nutrient requirements. The body of the malnourished child may have compensated for micronutrient deficiencies with lower metabolic and growth rates, and refeeding may unmask these deficiencies. Nutritional rehabilitation should be initiated and advanced *slowly* to minimize these complications. The initial approach involves correction of dehydration and anti-infective (bacteria, parasites) therapy if indicated. Oral rehydration is recommended over intravenous fluid to avoid excessive fluid and solute load and resultant heart or renal failure.

When nutritional rehabilitation is initiated, calories can be safely started at 20% above the child's recent intake. If no estimate of the caloric intake is available, 50% to 75% of the normal energy requirement is safe. High-calorie oral solutions or ready-to-use therapeutic foods (a mixture of powdered milk, peanuts, sugar, vitamins, and minerals) are frequently used in developing countries. Nutritional rehabilitation can be complicated by **refeeding syndrome**, which is characterized by fluid retention, hypophosphatemia, hypomagnesemia, and hypokalemia. Careful monitoring of laboratory values and clinical status with severe malnutrition is essential.

When nutritional rehabilitation has begun, caloric intake can be increased 10% to 20% per day, monitoring for electrolyte imbalances, poor cardiac function, edema, or feeding intolerance. If any of these occurs, further caloric increases are not made until the child's status stabilizes. Caloric intake is increased until appropriate regrowth or catch-up growth is initiated. Catch-up growth refers to gaining weight at greater than 50th percentile for age and may require 150% or more of the recommended calories for an age-matched, well-nourished child. A general rule of thumb for infants and children up to 3 years of age is to provide 100 to 120 kcal/kg based on *ideal* weight for height. Protein needs also are increased as anabolism begins and are provided in proportion to the caloric intake. Vitamin and mineral intake in excess of the daily recommended intake is provided to account for the increased requirements; this is frequently accomplished by giving an age-appropriate daily multiple vitamin, with other individual micronutrient supplements as warranted by history, physical examination, or laboratory studies. Iron supplements are not recommended during the acute rehabilitation phase, especially for children with kwashiorkor, for whom ferritin levels are often high. Additional iron may pose an oxidative stress; iron supplementation is associated with higher morbidity and mortality.

In most cases, cow's milk–based formulas are tolerated and provide an appropriate mix of nutrients. Other easily digested foods, appropriate for the age, also may be introduced slowly. If feeding intolerance occurs, lactose-free or semielemental formulas should be considered.

COMPLICATIONS OF MALNUTRITION

Malnourished children are more susceptible to **infection,** especially sepsis, pneumonia, and gastroenteritis. Hypoglycemia is common after periods of severe fasting but may also be a sign of sepsis. Hypothermia may signify infection or, with bradycardia, may signify a decreased metabolic rate to conserve energy. Bradycardia and poor cardiac output predispose the malnourished child to heart failure, which is exacerbated by acute fluid or solute loads. **Micronutrient deficiencies** also can complicate malnutrition. Vitamin A and zinc deficiencies are common in the developing world and are an important cause of altered immune response and increased morbidity and mortality. Depending on the age at onset and the duration of the malnutrition, malnourished children may have permanent growth stunting (from malnutrition in utero, infancy, or adolescence) and delayed development (from malnutrition in infancy or adolescence). Environmental (social) deprivation may interact with the effects of the malnutrition to impair further development and cognitive function.

Chapter 31

VITAMIN AND MINERAL DEFICIENCIES

Micronutrients include vitamins and trace elements. In industrialized societies, frank clinical deficiencies are unusual in healthy children, but they can and do occur in certain high-risk circumstances. Risk factors include diets that are consistently limited in variety, especially with the exclusion of entire food groups, malabsorption syndromes, and conditions causing high physiologic requirements. Various common etiologies of vitamin and nutrient deficiency states are highlighted in Table 31-1, and characteristics of vitamin deficiencies are outlined in Table 31-2. Treatment is noted in Table 31-3.

WATER-SOLUBLE VITAMINS

Water-soluble vitamins are not *stored* in the body except for vitamin B_{12}; intake therefore alters tissue levels. Absorption from the diet is usually high, and the compounds exchange readily between intracellular and extracellular fluids; excretion is via the urine. Water-soluble vitamins typically function as coenzymes in energy, protein, amino acid, and nucleic acid metabolism; as cosubstrates in enzymatic reactions; and as structural components.

Ascorbic Acid

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Anemia

The principal forms of vitamin C are ascorbic acid and the oxidized form, dehydroascorbic acid. Ascorbic acid accelerates hydroxylation reactions in many biosynthetic reactions, including hydroxylation of proline in the formation of collagen. The needs of full-term infants for ascorbic acid and dehydroascorbic acid are calculated by estimating the availability in human milk.

A deficiency of ascorbic acid results in the clinical manifestations of **scurvy.** Infantile scurvy is manifested by irritability, bone tenderness with swelling, and pseudoparalysis of the legs. The disease may occur if infants are fed unsupplemented cow's milk in the first year of life or if the diet is devoid of fruits