

**Table 9-10** Selected Trace Elements and Deficiency Syndromes

Element	Function	Basis of Deficiency	Clinical Features
Zinc	Component of enzymes, principally oxidases	Inadequate supplementation in artificial diets Interference with absorption by other dietary constituents Inborn error of metabolism	Rash around eyes, mouth, nose, and anus called acrodermatitis enteropathica Anorexia and diarrhea Growth retardation in children Depressed mental function Depressed wound healing and immune response Impaired night vision Infertility
Iron	Essential component of hemoglobin as well as several iron-containing metalloenzymes	Inadequate diet Chronic blood loss	Hypochromic microcytic anemia (Chapter 14)
Iodine	Component of thyroid hormone	Inadequate supply in food and water	Goiter and hypothyroidism (Chapter 24)
Copper	Component of cytochrome <i>c</i> oxidase, dopamine $\beta$ -hydroxylase, tyrosinase, lysyl oxidase, and unknown enzymes involved in cross-linking collagen	Inadequate supplementation in artificial diet Interference with absorption	Muscle weakness Neurologic defects Abnormal collagen cross-linking
Fluoride	Mechanism unknown	Inadequate supply in soil and water Inadequate supplementation	Dental caries (Chapter 16)
Selenium	Component of glutathione peroxidase Antioxidant with vitamin E	Inadequate amounts in soil and water	Myopathy Cardiomyopathy (Keshan disease)

disease in growing children and by hemorrhages and healing defects in both children and adults. Sailors of the British Royal Navy were nicknamed “limeys,” because at the end of the eighteenth century the Navy began to provide lime and lemon juice (rich sources of vitamin C) to sailors to prevent scurvy during their long sojourn at sea. It was not until 1932 that ascorbic acid was identified and synthesized. Ascorbic acid is not synthesized endogenously in humans; therefore, we are entirely dependent on the diet for this nutrient. Vitamin C is present in milk and some animal products (liver, fish) and is abundant in a variety of fruits and vegetables. All but the most restricted diets provide adequate amounts of vitamin C.

**Function.** Ascorbic acid functions in a variety of biosynthetic pathways by accelerating hydroxylation and amidation reactions. The best established function of vitamin C is the activation of prolyl and lysyl hydroxylases from inactive precursors, providing for hydroxylation of procollagen. Inadequately hydroxylated procollagen cannot acquire a stable helical configuration, so it is poorly secreted from the fibroblast. Those molecules that are secreted are adequately cross-linked, lack tensile strength, and are more soluble and vulnerable to enzymatic degradation. Collagen, which normally has the highest content of hydroxyproline of any polypeptide, is most affected, particularly in blood vessels, accounting for the predisposition to hemorrhages in scurvy. In addition, a deficiency of vitamin C suppresses the rate of synthesis of procollagen, independent of effects on proline hydroxylation.

Vitamin C also has antioxidant properties. Vitamin C can scavenge free radicals directly and can act indirectly by regenerating the antioxidant form of vitamin E.

**Deficiency States.** Consequences of vitamin C deficiency (scurvy) are illustrated in Figure 9-29. Because of the abundance of ascorbic acid in many foods, scurvy has ceased to be a global problem. It is sometimes encountered even in affluent populations as a secondary deficiency, particularly among older individuals, persons who live alone, and

chronic alcoholics, groups that often have erratic and inadequate eating patterns. Occasionally, scurvy occurs in patients undergoing peritoneal dialysis and hemodialysis and among food faddists. The condition also sometimes appears in infants who are maintained on formulas of evaporated milk without supplementation of vitamin C.

**Vitamin C Excess.** The popular notion that megadoses of vitamin C protect against the common cold, or at least allay the symptoms, has not been borne out by controlled clinical studies. Such slight relief as may be experienced is probably due to the mild antihistamine action of ascorbic acid. Similarly, there is no evidence that large doses of vitamin C protect against cancer development. The physiologic availability of excess vitamin C is limited due to its inherent instability, poor intestinal absorption, and rapid urinary excretion. Fortunately, toxicities related to high doses of vitamin C are rare, consisting of possible iron overload (due to increase absorption), hemolytic anemia in those with glucose-6-phosphate dehydrogenase (G6PD) deficiency (Chapter 14), and calcium oxalate kidney stones.

Other vitamins and some essential minerals are listed and briefly described in Tables 9-9 and 9-10 and are discussed in other chapters.

## KEY CONCEPTS

### Nutritional Diseases

- Primary PEM is a common cause of childhood deaths in poor countries. The two main primary PEM syndromes are marasmus and kwashiorkor. Secondary PEM occurs in the chronically ill and in patients with advanced cancer (as a result of cachexia).
- Kwashiorkor is characterized by hypoalbuminemia, generalized edema, fatty liver, skin changes, and defects in immunity. It is caused by diets low in protein but normal in calories.
- Marasmus is characterized by emaciation resulting from loss of muscle mass and fat with relative preservation of