Early Feeding: Setting the Stage for Healthy Eating Habits

Julie A. Mennella, Alison K. Ventura

Monell Chemical Senses Center, Philadelphia, PA, USA

Abstract

Food habits, an integral part of all cultures, have their beginnings during early life. This chapter reviews the development of the senses of taste and smell, which provide information on the flavor of foods, and discusses how children’s innate predispositions interact with early-life feeding experiences to form dietary preferences and habits. Young children show heightened preferences for foods that taste sweet and salty and rejection of that which tastes bitter. These innate responses are salient during development since they likely evolved to encourage children to ingest that which is beneficial, containing needed calories or minerals, and to reject that which is harmful. Early childhood is also characterized by plasticity, partially evidenced by a sensitive period during early life when infants exhibit heightened acceptance of the flavors experienced in amniotic fluid and breast milk. While learning also occurs with flavors found in formulae, it is likely that this sensitive period formed to facilitate acceptance of and attraction to the flavors of foods eaten by the mother. A basic understanding of the development and functioning of the chemical senses during early childhood may assist in forming evidence-based strategies to improve children’s diets.

Introduction

The unhealthy eating habits that plague adults – too many calories and salty, sweet, and fatty foods, too few fruits and vegetables – are also rampant in the youngest members of society. Infants and toddlers consume an estimated 10–31% more energy than recommended [1], but not by overconsumption of fruits, vegetables, whole grains, or lean proteins – French fries are the ‘vegetable’ they most commonly consume [2, 3]. Eighteen to 33% of infants and toddlers consume no servings of vegetables on a given day, and 23–33% consume no servings of fruits [2]. Additionally, almost half of infants and toddlers consume desserts, sweets, or sweetened beverages daily [2, 3].
The negative impact of these dietary patterns manifests in increasing obesity among children, a worldwide public health crisis [4–8]. Health professionals recommend that children reduce intakes of added sugars, sodium, and saturated fats and increase intakes of whole grains, fruits, and vegetables (especially dark green leafy vegetables) [9–11]. However, this advice is difficult for adults to comply with, let alone young children whose intake patterns are largely driven by taste preferences, not health considerations [12].

Two major factors conspire to predispose children to consume diets high in sugar, fat, and salt that may lead to obesity. First, humans have an evolutionarily drive toward heightened preferences for sweet and salty foods and rejection of bitter tastes. Second, children must be repeatedly exposed to the flavors of healthy foods beginning early in life to promote their acceptance of these foods.

**Flavor Biology in Children**

*Biological Substrates of Flavor Learning*

The perceptions arising from the senses of taste and smell combine in the oral cavity to determine flavor. These perceptions are often confused and misappropriated with olfactory sensations such as vanilla, fishy, and strawberry being erroneously attributed to the taste system per se when, in fact, much of the sensory input is due to retronasal olfaction. Because these senses are the major determinants of whether young children will accept a food (i.e., children eat only what they like), they take on even greater significance in understanding the bases for food choices in children than they do for adults.

We now know that flavor perception develops and functions in utero, and the senses of taste and smell continue to develop postnatally [13, 14]. The fetus begins to swallow and inhale large amounts of amniotic fluid around the 12th week of gestation [15, 16], and by the last trimester the receptors underlying taste and odor perception begin to communicate with the central nervous system in response to a variety of taste and odor stimuli [for a review, see 14]. Amniotic fluid, the first food of infants, contains a wide range of nutrients, such as glucose, fructose, lactic acid, fatty acids, and amino acids [17], as well as flavors (for which the odors are perceived retronasally) of the foods consumed by the mother [18, 19]. The fetus can detect these tastants and flavors, as infants prefer flavors previously experienced in amniotic fluid [18, 20–22].

Fetal swallowing frequency increases in response to the introduction of sweet solutions into the amniotic fluid and decreases in response to the introduction of bitter solutions [17, 23], which may be one of the first indications that our basic biology favors consumption of sweet tastes and avoidance of bitter tastes. A similar response pattern is seen shortly after birth. Within hours and days of being born, young infants react as would be expected to
pleasurable and aversive taste stimuli [24–33]: provision of sweet or umami solutions to neonates elicits rhythmic tongue protrusions, lip smacks, lip and finger sucking, and elevation of the corners of the mouth, all of which have been interpreted as a positive or hedonic response [27, 31]. In contrast, neonates gape, wrinkle their noses, shake their heads, flail their arms, and frown in response to a bitter solution [27, 29]. Concentrated sour solutions elicit lip pursing and, to a certain extent, gaping, nose wrinkling, and arm flailing as well as tongue protrusions and lip smacking [27, 29, 34]. Unlike the other basic tastes, neonates respond neutrally to salt taste – the taste for salt does not emerge until later in infancy and then remains throughout childhood and adolescence [35].

These specific affective reactions to differing taste stimuli are strikingly similar across cultures [25, 34, 36] and species [27, 37–40], also suggesting a basic biological underpinning for the flavors and foods youngsters prefer and avoid. Thus, when we examine children’s dietary patterns from the perspective of the ontogeny of taste development, the foods children naturally prefer are not surprising and reflect their basic biology.

**Heightened Sensitivity to Bitter and Preferences for Sweets and Salt in Young Children**

Like infants, children live in different sensory worlds than do adults. Children have higher preferences for sweet [41–43], salt [44], and sour [45] tastes and are more rejecting of some bitter tastes [42] than adults. A vast amount of learning occurs during infancy and childhood, and a significant portion of that learning is about what and how to eat. Thus, reactions to taste qualities likely evolved to detect and reject that which is harmful and to seek out and ingest that which is beneficial [46]. Sweetness is associated with readily available calories from carbohydrate sources such as mother’s milk or fruits [47], and saltiness is associated with needed minerals [48], whereas bitterness signals toxins and poisons [49]. Hence, from an evolutionary perspective, it makes sense that preferences for sweet and salty foods are inborn while preferences for bitter-tasting foods (e.g. coffee, dark green vegetables) are learned. It also makes sense that it would be protective for young children, who are trying to learn about what and how to eat, to be more sensitive to the cues proffered by foods; this heightened sensitivity would allow them to quickly protect them from that which causes harm and to encourage them to eat that which is beneficial for growth.

Only very recently in human history are foods omnipresent in many parts of the world and readily available for consumption. Rather, our taste preferences evolved in times of ‘feast or famine’. Under such circumstances, preferences for sweet and salt and aversion to bitter were essential for ensuring that energy- and nutrient-dense foods were consumed and harmful substances were avoided. Now, in many parts of the world, a mismatch exists between children’s physiology and the current food environment: many children live in
an environment that provides food everywhere – it is inexpensive, good tasting, and served in large portions. Further, the increased levels of sugar, fat, and salt in processed foods cater to children’s natural taste predispositions.

**Flavor Learning in Children**

Sensory and biological considerations shed light on why children are predisposed *not* to favor low-sugar, low-sodium, and vegetable-rich diets and why it is difficult for children to eat nutritious foods when they are unfamiliar and do not taste good to them. However, while we cannot easily change children’s basic biology, we can modulate children’s flavor preferences by providing early exposure, starting in utero, to a wide variety of healthy flavors available within the culture.

**Flavor Learning in Amniotic Fluid**

Learning from mother is a fundamental feature of all mammals [50, 51]. In part, young mammals learn about things like body control, fine and gross motor movements, and social behaviors from what is modeled or transmitted by their parents [52]. Learning about flavors and foods is no different: young mammals first learn about what and how to eat through information transmitted by mothers, and these lessons come in many different forms.

Amniotic fluid is the first medium for flavor learning within which offspring experience the flavors of the mothers’ diet. Flavors and chemicals consumed by the mother appear in the amniotic fluid [18, 19], and the fetus detects and responds to them. Human infants orient toward the odor of their own amniotic fluid within days of birth and prefer this odor to new odors experienced during the first few days of formula feeding [53, 54]. Shortly after birth, infants will respond differently to flavors experienced in amniotic fluid. For example, neonates whose mothers consumed an anise-flavored beverage or ate garlic-containing foods throughout pregnancy were more accepting of and interested in (as measured by mouthing and orienting) anise and garlic odors [21, 22]. Similar findings were observed with alcohol odors [20].

That these early flavor experiences can influence the acceptance of foods was first demonstrated in a randomized, controlled study of mothers who consumed carrot juice or water during their last trimester of pregnancy. Infants of mothers who consumed carrot juice were more accepting of carrot-flavored cereal at 5–6 months of age than were infants of mothers who consumed water [18]. In animal models, the influence of flavors experienced in utero has been shown to persist into adulthood, even without subsequent postnatal influence with the flavor [55, 56]. Thus, flavor learning begins in utero, long before actual experience with solid foods.
Flavor Learning with Mother's Milk

Flavor learning continues when infants experience the flavors of the mother's diet transmitted in breast milk. To date, many flavors (e.g., anise, garlic, ethanol, carrot, mint, vanilla, bleu cheese) have been empirically shown to pass from mother to offspring through the breast milk of many types of mammals [18, 50, 57–66]. Human infants detect the flavors in mother's milk, as evidenced by changes in their sucking rate, patterning and duration of feeding and intake [18, 62–64, 66], and differential acceptance of similarly flavored foods [18, 67].

At weaning, similar to other mammals [for review, see 50], human infants show greater liking for and acceptance of flavors and foods to which they have had early exposure. They were more accepting of cereal if it was prepared with mother's milk or if it contained a flavor (e.g. carrot) previously experienced in mother's milk [68, 69]. Similarly, breastfed infants were more accepting of fruits and vegetables than were formula-fed infants, but only if their mothers regularly ate these foods themselves, thus highlighting the importance of a varied diet for both pregnant and lactating women [67].

Several experimental studies have also shown that when breastfed or formula-fed infants are repeatedly exposed to a single fruit or vegetable for anywhere between 9 and 20 days, their preference for that fruit or vegetable increases and is higher than in infants who were not repeatedly exposed to that food [67, 70, 71]. Similar effects have been observed in studies with preschool-age children [72–78].

Exposure to a variety of flavors, not just repeated exposure to a single flavor or food, also appears to facilitate acceptance of novel foods. Infants who were repeatedly exposed to a different starchy vegetable each day ate as many carrots after the exposure as did infants who were repeatedly exposed to carrots [70]. Similarly, repeated experience with a variety of fruits enhanced acceptance of a novel fruit but had no effect on infants' acceptance of green vegetables [71]. Because rejection of bitter taste is innate, infants may need actual experience with bitter taste, or more exposures, to enhance acceptance of green vegetables [67, 71]. That varied experiences with food flavors increase food acceptance may help explain why children who were breastfed are less picky during childhood [79].

Flavor Learning with Formula

Flavor learning is not specific to breastfed infants, as formula-fed infants learn to prefer the flavors of the formulae they are fed. However, formula does not have the variety of flavors experienced in breast milk. Further, the flavors of the different formulae may predispose infants to develop preferences for particular flavors. Traditional cow milk-based formulae (CMFs) have low levels of sweet, sour, and ‘cereal-like’ flavors; soy formulae have a combination of sweet, sour, and bitter flavors, and protein hydrolysate formulae (PHFs) have a combination of sour, savory, and bitter flavors and odors [80, 81]. PHFs are unpalatable to
older children and adults who have not had prior experience with them, but if introduced early enough, these formulae are preferred by infants who fed them [81]. That children attach to the flavor of the formula is evidenced by findings that they prefer the specific formula they were fed throughout infancy [82, 83].

**Flavor Learning at Weaning**

The type of formula an infant feeds modifies the infant’s taste preferences both at weaning and later in life. PHF-fed infants showed greater acceptance of savory-, bitter-, and sour-tasting cereals during weaning [84]. Additionally, 38% of breastfed infants and 25% of infants who were fed CMF gaped while eating bitter-flavored cereal, while none of the infants fed PHF made this facial expression of distaste [84]. The effects of early exposure to such flavors were particularly persistent, leading to heightened preferences for the taste and aroma of the formula as well as foods that contain similar volatiles or tastes (e.g. broccoli, chicken) several years after children’s last exposure [83].

Children at weaning look to their mothers to learn about what and how to eat. Research in animal models reveals this learning can be quite complex. For example, calves or lambs that see their mother avoiding larkspur also do not eat this plant [85]. Mothers serve as models to their young, teaching them which plants to avoid and when plants are at their peak nutritional content [86]. In humans, the extent to which mothers consume healthy foods and make these foods available to their children is positively correlated with their children’s intake of healthful foods [79, 87–89]. Experimental studies have provided strong support for the influence of adult models on young children’s acceptance of novel foods [90–93], further demonstrating that children are primed to learn the flavors and foods made available by mothers.

**Sensitive Periods in Human Flavor Learning**

Based on the evidence cited above, it is likely that early human flavor exposure, particularly in utero and in the context of breastfeeding, influences later flavor acceptability. Although there is emerging experimental evidence supporting this hypothesis [18, 67], recent studies, which exploit the inherent flavor variation in infant formulae, have revealed an apparent ‘sensitive window’ during the early infancy for increased acceptance of a complex flavor – that of PHF [81].

PHF, developed a half-century ago, is currently the feeding regimen of choice for formula-fed infants who cannot tolerate cow milk and other intact proteins [94]. Pediatricians have remarked anecdotally that although it is easy to introduce this type of formula to infants during the first weeks of life, it becomes extremely difficult to do so later in infancy [95]. This early acceptance has been attributed to the young infant’s ‘lack of taste perception’ since these formulae are reported by adults to have an extremely unpalatable,
offensive off-flavor. However, as discussed above, basic research in taste has shown that young infants will reject extreme sour [29] and bitter tastes [96] and they can detect a variety of odors such that their sensitivity may equal or surpass that of adults [for a review, see 14].

During the past two decades, we have experimentally investigated the age-related changes in the infants’ willingness to feed PHF [81, 97, 98]. By comparing the acceptability of PHF by infants at 2 months and then at 7 months of age, we found that the younger infants were clearly willing to accept substantial amounts of PHF and fed to satiation, as observed previously [99, 100], even though they could detect the difference between the PHF and their familiar CMF. However, these infants invariably rejected PHF when retested at 7 months of age. This rejection was evident within the first minute of the feed, suggesting that the sensory qualities of the formula were responsible, at least in part, for the rejection.

To better characterize the timing of the sensitive period, we conducted a randomized clinical trial that varied the age and duration of PHF feeding [81]. This revealed a ‘window’ of acceptance during early life when infants readily accept PHF. Then, beginning around 4 months of age and continuing through adulthood, its flavor is rejected unless the individual has been exposed to PHF during early life. That is, PHFs have a completely different hedonic tone depending on whether the infant was exposed to this formula during the first few months of life.

Why should there be a sensitive period in the early acceptance of hydrolyzed formulae? First, presuming there is an adaptive reason, it clearly has nothing directly to do with hydrolyzed protein formulae, which were introduced only a half-century ago. Indeed, these observations with formulae may conveniently expose a much more fundamental aspect of early mammalian flavor learning. We hypothesize that it is important for the human infant to accept and be particularly (but not exclusively) attracted to the flavors that are consumed by the culture and, more specifically, by the mother. All else being equal, these are the flavors that are associated with nutritious foods or, at the very least, foods the mother has access to – and the foods and flavors that the infant will experience at weaning and probably thereafter. Under this hypothesis, much of the normal exposure would occur in utero and during breastfeeding, where flavors mothers consume are transferred to these chemosensory environments. Additional research is needed to determine the extent to which early exposure to these flavors, perhaps during sensitive periods of development, helps establish enduring preferences for foods and flavors.

**Conclusion**

The unhealthy eating habits that plague adults also contribute to the increasing global prevalence of obesity among children. Although children
have an evolutionarily driven heightened preference for sweet and salty foods and for rejection of bitter tastes, research shows that repeated, early exposure to the flavors of healthy foods may help promote their acceptance of these foods later in life. Taste and flavor perception develop and function in utero, and flavor learning continues when infants experience the flavors of the mother’s diet in breast milk and the flavors of formulae. Children just beginning to consume solid foods look to their mothers to learn about what and how to eat. Based on the evidence cited in this chapter, it is likely that flavor exposure before 4 months of age, including repeated exposures to a wide variety of healthy foods, and good eating behaviors modeled by parents will modify the infant’s food preferences both in childhood and later in life. Thus, early life represents a critical window of opportunity to influence healthy food choices throughout an individual’s lifetime.

References

Early Feeding Affects Healthy Eating

76 Koivisto UK, Edlund B, Sjoden PO: Exposure to milk or water at preschool lunch for 3 months influences children's choice of elementary school lunch drink 4 months later. Appetite 1994;23:265–273.
91 Hendy HM, Raudenbush B: Effectiveness of teacher modeling to encourage food acceptance in preschool children. Appetite 2000;34:61–76.
Discussion

Dr. Haschke: One comment related to terminology. You consider Nutramigen to be a PHF, i.e. a partially hydrolyzed formula.

Dr. Mennella: PHF is often used to symbolize protein hydrolysate formula.

Dr. Haschke: Nutramigen is an extensively hydrolyzed formula (EHF).

Dr. Mennella: PHF is used to denote protein hydrolysate formula which can be further specified as pPHF = partial hydrolysate formulas, and ePHF = extensively protein hydrolysate formulas.

Dr. Haschke: Another comment is on growth. We have good data from the GINI study in Germany where 3,000 infants were followed until 10 years of age. They were either breastfed, received partially hydrolyzed formula, extensively hydrolyzed formula, or cow’s milk-based formula. There was a transient effect on growth. It disappeared completely at 5 years of age. Children no matter what the initial feeding was had the same body mass index, same height. Now the data are out for 10 years, and again there is no difference between the groups.

Dr. Mennella: Many infants in the past studies were also breastfed confounding the findings. The most recent study was a randomized clinical trial that consisted of term infants who were exclusively formula fed.

Dr. Haschke: But I am just referring to the GINI study.

Dr. Mennella: When we looked at the longer term growth, these effects seem to go away by 5–6 years. I think that the differential growth patterns (specifically the more accelerated growth among infants fed cow's milk formulas) are still quite important. I would focus on what these data are telling us about infant satiety and satiation. There is a convergence of findings from these trials showing difference in growth patterns based on the type of formula fed during the time in life when formulas are these infants' primary source of nutrition. For the first time, we found that differences in growth may be due in part to differences in satiation when feeding ePHF. To me, that's a fascinating discovery.

Dr. Saavedra: I have two comments. One is that when studying these things we need to be absolutely clear about what it is that we are testing. The other is the percentage of amino acids in these formulas. Most extensive hydrolysates, for example, have between 40 and 50% free amino acid as opposed to partial hydrolysates which have hardly any. Intact proteins, which actually do have some free amino acids, probably also have some taste influence. So here again, the generalizations are going to be tough when it comes to those.

Dr. Mennella: We analyzed a number of formulas, and each formula has its own different free amino acid profile which may contribute to the different taste profiles, so I agree.

Dr. Saavedra: So again, this is just for the purposes of specificity when we are reporting these kinds of results. But the other question that you bring up is more fascinating. What, if anything, can we do for a child that is getting the same thing, whatever it is that they are getting when they are not breastfeeding? Are there for example data or experience on variety of acceptability of tasting from children who are breastfed versus children who have been on a formula for a period of time?

Dr. Mennella: Dr. Birch has done work showing that breastfed infants were more accepting of a new food and were less picky eaters as they grew. We have conducted a number of experiments on infants at the time of weaning. Infants learn through repeated exposure, through experiences with dietary variety and through flavor experience in breast milk. Breastfeeding is clearly giving the baby an advantage for food acceptance. If the mother eats fruits and vegetables, their baby is more accepting of those foods. The mother has to eat the food in order to have an effect on the infant.
It’s a beautiful and elegant system which should be modeled throughout all of the lifespan.

*Dr. Kleinman:* Salty taste seems to be much better tolerated in infancy than later on. Oral rehydration solution, for example, is well accepted by infants but pretty hard to give to anybody over the age of 1. Thus, there appear to be thresholds over time where excessively sweet and salty tastes are no longer accepted. Do we know the biological basis for that?

*Dr. Mennella:* While babies are born preferring sweet taste, they cannot detect salt tastes until they are 4 months of age. From that time onwards, children prefer salt and sweet taste. Now, when it comes to the intensity of sweetness or salt that a child likes, a child will prefer a much more intense sensation. Children prefer, on average, a 0.6 M sucrose solution; for reference, the level of sweetness in a Coca Cola is 0.3 M. The same is true for salt – they prefer much higher levels than adults. Children are clearly living in different sensory worlds than adults!

*Dr. Kleinman:* And that’s a learned behavior?

*Dr. Mennella:* No, I think it’s their basic biology. I think that the child is attracted to sweet and salt during periods of growth; sweet is our taste signal for carbohydrates and salt is our taste signal for needed minerals.

*Dr. van Goudoever:* With regard to hydrolyzed formula and complementary feeding tolerance, from what I understood you have to try offering it over and over again, and basically the turning point is when you’ve offered it about 8 times; then there is some acceptance. What are the newest data on that, and does that account for hydrolyzed formula as well?

*Dr. Mennella:* It’s extremely difficult to introduce ePHF when the baby is 4 months of age or older. It’s not that it can’t be done but it’s difficult. Common strategies (that are not evidence based) include mixing ePHF with cow’s milk formula and then gradually increasing the amount of ePHF in the mix over time. Now, when it comes to complementary foods, and I think you will hear more of this tomorrow, 8–9 exposures result in greater acceptance. Merely looking at the food is not sufficient. Rather, children had to taste the food to learn to like it. We do not know the minimum amount of exposure needed and I would hypothesize that, depending on the food, it may be different for a child based on his/her taste sensitivity. For example, children who are more sensitive to bitter tastes may need more exposures.

*Dr. van Goudoever:* Then a further short question, what kind of growth charts did you use in the pediatrics tables?

*Dr. Mennella:* The WHO and then we did CDC too, the results aren’t changed.

*Dr. Stettler:* I like your comment on the two things that are going on right now in the US. One of them is new formulas that have been marketed for children as young as 10 months that are flavored with chocolate and vanilla. It looks like they are now marketing it to 12 months or even 24 months and after. And then the other thing is the heavy marketing for school age children by the National Dairy Council of chocolate-flavored sweetened milk in the schools. So I would like to hear your comments on that. Obviously, these are periods that are further down than what you studied, so should we not be concerned at all about long-term choices after a certain age, and what would that age be?

*Dr. Mennella:* I don’t know what that magic age is, but I think that learning about foods begins very early. We first learn about flavors of our mothers’ diet during pregnancy and lactation. These are the foods that a part of the culture in which the child is born and will be the foods that are offered to the child as he or she grows. For children, acceptance of many foods/products is enhanced if you make it taste sweeter. Through experiences with these sweetened products, children are learning that these milks should taste sweet. I often wonder what the consequences of feeding these flavored
follow-on formulas have on children's acceptance of cow's milk. There is inherent plasticity in the senses which tell us this food tastes good, this food doesn't, and these experiences are particularly salient during their early development. In all cultures around the world, children's diets are usually a modification of the adult diet. It has only been in recent history that we are starting to feed children different types of food. I think we have to take a lifespan approach to feeding and realize that these foods are teaching the child the food culture of their families.

**Dr. Lack:** I am intrigued by the evolutionary significance of this period of gustatory promiscuity from 0 to 4 months. What are the implications of this? Is it that infants less than 4 months should be allowed to touch, smell and perhaps even taste complementary foods, or is it all mediated through the mother's diversity in her diet during pregnancy and lactation? Is there an accompanying drive in the mother's appetite? Does her behavior change in pregnancy and does she start eating more fruits, could it explain cravings for certain foods?

**Dr. Mennella:** These are excellent questions and there is not a lot of experimental work. I think that if we were looking at other animals, and especially some of the work that is coming out of wildlife and field biology, the first way animals learn about flavors is in amniotic fluid and the mother's milk. But it's the first way, not the only way. Learning about foods continues, and if these foods continue to be experienced in a variety of contexts, this learning gets reinforced as the child grows. So we can't just expect to give the experience with the flavor of broccoli in formula, for example, and expect that their preference for broccoli is going to remain strong even if the mother doesn't eat broccoli or provide broccoli for the child to eat. It's a gradual process that builds on the familiar; it's the most fundamental aspect of learning.

**Dr. Zlotkin:** Is there a relationship between taste and hunger and appetite? In my clinical practice, I see children with a very maladapted behavior, that is children who seem not to have any appetite and actually refuse to eat. Often, they are survivors of preterm birth, but sometimes they are not and they seem to come from families whose background is seemingly normal, and I continue to be surprised by these children who seem absolutely unwilling to eat, have no appetite, and I am just wondering if there is a relationship between taste, hunger and appetite.

**Dr. Mennella:** There again, I looked at the non-human animal studies when I first designed this work on human infants. I always tested the babies a half hour to an hour before they are scheduled to feed because if you test them when they are very hungry taste isn't a salient. Another important issue is whether there are sensitive periods for learning about foods. In particular, what happens if you are deprived of these experiences, as in the case of tube-fed infants who often have difficulty with later feeding. This is an important area that needs research.

**Dr. Chittal:** I was just wondering, it's a little simplification of the very complex issue of taste, but taste is an acquired parameter almost like the heart function, and babies who are on hydrolyzed protein formula find it easy to accept a similar formula later on in life. Having been used to the taste of hydrolyzed protein formula do they find it difficult to accept cow's milk formula later on? I will ask a second question if you don't mind. In the previous papers on the early introduction of raw cow's milk, I suspected that this introduction was by default or by choice because many of the infants who have been on cow's milk formula refuse to accept it after a particular amount of time, and they instinctly accept raw cow's milk. So, is there a taste factor?

**Dr. Mennella:** I will speak to the protein hydrolysate question first. We have followed these children for several years; these children are more accepting of ePHF flavors and sour and bitter tastes several years after their last ePHF feeding. Also, there is a volatile in ePHF that is found in broccoli, and we found that children who
are fed protein hydrolysate tend to like broccoli more. Other reports of long-term effects of feeding PHF come from the literature on children and teenagers who have phenylketonuria; nutritionists report that they prefer sour flavors added to the formula diet. I think that through these flavor experiences in milk or formula, children develop preference for flavors they experience. It raises a very interesting question: How different does the formula have to taste for the infant to detect a difference in it? Unlike formula which is rather monotonous from day to day, the flavor of breast milk changes throughout the course of a feed (the fat content more than doubles) and changes from meal to meal since the mother’s diet is changing from morning to evening, etc.

Dr. Shreffler: In patients that I see who have multiple food allergies and food aversions, I have thought of that as largely a motor issue, and have made the point to intervene with chewing, etc. Obviously, your data suggest that taste is to some extent part of that development of aversions. What is known about interactions between receptors for histamine, substance P, other mediators, and taste receptors, because it’s a striking clinical observation that even after outgrowing food allergies these kids often have very strong aversions to specifically those offending foods.

Dr. Mennella: I don’t know of anything. But I think it’s extremely important because if there is learning that’s occurring, one would imagine that these sensory features could trigger other types of responses. Unfortunately, I don’t know of any studies that have looked at that.

Dr. Guandalini: I just wanted to add a comment on the early onset of preferences toward sugary taste. In reality, if one looks at the ontogeny of the human intestinal disaccharidases, one is confronted by the fact that the enzyme sucrase isomaltase (that digests sucrose, a carbohydrate only found in the plant kingdom) is developing very early on so that at term the activity of sucrase is comparable to that of adults [1]; it looks like mother nature makes us geared towards early utilization of sugars.

Dr. Mennella: Whether you look at the near-term fetus, the premature infants, newborns, the convergence of findings from countries around the world is that babies like sweet and it’s part of their biology. That is, the liking for sweets is not a consequence of modern day food environment. I think what the food industry has done is provided more experiences for children to learn the context for sweets. However, they did not create the inborn liking of sweets.

Dr. Klish: In my early days of treating children with feeding aversions, our ability to concentrate calories was limited. Infants with chronic congestive heart failure from congenital heart disease were very difficult to feed, and their growth mandated their eligibility for corrective surgery. The only additives I had to increase the caloric content of formula were vegetable oil and maltodextrin. Many of these children developed an aversion to sweetness because everything they ate had maltodextrin added. So the ability to tolerate sweet obviously has a limit.

Dr. Mennella: Did they get sick?

Dr. Klish: Yes, they would get sick in the sense that they would regurgitate the formula as well as refuse it. They looked like the child you had on your slide.

Dr. Mennella: Yes, that’s taste aversion learning; how the consequence of the taste experience (illness) can shift its hedonic tone; it’s a powerful mechanism.

Dr. Stathatos: Are early gustatory signals in any way connected with the later high carbohydrate consumption, French fries and so on?

Dr. Mennella: Children like more intense sweetness and industry seems to be catering to their basic biology. Since the 19th century, the first thing a child has ever bought with their money is a candy. I think it also speaks to the saliency of this taste in a life of a child. It’s the sweet taste of childhood.
Reference