7

Feeding the Term Infant

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Growth, particularly in weight, length, and additional anthropometric measurements, remains a measure of adequacy of nutritional regimens for the growing infant and child. Infant feeding decisions have an impact on lifelong medical illnesses, growth, and developmental abilities well beyond infancy. This section will review normal growth and requirements in healthy term infants.

Growth

The average weight of a healthy term infant is 3.5 kg. With an anticipated loss of 10% in body weight in the first week of life, birth weight is regained by two weeks of age in both breast-fed and formula-fed infants, with the formula-fed infants demonstrating a tendency to regain birth weight sooner than their breast-fed counterparts.

Body weight should be measured with an electronic scale or a beam balance without detachable weights, with the balances capable of weighing to the nearest 10 g. Even with the use of electronic scales, balances should be tared with calibrated weights at least two times a year. Mean weight and selected centiles for weight are summarized in Table 7.1. In clinical practice, however, weight and other anthropometric measurements including length, head circumference, and weight for length are plotted on growth charts (Figures 7.1 and 7.2) adapted from Hamill et al.[1] The plotting of growth on these charts will suffice for monitoring of normal infants; however, a different and more sensitive approach will be needed for infants with faltering growth. The "reference data" provided by Fomon[2] combine data from the University of Iowa and the Fels Longitudinal Study, the latter data used in the growth charts.

Length

Length should be measured by two examiners using a calibrated length board with a fixed headpiece and a movable foot board. The head is held by one examiner with the Frankfort plane (defined as a line that passes through the left porion, the right porion, and the orbits)

TABLE 7.1

Mean Body Weight and Selected Centiles for Males and Females, 0–12 Months of Age

Age	Mean	5th centile (g)	50th centile (g)	95th centile (g)
Mean body weight and selected centiles for males, 0–12 months of age				
Birth	3350	2685	3530	4225
1 mo	4445	3640	4448	5238
2 mo	5519	4574	5491	6475
3 mo	6326	5321	6323	7393
6 mo	7927	6670	7877	9146
9 mo	9087	7785	9008	10,448
12 mo	10,059	8606	9978	11,676
Mean body weight and selected centiles for females, 0–12 months of age				
Birth	3367	2750	3345	4095
1 mo	4160	3548	4123	4885
2 mo	5049	4301	5009	5878
3 mo	5763	4837	5729	6712
6 mo	7288	6063	7239	8547
9 mo	8449	7072	8373	9723
12 mo	9425	7942	9362	10,863

Modified from Fomon S.J. and Nelson S.E. In *Nutrition of Normal Infants,* CV Mosby, 1993, 36, p. 155.

in the vertical position, and gentle traction is placed to bring the head into contact with the headpiece. A second examiner holds the infant's feet with the toes pointing upwards, and while applying gentle traction, brings the footpiece to rest firmly against the infant's heels. Measurements agreeing to within 0.4 cm are considered adequate, and the importance of length measurements is underscored, particularly when serial measurements are made in a longitudinal fashion. It is generally agreed that faltering in length as well as weight suggests growth faltering of a longer duration than when weight alone is affected.

Head Circumference

Head circumference is measured by a narrow flexible steel or paper tape applied to the head above the supraorbital ridges and encircling the most prominent parts of the forehead and the occiput. The maximum of three measurements should be used as the maximal circumference. Weight-for-length measurements (Figures 7.1 and 7.2) are also available and are useful in defining obesity as well as leanness.

A variety of other measures to define growth include skin fold thickness, limb length and circumference, and body mass index. The latter, body mass index, is calculated by dividing weight in kilograms by length in meters squared, replacing weight for length in older children. In any case, accurate measurements are essential to the interpretation of growth charts.

Normal growth is a strong indicator of nutritional sufficiency and overall health of an infant. Since infancy is a period of rapid growth, particularly early infancy, identifying growth failure is important and requires prompt medical attention. As we understand more about the complex interactions between genetic, immunologic, metabolic, physiologic, and psychologic factors and their effects on long-term outcomes of infant feeding decisions, defining appropriate growth becomes a very important issue for health care providers of children.

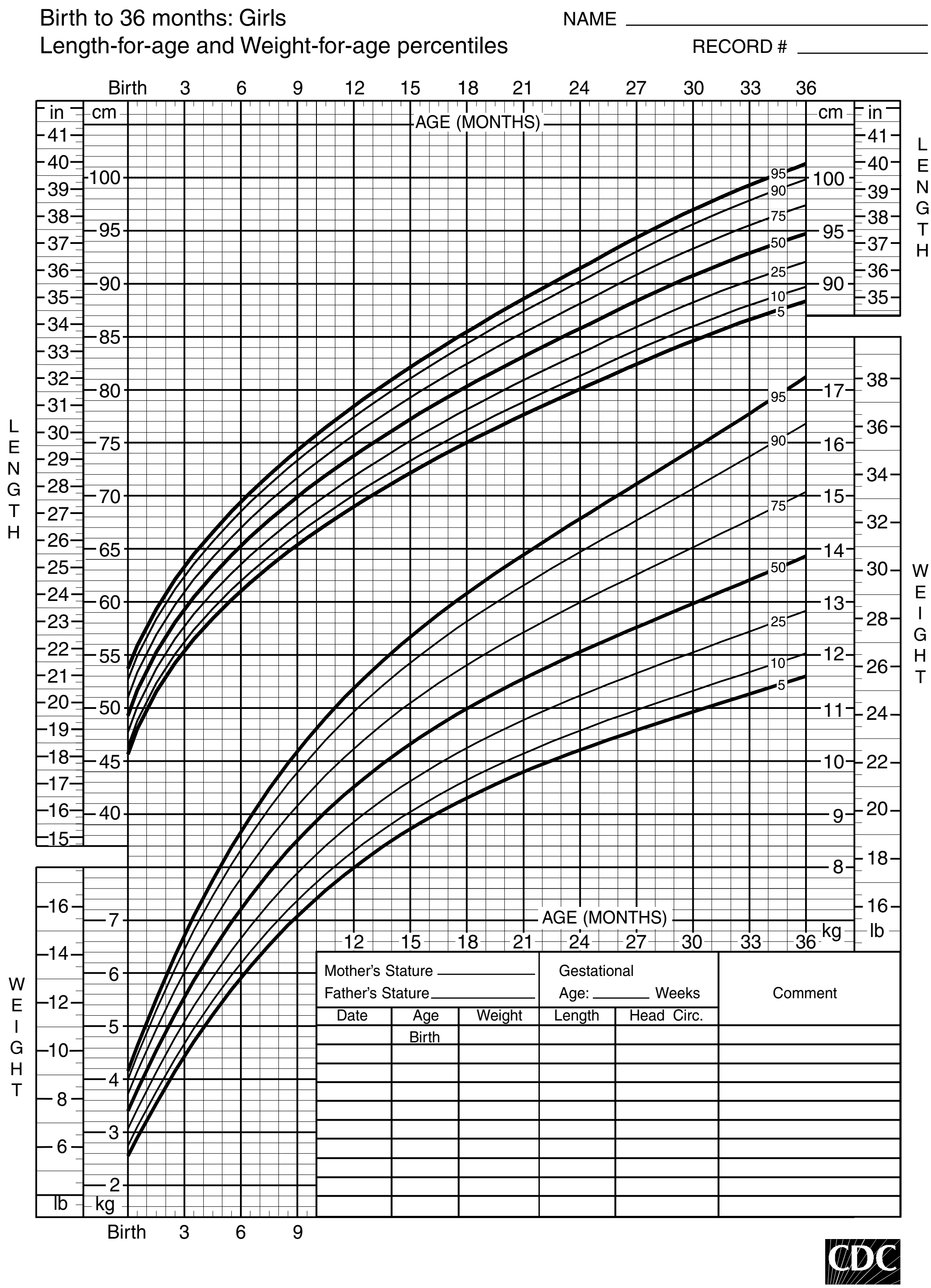

FIGURE 7.1
Girls: birth to 36 months: physical growth NCHS percentiles.

Birth to 36 months: Girls
Head circumference-for-age and
Weight-for-length percentiles

NAME ______________________

RECORD # __________

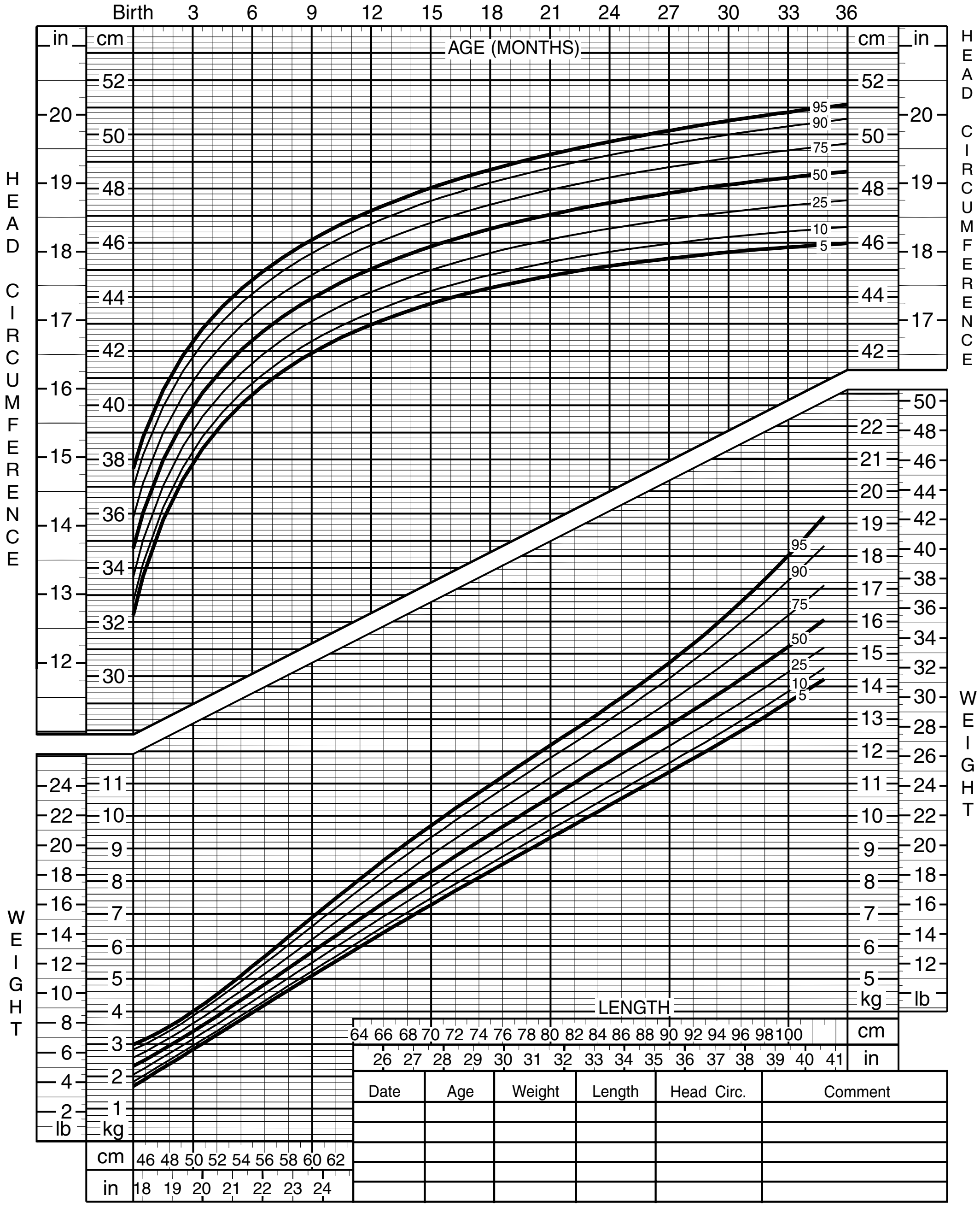

FIGURE 7.1
Continued.

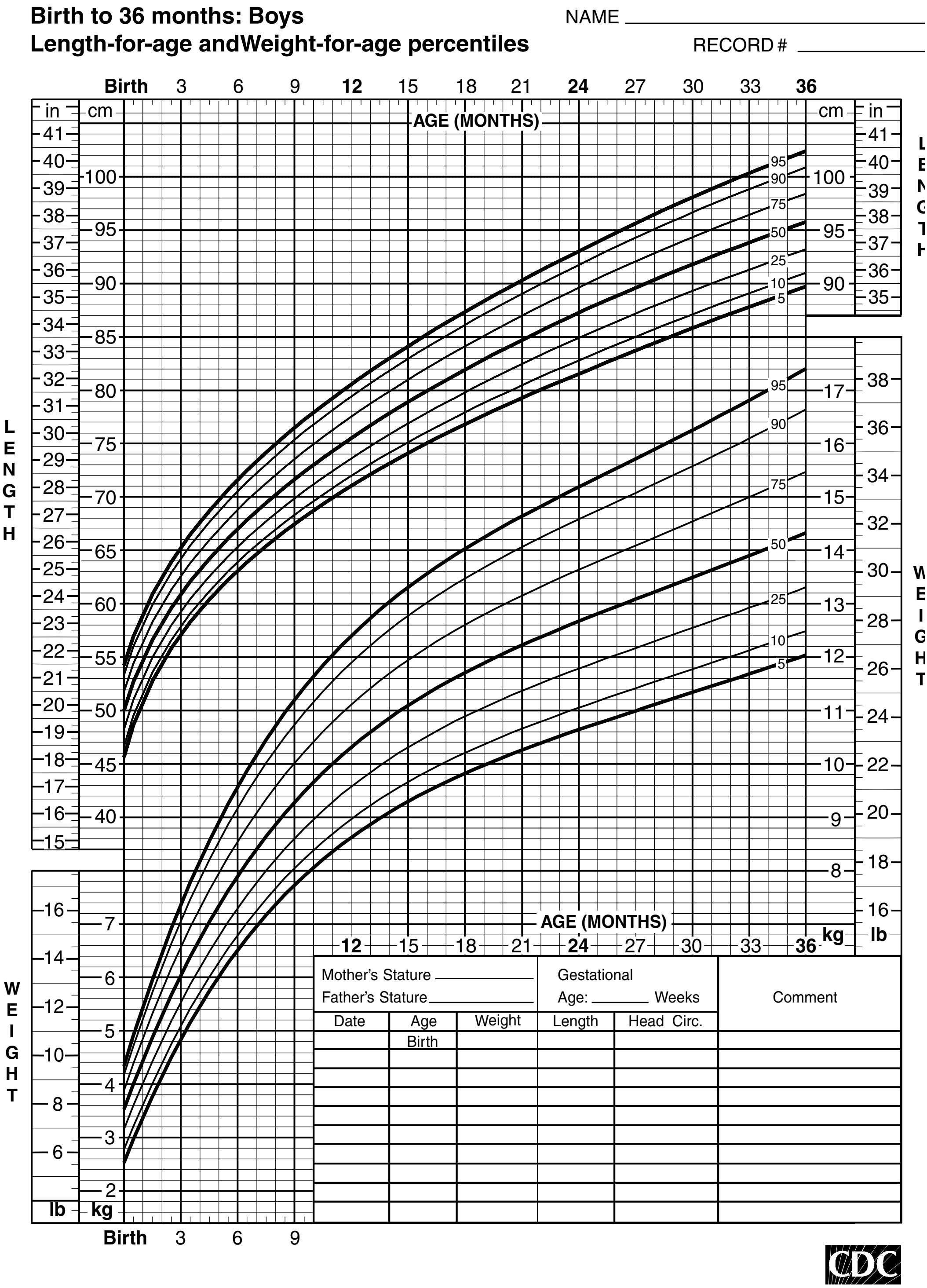

FIGURE 7.2
Boys: birth to 36 months: physical growth NHS percentiles.

Birth to 36 months: Boys
Head circumference-for-age and
Weight-for-length percentiles

NAME ______________________

RECORD # __________

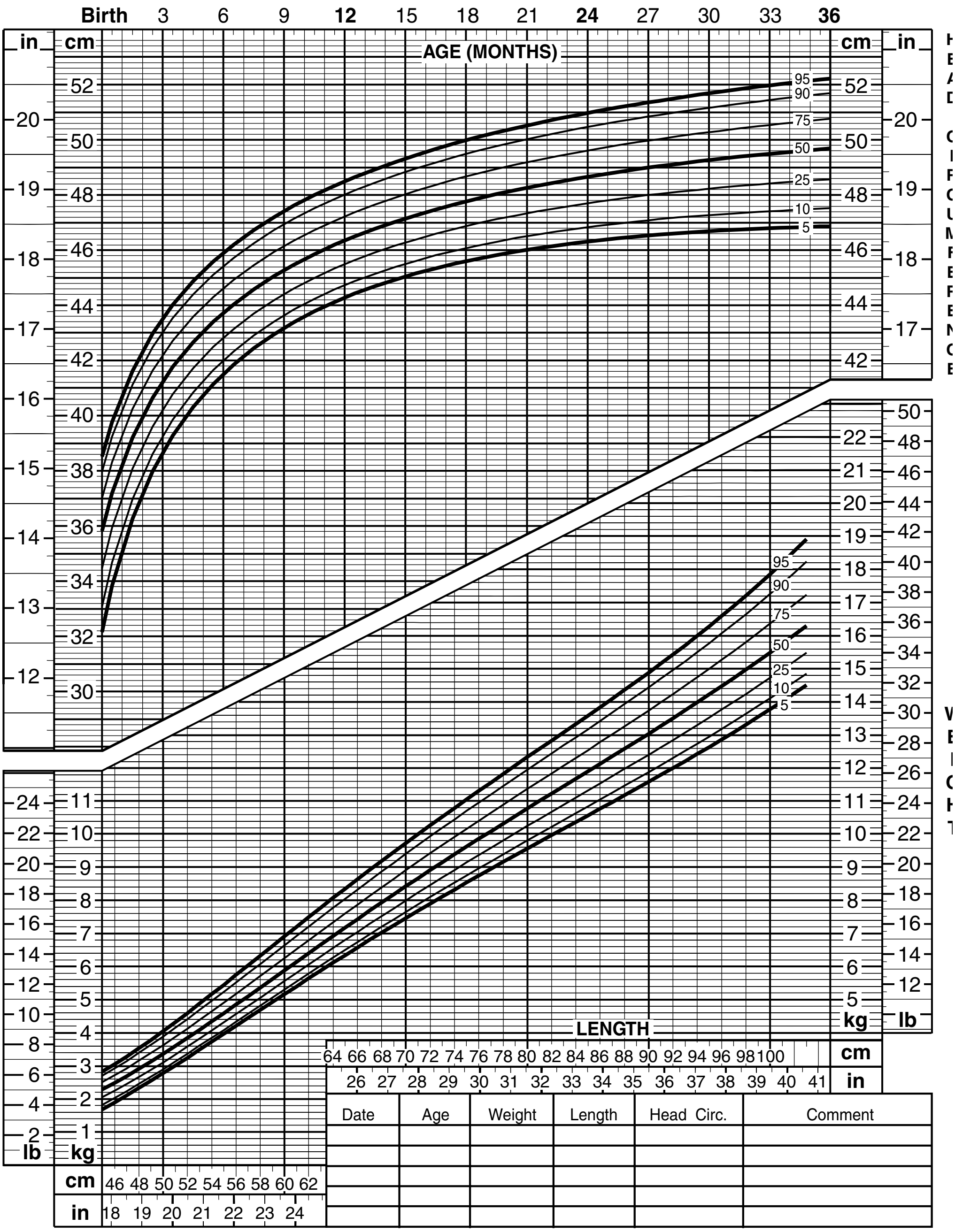

FIGURE 7.2
Continued.

Energy

Energy requirements during infancy may be partitioned into basal metabolism, thermic effect of feeding, thermoregulation, physical activity, and growth. The energy requirements for growth relative to maintenance, except in early infancy, are small, and satisfactory growth can be considered a sensitive indicator that energy requirements are being met. Energy balance may be defined as gross energy intake = energy excreted + energy expended + energy stored. Gross energy intake, measured by the heat of combustion, is greater than energy available when fed because most foods are not completely digested, and protein oxidation is incomplete. Fat absorption varies widely among infants fed various formulas, particularly in infancy. Urea and other nitrogenous compounds are excreted in the urine. Gross intake is calculated as 5.7 kcal/g, 9.4 kcal/g, and 4.1 kcal/g obtained from protein, fat, and carbohydrate, respectively, and therefore it varies given the type of diet fed. The term "digestible energy" refers to gross energy intake minus energy excreted in the feces. Metabolizable energy is defined as digestible energy minus energy lost in urine. The metabolizable energy values for protein, fat, and carbohydrate are close to 4, 9, and 4 kcal/g, respectively. Losses of energy, other than feces and urine, are negligible and are ignored for practical purposes.

The energy intake of normal infants per unit body weight is much greater than in adult counterparts. Energy requirements for term infants have been estimated by various groups and vary from 100–116 kcal/kg/d from 0–3 months and decline to about 100 kcal/kg/d by the end of the first year.[3-7] These recommendations are based on the median intake of thriving infants; the intakes of breast-fed infants are lower than that of formula-fed infants, with an average of 3–4% lower in the first three months, and 6–7% from three to six months. As new, more precise estimates of energy expenditure become available, these recommendations are apt to change, given that current recommendations are higher than the "gold" standard — the breast-fed infant. Energy intakes of infants from 6 to 12 months of age have been reported to be between 91 and 100 kcal/kg/d.[8-10]

Protein

Intakes of protein and essential amino acids are generally sufficient in developed countries, in contrast to developing countries where protein and protein-energy malnutrition are still a frequent occurrence. In appropriately fed infants, protein is not a limiting dietary component in infancy and is clearly essential for normal growth and development. For the human infant, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine are considered essential amino acids. The data for cysteine are conflicting[11,12] for the term infant, although the data are clear for the preterm infant. Conditionally essential amino acids are those that become essential under certain circumstances, since they may be produced in inadequate amounts endogenously. An example of this is taurine, which is now added to formulas based on reports of greater concentrations of taurine in the plasma and urine of preterm[13,14] and term[15] infants. The concern about taurine depletion stems from the observations of growth retardation, abnormal retinal findings, and impaired bile acid metabolism in taurine-deficient animals and humans.

Recommended dietary intakes of protein are summarized in Table 7.2. In contrast, intakes recommended by WHO[16] are 2.25, 1.86, 1.65, and 1.48 g/100 kcal from 1–2, 3–6,

TABLE 7.2

Recommended Dietary Intakes of Protein

Age Interval (mo)	Recommended Dietary Intake ($g \cdot kg^{-1} \cdot d^{-1}$)	(g/100 kcal)
0 to 1	2.6	2.2
1 to 2	2.2	2.0
2 to 3	1.8	1.8
3 to 4	1.5	1.6
4 to 5	1.4	1.6
5 to 6	1.4	1.6
6 to 9	1.4	1.5
9 to 12	1.3	1.5

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6–9, and 9–12 months, respectively. Both of these recommendations are generally higher than the intakes observed in human milk-fed infants.

Fat

The importance of dietary fat is underscored by the fact that 35% of the weight gain of an infant in early infancy is accounted for by fat.[17] Most of the dietary fat is in the form of triglyceride formed by three fatty acids esterified to a glycerol backbone. In the body, triglycerides are the main form of storage and transport of fatty acids. Phospholipids and cholesterol are indispensable components of the lipid bi-layer of all cell membranes, and the amount of different phospholipids and cholesterol, as well as the fatty acid pattern of incorporated phospholipids, modulate membrane fluidity, permeability, enzyme and receptor activity, and signal transduction. Cholesterol is required for the synthesis of steroids and bile acids, although the majority of the cholesterol pool in tissue and plasma is derived from endogenous synthesis; dietary cholesterol contributes to the pool, and diet modifies liver synthesis.[18] Fatty acids (4-26 carbon atoms) are either saturated (no double bonds in the carbon chain), mono-unsaturated (one double bond) or polyunsaturated (two or more double bonds). Double bonds occur in two isomeric forms: cis and trans; unsaturated fatty acids are folded at the site of each double bond, cis, and trans-fatty acids have straight carbon chains.

Human milk contains approximately 4% lipids, but the reported variation is between 3.1 and 5.2%,[19,20] with 99% of the fat present in the form of triglycerides and the rest in the form of diglycerides, monoglycerides, free fatty acids, phospholipids, and cholesterol. The fat content of human milk increases with duration of lactation.[19,21] During this period, the average size of the fat globules increases, and the ratio of phospholipids and cholesterol to triglycerides decreases.[22] The concentration of fat in human milk remains similar regardless of maternal diet or nutritional status, although poor nutrition has been shown to decrease fat content.[23] Fatty acid content of human milk has been reported by numerous investigators and demonstrates a wide range, as summarized by Fomon.[2] Fatty acid content of human milk is also altered by dietary manipulation.[24-27] Human milk fat provides the essential fatty acids linoleic and α-linolenic acids, along with the long-chain polyunsaturated fatty acids such as arachidonic and docosahexaenoic acids. The decrease of milk phospholipid content during the first few weeks after birth is accompanied by a decrease in arachidonic and docosahexaenoic acids.[28] Fat content of human milk and commonly used formulas is summarized in Table 7.3.

TABLE 7.3

Nutritional Composition of Human Milk and Commonly Used Formulas

	Kilocalories/ oz.	Protein Source	Protein gm/dl	Fat Source	Fat gm/dl	Carbohydrate Source	Carbohydrate gm/dl	Na mEq/dl	K mEq/dl	Phosphorus mg/dl	Calcium mg/dl	Osmolality mOsm/kg water
Mature human milk	20	Human milk	1.0	Human milk	4.4	Lactose	6.9	0.7	1.3	14	32	300
Enfamil (Mead Johnson)	20	Whey, nonfat milk	1.5	Palm olein, soy coconut, high-oleic sunflower oils	3.6	Lactose	7.3	0.8	1.9	36	53	300
Enfamil AR (Mead Johnson)	20	Nonfat milk	1.7	Palm olein, soy coconut, sunflower oils	3.5	Lactose, rice starch maltodextrin	7.4	1.2	1.9	36	53	240
Good Start (Nestle/ Carnation)	20	Enzymatically hydrolyzed reduced mineral whey	1.6	Palm olein, soybean, coconut, high-oleic safflower oils	3.4	Lactose, maltodextrin	7.4	0.7	1.7	24	43	265
Lactofree (Mead Johnson)	20	Milk protein isolate	1.4	Palm olein, soy coconut, high-oleic sunflower oils	3.6	Corn syrup solids	7.4	0.9	1.9	37	55	200
Similac Improved (Ross)	20	Nonfat milk, whey	1.4	High-oleic safflower, coconut, soy oils	3.7	Lactose	7.3	0.7	1.8	28	53	300
Similac Lactose Free (Ross)	20	Milk protein isolate	1.4	Soy, coconut oils	3.6	Corn syrup solids, sucrose	7.2	0.8	1.8	38	57	230
Similac PM/ 60/40 (Ross)	20	Whey, sodium caseinate	1.5	Soy, corn, coconut oils	3.8	Lactose	6.9	0.7	1.5	19	38	280
Alsoy (Nestle/ Carnation)	20	Soy protein isolate with L-methionine	1.9	Palm olein, soy, coconut, high-oleic safflower oils	3.3	Corn maltodextrin, sucrose	7.5	0.9	2.0	41	71	200

TABLE 7.3 *(Continued)*

Nutritional Composition of Human Milk and Commonly Used Formulas

	Kilocalories/ oz.	Protein Source	Protein gm/dl	Fat Source	Fat gm/dl	Carbohydrate Source	Carbohydrate gm/dl	Na mEq/dl	K mEq/dl	Phosphorus mg/dl	Calcium mg/dl	Osmolality mOsm/kg water
Babysoy (pwd) (Wyeth Nutritionals, Inc.)	20	Soy protein isolate with L-methionine	2.1	Oleo, coconut, high-oleic (saff. or sun.), soybean oils	3.6	Corn syrup solids, sucrose	6.9	0.9	1.8	42	60	228
Isomil (Ross)	20	Soy protein isolate with L-methionine	1.7	High-oleic safflower, coconut, soy oils	3.7	Corn syrup, sucrose	7.0	1.3	1.9	51	71	230
Isomil DF (Ross)	20	Soy protein isolate with L-methionine	1.8	Soy, coconut oils	3.7	Corn syrup, sucrose, soy fiber	6.8	1.3	1.9	51	71	240
ProSobee (Mead Johnson)	20	Soy protein isolate with L-methionine	1.7	Palm olein, soy, coconut, high-oleic sunflower oils	3.7	Corn syrup solids	7.3	1.0	2.1	56	71	200
Alimentum (Ross)	20	Casein hydrolysate with added amino acids	1.9	MCT 33%, safflower, soy oils	3.7	Sucrose, modified tapioca starch	6.9	1.3	2.0	51	71	370
Nutramigen (Mead Johnson)	20	Casein hydrolysate with added amino acids	1.9	Palm olein, soy, coconut, high-oleic sunflower oils	3.4	Corn syrup solids, modified corn starch	7.5	1.4	1.9	43	64	320
Pregestimil Powder (Mead Johnson)	20	Casein hydrolysate with added amino acids	1.9	MCT (55%), corn, soy, high-oleic oils	3.8	Corn syrup solids, dextrose, modified corn starch	6.9	1.4	1.9	51	78	340

Pregestimil Liquid (Mead Johnson)	20	Casein hydrolysate with added amino acids	1.9	MCT (55%), soy, high-oleic safflower oils	3.8	Corn syrup solids, modified corn starch	6.9	1.4	1.9	51	78	280
Neocate (SHS)	20	L-amino acids	2.1	Hybrid safflower, refined vegetable oils, (coconut, soy)	3.0	Corn syrup solids	7.8	1.1	2.7	62	82	342
Follow-Up (Nestle/ Carnation)	20	Nonfat milk	1.8	Palm olein, soy, coconut, high-oleic safflower oils	2.8	Corn syrup solids, lactose	8.9	1.2	2.3	61	91	326
Follow-Up Soy (Nestle/ Carnation)	20	Soy protein isolate with L-methionine	2.1	Palm olein, soy, coconut, high-oleic safflower oils	3.0	Corn maltodextrin, sucrose	8.1	1.2	2.0	61	91	200
Whole cow's milk	20	Cow's milk	3.3	Cow's milk	3.7	Lactose	4.7	2.1	3.9	93	119	288
Next Step (Mead Johnson)	20	Nonfat milk	1.8	Palm olein, soy, coconut, high-oleic sunflower oils	3.4	Lactose, corn syrup solids	7.5	1.2	2.3	57	81	270
Next Step Soy (Mead Johnson)	20	Soy protein isolate with L-methionine	2.2	Palm olein, soy, coconut, high-oleic sunflower oils	3.0	Corn syrup solids, sucrose	8.0	1.3	2.6	61	78	260

Essential Fatty Acid Metabolism

Human milk lipids contain preformed long-chain polyunsaturated fatty acids (LC-PUFA) in considerable amounts, whereas vegetable oils (with the exception of coconut oil) are also rich in PUFA. The latter has a higher percentage of medium- and short-chain fatty acids.

For the healthy full term infant, the concerns of the premature infant may not apply given the larger body stores of LC-PUFA at birth and the lower requirements compared to the preterm infant because of slower growth. However, nutritional requirements for PUFAs are not clearly defined for infants, and the issue is complicated by the fact that linoleic acid (18:2n-6) and α-linolenic acid (18:3n-3) can be converted to both 20 and 22 carbon length long-chain PUFAs with significant biological activities. The absence of linoleic acid in the diet results in growth retardation and dermatologic manifestations. Intakes of linoleic acid, as low as 0.6% of daily energy intake, can obviate essential fatty acid deficiency as defined by the triene to tetraene ratio, and current recommendations[29] specify the minimum level of 0.3g/100 kcal in infant formulas.

Fully breastfed infants have a dietary lipid intake of approximately 50% of their energy intake (3.1 to 5.2g/dL, see earlier discussion), whereas formulas contain between 3.4 and 3.8 g/dL. Although the importance of limiting the dietary intake of saturated and total fats to prevent cardiovascular disease, obesity, and diabetes is well recognized, adverse effects of limiting fat on weight gain and growth[30,31] should be balanced against providing increased amounts of fat.

Carbohydrate

Carbohydrates generally account for 35 to 42% of the energy intake of breast- or formula-fed infants, and the usual carbohydrates in infants' diets are listed in Table 7.4. Carbohydrates may be classified as monosaccharides, oligosaccharides, and polysaccharides. *Monosaccharides* can be further defined as aldoses (glucose, galactose, xylose, for example) or ketoses (fructose). *Oligosaccharides* are consumed in the diet mainly in milk with lactose, maltose and sucrose being the main sugars present. *Polysaccharides* are starches, starch hydrolysates, glycogen, or components of fiber. The major carbohydrate in human milk is lactose, although small amounts of glucose and other oligosaccharides are also present. Carbohydrate content of human milk and various formulas is listed in Table 7.3. Carbohydrate malabsorption, apart from genetic causes, is unusual. When the colonic capacity to ferment carbohydrate is exceeded by the unabsorbed load, symptoms of carbohydrate intolerance, usually in the form of diarrhea, occur. The diarrhea improves when dietary carbohydrates are reduced or eliminated from the diet, making the diagnosis of carbohydrate intolerance. Normally, electrolytes in the distal gastrointestinal tract and unabsorbed

TABLE 7.4

Usual Carbohydrates and Related Enzymes

Carbohydrate	Enzyme
Lactose	Lactase
Sucrose	Sucrase-isomaltase
Isomaltose	Sucrase-isomaltase
Maltose	Maltase-glucoamylase
Amylose	α-Amylase
Amylopectin	β-Amylase

TABLE 7.5

Commonly Used Formulas and Their Indications

Commonly Used Formulas and Their Indications				
Formula	**Carbohydrate**	**Protein**	**Fat**	**Indication**
Bovine milk-based	Lactose	Bovine whey and casein	Vegetable, animal	Normal function
Soy-protein-based	Sucrose, glucose	Soy	Soy	Lactose intolerance
Hydrolyzed protein	Sucrose, glucose	Hydrolyzed whey or casein	Medium chain triglycerides	Cow milk and soy protein hypersensitivity; pancreatic insufficiency
Casein-based (modular)	Modified tapioca starch, added carbohydrate	Casein hydrolysate with added amino acids	MCT oil, corn oil	Lactase, sucrase and maltase deficiency, impaired glucose transport
Elemental	Lactose- and sucrose-free, corn syrup solids, modified corn starch	Hydrolyzed casein	Vegetable	Cow milk allergy
"Metabolic"	Depends on condition	Corn syrup solids/ sucrose	Corn oil/ coconut oil	Specific metabolic disorders

carbohydrates (fermented to volatile fatty acids) are rapidly absorbed. Inadequate colonic salvage results in diarrhea. In young infants and children with disorders of carbohydrate metabolism, the ultimate goal of carbohydrate digestion and absorption is to render all available carbohydrates into smaller compounds that the body can use; chiefly, glucose and fructose. *Lactase deficiency* is exceedingly rare in newborn infants. Infants usually develop diet-induced diarrhea following introduction of lactose-containing milk. The disease, thought to be autosomal recessive, is treated with the elimination or limitation of lactose in the diet. More commonly, a transient lactose intolerance can occur after acute or repeated bouts of diarrhea. *Sucrase-Isomaltase deficiency* is a rare disease that does not appear until diets containing sucrose, dextrin, or starch are begun. Bouts of diarrhea may be observed in infants with this deficiency, and management includes eliminating sucrose and limiting starch in the diet. Older affected children and adults usually tolerate normal quantities of carbohydrates. *Glucose-Galactose deficiency* manifests itself with diet-induced diarrhea soon after birth and responds to withdrawal of these carbohydrates from the diet. The defect appears to be a specific absence of glucose and galactose transport mechanisms, whereas amino acid transport is normal. Fructose transport is normal, and these infants respond to a diet containing fructose with relief from diarrhea. With age, variable amounts of starch and milk may be tolerated. Commonly used formulas for various forms of intolerance are listed in Table 7.5.[32]

Iron

Iron deficiency is the most common nutritional deficiency in the U.S. and worldwide, with young children the most susceptible. The increased susceptibility comes from an increased iron requirement for the rapid growth during this period and inadequate amounts of iron in the diet unless adequately supplemented.[33] According to the third National Health and Nutrition Examination Survey (NHANES, 1991), ~5% of children between one and two

TABLE 7.6

Stages of Iron Deficiency

Iron Nutritional Status	Indices
Adequate stores	Normal
Decreased stores	Decreased ferritin (10–20 ng/mL), transferrin normal, erythtrocyte protoporphyrin normal, MCV normal, hemoglobin normal, transferrin receptor normal
Iron deficiency	Decreased ferritin, transferrin saturation decreased, erythrocyte protoporphyrin increased, MCV normal, hemoglobin normal, transferrin receptor increased
Iron deficiency anemia	Decreased ferritin, transferrin saturation decreased, erythrocyte protoporphyrin increased, MCV decreased, hemoglobin decreased, transferrin receptor increased

years of age had evidence of iron deficiency, and about half were also anemic. However, between the two previously published studies, NHANES II and I, prevalence of iron deficiency was observed to be decreasing.[34] Stages of iron nutritional status are listed in Table 7.6.

One should distinguish between anemia and iron deficiency anemia, since the latter occurs when hemoglobin concentration falls below the 90 to 95% range for the same age and sex.[34] A diagnosis of iron deficiency is made when the anemia is accompanied by evidence of iron deficiency or when there is a rise in hemoglobin following treatment with iron. In this regard, serum transferrin receptor may offer an advantage for screening for iron deficiency, since it rises with iron deficiency and is not affected by infection or acute liver disease.[35]

Iron deficiency peaks between six and nine months of age and is a consequence of multiple factors: rapid growth, depleted stores, low iron content of the diet, and early feeding of cow's milk.[36,37] Since a milk-based diet is the predominant source of energy, at least in the first six months of life, the iron content and its bioavailability are strong predictors of iron nutritional status.[38] The estimated requirement of absorbed iron from birth to one year is 0.55 to 0.75 mg/d, thereby underscoring the need for adequate iron in the diet to meet these needs. Iron concentration in human milk is low (0.3 to 0.5 mg/L), and although well absorbed, iron content declines between 14 and 183 days of age.[39] Therefore, even given the better absorption as milk intake increases and iron content decreases, it is easy to see that the amount of absorbed iron will be inadequate to meet the estimated requirements. Therefore, breastfed infants who do not receive iron supplements or iron from other sources are at risk of becoming iron deficient between 6 and 12 months of age.[40] Iron-fortified cow's milk or soy-based formulas are effective in preventing iron deficiency, and the decline in iron deficiency anemia over the past few decades has been attributed to their use.[34] Systemic manifestations of iron deficiency anemia include behavioral and cognitive abnormalities expressed as lower scores on tests of psychomotor development. These effects have to be interpreted keeping the confounding variables of poor nutrition, environment, and poor socioeconomic background that often coexist. The studies suggest that infants with iron deficiency anemia, but not iron deficiency without anemia, have impaired performance of mental and psychomotor development.[41-45] These deficiencies do not improve with iron therapy, and follow-up studies at five to six years of age still demonstrate poorer scores in the children who were previously anemic.[43,44] Strategies to prevent iron deficiency could include the feeding of iron-fortified formulas, avoidance of non-iron fortified milks and cow's milk (the latter, at least, till beyond 12 months of age), the feeding of meats and iron-fortified foods, and, if needed, medicinal iron supplementation in the form of ferrous sulfate.

TABLE 7.7

Unique Constituents of Breast Milk

Unique Constituents of Breast Milk	
Docosahexanoic acid	Necessary for growth and development of the brain and retina and for myelinization of nervous tissue
Cholesterol	Enhances myelinization of nervous tissue
Taurine	Second most abundant amino acid in human milk, important for bile acid conjugation
Choline	May enhance memory
Enzymes	Numerous enzymes such as lipases that are important in digestion and absorption of fat
Lactoferrin	Prevents iron from being available to bacteria
Inositol	Enhances synthesis and secretion of surfactant in immature lung tissue
Poly- and Oligosaccharides	Inhibit bacterial binding to mucosal surfaces
Protein (such as α-lactalbumin)	Supply amino acids to the infant, help synthesize lactose in the mammary gland, and bind calcium and zinc
Bifidobacterium species	Predominant bacterial flora in the gastrointestinal tract of breastfed infants, creates unfavorable pH conditions for the growth of enteric pathogens
Macrophages	Macrophages in human colostrum have high concentrations of slgA which is released during phagocytosis
Epidermal growth factor	Promotes cell proliferation in the gastrointestinal mucosa

Breastfeeding

The benefits of breastfeeding to the infant, mother, family, and society are numerous and impressive, but they must be put into context when making individual decisions about breast feeding. These include ready availability, possible enhancement of intestinal development, resistance to infection, and bonding between mother and infant. It is the preferred feeding method for the normal infant. Breast milk, in addition to providing the required nutrients for the healthy infant, has unique constituents, as listed in Table 7.7.

Protein

Approximately 20% of the total nitrogen in human milk is in the form of non-protein nitrogen compounds such as free amino acids, and urea, which is considerably greater than the 5% found in bovine milk,[46] although there remains a debate about their contribution to nitrogen utilization.[47] The quality of the protein differs from that of bovine milk as well, with the whey-to-casein protein ratios being 70:30 and 18:82 in human and bovine milk, respectively. These differences in whey-to-casein ratio are reflected in the plasma amino acid profile of infants and are readily observed within the first three days of age.[48] Further, plasma amino acid patterns in human milk-fed infants has been used as a reference in infant nutrition.[49,50] In addition, specific human whey proteins — lactoferrin, lysozyme, and slgA — are involved in host defense.[51,52]

Lipids

Lipids in human milk provide 40 to 50% of the energy content and are vehicles for fat soluble vitamins. The total fat content varies from 2% in colostrum to 2.5–3.0% in transitional milk, and 3.5–4.5% in mature human milk.[19] Cholesterol, phospholipids, and essential fatty acids are highest in colostrum, and more than 98% of human milk fat comes from 11 major fatty acids of 10-20 carbon length. Human milk lipids can inactivate enveloped viruses including herpes simplex I, measles, and cytomegalovirus, to name a few. Monoglycerides also exert antiviral activity.

Fat content of human milk is variable, with the fat content rising throughout lactation but with changes apparent within the course of one day, within feeds and between women.[53] The effects of these differences in thriving infants is not clear, even given that hind milk has a higher fat content than fore milk. Human milk lipids provide preformed LC-PUFAs in amounts sufficient to meet nutrient needs. In term infants, plasma concentrations of essential fatty acids (arachidonic acid) at two and four weeks of age were significantly lower in infants fed formula without LC-PUFA compared to breastfed infants. Docosahexanoic acid concentrations were similarly lower at four and eight weeks of age. Neuringer and colleagues showed that visual acuity and learning abilities correlate well with the amount of DHA in the retina and brain phospholipids.[54]

Nucleotides

Nucleotides represent 2 to 5% of the non-protein nitrogen in human milk.[55] Nucleotides participate in many biological functions such as forming the basis of genetic information (DNA, RNA) and storing energy (AMP, GMP), and they play roles in immunity as well as cellular activities. Although they can be produced by the liver, the body's requirements vary considerably, especially during infancy.[56] The effect of nucleotides on immune function is not well understood, but infants fed breast milk or nucleotide-supplemented formula have been shown to exhibit increased natural killer cell activity compared to infants fed unsupplemented formula.[57] Infants fed nucleotide formulas had enhanced Haemophilus influenza type B and diphtheria humoral responses compared to non-supplemented infants.[58] Feeding of human milk resulted in significantly higher neutralizing antibody titers to polio virus at six months of age than were found in control or formula-fed cohorts. These data suggest that dietary factors play a role in the antibody response to immunization, and more studies are needed to better understand the mechanisms involved.

Infection

There are several enzymes present in human milk that appear to be important in the prevention of infection. These include glutathione peroxidase, alkaline phosphatase, and xanthine oxidase. In addition, other anti-inflammatory agents such as catalase, lactoferrin, immunoglobulins, and lysozyme are also present in human milk. The antimicrobial activities of these are generally found at mucosal surfaces, such as the gastrointestinal, urinary, and respiratory tracts. Specific factors, such as lactoferrin, lysozyme, and slgA, resist proteolytic degradation and can line the mucosal surfaces, preventing microbial attachment and inhibiting microbial activity. Each of the mammary immune systems is active against a variety of antigens. Prospective studies in developing countries indicate that breast milk feeding reduces the incidence or severity of diarrhea,[59] lower respiratory tract infection,[60] otitis media,[61] bacteremia,[62] bacterial meningitis,[63] botulism,[64] urinary tract infection,[65] and necrotizing enterocolitis.[66]

Hyperbilirubinemia is more common in breast-fed than formula-fed infants. This is usually transient, and discontinuation of breast feeding is not recommended unless bilirubin values reach excessively high levels or the jaundice persists. Usually, switching to a formula for one to two days is therapeutic and diagnostic, and breastfeeding can be safely resumed. Other causes of jaundice should be sought before making a firm diagnosis of breast-milk jaundice.

Certain chemicals, drugs, foreign proteins, and viruses may be present in human milk.[67] However, the risk–benefit ratio of artificial milk needs to be weighed, especially if the water sources for mixing the milk are contaminated. Breastfeeding is currently contraindicated in disease states such as active herpes, tuberculosis, and AIDS.

Formula Feeding

A variety of formulas are available for feeding infants (Table 7.3). The most commonly used formulas are from bovine milk, and nutrient specifications for infant formulas are available.[68] Commercially available formulas are recommended when breast feeding is not chosen. Cow's milk is not recommended in the first year of life due to its nutritional limitations and inappropriate nutrient concentrations. Cow's milk has higher concentrations of protein and phosphorus, a lower calcium-to-phosphorus ratio, limited iron, less essential fatty acids, vitamin C, and zinc than human milk. Increased renal solute load due to cow's milk and increased occult blood loss via the gastrointestinal tract leading to iron deficiency and anemia in infants fed cow's milk unsupplemented by other nutrients are additional reasons to discourage the feeding of cow's milk in early infancy.

Soy Protein-Based Formulas

The Committee on Nutrition of the American Academy of Pediatrics reviewed the indications of soy protein-based formulas.[69] Some of the conclusions include:

1. Isolated soy protein-based formulas are safe and effective alternatives to provide appropriate nutrition if breast milk or cow milk-based formulas do not meet the nutritional needs in term infants. However, no advantage is provided over cow's milk protein-based formulas as a supplement for breast feeding.
2. Soy protein-based formulas are appropriate for use in infants with galactosemia and hereditary lactase deficiency.
3. There is no proven value of the routine use of soy-protein based formula in the prevention or management of infantile colic.
4. There is no proven value of the routine use of soy protein-based formula in the prevention of atopic disease in healthy or at-risk infants.
5. Infants with documented cow milk protein-induced enteropathy or enterocolitis should not be given soy protein-based formula routinely.

The nutritional needs of infants zero to six months can be met by breast milk or infant formulas. Although both groups of infants need to have health surveillance including growth and development, breastfed infants need to be followed closely over the first few weeks to assure appropriate feeding practices and resultant growth. Appropriate counseling for common breast feeding problems needs to be provided, and community support groups can be involved if needed. Beyond six months, recommendations for infant feeding are variable, and the recommendations are largely based on extrapolation from data on younger infants. Nutritional composition of "follow-up" formulas is specified with minimum lower limits for energy (60 kcal/dL), higher minimum limits for protein (2.25 to 3.0 g/100 kcal) and lower minimum limits for fat (3.0 to 4.0 g/100 kcal) compared to formulas for younger infants. Nonetheless, iron-fortified formulas designed for younger infants may be safely fed from 6 to 12 months. Infants by this age are physiologically and developmentally ready to accept a variety of dietary items, and feeding practices vary based on ethnic, cultural, and economic reasons. As stated earlier, feeding of bovine milk is discouraged during this period, although a substantial number of infants are indeed fed bovine milk.[70] In addition, there are concerns about the substitution of low-fat or skimmed milks during this period because of higher intakes of protein and sodium and lower intakes of iron and essential fatty acids. However, if infants are being fed non-milk foods, the actual intake of energy may not be lower than of infants fed bovine milk or formula.[71]

Weaning

The transition from suckling to eating of non-milk foods occurs during the first year of life based on cultural beliefs and practices, physicians beliefs, mothers' perceptions of their infants' needs, and economic realities. Complementary foods are introduced from before three months to by six months of age, and a variety of foods are offered.[72-74] In the U.S., the total transition to beikost usually occurs by the end of the first year of life and continues during the second year.

The weaning process can be considered in three ways. First, it could be the weaning from breast feeding to other milks which may replace breast feeding partially or completely. In the second form, weaning could be considered the transition from liquid to non-liquid diet. Health concerns may arise during this period if the added foods are too nutrient dense (protein or energy) or nutrient-deficient (iron, protein), thus altering the protein:energy ratio or causing deficiency of specific nutrients. The third aspect of weaning may be the transition from human milk or formula to bovine milk in addition to the provision of beikost. Since weaning typically occurs during a period of rapid growth, attention to both nutritional and developmental issues during this period is warranted. Complementary foods, in addition to providing the required nutrients, are also important in establishing lifelong patterns of eating.

Failure to Thrive

Growth, as assessed by weight, length (and subsequently height) and head circumference, is an important part of anticipatory guidance provided in well child care. These anthropometric measurements, especially weight, can be used to detect inadequate attained growth or reduced growth velocity. The average birth weight of a full term infant is 3300 to 3500 g; after a weight loss of ~10%, infants should regain their birth weight by two weeks, with formula-fed infants tending to regain their birth weight a little sooner than their breastfed counterparts. On an average, infants gain about 1 kg per month for the first three months, 1/2 kilogram per month for the next three months, 1/3 kilogram per month from 6 to 9 months and 1/4 kilogram per month from 9 to 12 months. Full term infants double their weight by 4 months and triple their weight by 12 months, while doubling their length during the same period. Both weight and length gain are slower in the second year of life, underscoring the anticipatory nutritional guidance needed during that period. Growth faltering, or failure to thrive, a descriptive term, is then identified by the following criteria: (1) weight less than 80 to 85% of the 50th percentile on the National Center for Health Statistics (NCHS) growth charts, (2) weight for age less than the 3 to 5 percentile on the NCHS growth charts, (3) drop in weight that crosses two or more percentile categories on standard growth charts from previously established pattern of adequate growth, and (4) a Z-score of –2 SD below the normal 50th percentile. If growth velocity is used, a decrement of 2 SD over a 90-day period and loss of >1 SD Z score over 90 days is used as a measure of growth faltering.

Since decline in rate of weight gain or growth velocity is more sensitive than decline in length or head circumference, serial measurements of weight are an important part of the anticipatory guidance given during well child checks, and provide an early warning of growth faltering.[75,76] The Body Mass Index (BMI), calculated by dividing weight in kilograms by length/height in meters squared, has largely replaced weight for stature. It should be recognized that there are growth differences between breast and formula-fed infants. As reported by Nelson et al.,[77] mean gains in both weight (g/d) and length (cm/d) were greater in formula-fed males and females than their breastfed counterparts from 8–122 days of age. Since the NCHS growth charts were made from data that was cross-sectional and the infants were fed formulas, attention to growth faltering in the breastfed infant requires both understanding of the growth of breastfed infants and the early recognition of decrease in weight or growth velocity.[78] There are numerous organic and non-organic causes of growth failure or faltering which need to be addressed during such an evaluation. It is important to realize that failure to thrive or malnutrition may occur in hospitalized infants and children, as well, and efforts to recognize and nourish these infants and children should be made.

Summary

In summary, the period of infancy is one of rapid changes in growth and attainment of developmental milestones. This period imposes unique nutritional needs and challenges for the health care provider. Understanding nutritional needs, ways of meeting these needs (Table 7.8), deviations in growth and their causes, and providing nutrition in age-appro-

TABLE 7.8

Recommendations for Feeding Healthy Full-Term Infants

Breastfeeding is strongly recommended.
Infant formulas that meet AAP guidelines are recommended when breastfeeding is not chosen or breast milk is not available.
Breast milk or infant formula is the preferred feeding in the first year of life.
Adequate intakes of human milk or formula meet all nutrient requirements for the first 6 months of life (exception may be vitamin D in dark-skinned, sun deprived breast fed infants). Infant formula or "follow-up" formula may be fed in the second 6 months of life.
Introduction of complementary foods should be based on growth, developmental, cultural, social, psychological and economic considerations. As a general rule, when an infant is consuming 32 ounces of milk per day and appears to want more, supplemental feedings may be indicated. This usually occurs between 4 and 6 months of age.

priate, culturally and ethnically sensitive ways while addressing economic issues is the task of the health care team. Ideally, the infant's nutritional need (expressed as hunger), developmental progress (as observed in attainment of feeding skills), and mother's and care provider's beliefs within the context of the family will guide the infant's feeding experience and transition to the next phase in life.

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