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The Development of Eating Behavior - Biology and Context

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Abstract

Eating is necessary for survival, gives great pleasure and can be perturbed leading to undernutrition, overnutrition and eating disorders. The development of feeding in humans relies on complex interplay between homeostatic mechanisms; neural reward systems; and child motor, sensory and socio-emotional capability. Furthermore, parenting, social influences and the food environment influence the development of eating behavior. The rapid expansion of new knowledge in this field, from basic science to clinical and community-based research, is expected to lead to urgently needed research in support of effective, evidence-based prevention and treatment strategies for undernutrition, overnutrition and eating disorders in early childhood. Using a biopsychosocial approach, this review covers current knowledge of the development of eating behavior from the brain to the individual child, taking into account important contextual influences.

Key Terms

eating; feeding behavior; child development; social environment; parenting

INTRODUCTION

Human eating behavior develops rapidly from infancy to school age. Normal development should lead to adequate but not excessive weight gain during childhood and healthy eating behaviors throughout the life-course. We review multilevel influences on eating behavior including neural mechanisms, individual child development, parent-child interaction and social influences. This review brings together the biological basis of energy regulation; current understanding of sensory determinants; research related to social influences; and eating behavioral processes that influence the development of food acceptance and appetite regulation. Exciting advances in neurosciences inform our understanding of the complexities of eating for energy balance and for pleasure. The developmental focus of this article is on the prenatal to school-age periods and does not include adolescent and adult eating disorders or treatment approaches to infant, toddler and school-age eating problems.

ENERGY REGULATION

Biological basis

Physiological signals can induce or suppress feeding. The neurophysiology of eating regulation involves the hypothalamus and brain stem, gastrointestinal system, pancreas, and adipose tissue through neuroendocrine feedback loops (Figure 1). During periods of energy deficit, ghrelin, a peptide, is released from the stomach signaling the hypothalamic arcuate

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nucleus to release agouti-related peptide, neuropeptide Y and orexin, for appetite stimulation. [1] After eating, pancreatic insulin, intestinal peptide YY, and leptin from adipocytes decrease the release of appetite-stimulating peptides and orexin from the arcuate nucleus, inhibiting appetite stimulation. [2, 3] In the face of energy surplus, cholecystokinin and leptin influence the release of pro-opiomelanocortin and cocaine-amphetamine regulated transcript neurons from the arcuate nucleus to inhibit appetite. [4–6] Leptin increases the desire to eat when levels are low and decreases hunger when levels are high. [2] Adipocytes also release adiponectin with increasing levels in response to fasting and decreasing levels in case of obesity. [7]

Sophisticated biological systems exist to promote energy balance, avoiding starvation whenever possible and decreasing likelihood for obesity. Recent research confirms the existence of individual differences in sensitivity to energy balance and suggests that gene-environment interactions could influence body weight homeostasis. [8] Furthermore, humans can override these systems. [9–11] For example, during famine, people can focus on a variety of activities until they become debilitated. In the opposite extreme, when palatable food is available in excess, many people consume more than they need. [12] On a day-to-day basis, human eating behavior is strongly influenced by features independent of energy need, especially characteristics of available food and the environment. [13] Flavor, odor, texture, temperature and food presentation are important determinants. Furthermore, social factors may be even more important than the sensory cues of the foods themselves in influencing the development of eating behavior. [14–18]

Infant Regulation of Energy Intake

Breastfed infants benefit from a positive feedback loop that relates suckling to milk production.[19, 20] In the first months of life, formula fed infants are also capable of self-regulating milk intake. Under experimental conditions, 3-day old infants responded negatively to the odor of their formula within several hours of a feeding, but not if more time had lapsed. [21] This suggests that newborns are less interested in feeding when satiated. In a study of 7- to 14-week-old infants, milk volume intake related to time since the last feeding. [17] The link between time elapsed and milk intake was unexpected, as newborn experimental animals maximize intake of available milk. Exactly what the infant senses as a correlate of time since last feeding remains unclear but could include energy expended, sensation of gastric filling, or desire to suckle. Breastfed infants reduce milk volume intake with pacifier use, suggesting a role for suckling in self-regulation of intake. [22, 23] It is also possible that hormonal mechanisms increase pleasure related to feeding after some time has passed. Whether infants self-regulate their intake for energy balance or energy excess is not known, but is one of the most important scientific questions related to early feeding and risk for obesity. Even in adults, it is not clear whether energy is regulated around a set point, settling point, or a different model that better explains gene-by-environment interaction. [24] Behavioral and basic research testing drivers of infant satiety and satisfaction, bringing together longitudinal studies of different feeding strategies with careful measurement of possible regulators promise to begin to solve this important puzzle. [25–30]

REWARD MECHANISMS RELATED TO EATING

Recent advances in neuroscience relating eating behavior to brain reward systems hold promise for understanding disorders of under-eating and overeating (Figure 2). [31] Brain-based reward systems work in concert with hormonal regulators of energy balance. [32, 33] While early development of reward systems remain incompletely understood, it seems likely that pleasure and reward come into play in young children. Humans are unlikely to overeat bland foods, but palatable foods are frequently eaten in excess of energy requirements. [34–

38] Delicious foods are known to enhance mood by activating reward systems.[39] The striatum, insula, anterior cingulate cortex and midbrain regions including the ventral tegmental area and substantia nigra are active in representing reward in response to food. [31] Dopamine is involved in reward response to palatable food consumption. [40] In addition, the orbito-frontal cortex encodes specific types of reward stimuli including various aspects of food: odor; visual input; temperature, viscosity, astringency and fat texture; and taste. [41–44] Neurons respond strongly at the beginning of an eating episode and become less responsive as satiety for a specific food is reached. Behavioral research suggests that this phenomenon is already present in 2.5- to 5-year-old children. [45] As interest diminishes for one food, neurons remain capable of a reward response to other foods. Having a variety of foods available may lead to increased consumption. [46] This may have had evolutionary advantage in ensuring intake of a variety of nutrients. In the current era, it could be one factor related to population risk for obesity. Similarities between overeating in obesity and excessive drug use in addiction suggest that both may relate to a change from “liking to wanting”. [43] Novel research strategies are bringing energy homeostasis and reward homeostasis together in new models of appetite regulation to disentangle “liking” from “wanting”. [24, 47–50]

DEVELOPMENT OF SENSORY PREFERENCES – GENES AND EXPOSURE

Recognition of tastes and odors develops before birth with fetal exposure, as the fetus swallows amniotic fluid, flavored by the mother’s diet including aromatic compounds from garlic, anise and onion. [51–54] Infants exposed to carrot juice in the mother’s diet during the third trimester of pregnancy or lactation were more likely to prefer infant cereal made with carrot juice compared to those without early life exposure. [55] There is considerable interest in prenatal programming of taste preferences as it could lead to interventions to influence early acceptance of nutritious foods. [55, 56] Longitudinal studies of infant taste preferences could be designed by enrolling infants born to mothers participating in randomized controlled trials testing interventions to promote healthier diets diets during pregnancy. [57–59]

After birth, breastfed infants are still exposed to flavors from the maternal diet. [55] Months before the first tastes of baby foods or non-milk beverages, these exposures establish and modify taste preferences in the infant, at least in the short term. Early in life, most infants and children prefer sweet and salty flavors [60–62], preferences that are enhanced by increased exposure and decrease slightly by adulthood. [63–66] Bitter flavors, such as those in vegetables, are often rejected when first experienced, but liking increases with exposure. For example, infancy exposure to soy and hydrolyzed protein formulas was associated with accepting these formulas 4 years later. [67] During early childhood, repeated exposure to a variety of foods is associated with initially non-preferred foods. [68] In some cultures, children are deliberately exposed to strong flavors. For example in Mexico, they are given food flavored with chili peppers at gradually increasing strength. [69, 70] Learning to like initially unpalatable foods may be part of a process of socialization. [71] Taste preferences relate to prior experience, developmental stage, and genes that influence flavor perception. [72] A well-studied example is the ability to taste the bitter compound, 6-n-propylthiouracil (PROP), mediated in part by the TAS2R38 gene. [73] Children who do not taste PROP may be more likely to accept vegetables. Insensitivity to, PROP, occurs in approximately 30% of Europeans and varies worldwide. [74] The ability to taste PROP is associated with perceiving bitter foods as less palatable, lower vegetable intake, more food aversions, and risk for childhood obesity. [75–82]

EARLY DEVELOPMENT

During the first 2 years, infants progress through three developmental feeding periods: the nursing period, the transitional feeding period, and the modified adult feeding period. Feeding development typically proceeds based on well-described neuro-developmental milestones (Table 1).

Nursing Period

Dependence on milk feeding characterizes the nursing period (birth to 6 months). The full term neonate possesses primitive reflexes, including sucking and rooting, allowing feeding during first hours of life. [83] Another primitive reflex, gagging, protects the airway and sometimes interferes with suckling. [84] The small volume of colostrum decreases the chance of choking and regurgitation. As coordinated sucking and swallowing rapidly improve, the volume of transitional milk gradually increases over the first 4 to 10 days. Most full term infants are accomplished “nursers” within 2 weeks. Competent infant sucking is necessary for the dyadic process of breastfeeding. Therefore, breastfeeding is perturbed when the infant is sleepy or neurologically impaired.

Breastfeeding mothers experience important physiological changes related to infant feeding, including a surge in oxytocin and prolactin production by the fourth postpartum day. [85, 86] Oxytocin promotes maternal-infant bonding and prolactin inhibits sexual interest. Both hormones remain high during lactation and are highest during exclusive breastfeeding. Oxytocin and prolactin contribute to maternal-infant responsiveness and decreased attention to other interests. The reciprocal process of breastfeeding is the prototype of dyadic maternal-infant feeding. [87] Social feeding behaviors, holding, rocking, stroking, and visual engagement, occur during breast- and bottle-feeding. Fatigue, distraction, stress and depression can disrupt adaptive feeding interaction. [88]

Complementary feeding

Complementary foods, nutritionally inferior to human milk or iron-fortified infant formula, are frequently offered to infants less than 6-months old. In developing countries, this practice can be a major cause of malnutrition. [89] By 6 months, infant caloric and iron needs typically exceed the capacity of breastfeeding, beginning the “transitional feeding period”. Between 6 and 12 months, infants gradually increase consumption of complementary foods as calories continue to come predominantly from milk. Current U.S. recommendations for infant feeding include: exclusive breastfeeding for 6 months; using infant formulas to supplement breastfeeding, if necessary; and introduction of complementary foods at 4 to 6 months with breastfeeding and complementary foods continuing to 12 months. [90] World Health Organization recommendations are for exclusive breastfeeding for 6 months followed by complementary foods and breastfeeding until 2 years.[91] Feeding practices during this period have varied widely by history, culture and custom. In the U.S., feeding practices changed radically from the early 1900s to the 1960s. At the turn of the last century, supplemental foods were not routinely provided until the end of the first year. Concern about malnutrition including rickets led to the development of precooked infant cereal. The initial product, introduced in 1930, was made of wheat, oatmeal, corn meal, bone meal, dried brewer’s yeast, and powdered alfalfa leaf, fortified with reduced iron, providing minerals and vitamins A, B_1, B_2, D, and E. [92] By 1950, most pediatricians recommended complementary foods for infants beginning at 3 to 8 weeks. [93] This trend toward very early feeding was reversed over the next 2 decades. [94] The fact that most infants accommodate to varying cultural and historical feeding patterns and achieve adequate growth is a testimony to infant adaptability and resilience.

Development

Recommendations to begin complementary feeding at 6 months are based on current understanding of nutritional needs and infant neurodevelopmental capacity (Table 1). Important considerations include the ability of the infant to accept non-liquid food without choking, gagging or tongue thrusting. One primitive reflex, the extrusion reflex, protects the infant from choking by a tongue thrust in response to food placed on the tongue. This reflex gradually diminishes over the first 2 to 4 months. The development of neck stability, sitting and reaching are also important milestones related to feeding. Six-month-old infants sit with support and indicate interest and disinterest in feeding. Near the end of the first year, infants become capable of handling more textured foods and partial self-feeding. The timing of cup feeding varies by context. For example, in Australia, public health messages encourage cup feeding as early as 6 months, because of bottle feeding-related tooth decay. [95]

Modified adult diet

In the second year, toddlers consume a diet that resembles their families' preferences. Introduction of a variety of nutritious foods and flavors is important during both the transitional and modified adult periods as younger toddlers are initially more accepting of novel foods compared to preschool children, who may be reluctant to try new foods. The reluctance to try new foods is low at weaning and rapidly rises to a peak between 2 and 6 years, with considerable variability. [96] Neophobia is often more pronounced for eating than it is in other developmental domains. [97–100] It is possible that food neophobia provided selective advantage, protecting individuals from eating unfamiliar, potentially toxic plants. [101] Highly neophobic children eat fewer vegetables, fruits, and meats compared to others. Some children, such as those with autistic spectrum disorder, are at greater risk for nutritional problems because of selective food intake. [102]

Cultural influences

Cultural norms for caring for infants and toddlers influence feeding practices. [103] Customs related to clothing, carrying, sleeping, holding and placing the infant when not held, play a role in feeding. [104] In some cultures, mothers are expected to chew food for their infants and toddlers while in other cultures this practice is considered unsanitary and possibly harmful. [105] Toddlers may be placed in a feeding chair, fed in the arms of the parent, or allowed to walk from person to person at the family table. [106] Cultural feeding practices often persist in first generation immigrants, perhaps more so when grandparents from the country of origin are involved. [106] Furthermore, authoritarian feeding practices have been noted to increase in first generation immigrants and lessen during the second generation. The diversity of feeding practices by culture reinforces the concept that infants and toddlers, as a group, can adapt to vastly differing approaches to feeding. However, individual vulnerabilities may lead to feeding perturbations even when the feeding practices are culturally acceptable.

Many families do not follow expert feeding recommendations. [107] Given the historical context, clinicians might accept some variation for infants who are gaining appropriate weight with positive affect during feeding. However, certain culturally-appropriate feeding strategies might increase risk for excess or inadequate weight gain, or feeding problems. [103] A current concern, the dramatic increase in childhood obesity over the last 40 years, occurred during a period of stable recommendations related to infant feeding. As formula feeding and early complementary feeding are associated with more rapid infant growth and risk for obesity, cultural norms at odds with current infant feeding recommendations could be one factor in obesity risk. [108–116] Cultural influences on infant feeding practices have been documented in the medical literature for more than 35 years and there is a vast literature related to culturally-tailored interventions to promote breastfeeding initiation and

longer breastfeeding duration. [117–121] Research aimed at developing culturally-tailored approaches to optimizing early life growth and feeding development is needed. Culturally tailored interventions to promote healthful toddler feeding are similarly important. [122]

The amount of toddler feeding independence allowed or encouraged varies greatly by culture and often relates to how independence and interdependence are valued. [106] In the U.S., toddlers are expected to self-feed early, but in some cultures, toddlers may be consistently fed by adults until much later. Infants depend on the caretaker's capacity to understand their cues related to hunger and satiety. The dyadic nature of feeding continues into the transitional period. As infants approach the end of the first year, they are increasingly able to express their wants and needs and gradually express increasing desire for independence in many activities, including feeding. Strategies to allow increasing self-feeding as competence develops may prevent mealtime distress and, in some cases, feeding disturbance.

PARENT-CHILD INTERACTION

Temperament

Infant and child temperament may influence parental feeding strategies and, in some cases, may be an independent factor related to eating behavior. Infant-caretaker interaction difficulties or poor "fit" can lead to failure to thrive. [123] The caretaker may be unable to understand the infant's cues and the infant may not adequately express wants and needs. Difficult infants are more prone to develop feeding problems. [124–128] Early food refusal may predate weaning problems, and less positive maternal perceptions of parenting. [129] In several observational studies infants perceived to have more difficult temperaments were less likely to be exclusively breastfed in the first 6 months and more likely to receive early complementary feeding. [107] In school age children, a number of published studies have found no cross-sectional relationship between temperament and eating behavior. However, a Canadian study of 81 sibling pairs concluded that shyness was correlated with increased risk for food neophobia. [130] Another study from Australia, found that infant temperamental characteristics were associated with increased risk for eating disorder symptoms at 12 to 13 years. [131] While these studies, as a whole, do not support infant temperament as a strong predictor of short term or long term eating behaviors, they do suggest that infant temperament plays a role in parent-child interaction related to feeding. Including observational repeated measures of infant temperament and caretaker-infant interaction in longitudinal studies would shed led on the relationships between infant temperament, parenting practices and eating behaviors across childhood.

Parenting styles

Parenting styles, defined by how demanding and responsive parents are in relationship to child behaviors, are important environmental determinants of child emotional maturity, self regulation and behavioral inhibition. [132–136] Research on the influence of parenting on child outcomes have relied on 4 parental prototypes—described as authoritative, authoritarian, permissive, and rejecting/neglecting—developed by Baumrind almost four decades ago. [137] According to this schema, parents are classified according to how they reconcile the joint needs of children for nurturance and limit setting. Authoritative parents are demanding and responsive, and are characterized by high levels of control and warmth. They monitor the child's behavior and convey clear standards without resorting to intrusive or restrictive approaches. Parents categorized as authoritarian are demanding and directive with low levels of responsiveness. They exhibit high levels of control (similar to authoritative parents), but in contrast show lower levels of warmth. Permissive parents are less likely to be demanding and to require mature behavior, but exhibit high levels of

responsiveness. They tend to be lenient and avoid confrontation. The fourth prototype, parents who exhibit a rejecting/neglecting parenting style, are neither demanding nor responsive. Using this construct, children exposed to authoritative parenting show the highest levels of self efficacy, self-discipline, and emotional maturity. Recent research on eating behavior has examined parenting style as a potential environmental determinant of children's eating behavior. Indulgent or permissive parental feeding style has been positively related to child BMI in preschool children from low-income U.S. and Australian samples and in middle class U.S. first graders. [138, 139] Permissive parenting has also been associated with lower monitoring of unhealthy dietary intake in school-age U.S. children. [140, 141] Parenting characterized by low responsiveness was also a risk for obesity and for emotional eating (associated with disregulated eating and risk for obesity) in U.S. first graders, sampled from the longitudinal NICHD Early Child Care Study. [138] In both U.S. and British samples—sampled from a large longitudinal study and small observational cohort, respectively—authoritative parenting and warmth are protective against emotional eating and risk for obesity. [138, 140]

Restriction, control and monitoring

Parental control of child feeding has been extensively studied relative to highly directive feeding, including restriction. [142, 143] It has become clear that it is important to differentiate between overt and covert parental control of children's eating behavior and food choices. Overt control includes both restricting, and pressure to eat. Covert control includes strategies such as purchasing only healthy foods for the home and avoiding stores and restaurants that sell unhealthy foods. [144] Overt control can be detected by the child, while covert control involves management that the child may not recognize. Parental eating behaviors also play a role in covert control [144, 145], as parents model healthy eating behaviors for their children. Most parents use some overt and some covert controlling strategies. [146] Furthermore, they may be controlling in some situations but not in others. Parents report changing strategies as the child's needs evolve. Because child feeding involves a bidirectional process, parent and child characteristics are both instrumental in determining parental control of child eating. Parental control is also influenced by family and cultural norms related to diet and to child eating behavior. Controlling or restrictive feeding practices play an important role in the development of feeding behavior. [14, 142] A large body of research shows that overtly restricting access to certain foods or to desired quantities of food may be counterproductive and associated with increased caloric intake and disinhibited eating. For example, girls exposed to higher levels of maternal restriction at 5 years, were more likely to exhibit disinhibited eating, measured experimentally in the laboratory as "eating in the absence of hunger" at age 7 and 9 years. The relationship was stronger if they were overweight. [14, 145, 147, 148] The investigators hypothesized that overt restricting and controlling could blunt ability to self-regulate caloric balance and energy needs and lead to varying degrees of uncontrolled eating, weight gain, obesity, and risk for eating disorders. In this longitudinal study, child obesity was not a precondition of restriction. In other studies, parental restriction has been shown to develop in relationship to perceiving the child as overweight or tending to overeat, or maternal body image. [149] The important work of Birch has been based largely on a longitudinal cohort of approximately 200 white, middle class girls from non-urban Pennsylvania, and is best understood in that context. [150] Birch and her research team have continued to investigate these relationships as the participants age using both laboratory-based to naturalistic settings. [142] The paradigm of eating in the absence of hunger has been used in research in a variety of different contexts, including Latino adolescents and urban samples. [34, 151, 152]

Other aspects of parental control merit specific mention, including rewards, prompts to eat, intrusiveness and monitoring. More than 20 years ago, Birch showed that using rewards to

promote consumption of healthy foods, or to "clean your plate" resulted in declining preference for those healthy foods. [153] In another study, mothers with less education were more likely to prompt their 3- to 6-year olds to eat. This was especially true if the child was younger and the food was novel. While obese mothers were not more likely to prompt their child to eat than non-obese mothers, [154] when prompted, their children were more likely to accept the food (compliant) than children whose mothers were not obese. This research highlights the complexity of the dyadic interaction related to feeding and suggests that unmeasured variables (i.e. mother-child relationship, genes) may promote the child to eat more in certain settings. Conversely, high maternal promotion of feeding has also been noted to adversely influence growth in infants with failure to thrive, in certain settings. [155] More aberrant parenting behaviors, including intrusiveness, have been associated with infant eating disorders. [156] Intrusive feeding patterns manifest when parents are unresponsive to the child's feeding cues, in favor of their own perceptions or needs. Examples include insistence on finishing the last bite, coercion and, in the, extreme, force-feeding. To date studies related to pressure and intrusiveness in infant feeding are mostly cross sectional making it difficult to infer temporal precedence.

Parental monitoring of child intake, one of three factors assessing parental control attitudes and practices in Birch's validation of the Child-Feeding Questionnaire, [157] was included in the construct of parental control that was associated with increased risk for disinhibited eating. However, recent research, assessing monitoring as a separate construct, suggests that parental monitoring can, in fact, positively influence children's growth and eating behavior. Monitoring has been related to appropriate weight gain and to weight loss in the case of obesity. [158, 159] Recent research using the NICHD Early Child Care Study showed that parental dietary monitoring of 3rd grade girls was not related to increased risk for eating disorders, 3 years later, [160] supporting the distinction between restricion and monitoring. Furthermore, evidence-based weight loss programs include monitoring and control, and these programs do not promote eating disorders in obese children (who are known to be at increased risk). [146, 161]

In summary, a vast body of work on parenting behaviors related to child eating suggests that most parents use some overt or covert strategies related to promoting what they perceive as optimal eating behavior and diet. In the current obesogenic environment, control and monitoring of children's food environment seems essential. However, some strategies can be counterproductive, including rewarding the consumption of certain foods, some overt controlling practices and intrusive feeding strategies.

SOCIAL INFLUENCES ON ENERGY INTAKE AND EATING BEHAVIOR

Eating is among the most social of human activities. [162] Experimental evidence suggests social influences on energy regulation in infants. In an elegant experiment with 7- to 14-week-old infants, volume of intake was related to social interaction. Infants who were held, compared to infants fed in an infant seat, had intake linearly related to time since the last feeding. [17] However, when a novel feeder visually engaged with the infant, there was a lower association between volume and time since last feeding. The investigators concluded that "social influences exert strong immediate impacts on suckling". Suckling provided nutrition and an opportunity to obtain social information about the feeder. Disregulation of volume from time since last feeding, did not occur if the mother was the feeder and socially engaged with the infant during the feeding.

Social facilitation, increased behavior based on the sight or sound of others engaged in the same behavior, has been demonstrated as a determinant of eating behavior in primates, and human children and adults. [15, 163–173] Social facilitation is believed to be based on either

increased arousal or time extension. In an experimental study, preschool children showed increased consumption, when groups were large and snack time was longer (≥11 minutes). [15] Children in larger groups initiated the snack more rapidly and ate slightly faster. Increased consumption only achieved significance when there was adequate time, as eating rates were marginally different. When the children socialized during the meal, their consumption was lower. Adult prompting had no effect on amount consumed. [15]

Adult testimony and modeling promote children's acceptance and liking of novel foods. Children as young as 18-months old recognize that they may not like the same foods adults do, but are more likely to try foods that adults recommend. [174] By 3 years, children understand that adult testimony is not always reliable, yet still tend to try foods based on adult recommendations. Later, children are more likely to remember these flavors, and children over 4-years old have increased odds of "liking" the flavor. [175] Testimony regarding palatability is likely to be trusted by 3- to 6-year olds especially when absolute terms ("great", "delicious") instead of relative terms ("better", "more") are used. [174] Adult modeling is a remarkably effective method of persuading preschool children to eat novel foods. [96, 174] Acceptance of a novel food is enhanced if offered by a familiar adult, who is eating food identical in shape, size and color. [96] This differentiates human children from juvenile primates who accept novel foods based on social facilitation alone.

Social suggestion can also modify children's food preferences. In 1938, social psychologist, Karl Duncker, studied the efficacy of social suggestion in influencing British preschool child behaviors and endorsed preferences. [176] The children tasted and rank-ordered preferences for six different foods. One week later, they were exposed to a classmate's preferences. Most children changed their rank order to match their classmate's, especially if he/she was slightly older, or particularly admired. Change in food preference was likely to persist for 2 months if there were multiple exposures over several weeks. In another experiment, children who listened to a social story in which the hero "saved his people" by providing an unpalatable food, were likely to choose to eat the unpalatable food over chocolate. (They had tasted both foods before). The preference was prolonged by hearing the story again. It appears that social suggestion is a powerful modifier of children's food preferences. This becomes important with increasing peer influence during adolescence and young adulthood, often resulting in preferences for less healthy foods. [177]Furthermore, the power of social suggestion is not lost on industries that successfully influence children's food preferences and choices, the effects being strongest for the least healthy foods. [176, 178, 179] In summary, behavioral research suggests that social factors from family, peers and larger social groups strongly influence food selection and development of preferences.

CONCLUSION

While there are many unanswered questions related to the development of eating behavior, we are in a period of rapid expansion of our understanding of the intricate and sophisticated processes of energy regulation and reward regulation. Advances in neurosciences and genomics promise to elucidate individual differences in energy regulation, taste preferences, and reward seeking behavior related to food. Future research promises to change the way we think about energy and reward regulation by addressing many questions including the following. How does exposure increase liking? To what extent do specific sensory cues and social influences account for acceptance and liking of foods? Is food an addictive substance for some people? Furthermore, behavioral research is shedding light on how feeding experiences, parent-child interactions and larger social influences modify eating behavior. Understanding the development of eating behavior is important as many clinical and public health problems, including failure to thrive, eating disorders and obesity, are better understood when development is taken into account. Complex biological, developmental,

psychological and social systems drive the development and maintenance of eating behaviors. Increasing understanding of each level will inform prevention, intervention and treatment of eating behavior related conditions.

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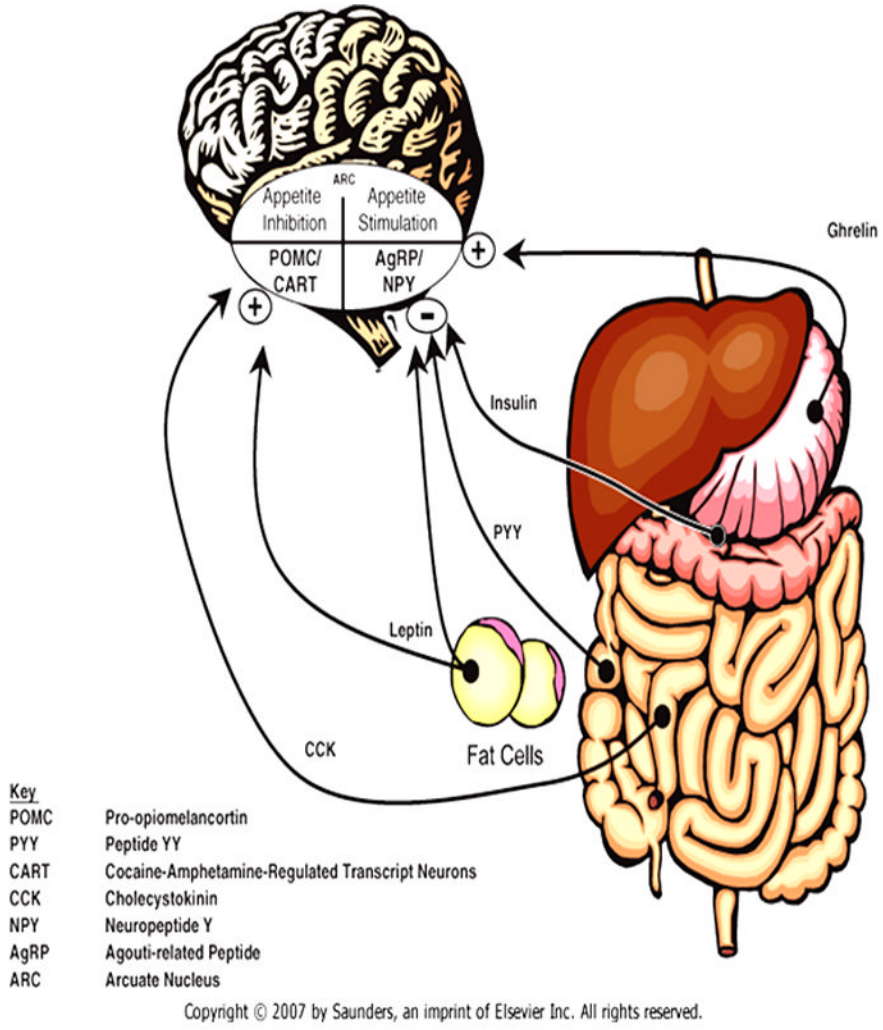

Figure 1.
Control of appetite
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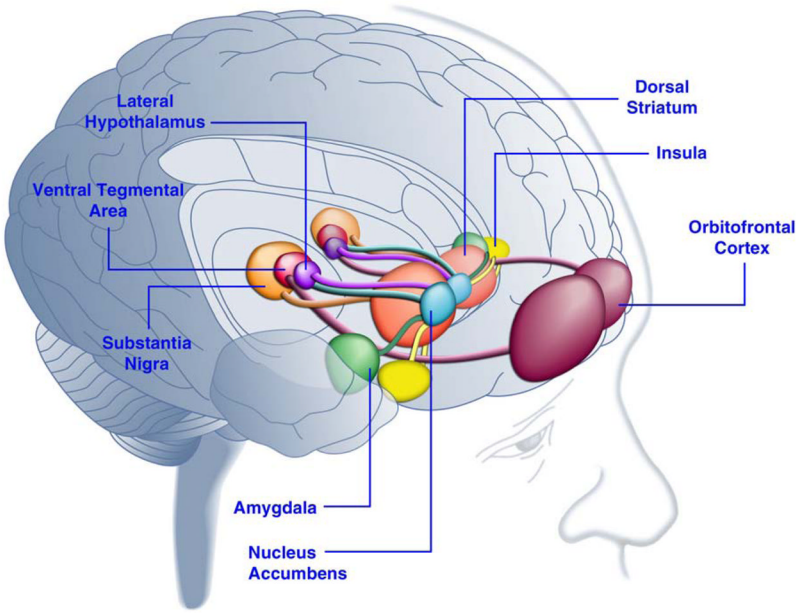

Figure 2.

Areas of the Human Brain Activated in Response to Palatable Food or Food-Associated Cues

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Table 1

Selected neurodevelopmental milestones related to feeding [144–146]

Gestational age (weeks)	
16–20	Swallows amniotic fluid
18–24	True suckling
34–37	Coordinated suck and swallow
Postnatal age (months)	
2–4	Loss of extrusion reflex
10–12	Pincer grasp
8–18	Self-feeding develops
9–12	Cup drinking
18–24	Precise up and down tongue movements
24–26	Circulatory jaw rotation