CHAPTER 1: NUTRITIONAL NEEDS OF INFANTS

Introduction

Good nutrition is essential for the growth and development that occurs during an infant's first year of life. When developing infants are fed the appropriate types and amounts of foods, their health is promoted. Positive and supportive feeding attitudes and techniques demonstrated by the caregiver help infants develop healthy attitudes toward foods, themselves, and others.

Throughout the first year, many physiological changes occur that allow infants to consume foods of varying composition and texture. As an infant's mouth, tongue, and digestive tract mature, the infant shifts from being able to only suckle, swallow, and take in liquid foods, such as breast milk or infant formula, to being able to chew and receive a wide variety of complementary foods. See Chapter 5, page 101, for more information regarding complementary foods. At the same time, infants progress from needing to be fed to feeding themselves. As infants mature, their food and feeding patterns must continually change.

For proper growth and development, an infant must obtain an adequate amount of essential nutrients by consuming appropriate quantities and types of foods. During infancy, a period of rapid growth, nutrient requirements per pound of body weight are proportionally higher than at any other time in the life cycle. Although there are many nutrients known to be needed by humans, requirements have been estimated for only a limited number of these.

This chapter includes sections on nutrition assessment, the Dietary Reference Intakes (DRIs), and background information on important nutrients needed during infancy. Counseling points that relate to the information presented in this chapter are found in Chapter 8, pages 157–158.

Nutrition Assessment

To determine an infant's nutritional needs and develop a nutrition care plan, an accurate assessment of the infant's nutritional status must be performed. The nutrition assessment provides the nutritionist or health counselor with important feeding practices and other information pertinent to an infant's health. Nutrition education sessions can then be designed to encourage positive, appropriate feeding practices and, if necessary, recommend strategies to correct inappropriate practices. By communicating periodically with a caregiver about an infant's nutritional needs in the first year of life, better care for the infant is assured.

The assessment should include an examination of:

- **Health and medical information –** Information gathered through chart review, caregiver interview, health care provider referral form(s), or other sources that may include history of chronic or acute illnesses or medical conditions, birth history, developmental disabilities, a clinical assessment identifying signs of nutritional deficiencies, and other pertinent information (e.g. immunization record);[1, 2]

- **Dietary intake data:**[1, 3]
  - *Feeding history* – Eating behaviors, feeding techniques, feeding problems, and environment;
  - *Appetite and intake* – Usual appetite, factors affecting intake such as preferences, allergies, intolerances, chewing/swallowing problems, feeding skills;
  - *Diet history* – Breastfed and/or infant formula-fed; frequency and duration of breastfeeding; frequency and amount of infant formula or complementary foods fed; age at introduction of complementary foods; variety of complementary foods provided; vitamin/mineral or other

supplements given; and problems such as vomiting, diarrhea, constipation, or colic; and

- *Socioeconomic background* – Primary and other caregivers, food preparation and storage facilities, use of supplemental feeding and financial assistance programs, access to health care, and ethnic and/or cultural influences on the diet.[1]

- **Anthropometric Data –** Anthropometric measurements, i.e., weight for age, length for age, weight for length, and head circumference for age;[1] and

- **Biochemical Data –** Data used to diagnose or confirm nutritional deficiencies or excesses;[1,4] in the WIC Program, hemoglobin, hematocrit, or other hematological tests are performed to screen for iron deficiency anemia.

Dietary Reference Intakes (DRIs)

The Dietary Reference Intakes (DRIs), developed by the Institute of Medicine's Food and Nutrition Board, are four nutrient-based reference values intended for planning and assessing diets. They include the Estimated Average Requirement (EAR), the Recommended Dietary Allowance (RDA), the Adequate Intake (AI), and the Tolerable Upper Intake Level (UL).[5]

Recommendations for feeding infants, from infant formula to complementary foods, are based primarily on the DRIs. The DRIs for infants are based on the nutrient content of foods consumed by healthy infants with normal growth patterns, the nutrient content of breast milk, investigative research, and metabolic studies. It is difficult to define precise nutrient requirements applicable to all infants because each infant is unique. Infants differ in the amount of nutrients ingested and stored, body composition, growth rates, and physical activity levels. Also infants with medical problems or special nutritional needs (such as metabolic disorders, chronic diseases, injuries, premature birth, birth defects, other medical conditions, or being on drug therapies) may have different nutritional needs than healthy infants. The DRIs for vitamins, minerals, and protein are set at levels thought to be high enough to meet the nutrient needs of most healthy infants, while energy allowances, referred to as Estimated Energy Requirement (EER), are based on average requirements for infants. See page 15 for more information regarding EER.

See Appendix A, pages 180–182, for a complete table of DRIs for infants.

Important Nutrients

The following sections include information on the food sources, functions, and concerns regarding major nutrients and nutrients considered to be of public health significance to infants in the United States.

For additional information on the function, deficiency and toxicity symptoms, and major food sources of the nutrients discussed below, as well as

- EAR is the median usual intake that is estimated to meet the requirement of half of the healthy population for age and gender. At this level of intake, half the individuals will have their nutrient needs met. The EAR is used to establish the RDA and evaluate the diet of a population.
- RDA is the average dietary intake level sufficient to meet the nutrient requirement of nearly all (97–98 percent) healthy individuals. If there is not enough scientific evidence to establish an EAR and set the RDA, an AI is derived.
- AI represents an approximation of intake by a group of healthy individuals maintaining a defined nutritional status. It is a value set as a goal for individual intake of nutrients that do not have a RDA.
- UL is the highest level of ongoing daily intake of a nutrient that is estimated to pose no risk in the majority of the population. ULs are not intended to be recommended levels of intake, but they can be used as guides to limiting intakes of specific nutrients.

other nutrients not discussed, refer to Appendix C: Nutrient Chart: Function, Deficiency and Toxicity Symptoms, and Major Food Sources of Nutrients, pages 190–194.

Energy

Energy Needs

Infants need energy from food for activity, growth, and normal development. Energy comes from foods containing carbohydrate, protein, or fat. The number of kilocalories (often termed "calories") needed per unit of a person's body weight expresses energy needs. A kilocalorie is a measure of how much energy a food supplies to the body and is technically defined as the quantity of heat required to raise the temperature of 1 kilogram of water 1 degree Celsius. An infant's energy or caloric requirement depends on many factors, including body size and composition, metabolic rate (the energy the body expends at rest), physical activity, size at birth, age, sex, genetic factors, energy intake, medical conditions, ambient temperature, and growth rate. Infants are capable of regulating their intake of food to consume the amount of kilocalories they need. Thus, caregivers are generally advised to watch their infants' hunger and satiety cues in making decisions about when and how much to feed. See Table 2, page 46; Figure 1, page 42; page 59; page 87; and page 123 for more information regarding hunger and satiety cues.

Recommended Energy Allowances

The World Health Organization's (WHO) expert report on energy and protein requirements states: [6]

The energy requirement of an individual is a level of energy intake from food that will balance energy expenditure when the individual has a body size and composition and level of physical activity, consistent with long-term good health; and that would allow for the maintenance of economically necessary and socially desirable physical activity. In children and pregnant or lactating women the energy requirement includes the energy needs associated with the deposition of tissues or the secretion of milk at rates consistent with good health.

Using this rationale, the Institute of Medicine Food and Nutrition Board has determined that the EER for infants should balance energy expenditure at a level of physical activity consistent with normal development and allow for deposition of tissues at a rate consistent with health. See Table 1, page 15, for the EER, reference weights, and reference lengths for infants. Modification of these requirements may be required based on individual needs and growth patterns.[7] The kilocalories needed per unit of body weight decrease over the first year because infants older than 6 months grow more slowly.

Energy Intake and Growth Rate

A general indicator of whether an infant is consuming an adequate number of kilocalories per day is the infant's growth rate in length, weight, and head circumference. However, physical growth is a complex process that can be influenced by size and gestational age at birth, environmental and genetic factors, and medical conditions, in addition to dietary intake. An infant's growth rate can be assessed by periodically plotting the infant's weight, length, and head circumference for age and weight for length on Centers for Disease Control (CDC) growth charts throughout the first year of life. See Appendix B: Use and Interpretation of CDC Growth Charts, pages 183–189. Appendix B includes basic instructions on how to collect, record, and interpret weight, length, and head circumference measures and the CDC WIC growth charts for infants. Refer to Kleinman,[8] Lucas,[9] National Center for Chronic Disease Prevention and Health Promotion,[10] and reference textbooks on pediatric nutrition or nutrition assessment for more detailed information on the anthropometric assessment of infants.

In general, most healthy infants double their birth weight by 6 months of age and triple it by 12 months of age.[11] However, keep in mind that there are normal differences in growth between healthy breastfed and formula-fed infants during the first year of life. After 3 months of age, the rate of weight gain in the breastfed infant may be lower than that of formula-fed infants, but differences are generally not reported between these infants for length and head circumference.[12] Ultimately, each infant's growth must be individually assessed.

In addition to health and medical information, anthropometric data, and biochemical data, the nutrition assessment of an infant should include an evaluation of breastfeeding frequency and duration, infant formula dilution and intake, appropriate amount and types of complementary foods, and feeding skill development. For more information regarding nutrition assessment see pages 11–12. Assessing this dietary intake data will be helpful in determining which factors are influencing the growth rate if an infant's growth per the CDC growth charts appears to be abnormally slow or rapid. For infants with an abnormal rate of growth, assess the feeding relationship for negative interactions associated with feeding that may be contributing. For more information on the feeding relationship refer to page 45. Infants with abnormally slow or rapid growth rates or recent weight loss should be referred to a health care provider for assessment.

Carbohydrates

AI for Infants	
0–6 months	60 g/day of carbohydrate
7–12 months	95 g/day of carbohydrate

Carbohydrates fall into these major categories: simple sugars or monosaccharides (e.g., glucose, galactose, fructose, and mannose), double sugars or disaccharides (e.g., sucrose, lactose, and maltose), and complex carbohydrates or polysaccharides (e.g., starch, dextrins, glycogen, and indigestible complex carbohydrates such as pectin, lignin, gums, and cellulose). Dietary fiber is another name for indigestible complex carbohydrates of plant origin (these are not broken down by intestinal digestive enzymes). Sugar alcohols, including sorbitol and mannitol, are also important to consider for infants.

Functions

Carbohydrates are necessary in the infant's diet because they:

- Supply food energy for growth, body functions, and activity;
- Allow protein in the diet to be used efficiently for building new tissue;
- Allow for the normal use of fats in the body; and
- Provide the building blocks for some essential body compounds.

Carbohydrates serve as primary sources of energy to fuel bodily activities while protein and fat are needed for other essential functions in the body, such as building and repairing tissues.

Sources

The major type of carbohydrate normally consumed by young infants is lactose, the carbohydrate source in breast milk and cow's milk-based infant formula. Lactose-free infant formulas, such as soy-based infant formulas, provide carbohydrates in the form of sucrose, corn syrup, or corn syrup solids. These infant formulas are prescribed to infants who cannot metabolize lactose or galactose, a component of lactose. Some specialty infant formulas contain other carbohydrates in the form of modified corn starch, tapioca dextrin, or tapioca starch.

In later infancy, infants derive carbohydrates from additional sources including cereal and other grain products, fruits, and vegetables. Infants who consume sufficient breast milk or infant formula and appropriate complementary foods later in infancy will meet their dietary needs for carbohydrates.

Carbohydrates in Fruit Juices

Some fruit juices, such as prune, apple, and pear, contain a significant amount of sorbitol and proportionally more fructose than glucose. Infants can absorb only a portion of the sorbitol (as little as 10 percent) and fructose in these juices.[13] Unabsorbed carbohydrate is in these

Table 1 – Estimated Energy Requirements (EER) of Infants (Based on the 2000 Dietary Reference Intakes)

Males

Age (mo)	Reference Weight (kg)	Reference Weight (lb)	Reference Length (cm)	Reference Length (in)	Estimated Energy Requirements (kcal/day)
1	4.4	9.7	54.7	21.5	472
2	5.3	11.7	58.1	22.9	567
3	6.0	13.2	60.8	23.9	572
4	6.7	14.8	63.1	24.8	548
5	7.3	16.1	65.2	25.7	596
6	7.9	17.4	67.0	26.4	645
7	8.4	18.5	68.7	27.0	668
8	8.9	19.6	70.2	27.6	710
9	9.3	20.5	71.6	28.2	746
10	9.7	21.4	73.0	28.7	793
11	10.0	22.0	74.3	29.3	817
12	10.3	22.7	75.5	29.7	844

Females

Age (mo)	Reference Weight (kg)	Reference Weight (lb)	Reference Length (cm)	Reference Length (in)	Estimated Energy Requirements (kcal/day)
1	4.2	9.3	53.5	21.1	438
2	4.9	10.8	56.7	22.3	500
3	5.5	12.1	59.3	23.2	521
4	6.1	13.4	61.5	24.2	508
5	6.7	14.8	63.5	25.0	553
6	7.2	15.9	65.3	25.7	593
7	7.7	17.0	66.9	26.3	608
8	8.1	17.8	68.4	26.9	643
9	8.5	18.7	69.9	27.5	678
10	8.9	19.6	71.3	28.1	717
11	9.2	20.3	72.6	28.6	742
12	9.5	20.9	73.8	29.1	768

juices.[13] Unabsorbed carbohydrate is fermented in the lower intestine causing diarrhea, abdominal pain, or bloating. These symptoms are commonly reported in infants and toddlers who drink excessive amounts of juice. For this and other reasons, infants up to 6 months of age should not be offered fruit juice; infants over 6 months should be offered no more than 4 to 6 ounces daily of pasteurized, 100 percent juice from a cup.[14] See pages 107–108 for more information regarding infants and fruit juice. Fermentable carbohydrates also contribute to the development of tooth decay. See pages 131–132 for information regarding the role of certain carbohydrates in tooth decay.

Fiber

Dietary fiber is found in legumes, whole-grain foods, fruits, and vegetables. Breast milk contains no dietary fiber, and infants generally consume no fiber in the first 6 months of life. As complementary foods are introduced to the diet, fiber intake increases; however, no AI for fiber has been established. It has been recommended that from 6 to 12 months whole-grain cereals, green vegetables, and legumes be gradually introduced to provide 5 grams of fiber per day by 1 year of age.[15] See pages 136–139 for more information on vegetarian diets, where fiber intake may be high.

Protein

AI for Infants	
0–6 months	**9.1 g/day of protein**
RDA for older infants	
7–12 months	**11 g/day of protein**

All proteins are combinations of about 20 common amino acids. Some of these amino acids are manufactured in the body when adequate amounts of protein-rich foods are eaten. Nine amino acids that are not manufactured by the human body and must be supplied by the diet are called “essential” or “indispensable” amino acids. These include: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Two other amino acids, cystine and tyrosine, are considered essential for the preterm and young term infant because enzyme activities involved in their synthesis are immature.[16]

Functions

Infants require high quality protein from breast milk, infant formula, and/or complementary foods that:

- Build, maintain, and repair new tissues, including tissues of the skin, eyes, muscles, heart, lungs, brain, and other organs;
- Manufacture important enzymes, hormones, antibodies, and other components; and
- Perform very specialized functions in regulating body processes.

Protein also serves as a potential source of energy if the diet does not furnish sufficient kilocalories from carbohydrate or fat. As with energy needs, protein needs for growth per unit of body weight are initially high and then decrease with age as growth rate decreases.

DRIs for Protein

The DRIs for protein were devised based on the intake of protein from breast milk for the exclusively breastfed infant 0–6 months old.[16] Infant formula provides higher amounts of protein than breast milk, but the protein is not used as efficiently. The contribution of complementary foods to total protein intake in the second 6 months of infancy was considered in establishing the RDA for this age.

Sources

Breast milk and infant formulas provide sufficient protein to meet a young infant’s needs if consumed in amounts necessary to meet energy needs. In later infancy, sources of protein in addition to breast milk and infant formula include meat, poultry, fish, egg yolks, cheese, yogurt, legumes, and cereals and other grain products. When an infant starts receiving a substantial portion of energy from foods other than breast milk or infant formula, these complementary foods need to provide adequate protein. See pages 109–111 for information

regarding the introduction protein-rich complementary foods into an infant's diet.

Proteins in animal foods contain sufficient amounts of all the essential amino acids needed to meet protein requirements. In comparison, plant foods contain low levels of one or more of the essential amino acids. However, when plant foods low in one essential amino acid are eaten on the same day with an animal food or other plant foods that are high in that amino acid (e.g., legumes such as pureed kidney beans [low in methionine, high in lysine] and grain products such as mashed rice [high in methionine, low in lysine]), sufficient amounts of all the essential amino acids are made available to the body.[17] The protein eaten from the two foods would be equivalent to the high-quality protein found in animal products. See page 137 regarding protein concerns in vegetarian diets.

Protein Deficiency

In developing countries, infants who are deprived of adequate types and amounts of food for long periods of time may develop kwashiorkor, resulting principally from a protein deficiency; marasmus, resulting from a deficiency of kilocalories; or marasmus-kwashiorkor, resulting from a deficiency of kilocalories and protein. In the United States, very few infants suffer from true protein deficiency and cases of kwashiorkor are rare.

Lipids

AI for Infants

0–6 months	31 g/day of fat
7–12 months	30 g/day of fat

Lipids are a group of substances including fats, oils, and fat-like substances, such as cholesterol. Fatty acids are the major constituent of many lipids. Fatty acids that must be provided in the diet to maintain health are called essential fatty acids. Linoleic acid (abbreviated 18:2n-6 or LA) and α-linolenic acid (18:3n-3 or ALA) are both essential fatty acids. Small amounts of linoleic and α-linolenic acid must be provided in the diet. Two other fatty acids, arachidonic acid (20:4n-6 or ARA) and docosahexaenoic acid (22:6n-3 or DHA), also known as long-chain polyunsaturated fatty acids (LCPUFA), are derived from linoleic acid and α-linolenic acid respectively. They are considered essential fatty acids only when linoleic acid and α-linolenic acid are lacking in the diet.

AI for n-6 Polyunsaturated Fatty Acids (Linoleic acid [LA], Arachidonic acid [ARA])

0–6 months	4.4 g/day of n-6 polyunsaturated fatty acids
7–12 months	4.6 g/day of n-6 polyunsaturated fatty acids

AI for n-3 Polyunsaturated Fatty Acids (α-Linolenic acid [ALA], Docosahexaenoic acid [DHA])

0–12 months	0.50 g/day of n-3 polyunsaturated fatty acids

Functions

Infants require lipids in their diets because they:[18]

- Supply a major source of energy – fat supplies approximately 50 percent of the energy consumed in breast milk and infant formula;
- Promote the accumulation of stored fat in the body which serves as insulation to reduce body heat loss, and as padding to protect body organs;
- Allow for the absorption of the fat-soluble vitamins A, D, E, and K; and
- Provide essential fatty acids that are required for normal brain development, healthy skin and hair, normal eye development, and resistance to infection and disease.

Sources

Breast milk and infant formula are important sources of lipids, including essential fatty acids, during infancy. The lipid content of breast milk varies, but after about the first 2 weeks postpartum, breast milk provides approximately 50 percent of its calories from lipids.[19] Infant formulas also provide approximately 50 percent of their calories as fat. Breast milk provides approximately 5.6 g/liter of linoleic acid,[16] while infant formulas currently provide 3.3–8.6 g/liter. In addition, breast milk provides approximately 0.63 g/liter of n-3 polyunsaturated fatty acids[16] (including α-linolenic acid and docosahexaenoic acid) while infant formulas provide 0 to 0.67 g/

liter. Manufacturers of infant formulas add blends of vegetable oils, which are high in linoleic acid, to improve essential fatty acid content. Food sources of lipids in the older infant's diet, other than breast milk and infant formula, include meats, cheese and other dairy products, egg yolks, and any fats or oils added to home-prepared foods.

Cholesterol and Fatty Acids in Infant Diets

In agreement with the National Cholesterol Education Program,[20] the American Academy of Pediatrics (AAP) states that "no restriction of fat and cholesterol is recommended for infants <2 years when rapid growth and development require high energy intakes."[21] The fast growth of infants requires an energy-dense diet with a higher percentage of kilocalories from fat than is needed by older children.

Cholesterol performs a variety of functions in the body but is not an essential nutrient because it is manufactured by the liver. Cholesterol is not added to infant formulas whereas breast milk contains a significant amount of cholesterol. In recent years, there has been interest in whether the cholesterol content of breast milk has a beneficial or adverse effect on later development of atherosclerosis. A comprehensive analysis of 37 studies confirmed total cholesterol was higher in breastfed than formula-fed infants, no different in children or adolescents who had been breast versus formula-fed, and lower in adults who were breast versus formula-fed, reinforcing the possible protective effect of cholesterol exposure in infancy.[22] It has been suggested that breast milk's high level of cholesterol stimulates the development of enzymes necessary to prepare the infant's body to process cholesterol more efficiently in later life,[23] but carefully designed, well-controlled studies need to be conducted to confirm this possibility.[19]

Trans fats, which are believed to be similar to saturated fats in their atherosclerotic affect, are found in fat that has been modified to a more solid form, such as polyunsaturated oils used to make spreadable margarine. They are present in most American diets, thus may be present in breast milk but serve no physiologic purpose. Trans fats are not routinely used in the preparation of infant formulas.[24] Further research is needed to determine the long-term effects of the consumption of trans fats by infants.[25]

In the last several years, interest has increased concerning the content of LCPUFA in breast milk versus infant formula. Of primary interest are ARA and DHA, which are major fatty acids important for brain and retina development. Breast milk naturally contains ARA and DHA with levels varying according to the mother's diet. Some infant formulas contain the precursors of DHA, ARA, linoleic acid, and α-linolenic acid. Infants can make DHA and ARA from these precursors. Formula-fed infants have been observed to have lower plasma levels of ARA and DHA than breastfed infants, therefore questions have been posed about the formula-fed infant's ability to synthesize these fatty acids.[18] Research demonstrating better cognitive function and visual acuity in breastfed infants has led to some support for the addition of ARA and DHA to infant formula.[18, 19] This issue remains controversial.

Vitamin and Mineral Supplements

Caregivers should not supplement their infants' diets with vitamins or minerals during the first year of life unless they are prescribed by a health care provider. If a supplement is prescribed, it is important that only the dosage prescribed be given to the infant and the supplement bottle be kept out of the reach of infants and children. Excessive amounts of certain vitamins and minerals, in the form of drops or pills, can be toxic or even fatal to infants.

Vitamin D

AI for Infants	0–12 months	5 µg (200 IU)/day
UL for Infants	0–12 months	25 µg (1,000 IU)/day

Functions

Vitamin D, a fat-soluble vitamin, is essential for:

- Proper formation of bones and

- Utilization of calcium and phosphorus in the body.

Sources

Vitamin D is manufactured in the skin by the action of ultraviolet light (from the sun) on chemicals naturally present in the skin. The requirement for dietary vitamin D depends on the amount of exposure an infant gets to sunlight. In the United States, fortified milk products, including milk-based infant formulas, are the major dietary source of vitamin D. Fish, liver, and egg yolk are also sources of this vitamin.

Breast milk contains a small amount of vitamin D. AAP states:

> Infants who are breastfed but do not receive supplemental vitamin D or adequate sunlight exposure are at increased risk of developing vitamin D deficiency or rickets. Human milk typically contains a vitamin D concentration of 25 IU/L or less. Thus the recommended adequate intake of vitamin D cannot be met with human milk as the sole source of vitamin D for the breastfeeding infant.[26]

There is evidence that limited sunlight exposure prevents rickets in many breastfed infants. However, experts recommend limiting sunlight exposure among young infants because of recent concerns raised about the increased risk of skin cancer which may result from early exposure to sunlight. As a result of these factors, the AAP recommends that all healthy infants have a minimum intake of 200 IU of Vitamin D per day during the first 2 months of life to prevent rickets and vitamin D deficiency.[26] A supplement of 200 IU per day is recommended for the following: [26]

- All breastfed infants unless they are weaned to at least 500 mL per day of vitamin D-fortified infant formula and
- All nonbreastfed infants who are consuming less than 500 mL per day of vitamin D-fortified infant formula.

Vitamin D Deficiency

An infant not receiving sufficient vitamin D through supplementation, diet, or sun exposure can develop a deficiency. Vitamin D deficiency leads to inadequate intestinal absorption of calcium and phosphorus resulting in improper bone formation and tooth mineralization. Rickets is a disease that can result from vitamin D deficiency and is characterized by swollen joints, poor growth, and bowing of the legs or knocked knees.[28]

Rickets was common in the early 1900s; in recent years it was thought that rickets had all but been eliminated.[29] However, a significant number of cases were reported in the 1990s, most often among African-American infants.[30] These infants were breastfed, did not receive supplemental vitamin D, and had limited exposure to sunlight.[31,32] This recent resurgence of rickets as well as concerns regarding early sun exposure resulted in the recent recommendations on supplemental vitamin D.

Vitamin A

AI for Infants	
0–6 months	**400 µg Retinol Active Equivalent/day of vitamin A**
7–12 months	**500 µg Retinol Active Equivalent/day of vitamin A**
UL for Infants	
0–12 months	**600 µg/day of preformed vitamin A**

Vitamin A, a fat-soluble vitamin, refers to a group of compounds including preformed types of the vitamin found in animal products and carotenes, precursors of vitamin A, found in plants.

Functions

Vitamin A is essential for:

- Formation and maintenance of healthy skin, hair, and mucous membranes;
- Proper vision;
- Growth and development; and
- Healthy immune and reproductive systems.

Sources

Breast milk and infant formula are major food sources of vitamin A. Additional sources of vitamin A or carotenes for infants consuming complementary foods include: egg yolks, yellow and dark green leafy vegetables and fruits (e.g., spinach, greens, sweet potatoes, apricots, cantaloupe, peaches), and liver. Some infants may have allergic reactions to certain fruits or vegetables. See pages 104–105 for precautions that caregivers should follow when introducing new foods to infants.

Vitamin A Deficiency

Although rare in the United States, vitamin A deficiency is a major nutritional problem in developing countries.[33] This deficiency can result from insufficient vitamin A intake, infection, or malnutrition and can lead to damage of varying severity to the eyes, poor growth, loss of appetite, increased susceptibility to infections, and skin changes.

Vitamin E

AI for Infants	
0–6 months	4 mg/day of α-tocopherol
7–12 months	5 mg/day of α-tocopherol

Functions

Vitamin E, a fat-soluble vitamin, performs the following roles:

- Protects vitamin A and essential fatty acids in the body and
- Prevents the breakdown of tissues.

Sources

Infants receive vitamin E from breast milk and infant formula. Other vitamin E sources for older infants include green leafy vegetables; vegetable oils and their products; wheat germ; whole-grain breads, cereals, and other fortified or enriched grain products; butter; liver; and egg yolks. Vitamin E can be destroyed through processing and cooking.

Vitamin K

AI for Infants	
0–6 months	2.0 µg/day of vitamin K
7–12 months	2.5 µg/day of vitamin K

Functions

Vitamin K, a fat-soluble vitamin, is necessary for proper blood clotting.

Sources

Sources of vitamin K include infant formula, green leafy vegetables, pork, and liver. Although this vitamin is manufactured by bacteria normally found in the intestine, this process is not fully developed in the early stages of an infant's life. Since breast milk is normally low in vitamin K, exclusively breastfed infants are at risk of developing a fatal brain hemorrhage due to vitamin K deficiency. Therefore, it is recommended that all infants be given an intramuscular injection of vitamin K at birth, regardless of the mothers' plans to breast- or formula-feed.[34] Infants fed an adequate amount of infant formula receive sufficient vitamin K. No requirement for vitamin K supplementation of breastfed infants after hospital discharge has been established, but some experts recommend that mothers be supplemented while they are breastfeeding.[19]

Vitamin C

AI for Infants	
0–6 months	40 mg/day vitamin C
7–12 months	50 mg/day vitamin C

Functions

The major functions of Vitamin C (ascorbic acid), a water-soluble vitamin, include the following:

- Forming collagen, a protein that gives structure to bones, cartilage, muscle, blood vessels, and other connective tissue;
- Helping to maintain capillaries, bones, and teeth;
- Healing wounds;
- Playing a role in the body's ability to resist infections; and
- Enhancing the absorption of iron.

Sources

Breast milk and infant formulas are major food sources of vitamin C. Additional vitamin C sources include vegetables (e.g., tomatoes, cabbage, potatoes), fruits (e.g., citrus fruits, papaya, cantaloupe, and strawberries), and infant and regular fruit and vegetable juices naturally high in or fortified with vitamin C. Cooking home-prepared vegetables (or fruits if they need to be cooked) for the minimum time required to process them reduces the destruction of vitamin C in the food. See pages 108–109 for precautions that caregivers should follow when introducing vegetables and fruits.

Vitamin C Deficiency

Vitamin C deficiency can eventually lead to scurvy, a serious disease with the following symptoms in infants: poor bone growth, bleeding, and anemia.[35] Since breast milk and infant formula are both good sources of vitamin C, infantile scurvy is rarely seen. It should be kept in mind that cow's milk, evaporated milk, and goat's milk contain very little vitamin C.

Vitamin B12

AI for Infants	
0–6 months	0.4 µg/day of vitamin B12
7–12 months	0.5 µg/day of vitamin B12

Functions

Vitamin B12, a water-soluble vitamin, is necessary for:

- Healthy blood cells and
- Proper functioning of the nervous system.

Sources

An infant's vitamin B12 stores at birth generally supply his or her needs for approximately 8 months. Major food sources of vitamin B12 are breast milk and infant formulas. Infants consuming appropriate amounts of breast milk from mothers with adequate B12 stores or infant formula receive adequate amounts of this vitamin. Complementary foods such as meat, egg yolks, and dairy products provide this vitamin later in infancy as well.

Vitamin B12 Deficiency, Breastfed Infants, and Vegetarian Diets

Vitamin B12 status at birth is strongly associated with the mothers' vitamin B12 status and the number of previous pregnancies.[36] After birth, the exclusively breastfed infant's vitamin B12 intake depends on the mother's intake and stores. Concentrations of vitamin B12 in breast milk are adequate as long as the maternal diet is adequate. However, infants of breastfeeding mothers who follow strict vegetarian (vegan) diets or eat very few dairy products, meat, or eggs are at risk for developing vitamin B12 deficiency.[37, 38] In these infants, vitamin B12 status may be abnormal by 4 to 6 months of age.[39] Signs of vitamin B12 deficiency in infancy include failure to thrive, movement disorders, delayed development, and megaloblastic anemia. The Institute of Medicine's Food and Nutrition Board recommends that infants of vegan mothers be supplemented from birth with vitamin B12 at the AI for age (0–6 months, 0.4 µg/day; 7–12 months, 0.5 µg/day).[39] Vitamin B12 is also a concern for an infant on a strict vegetarian or vegan diet and supplementation is indicated.[40] Advise caregivers of infants on a strict vegetarian or vegan diet to consult their health care provider regarding B12 supplementation. See page 137-138 for more information regarding vitamin B12 in vegetarian and vegan diets.

Folate

AI for Infants	
0–6 months	65 µg/day of dietary folate equivalents
7–12 months	80 µg/day of dietary folate equivalents

Functions

Folate, a water-soluble or B-vitamin, is required for the following:

- Cell division
- Growth and development of healthy blood cells and
- Formation of genetic material within every body cell.

At times, folate is referred to as folic acid, but there is a difference between the two. Both are forms of the same B-vitamin, but they come from different sources. Folate occurs naturally in foods while folic acid is a synthetic form of the vitamin that is added to foods and supplements.

Sources

Infants receive folate from breast milk; infant formula; green leafy vegetables; oranges; cantaloupe; whole-grain breads, cereals, and fortified or enriched grain products; legumes; lean beef; egg yolks; and liver. Folate can be lost from foods during preparation, cooking, or storage.

Vitamin B6 (Pyridoxine)

AI for Infants	
0–6 months	0.1 mg/day of vitamin B6
7–12 months	0.3 mg/day of vitamin B6

Functions

Vitamin B6 (pyridoxine), a water-soluble vitamin, is necessary for:

- Helping the body use protein to build tissues and
- Aiding in the metabolism of fat.

The need for this vitamin is directly related to protein intake; as protein intake increases, the need for vitamin B6 in the diet increases.

Sources

Food sources of vitamin B6 include breast milk; infant formula; liver; meat; whole-grain breads, cereals, and other fortified or enriched grain products; legumes; and potatoes.

Thiamin (Vitamin B1)

AI for Infants	
0–6 months	0.2 mg/day of thiamin
7–12 months	0.3 mg/day of thiamin

Functions

Thiamin (vitamin B1), a water-soluble vitamin, is needed by infants to:

- Help the body release energy from carbohydrates during metabolism and
- Play a vital role in the normal functioning of the nervous system.

Sources

Food sources of thiamin include breast milk; infant formula; whole-grain breads, cereals, and other fortified or enriched grain products; legumes; lean pork; and potatoes.

Thiamin Deficiency

Thiamin deficiency can occur in breastfed infants of thiamin-deficient mothers. However, there have been no recent reports in the United States or Canada of thiamin deficiency in exclusively breastfed infants regardless of their mother's thiamin status.[39,41]

Riboflavin (Vitamin B2)

AI for Infants	
0–6 months	0.3 mg/day of riboflavin
7–12 months	0.4 mg/day of riboflavin

Functions

Riboflavin (vitamin B2), a water-soluble vitamin, helps the body release energy from protein, fat, and carbohydrates during metabolism.

Sources

Food sources of riboflavin include breast milk; infant formula; organ meats; dairy products; egg yolks; green vegetables (e.g., broccoli, asparagus, turnip greens); and whole-grain breads, cereals, and fortified or enriched grain products.

Riboflavin Deficiency Associated With Macrobiotic Diets

Riboflavin deficiency has not been reported among infants in the United States, although breastfed infants whose mothers are on a macrobiotic diet that excludes dairy products, red meat, and poultry may be at risk. See page 136 for a description of the macrobiotic diet. Riboflavin deficiency can lead to growth inhibition; deficiency symptoms include skin changes and dermatitis, anemia, and lesions in the mouth.

Niacin

AI for Infants
0–6 months **2 mg/day of preformed niacin**
7–12 months **4 mg/day of niacin equivalents**

Functions

Niacin, a water-soluble vitamin, helps the body release energy from protein, fat, and carbohydrates during metabolism. The need for niacin is normally met in part by the body's conversion of the amino acid tryptophan in the diet to niacin.

Sources

Food sources of niacin include breast milk; infant formula; egg yolks; poultry; meat; fish; and whole-grain breads, cereals, and fortified or enriched grain products. Niacin can be formed in the body from the tryptophan in these foods: meat, poultry, cheese, yogurt, fish, and eggs.

Calcium

AI for Infants
0–6 months **210 mg/day of calcium**
7–12 months **270 mg/day of calcium**

Functions

Calcium, a mineral, plays an important role in the following activities:

- Bone and tooth development
- Blood clotting and
- Maintenance of healthy nerves and muscles.

Sources

An infant can obtain sufficient calcium by consuming adequate amounts of breast milk or infant formula. Older infants can obtain additional calcium from complementary foods such as yogurt, cheese, fortified or enriched grain products, some green leafy vegetables (such as collards and turnip greens), and tofu (if the food label indicates it was made with calcium sulfate).

The absorption and use of calcium in the body is affected by the presence of other nutrients, such as vitamin D which must be available in the body for an infant to retain and use the calcium consumed. The calcium from breast milk is more completely absorbed than the calcium from cow's-milk-based or soy-based infant formulas. However, higher levels are present in these infant formulas to account for the difference in absorption.

Calcium Deficiency and Vegetarian Diets

Infants on certain strict vegetarian diets may be at risk for developing a calcium deficiency.[42] Use of soy-based infant formulas, which are fortified with calcium, are recommended for infants whose caregivers place them on a vegan diet, low in breast milk.[39] Soy-based beverages (sometimes called soy drink or soy milk), available in most retail food stores, typically do not provide sufficient calcium for infants and thus are not recommended for infants. See pages 86 and 137 for more information on soy-based beverages.

Calcium Deficiency and Lead Poisoning

Calcium deficiency is related to increased blood lead levels and perhaps increased vulnerability to the adverse effects of lead in the body.[43] Infants at risk for lead poisoning should receive the recommended amount of breast milk or infant formula to provide adequate dietary calcium.

Iron

AI for Infants
0 - 6 months **0.27 mg/day of iron**

RDA for Infants
7 - 12 months **11 mg/day of iron**

UL
0 - 12 months **40 mg/day of iron**

Functions

Iron, a mineral, is needed by infants for:

- Proper growth and formation of healthy blood cells and
- Prevention of iron-deficiency anemia.

This mineral is a vital component of hemoglobin, the part of red blood cells that carries oxygen throughout the body; myoglobin, the part of muscle cells that stores oxygen; and many enzymes in the body.

Sources

Most full-term infants are born with adequate iron stores that are not depleted until about 4 to 6 months of age.[33] In comparison, preterm infants and twins have lower iron stores at birth and, with their rapid growth rate, may deplete their iron stores by 2 to 3 months of age.[44]

Sources of iron for infants include breast milk; infant formula; meat; liver; legumes; whole-grain breads, cereals, or fortified or enriched grain products; and dark green vegetables. The ability to absorb the iron in food depends on the infant's iron status and the form of iron in the food. Absorption of iron from the diet is relatively low when body iron stores are high and absorption may increase when iron stores are low.[45]

Iron in food occurs in two major forms:

- **Heme iron –** found primarily in animal tissues, including red meat, liver, poultry and fish. This form is well absorbed into the body. Commercially prepared infant food plain meats contain more heme iron than infant food combinations and dinners.
- **Nonheme iron –** found in breast milk; infant formula; iron-fortified breads, cereals, or other grain products; legumes; fruits; and vegetables. Infants receive most of the iron in their diets as nonheme iron. This form is not as well absorbed into the body as heme iron and its absorption can be affected by other foods in the same feeding or meal. Vitamin C-rich foods or meat, fish, or poultry in a meal increase the absorption of nonheme iron. Thus, it is recommended to serve a vitamin C source (such as breast milk, iron-fortified infant formula, or vitamin C-rich fruit juices or foods) at the same meal as iron-fortified grain products or legumes. Dairy products reduce the absorption of iron.

Meeting Iron Requirements of Breastfed and Formula-Fed Infants

The AAP has carefully reviewed the need for iron supplementation in infancy.[46] To ensure adequate iron intake, they recommend the following: [44]

Breastfed Infants:

- Full-term, appropriate-for-gestational-age breastfed infants need a supplemental source of iron starting at 4 to 6 months of age (approximately 1 mg/kg/day) preferably from complementary foods. Iron-fortified infant cereal and/or meats are a good source of iron for initial introduction of an iron-containing food. An average of 2 servings (½ oz or 15 g of dry cereal per serving) is needed to meet the daily iron requirement.
- If a full-term, breastfed infant is unable to consume sufficient iron from dietary sources after 6 months of age, an oral iron supplemental should be used.
- For all infants younger than 12 months, only iron-fortified infant formula (10 to 12 mg/L) should be used for weaning or supplementing breast milk.

Formula-Fed Infants:

- For full-term infants, only iron-fortified infant formula should be used during the first year of life regardless of the age when infant formula is started. All soy-based formulas are iron-fortified to 12 mg/L.
- No common medical indication exists for the use of a low-iron infant formula. The AAP has recommended the discontinuation of the manufacturing of low-iron formula and that all infant formulas contain at least 4 mg/L of iron. Although some believe that iron-fortified infant formula increases gastrointestinal symptoms, no scientific evidence supports this belief. Consequently, using non-iron-fortified infant formula for healthy infants is not justified.

Other Milks

Cow's milk, goat's milk, and soy-based beverages (e.g., soy milk) contain relatively little iron or the iron they contain is poorly absorbed by infants. These milks can promote the development of iron-deficiency anemia by causing microscopic gastrointestinal bleeding and nutritionally significant blood loss in infants.[47] Studies show that blood loss induced by the consumption of cow's milk decreases in the older infant and disappears by 12 months of age.[48,49] For this and other reasons, cow's milk, goat's milk, or soy-based beverages are not recommended for infants less than 12 months old.[44] See pages 85–86 for additional information regarding other milks.

Iron Deficiency

The WIC Program screens for iron deficiency (deficiency in iron stores) using hematological tests, such as the hemoglobin and hematocrit tests. Hemoglobin is the iron-containing, oxygen-carrying protein in the blood. Hematocrit refers to the packed cell volume (volume of red blood cells and other particulate elements in the blood), that is, the percentage the red cell volume is of a total unit volume of blood. The symptoms of iron deficiency include anemia, malabsorption of food, irritability, anorexia, pallor, and lethargy. Studies have also shown that iron deficiency in infants and older children may be associated with irreversible behavioral abnormalities and abnormal functioning of the brain.[50] Elevated blood lead levels have been associated with iron deficiency; however, the relationship is unclear.[51] Current recommendations from the CDC are for infants at high risk for iron-deficiency anemia to be screened between 9 and 12 months of age regardless of blood lead levels.[51, 52] If an infant has a low hematocrit or hemoglobin level based on blood testing, it is appropriate to assess the infant's diet and refer him or her to a health care provider for further assessment and treatment.

Zinc

AI for Infants	0–6 months	2 mg/day of zinc
UL for Infants	0–6 months	4 mg/day of zinc
UL for Infants	7–12 months	5 mg/day of zinc
RDA for Infants	7–12 months	3 mg/day of zinc

Functions

Zinc, a mineral that is a component of many enzymes in the body, is involved in most metabolic processes.

Zinc plays a role in the following bodily functions:

- Formation of protein in the body and thus assists in wound healing
- Blood formation
- General growth and maintenance of all tissues
- Taste perception and
- A healthy immune system.

Sources

Infants obtain zinc from breast milk; infant formula; meat; poultry; liver; egg yolks; cheese; yogurt; legumes; and whole-grain breads, cereals, and other fortified or enriched grain products. Meat, liver, and egg yolks are good sources of available zinc, whereas whole-grain products contain the element in a less available form. Breast milk is considered to be a good source of zinc for the first 6 months, but is inadequate for the older infant.[33] In addition to breast milk or infant formula, complementary food sources of zinc, such as meats or fortified infant cereal, help meet an infant's zinc needs after 6 months of age.

Zinc in Vegetarian Diets

Some vegetarian diets may be deficient in zinc. Some researchers have recommended zinc supplementation for infants on vegan diets during weaning;[53,54] however, the AAP does not currently recommend supplementation because zinc deficiency among vegetarians is rare.[55] Advise caregivers of infants on vegan/vegetarian diets to consult their health care provider regarding supplementation. See page 138 for more information regarding zinc in vegetarian diets.

Zinc and Lead Poisoning

High levels of dietary zinc may inhibit absorption of lead; however, zinc supplementation is not recommended for infants with elevated blood lead levels.[51]

Fluoride

AI for Infants	
0–6 months	0.01 mg/day of fluoride
7–12 months	0.5 mg/day of fluoride
UL for Infants	
0–6 months	0.7 mg/day of fluoride
7–12 months	0.9 mg/day of fluoride

Functions

Fluoride is not considered an essential nutrient, but is a beneficial mineral. If consumed at appropriate levels, fluoride decreases the susceptibility of the teeth to dental caries (tooth decay). When allowed to come in contact with the teeth and to some extent when consumed before teeth erupt, this mineral is incorporated into the mineral portion of the teeth. Once fluoride is an integral part of the tooth structure, teeth are stronger and more resistant to decay.

Sources

Fluoride is present in small but varying concentrations in water supplies and in plant and animal foods. The major dietary sources for infants are fluoridated water, infant formulas made with fluoridated water, and some marine fish.[28] Since continued exposure to appropriate levels of fluoride throughout one's lifetime is effective in reducing the prevalence of dental caries, many communities add fluoride to the water supply if it is naturally low in that mineral. Most public water supplies are fluoridated to provide 0.7 ppm to 1.2 ppm of fluoride.

If the fluoride content of the home drinking water is unknown, the water should be tested. Some health departments will test water for fluoride at no cost, if the request is signed by a dental or medical health care provider. Private laboratories can also test for fluoride. Fluoride may not be specifically added to bottled waters, but the mineral may be inadvertently present. The majority of bottled waters do not contain adequate fluoride to meet daily needs. Manufacturers of bottled water are not required to include fluoride content on the label and few do. Thus, caregivers using bottled water (other than distilled water) to mix infant formula, prepare food, and drink should contact the manufacturer to determine its fluoride content or have it tested. Without this information it is impossible for the health care provider to adequately assess the amount of fluoride the infant is ingesting. Bottled waters manufactured and marketed specifically for infants may contain fluoride and must be labeled as such. In some cases, fluoride in these products may exceed the safe amount for an infant to ingest if used to prepare infant formula. Caregivers should be advised to discuss use of these products with a health care provider. Certain types of home water treatment systems, such as reverse osmosis and distillation units, may remove fluoride from the water.[56] Carbon and charcoal water filtration systems, the most common types used in homes, and water softeners do not significantly change the fluoride content of water. Commercially prepared infant food is generally prepared with nonfluoridated water.

Fluoride Supplementation for Infants

Recommended fluoride supplementation depends on the total amount of fluoride available to the infant from all sources, including infant formula, water, and commercially and home-prepared infant foods.

The AAP, the American Academy of Pediatric Dentistry (AAPD), and the CDC recommend no fluoride supplementation for infants less than 6 months old.[56,57,58] For infants older than 6 months, whose community drinking water contains <0.3 ppm fluoride, supplementation of 0.25 mg sodium fluoride/day is recommended.

Excessive Fluoride

Fluoride supplementation should not be given to infants who are consuming an adequate amount of fluoride from either naturally occurring or community-supplemented water supplies. Some infants and children may be drinking water that contains naturally occurring fluoride that exceeds the recommended levels for optimal dental health. To determine whether drinking water may contain excessive levels of fluoride, testing should be done as mentioned above. If a fluoride

Considerations for Breastfed Infants. Breast milk contains little fluoride even in areas with fluoridated water.[59] Since fluoride intake during the first 6 months does not affect the development of caries, no supplementation is indicated.[28] It should also be noted that fluoride supplementation may not be appropriate for older breastfed infants who are consuming either fluoridated drinking water, infant formula mixed with fluoridated water, or complementary foods (beverages or solids) prepared with fluoridated water.[57] Given the above controversies and concerns, caregivers of exclusively or partially breastfed infants should consult their infants' health care provider for advice on fluoride.

Considerations for Formula-Fed Infants. The amount of fluoride in concentrated or powdered infant formula depends on the amount of fluoride in the infant formula and in the water used for mixing. Ready-to-feed infant formulas are manufactured with nonfluoridated water. Infants receiving ready-to-feed infant formula as well as concentrated or powdered infant formula in areas where the water is not fluoridated may receive little or no fluoride. Infants fed infant formula made with fluoridated water may receive up to 1.0 mg/day of fluoride.[28] Given the variability of exposure to fluoride from infant formula and water used for mixing, caregivers of formula-fed infants should consult their infants' health care provider for advice on fluoride.

Considerations for Infants on Complementary Foods. Once a breastfed or formula-fed infant begins drinking fluoridated water or eating foods prepared with fluoridated water on a regular basis, the fluoride in the infant's diet will increase. Infants consuming primarily commercially prepared infant foods or infant formula, foods or beverages prepared with water low in fluoride should be referred to a health care provider for advice on fluoride.

supplement is prescribed, it is important for the caregiver to give only the amount prescribed. These concerns are important because fluoride (from natural sources or supplements), when consumed in excess over time, may cause staining or "mottling" of the teeth, termed dental fluorosis. Fluorosis affects approximately 22 percent of children, almost all to a mild to moderate degree.[56] An alternative water source is recommended when the home water supply contains 2.0 ppm or more of fluoride. The unintentional ingestion of toothpaste can cause an increase in daily fluoride intake. For this reason, caregivers should consult their health care provider concerning toothpaste use.

Sodium

Functions

Sodium, a mineral, is required to:

- Maintain the water balance in the body
- Regulate blood volume and
- Ensure the proper functioning of cell membranes and other body tissues.

Sources

Healthy, full-term infants consuming primarily breast milk or infant formula of standard dilution receive a relatively small amount of sodium but an amount adequate for growth. Estimated minimum requirements for infants are 100 to 200 mg/day.[60] The sodium level in cow's milk is greater than that in breast milk and most infant formulas; however, cow's milk is not recommended for infants. Salt is not added to commercially prepared infant foods; however, salt is added to "junior" or "toddler" foods designed for children from 1 to 4 years old to improve their taste. These foods are not recommended for infants. The amount of sodium consumed by an infant on home-prepared complementary foods reflects the cooking methods used in the home and the eating habits and cultural food patterns of the infant's family.

Water

Functions

Water is required by infants for the following activities:

- Body temperature regulation
- Transport route (fluid medium) for nutrients and metabolic waste products
- Cell metabolism and
- Normal kidney function.

Water and Renal Solute Load of Foods

The role that water plays in the excretion of waste products by an infant's kidneys is particularly important. The kidney needs water to easily excrete waste products, called solutes, via the urine. Solutes are "end products" formed after food has been fully digested and metabolized. Examples of solutes include compounds containing nitrogen from the breakdown of protein and the minerals sodium, potassium, and chloride that are consumed in excess of body needs. The term used to express the relative amount of solutes from a food or a mixture of foods presented to the kidney for excretion is "renal solute load."

The higher the renal solute load of a food, the more water is required to properly excrete the byproducts that result from digestion and metabolism of the food. The immature kidneys in very young infants have difficulty handling the byproducts of foods with a high renal solute load.[61] These foods include cow's milk and high protein foods. Breast milk has a lower renal solute load compared to infant formulas and diluted evaporated whole-milk formulas; cow's and goat's milk have a much higher renal solute load than infant formulas.[62] Due to their very high renal solute load, cow's milk, highly concentrated infant formula, undiluted evaporated milk, or boiled undiluted cow's milk should not be fed to infants. When milk is boiled, some of the water in it evaporates leading to an excessive concentration of protein and minerals.

Sources of Water

Infants' water needs are met from consuming breast milk, infant formula, and complementary foods. Water is also formed in the body in chemical reactions occurring to metabolize protein, fats, and carbohydrates. Under normal circumstances, the water requirements of healthy infants who are fed adequate amounts of breast milk or properly reconstituted infant formula are met by the breast milk or infant formula alone. Supplemental water is not necessary, even in hot, dry climates,[63] and may have severe consequences if given in excess. See page 29 for more information regarding excess water in the diet.

An infant's health care provider may recommend feeding a small amount of sterile water (~4 to 8 oz per day) in a cup when complementary foods are introduced at the appropriate time. Sterile water is water that is brought to a very bubbly boil, boiled for 1 to 2 minutes, and then allowed to cool. Instruct the caregiver to consult their health care provider concerning their infant's water needs when introduced to complementary foods.

Insufficient Water Intake

Infants may receive an insufficient amount of water under any of the following circumstances:[64]

Dietary Intake-Related Circumstances

- **Infant is fed infant formula that is too concentrated –** When too little water is added to liquid concentrate or powdered infant formula, the renal solute load of the infant formula will be high. Instruct the caregiver on proper infant formula preparation to avoid this problem.
- **Infant consumes much less infant formula or breast milk than usual, such as when ill –** Infants who are ill and are not feeding normally should be referred to a health care provider.
- **Infant consumes protein-rich or salty foods with a high renal solute load –** These foods include protein-rich foods such as home-prepared meats, commercially prepared infant meats and meat dinners, egg yolks,

and foods with added salt. Water (about 4 to 8 ounces per day) may be recommended for the infant when these foods are introduced at the developmentally appropriate time (usually after 6 months of age). See pages 109–111 for more information regarding introducing protein-rich complementary foods.

- **Infant is fed whole-fat, low-fat, or skim cow's milk –** These milks are not recommended because they have a high renal solute load and are dangerous for infant consumption.

Medical Condition-Related Circumstances (Water Requirements/Needs Are Increased)

- **Infant is vomiting or has diarrhea –** Refer infants with vomiting or diarrhea to a health care provider. Caregivers who attempt to self-treat diarrhea by, for example, feeding their infants large amounts of water or other liquids (e.g., fruit juices; soda; diluted fruit punches, drinks, or aides; tea; broth; or gelatin water), may actually worsen the condition. Home-prepared beverages can cause fluid from the body to be drawn into the intestinal tract and thus encourage greater fluid loss from the body. Caregivers should use an oral electrolyte solution (e.g. Pedialyte, Equalyte) to treat vomiting or diarrhea only when prescribed by a health care provider. See below for information regarding excessive water intake.
- **Infant has a fever –** Fever may increase an infant's water requirements. Refer infants whose caregivers report that they have a fever to a health care provider.
- **Infant has a medical condition that increases water requirements (e.g., diabetes insipidus) –** Infants with medical conditions, such as diabetes insipidus, should be under a health care provider's care.

Excessive Water in the Diet and Water Intoxication

Water intoxication can occur in either breastfed or formula-fed infants who are fed excessive amounts of water. This condition can develop in infants who consume infant formula over-diluted with water, those who are force-fed water, or those who are fed bottled water in place of breast milk or infant formula.[65, 66, 67] This condition, while preventable, can be life-threatening to an infant. Symptoms of the condition include irritability, sleepiness, hypothermia, edema, and seizures. Also, infants fed excessive water will not receive adequate kilocalories to meet their needs for growth and development.

Dehydration

Since dehydration (excessive loss of water from the body) can lead to death in infants, caregivers need to be aware of the signs of dehydration, which include the following:

- A reduced amount of urine, which is also dark yellow in color;
- Dry membranes in the mouth;
- No tears when crying;
- Sunken eyes; and
- Restlessness, irritability, or lethargy.

Refer the infant to a health care provider for immediate medical attention if the caregiver notes that the infant has any symptoms of dehydration.

Safety of the Water Supply

Formula-fed infants on concentrated or powdered infant formula consume a significant amount of water from the amount used in infant formula preparation. So, it is important that the water consumed be safe and free of potentially harmful contaminants. Water from public or municipal water systems is regularly tested for contaminants regulated by Federal and State standards, such as pathogens, radioactive elements, and certain toxic chemicals. Since 1999, public water suppliers have been required by the United States Environmental Protection Agency (EPA) to provide residents with a consumer confidence report on their water each year by July 1. They are also required to provide notification of any contamination when it is discovered.

Consumer Confidence Reports for public water systems must include:[68]

- The lake, river, aquifer, or other source of the drinking water;

- Information on the susceptibility of the source to contamination, the level of any contaminant found in the drinking water, the likely source of the contaminant, the EPA health-based standard (maximum allowed) for the contaminant, health effects of the contaminant, and the actions to restore safe water;
- The system's compliance with other drinking water-related rules;
- Educational information on avoidance of Cryposporidium for vulnerable populations and on nitrate, arsenic, and lead where these exceed 50 percent of the EPA standard; and,
- Information on how to get more complete information from the water supplier and the EPA's Safe Drinking Water Hotline, 1-800-426-4791.

Large water system suppliers often mail this report, while smaller system suppliers may publish it in a local newspaper. The largest systems are required to post their reports on the web and the EPA is working to have all reports posted on the Web. Reports from public water systems nationwide are available on the Web at **http://cfpub.epa.gov/compliance/resources/reports/accomplishment/sdwa/.**

Anyone with an infant or child and all pregnant women should be aware that contaminants can enter a home's or apartment's water supply from a variety of sources; e.g., via lead pipes, lead solder, or lead service lines; bacteria inside the home's or building's plumbing system, or community water system; or a contaminated ground water supply draining into a household well. If they suspect any of these sources could be contaminating their drinking water, they should strongly consider having their tap water tested. If contaminants are found, appropriate actions can be taken to reduce the risk to infants and children. Refer to pages 35–39 for more information regarding the safety of well water, lead, copper, and nitrate contamination, the use of bottled water, and home water treatment units.

For more information on health issues specific to drinking water contaminants (e.g., lead, nitrate, bacteria, pesticides) contact the EPA Safe Drinking Water Hotline at 1-800-426-4791. The hotline operates from 9:00 a.m. to 5:00 p.m. Eastern Standard Time (EST).

What to do if the parent/caregiver runs out of infant formula

Since the WIC and CSF Programs' infant formula allowance is intended to be supplemental and not meet the nutritional needs of all infants, caregivers will need to obtain additional infant formula beyond that provided by WIC or CSFP. If the amount of infant formula provided by the WIC or CSF Program is insufficient to meet an infant's needs, then:

- **Offer powdered infant formula instead of concentrated or ready-to-feed infant formula, since powdered infant formula has a higher yield.**
- **Refer the parent/caregiver to sources of financial or food assistance in the community that they may be eligible for.**

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Additional Information on Safety of the Water Supply

Well Water

About 14 to 15 million United States households get their drinking water from a private household well. Caregivers whose drinking water source is a private household or community well should be strongly urged to have their water tested for bacteria, nitrates, and other contaminants. Private wells are not regulated by the same Federal drinking water standards as a public water system. As a result, the burden is on the user to determine if the water is safe to drink. The Centers for Disease Control and Prevention (CDC) recommend that private wells be tested annually for germs and every 2 to 3 years for harmful chemicals.[1] Wells should also be tested if there is a problem with other wells in the area where there has been flooding, land disturbance, or nearby waste disposal or if any part of the well system is repaired or replaced.

Potential sources of contaminants of well water include the following:

- Naturally occurring chemicals like arsenic, lead, and cadmium found in rocks and soils;
- Human and animal waste coming from polluted storm water runoff, agricultural runoff, or flooded sewers;
- Nearby gas stations or factories;
- Improperly functioning septic systems;
- Any past and present activities in the area near the well, such as the application of lawn care or agricultural chemicals or improper disposal of household chemicals (e.g., used motor oil, paints and thinners, cleaning fluids).

Well water containing greater than 2.0 ppm (parts per million) levels of fluoride may cause dental fluorosis (staining or mottling of the teeth) if infants or children drink it during tooth formation for an extended time. Thus, well water should be tested for fluoride. When water contains 2.0 ppm or more of fluoride, advice should be obtained from a medical or dental health care provider to determine if the exclusive use of bottled water or the blending of home and bottled water is recommended.[2]

For information on testing well water and a list of State-certified laboratories in the area, caregivers can contact the local health or environmental department or the State drinking water office (usually located in the State health department or environmental agency). For advice and information on possible contaminants in well water, contact the local health department, the State drinking water office, the nearest public water utility, the Environmental Protection Agency's (EPA) Web site at **http://www.epa.gov**, or the EPA Safe Drinking Water Hotline at 1-800-426-4791 between 9 a.m. and 5 p.m. Eastern Standard Time (EST).

Lead

Lead levels are typically low in ground and surface water. Lead can enter drinking water from plumbing materials that carry water to and within homes and residential buildings. Until the Federal Government banned the manufacture of lead plumbing materials in 1986, pipes and solder containing lead were often used in water systems and homes.

Lead is a poison that can accumulate in the body and cause brain, nerve, and kidney damage; anemia; and even death. Lead is especially dangerous, even with short-term exposure, to infants, children, and pregnant women. While lead exposure through various sources (e.g., paint chips, lead dust, toys, and pottery) can occur, lead can be present in drinking water at sufficient levels to warrant concern.

Lead levels in drinking water are likely to be highest if:

- A home or water system has lead pipes
- A home has brass fixtures or
- A home has copper pipes with lead solder where:
  - The home is relatively new (i.e., built shortly before the 1986 ban on lead in pipes – it takes time for mineral deposits to build up and cover up the lead inside pipes)

- The home has soft water or
- Water sits in the pipes for several hours.

Since one cannot see, taste, or smell lead dissolved in water, household drinking water must be tested to determine its lead content. The local water utility or local department of environment or health can provide information and assistance regarding testing and how to locate a laboratory qualified to test for lead. Testing is especially important because flushing (described below) may not be effective in reducing lead levels in high-rise buildings with lead-soldered central piping or in homes receiving water through lead service lines (the local water utility company can be contacted for information on the pipes carrying water into a home).

Unless a caregiver is certain that there is no lead contamination in his or her water, precautions can be taken against the possible leaching of lead from metal water pipes in the home.

Caregivers can take these steps when using tap water to prepare powdered or concentrated infant formula or complementary food for their infants:

- Anytime a faucet has not been used for 6 or more hours, allow the cold tap water to run for 2 to 3 minutes to allow the water to get as cold as it will get before collecting it for infant formula or food preparation. This flushing is recommended for any faucet used to collect water for the infant. Flushing may help because the longer the water is exposed to lead pipes or lead solder, the more lead it may contain. As noted, flushing might not work in high-rise buildings or when lead service lines carry water into a home. Water for infant formula preparation should be collected in the evening after the water has been running for cooking or cleaning and stored in a clean lead-free container for use later or the next day. See page 120 for more information regarding lead and containers.
- Always draw water for infant formula preparation, drinking, and cooking from the cold water tap. Avoid feeding water from the hot water tap to infants or young children. Hot water is more likely to dissolve lead from plumbing materials and thus contain more lead. Infants have contracted lead poisoning from drinking infant formula made using hot tap water that was then boiled (this concentrates the lead).
- If water is to be boiled, do so by bringing the water to a rolling boil and boiling for 1–2 minutes. Avoid prolonged boiling or reboiling greater than 5 minutes; these practices will cause further water evaporation and concentration of any lead present. See page 91 for instructions on boiling water for infant formula preparation.
- Have their water tested for lead because lead can come from pipes inside or outside a home or apartment or from a well.
- If water treatment devices installed at the tap are used, be aware that their effectiveness in reducing lead in water varies. It may be affected by the location of the device in relation to the lead source and by compliance with the manufacturer's use and maintenance instructions. Some types of units, such as reverse osmosis and distillation, may be effective. Carbon, sand, and cartridge filters do not remove lead.

If caregivers are concerned about the lead level in water or if lead contamination is found through testing, encourage them to discuss this issue with their health care provider.

Copper

High levels of copper can dissolve from some pipes in areas with corrosive water. Copper, which is beneficial at lower levels, is a health risk at levels above 1.3 milligrams per liter in water. Acute exposure to copper results in gastrointestinal symptoms such as nausea, vomiting, stomach cramps, and diarrhea. Chronic exposure can cause liver or kidney damage. Infants are more sensitive to the effects of copper than are older children or adults. When water is tested, it can be tested for copper. If high levels of copper are found, encourage the caregiver to contact a health care provider for advice.

Nitrate

Drinking water from private household or community water system wells may become contaminated from nitrate derived from agricultural and home lawn and garden uses of nitrate fertilizers, septic tank wastes, and sewage sludge. Nitrate in drinking water above the national standard (10 milligrams nitrate per liter) poses an immediate threat to infants. In infants younger than 6 months of age, exposure to high levels of nitrate from well water may result in methemoglobinemia, also known as "blue baby syndrome," in which the blood's ability to carry oxygen is reduced.[3] Blueness may appear around the mouth, hands, and feet but does not necessarily mean that the infant is having breathing problems. This condition could result in a severe oxygen deficiency and could lead to death. Vomiting and diarrhea may also occur. Pregnant women are also susceptible and nitrate can pass through breast milk to breastfeeding infants.

It is recommended that caregivers with private household wells have their water tested for nitrate, especially if agricultural activities including home gardening occur in the area or if animal and human wastes are suspected of entering the well. Users of water from community wells who suspect that their water is contaminated can contact their State public water supply agency regarding contaminant levels in the water.

If the nitrate level in well water is confirmed to be above 10 mg/L, it is recommended that caregivers:

- Consult their health care providers about this problem
- Feed their infants only water from an alternate source that has less than 10 mg/L of nitrate and
- Avoid feeding their infants the nitrate-rich water plain or in infant formula, especially if boiled (boiling concentrates the nitrate). Ready-to-feed infant formula can be used as an alternative to concentrated or powdered infant formula that requires dilution with water.

Bacterial and Viral Contaminants

Bacteria and viruses can also contaminant private wells and cause disease. Three organisms of particular concern for infants are Cryptosporidium, *Escherichia coli* O157:H7, and rotavirus.

Cryptosporidium:[4] Cryptosporidiosis is caused by infection with the parasite Cryptosporidium, which can live in the intestines of humans or animals and is passed in feces. It has become one of the most common waterborne diseases in humans in the United States. Symptoms include watery diarrhea, dehydration, weight loss, stomach cramps, and slight fever. Rapid dehydration can be life-threatening for infants with cryptosporidiosis. Boiling water for at least 1 minute (3 minutes at high altitude) will kill or inactivate the parasite; reverse osmosis filters or filters with an absolute pore size of < 1 micron will also remove the parasite. If cryptosporidiosis is suspected, contact a health care provider right away.

***Escherichia coli* O157:H7:**[5] This strain of the *E. coli* bacteria lives in the intestines of healthy cattle. Infection may occur from eating meat, especially ground beef that has not been fully cooked, drinking unpasteurized milk or juice, or drinking sewage-contaminated water. While most types of *E. coli* are harmless, this strain produces a toxin that can cause severe bloody diarrhea and abdominal cramps. In infants and children under 5, a serious illness called hemolytic uremic syndrome (HUS) may result, leading to kidney failure. HUS occurs in 2 percent to 7 percent of infections with *Escherichia coli* O157:H7 and is the principal cause of acute kidney failure in children. Boiling contaminated water for 1 minute (3 minutes at high altitude) will kill or inactivate the bacteria; filtering is not an appropriate way to remove the bacteria. If infection with *E. coli* is suspected, contact a health care provider right away.

Rotavirus:[6] Rotavirus is the most common cause of severe diarrhea among infants and children, resulting in about 55,000 hospitalizations per year in the United States. It is found in water sources that have been contaminated with human feces, usually as a result of sewage overflows or sewage systems not working properly. It usually occurs in the winter with symptoms of vomiting and watery diarrhea and can lead to dehydration. Boiling water for 1 minute (3 minutes at high altitude) will kill or inactivate rotaviruses; filtration will not remove the virus. If infection with rotavirus is suspected, contact a health care provider right away.

Use of Bottled Water

Bottled water may be an alternative to tap water used in preparing infant formula and complementary foods for the following circumstances:

- The local water supply does not meet health-based drinking water standards
- Naturally occurring fluoride exceeds the recommended levels for safe drinking water or
- Corrosion of household plumbing causes lead and/or copper to enter the drinking water.

Bottled water is regulated by the Food and Drug Administration (FDA) as a food. *Bottlers are required to:* [7]

- Process, bottle, hold, and transport bottled water under sanitary conditions;
- Meet standards of identity established in 1995 that define types of waters (artesian, mineral, purified (distilled), sparkling, and spring water); and
- Meet standards of quality in terms of maximum allowable amounts of chemical, physical, microbial, and radiological contaminants.

FDA is responsible for inspecting and monitoring bottled waters and processing plants. Only optional microbial agents or fluoride may be added to bottled water. Bottled waters contain varying levels of fluoride and may have fluoride added, which will affect the amount of fluoride an infant consumes. Thus, caregivers who wish to feed their infants a specific brand of bottled spring or mineral water should consider contacting the manufacturer of the water product for information on the quality of their water.

If bottled water is to be used, distilled bottled water may be the best choice as it may contain fewer contaminants than bottled spring or mineral water. To help decide whether to use bottled water, caregivers can contact a health care provider and the local or State health department for information on local water quality problems and recommendations.

Home Water Treatment Units

Home water treatment units can potentially remedy a water contamination problem; however, it is important to keep in mind that no single household treatment unit will remove all potential drinking water contaminants. Treatment is very specific to the substances of concern. Before selecting a unit, the water should be tested to confirm the nature and extent of contamination. After identifying the substances to be removed, a unit can be selected. Home water treatment units do not eliminate the need for boiling water used to prepare infant formula for young infants. See page 91 for information regarding infant formula preparation.

A reliable source of information on home water treatment units is:

NSF International
3475 Plymouth Road
P.O. Box 130140
Ann Arbor, MI 48113-0140
(877) 867-3435
Web site: **http://www.nsf.org**

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Notes