's diet to amniotic fluid and to human milk. When mothers ingested either garlic or placebo prior to amniocentesis, the odor of garlic was judged to be stronger in amniotic fluid of those mothers who ingested garlic. In humans as well as in other species, flavors such as garlic, alcohol, and vanilla that are transmitted to milk can affect an infant's suckling response and intake of milk and can shape later preferences for flavors and foods (65, 91–94, 132).

During the transition to solid foods, social factors can play a powerful role in establishing food preferences and in reducing the neophobic response, and they provide an avenue for the transmission of food preferences across generations. Research by Galef & Henderson (64) showed that when rat pups were exposed to two novel diets, one of which had been the mother's diet, the pups showed a preference for that diet over the other one. The preference for the diet consumed by the mother is due to the flavor cues transmitted in the mother's milk, giving the rat pups familiarity with the maternal diet prior to ingesting solid foods. The transmission of flavor cues through mothers' milk provides a mechanism that can reduce the neophobic response and ease the transition to the adult diet by familiarizing the infant with the flavors in solid foods.

Research with a variety of other species (63) and research with humans has shown that observing others eating a new food can reduce the neophobic response. In making the transition to the adult diet, young rats learned to prefer the adult diet by observing eating by other rats, especially adults (63). Rat pups prefer to eat at locations where adult rats are eating, rather than eat at locations where no adults are present. Kittens who observe their mothers eating unusual foods will begin to eat and develop preferences for foods not normally consumed by cats, such as bananas (63). Surprisingly, social transmission does not function to establish aversions to foods that rats observe other rats consuming and becoming ill from (63).

Social factors are particularly important in shaping children's preferences as they make the transition to the adult diet. For children, adults and peers can also play an important role in inducing consumption of an initially disliked or unfamiliar food (13, 51). Children's preferences for and consumption of disliked vegetables were enhanced when children had opportunities to observe peers selecting and eating foods that the observing child disliked (13). Adults can also be effective by encouraging children to try new foods (70). In cultures where the "hot" chili "burn" is a common flavor principle, they play a major role in inducing children to begin to accept foods flavored with chili peppers (123). The effectiveness of role models in inducing children to try foods also differs depending on the relationship between the child and the model. Older children are more effective role models than younger ones (13, 51); mothers are more effective than strangers (70); and, for older preschool children, adult heroes were more effective models than more-ordinary adults. However, we do not understand how these social effects function to induce change. They may induce the individual to sample the foods, and once this occurs, associative learning processes that reduce neophobia can come into play. An alternative explanation is that children form associations between foods and the social context in which eating occurs.

PARENTS' CHILD-FEEDING PRACTICES: EFFECTS ON CHILDREN'S FOOD PREFERENCES

Parent-child interactions in the feeding context are important in shaping children's preferences and intake patterns. In particular, the child-feeding strategies parents use can influence children's food preferences. When children are given foods as rewards for approved behaviors, enhanced preference for those foods results (15, 26). In contrast, when children are offered rewards for eating, that is, when rewards are contingent on them eating ("If you eat your vegetables, then you can watch TV"), the foods eaten to obtain rewards become less preferred (18, 23, 99). Although these practices can induce children to eat more vegetables in the short run, evidence from our research suggests that in the long run, parental control attempts may have negative effects on the quality of children's diets by reducing their preferences for those foods.

When parents attempt to control their children's food intake, they hope to foster food preferences and patterns of intake consistent with good health and current dietary guidelines. However, despite the guidelines' emphasis on "moderation" and "variety," many adults still tend to categorize foods as either "good" or "bad" for them and to express the view that bad foods should be totally avoided and only good foods should be consumed (17, 118). Consistent with a simplified view of foods as either good or bad, parents who are concerned about their children's diets may encourage and coerce children to consume "good" foods while restricting the children's intake of "bad" foods, particularly foods high in sugar, salt, and fat. When parents were asked which strategies were effective in inducing food likes and dislikes in their children, they reported that restricting children's access to a food, or forbidding them to eat a food, was a good way to get them to dislike foods (35). Unfortunately, recent research indicates these child-feeding practices do not work. Evidence indicates that child-feeding strategies that restrict children's access to snack foods actually make the restricted foods more attractive, as indicated by children's greater selection and intake of restricted than unrestricted foods (58). Mothers who reported greater restriction of daughters' snack food intake had daughters who selected and ate more of the restricted foods when in an environment where the foods were made freely available to the child and mothers were not present to restrict intake (57).

Family Resemblances in Food Preferences

Parents shape children's eating environments in a number of ways important in the formation of children's food preferences, and we might expect to see substantial family resemblances in food preferences. Surprisingly, the evidence for family resemblances in food preferences between parents and children is weak when children are young (14). Results of research examining relationships between preschool children's food preferences and those of their parents revealed correlations for mother-child pairs that were only weakly positive (median $r = 0.11$), and in fact these relationships did not differ from those obtained from unrelated parent-child pairs in the sample. Parent-child similarities in food preferences increase as children approach adulthood (104, 108, 121), and preferences for siblings who are closer in age are more similar (108).

There are a number of reasons why parent-child resemblances increase as children develop. Older children (*a*) have a longer shared environmental history with their parents, (*b*) are more similar to their parents in taste sensitivity and taste preferences, and (*c*) have reached a similar degree of acculturation with respect to food and eating. Siblings also have the latter characteristics in common to a greater extent than do parents and younger children, so we might expect to see greater similarities in food preferences between siblings than between parents and younger children. This is precisely the pattern that Pliner & Pelchat (108) report. These findings and others addressing genetic factors in food preferences suggest that family environment is important and genetics plays a minimal role (103, 112, 122; but see 83).

LEARNED FOOD PREFERENCES AND AVERSIONS BASED ON POSTINGESTIVE CONSEQUENCES

Many species, including humans, can learn to associate foods' flavors with the consequences that follow eating. These consequences can be positive, such as the pleasant postingestive signals generated by normal satiety. Repeated association of food sensory cues with these positive postingestive signals can produce learned preferences. The association of a food with the negative gastrointestinal consequences of nausea and emesis leads to learned aversions (67, 125). Once an aversion is formed, the food will be avoided, and learned aversions are not readily extinguished. Aversions can be formed to highly preferred, familiar foods, although they are more readily formed to unfamiliar foods (125). Learned food aversions can be the result of a single pairing of the food with illness and, in humans, can persist for decades (66, 86, 125). In humans, food aversions can result even in cases where we "know" that the flu, not the food, was the cause of the illness.

Several surveys using retrospective reports (66, 86, 88, 95) reveal that a substantial number of people report one or a few aversions, and many report no aversions. In one study investigating individual differences in learned food aversions, Mattes (88) reported that nearly 40% of his sample of adults reported having a learned food aversion at one time, and he noted family resemblances in food aversions formation, with some families more prone to learned food aversions than others. He reported that aversions were formed most readily to protein foods of animal origin, and aversions to eggs, meats, and seafood were particularly common. This observation is consistent with the idea that there are links between aversions and disgust responses, and most disgust reactions are to substances of animal origin (119, 120). Investigation into conditioned aversions in humans has been limited to anorexia of patients treated for cancer with chemotherapy (3, 11, 33, 89). Bernstein's research (11) has shown that children undergoing chemotherapy formed aversions to new foods presented after chemotherapy treatments.

Children's diets are generally more limited than are adults' diets, and many foods are still unfamiliar to them. Because aversions form more readily to novel foods, aversions are potentially more problematic in the diets of children. Bernstein & Borson (12) reported that individuals suffering from chronic malaise due to a variety of chronic medical conditions may be at risk for learning aversions to a wide variety of foods, which could seriously compromise dietary quality. Children, especially those suffering chronic bouts of nausea and emesis, may be especially vulnerable to developing multiple learned food aversions that can adversely affect dietary quality. The possibility should be investigated that children with chronic feeding problems, who are described as fussy or finicky eaters, may have restricted diets as a result of multiple learned food aversions.

In contrast to learned food aversions, learned food preferences form more slowly and are more readily extinguished. Because learned food preferences form as a result of the more common consequences of normal eating, not as a result of pairing of food with illness, learned preferences probably have more pervasive but subtler effects on food intake than do learned aversions. In learned food preferences, foods can become associated with (*a*) other flavors, such as sweet taste, in flavor-flavor learning (34, 137) and (*b*) ingested nutrients, in flavor-nutrient learning (see 30, 31, 126, 127).

Humans can learn to prefer flavors that have been previously paired with the preferred sweet taste. Zellner et al showed that when sweetness was associated with some tea flavors and not others, the teas repeatedly paired with sugar became preferred flavors, even when they were unsweetened (137). If the sweet taste is provided by nonnutritive sweeteners, preference is a result of flavor-flavor learning; if sweetness is supplied by a sugar that supplies energy, preference may also be a result of flavor/nutrient learning. There is extensive evidence for flavor/nutrient learning in rats (29, 127) and in human adults (32) and children (16, 78, 81).

We reported evidence for learned preferences in children based on energy density (16, 25, 78, 81). When children repeatedly consumed fixed amounts of two novel drinks or foods that differed in flavor as well as in energy density, they learned to prefer the flavors associated with high energy density. For each child, one flavor was consistently paired with high energy density and one with low energy density. In some experiments, energy density was manipulated using carbohydrate (polycose) (25); in others, fat content was manipulated (78, 81). Children had repeated opportunities to consume fixed amounts of these foods or drinks, and measures of preference and intake were obtained in test situations where the flavor cues were presented in isoenergetic preparations of the foods. These findings provide evidence for flavor-nutrient learning. It is also possible that flavor-flavor learning contributes to children's preferences; however, no research has investigated this issue.

The findings provided clear evidence that children learned to prefer energy-dense foods over energy-dilute versions of those foods. As with other predispositions that shape our food preferences, a propensity to prefer energy-dense foods over foods that are more dilute energy sources would be adaptive in food environments where energy-dense foods were relatively scarce, as has been the case for most of human history. This ability might be especially adaptive for growing children, who need to maintain positive energy balance. However, in our current food environment, where many energy-dense foods, high in fat and simple carbohydrates, are readily accessible and available, this predisposition to prefer energy-dense foods may promote overweight and obesity among children.

SUMMARY AND CONCLUSIONS

In the United States today, food preferences influence food selection in ways that are inconsistent with dietary guidelines and that can promote being overweight and obese. Our genetic predispositions include the preference for sweet and salty tastes, the tendency to reject new foods, and food preferences based on the postingestive consequences and social contexts of eating. These genetic predispositions evolved over thousands of years of human history, when foods—

especially foods high in energy density—were relatively scarce, a food environment dramatically different from that in the United States today. Today, these predispositions are expressed in learned food preferences and food selection patterns in a food environment characterized by the ready availability of inexpensive, energy-dense foods, high in sugar, fat, and salt. Eating preferred foods is a major source of pleasure, and fear of having to give up eating preferred foods is reported as a major obstacle to consuming healthier diets. Because food preferences play a central role in determining food selection and diet quality, a better understanding of the development of food preferences could make important contributions to designing intervention strategies to promote healthy diets; perhaps children could learn to like foods that are good for them.

Food preferences are learned via our experience with food and eating. This emphasizes the critical role played by the food environment in determining the adequacy of diets. An infant's experience with flavors begins early, in utero, and during the period of exclusive milk feeding, when flavors from the mother's diet are transmitted to her amniotic fluid and later to her milk. Depending on the foods that are made available and accessible, children's learned food preferences can either promote or impede the consumption of nutritionally adequate diets. In the United States today, the ready accessibility of large portions of inexpensive, energy-dense foods, high in sugar, fat, and salt, contributes to an obesigenic food environment (75). Our genetic predispositions bias us to like sweet and salty foods, we don't have to learn to like these tastes; we are predisposed to learn to prefer energy-dense foods over those more energy dilute; and new foods, especially those that are not sweet or salty, will be initially rejected as a result of neophobia. Fortunately, if given the opportunity, we can learn to like many of the foods that are initially rejected. This analysis suggests why "healthy" foods such as complex carbohydrates and vegetables, which are neither sweet, salty, nor energy dense, are initially rejected by children. An analysis of the effects of child-feeding strategies used to encourage children to consume nonpreferred foods reveals that these feeding practices actually foster children's dislike rather than acceptance of these foods. Child-feeding practices that restrict children's intake of foods at the top of the food guide pyramid, those that are high in energy density, sugar, salt, and fat, actually promote their liking for and intake of those foods.

Our predispositions served an adaptive function, developed over thousands of years at a time in our history when food environments were very different and food was scarce. In today's obesigenic food environments, children's predispositions and adults' responses to them can promote patterns of food preference and intake that foster the development of overweight and obese individuals. This analysis also suggests that because food preferences are learned, they are modifiable, although the data suggest that the best chance for fostering patterns of preference consistent with healthier diets may be to focus on the very young.

Traditional nutrition education that has focused on imparting nutrition knowledge has not been successful at promoting healthy diets. However, the evidence presented here suggests new approaches to nutrition education that might meet with greater success. Such "nutrition education" approaches would incorporate what is known about the importance of the food environment and take advantage of knowledge about our predispositions to prefer and reject basic tastes, to reject new foods, and to learn to prefer foods based on the postingestive consequences and social contexts of eating. An initial step would be to augment information on children's nutrient needs by providing parents with information about the predispositions that infants and young children bring to the task of learning food preferences, and about the impact of child-feeding strategies on children's preferences and intake. This could reduce parental anxiety regarding child feeding and support parents' adoption of child-feeding strategies that foster the development of food preferences more consistent with current dietary guidelines. Such nutrition education for parents should include information on how children's food preferences are learned and what their children's normal and adaptive predispositions are to (*a*) prefer sweet and salty tastes and reject sour and bitter ones, (*b*) reject novel foods, and (*c*) learn to prefer foods based on the frequency of exposure and the contexts and consequences of eating. Practical suggestions based on our knowledge of these predispositions could help parents to structure food environments to increase children's acceptance of a variety of foods and foster healthier diets.

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