

Table I-9 Clinical Examination in Nutritional Deficiencies and Excesses

	Major Physiologic Functions	Deficiency Signs	Excess Signs	Important Food Sources	Potential Causes of Deficiency	Status Assessment
<i>Nutrient</i>						
Carbohydrate	Supplies energy at an average of 4 kcal/g (sparing protein) and is the major energy source for CNS function; unrefined, complex carbohydrates supply fiber which aids in normal bowel function	Ketosis	May cause diarrhea, obesity	Bread, cereals, crackers, potatoes, corn, simple sugar (sugar, honey), fruits and vegetables, milk, breast milk, infant formula	Malabsorption	Blood sugar, OGTT
Fat	Concentrated calorie source at an average of 9 kcal/g; constitutes part of the membrane structure of every cell; supplies essential fatty acids; provides and carries fat-soluble vitamins (A, D, E, K)	Essential fatty acid deficiency (dry, scaly skin, poor weight gain, hair loss); requirements are increased by cell turnover	Atherosclerosis may be affected by excessive intakes of certain dietary fats; altered blood lipid levels	Shortening, oil, butter, margarine, protein-rich foods (meat, dairy, nuts), breast milk, infant formula	Cystic fibrosis, biliary disease, short bowel syndrome, hereditary lipoprotein disorders	Total cholesterol, LDL, HDL
Protein	Supplies energy at an average of 4 kcal/g; regulates body processes as part of enzymes, hormones, body fluids, and antibodies that increase resistance to infection; provides nitrogen; constitutes part of the membrane structure of every cell	Dry, depigmented, easily pluckable hair; bilateral, dependent edema, cirrhosis, fatty liver, decreased visceral proteins; skin is dry with pellagroid dermatosis in severe cases	Azotemia, acidosis, hyperammonemia	Meat, poultry, fish, legumes, eggs, cheese, milk and other dairy products, nuts, breast milk, infant formula	Protein losing enteropathy, liver disease, gastrointestinal disease, renal disease	Albumin, retinol binding protein, prealbumin
<i>Fat soluble vitamins</i>						
Vitamin A	Formation and maintenance of skin and mucous membranes; necessary for the formation of rhodopsin of the rods governing vision in dim light; regulation of membrane structure and function; necessary for growth and normal immune function	Night blindness, degeneration of the retina, xerophthalmia, follicular hyperkeratosis, poor growth, keratomalacia, Bitot's spots	Fatigue, malaise, lethargy, abdominal pain, hepatomegaly, alopecia, headache with increased intracranial pressure	Carrots, liver, green vegetables, sweet potatoes, butter, margarine, apricots, melons, peaches, broccoli, cod liver oil, breast milk, infant formula	Liver disease, cystic fibrosis, short bowel syndrome, protein deficiency (alters transport)	Plasma retinol (HPLC), plasma retinol-binding protein, relative dose response, dark adaptation test, liver biopsy concentration
Vitamin D	Promotes intestinal absorption of calcium and phosphate, and renal conservation of calcium and phosphorus	Rickets, osteomalacia, costochondral beading, epiphyseal enlargement, cranial bossing, bowed legs, persistently open anterior fontanelle	Hypercalcemia, vomiting, anorexia, diarrhea, convulsions	Cod liver oil, fish, eggs, liver, butter, fortified milk, sunlight (activation of 7-dehydrocholesterol in the skin), infant formula	Liver disease, cystic fibrosis, short bowel syndrome, renal disease	Plasma 25-hydroxyvitamin D (HPLC), serum alkaline phosphatase, calcium and phosphate, radiography, bone densitometry
Vitamin E	Acts as an antioxidant and free radical scavenger to prevent peroxidation of polyunsaturated fatty acids in the body; neuromuscular function	Hemolytic anemia in the premature and newborn, enhanced fragility of red blood cells, increased peroxidative hemolysis	In anemia, suppresses the normal hematologic response to iron	Oils high in polyunsaturated fatty acids, milk, eggs, breast milk, infant formula	Cystic fibrosis, short bowel syndrome, liver disease	Plasma tocopherol (HPLC) (corrected for total or LDL-cholesterol), hydrogen peroxide hemolysis
Vitamin K	Necessary for prothrombin and the three blood-clotting factors VII, IX, and X; half of the vitamin K in humans is of intestinal origin, synthesized by gut flora; necessary for bone mineralization	Hemorrhagic manifestations (especially in newborns), prolonged clotting	Hemolytic anemia, nerve palsy	Green leafy vegetables, fruits, cereals, dairy products, soybeans, breast milk, infant formula	Liver disease, antibiotic therapy	Prothrombin time (prolonged), plasma phyloquinone, clotting factor levels, proteins induced by vit. K absence or antagonists-II (PIVKA-II)

(Continued)

Table I-9 Clinical Examination in Nutritional Deficiencies and Excesses (Continued)

	Major Physiologic Functions	Deficiency Signs	Excess Signs	Important Food Sources	Potential Causes of Deficiency	Status Assessment
<i>Water soluble vitamins</i>						
Ascorbic acid (vitamin C)	Forms collagen cross-linkage of proline hydroxylase, thus strengthening tissue and improving wound healing and resistance to infection; aids absorption of iron	Joint tenderness, scurvy (capillary hemorrhaging), impaired wound healing, acute periodontal gingivitis, petechiae, purpura, anemia	Documentation of a chronic high intake may result in "rebound" deficiency symptoms	Heat-labile; broccoli, papaya, orange, mango, grapefruit, strawberries, tomatoes, potatoes, leafy vegetables, breast milk, infant formula	Stress	Plasma level (enzyme assay/HPLC), leukocyte concentration (longer-term), whole blood concentration, urine concentration
Biotin	Component of several carboxylating enzymes; plays an important role in the metabolism of fat and carbohydrate	Anorexia, nausea, vomiting; glossitis; depression; dry, scaly dermatitis; thin hair; loss of eyebrows	None known	Liver, kidney, egg yolk, breast milk, infant formula	Certain inborn errors of metabolism	Plasma (microbiologic plasma lactate, assay), urine organic acids, lymphocyte carboxylase
Cobalamin (B <sub>12</sub> intrinsic factor required)	Cobalamin-containing coenzymes function in the degradation of certain odd-chain fatty acids and in the recycling of tetrahydrofolate	Megaloblastic anemia, neurologic deterioration	None known	Animal products, breast milk, infant formula	Ileal disease, strict vegetarian, lack of Intrinsic Factor	Plasma level (RIA or microbiologic), Schilling test, plasma homocysteine, deoxyuridine suppression test
Folacin	Utilized in carbon transfer and nucleotide synthesis	Megaloblastic anemia, stomatitis, glossitis, neural tube defects in pregnancy	None known	Liver, leafy vegetables, fruit, yeast, breast milk, infant formula	Liver disease, alcoholism, celiac disease, inflammatory bowel disease	Plasma level (RIA or microbiologic), red cell level
Niacin	Aids in energy utilization as part of a coenzyme (NAD <sup>+</sup> and NADP <sup>+</sup> ) in fat synthesis, tissue respiration, and carbohydrate utilization; aids digestion and fosters normal appetite; synthesized from the amino acid tryptophan	Pellagra (dermatitis, diarrhea, dementia, death), cheilosis, angular stomatic inflammation of mucous membranes, weakness	Dilation of the capillaries, vasomotor instability, "flushing" (utilization of muscle glycogen, serum lipids, mobilization of fatty acids during exercise)	Liver, meat, fish, poultry, peanuts, fortified cereal products, yeast, breast milk, infant formula	B <sub>6</sub> deficiency (impairs conversion of tryptophan to niacin)	Urine ratio of metabolites (N-methylnicotinamide/2-pyridone), tryptophan load, red cell NAD or NAD/NADP ratio
Pantothenic acid	Component of coenzyme A; plays a role in release of energy from carbohydrates and in synthesis and degradation of fatty acids	Infertility, abortion, slow growth, depression, vomiting, malaise, abdominal stress	Diarrhea, water retention	Meat, fish, poultry, whole grains, legumes, breast milk, infant formula	Severe malnutrition	Urine excretion, whole blood level (RIA/microbiologic)
Pyridoxine (B <sub>6</sub> )	Coenzyme component for many of the enzymes of amino acid metabolism; all compounds implicated as neurotransmitters are synthesized and/or metabolized in B <sub>6</sub> -dependent reactions	Convulsions, weight loss, abdominal distress, vomiting, hyperirritability, depression, confusion, hypochromic and macrocytic anemia	Neuropathy	Fish, poultry, meat, wheat, breast milk, infant formula	Elderly, high protein intake	Red cell aminotransferase activity, pyridoxal phosphate (HPLC), tryptophan load test, urine 4-pyridoxic acid
Riboflavin (B <sub>2</sub> )	Functions primarily as the reactive portion of flavoproteins concerned with biologic oxidations (cellular metabolism)	Cheilosis, glossitis, photophobia, angular stomatitis, corneal, vascularization, scrotal skin changes, seborrhea, magenta tongue	None known	Dairy products, liver, almonds, lamb, pork, breast milk, infant formula	Alcoholism, starvation, chronic diarrhea, malabsorption	Red cell glutathione reductase activity (EGR), red cell flavine adenine dinucleotide, urine riboflavin/creatinine ratio
Thiamine (B <sub>1</sub> )	Aids in energy utilization as part of coenzyme component to promote the utilization of carbohydrate; promotes normal functioning of the nervous system; coenzyme for oxidative carboxylation of 2-keto acids	Beriberi, neuritis, cardiac failure, anorexia, restlessness, confusion, loss of vibration sense and deep tendon reflexes, calf tenderness, edema	None known	Lean pork, nuts, whole grain and fortified cereal products, breast milk, infant formula	Alcoholism, refeeding syndrome, prolonged dialysis	Red cell transketolase activity, whole blood level (HPLC), urine thiamine/creatinine ratio

(Continued)

Table I-9 Clinical Examination in Nutritional Deficiencies and Excesses (Continued)

	Major Physiologic Functions	Deficiency Signs	Excess Signs	Important Food Sources	Potential Causes of Deficiency	Status Assessment
<i>Minerals</i>						
Calcium	Essential for calcification of bone (matrix formation); assists in blood clotting; functions in normal muscle contraction and relaxation and in normal nerve transmission	Osteomalacia, osteoporosis	Hypercalcemia, vomiting, anorexia, lethargy	Dairy products (milk, cheese), sardines, oysters, salmon, herring, greens, breast milk, infant formula	Renal disease, liver disease	Plasma total calcium, plasma free calcium in altered protein binding (e.g. hypoalbuminemia), acidosis, radiographs, CT, photon densitometry
Magnesium	Essential part of many enzyme systems; important for maintaining electrical potential in nerves and muscle membranes and for energy turnover	Tremor, convulsions, hyperexcitability (hypocalcemia tetany)	Diarrhea, transient hypocalcemia	Widely distributed, especially in food of vegetable origin; breast milk, infant formula	Protein calorie malnutrition, refeeding syndrome	Plasma total or free magnesium, magnesium loading test
Phosphorus	Important intracellular anion; involved in many chemical reactions within the body; necessary for energy turnover (ATP)	Weakness, anorexia, malaise, bone pain, growth arrest	Hypocalcemia (when parathyroid gland not fully functioning)	Dairy products, fish, legumes, pork, breast milk, infant formula	Renal disease, liver disease, refeeding syndrome	Plasma concentration, alkaline phosphatase activity, radiography, densitometry, renal tubular excretion threshold
<i>Trace elements</i>						
Chromium	Maintenance of normal glucose metabolism, cofactor for insulin	Disturbed glucose metabolism (lower glucose tolerance caused by insulin resistance)		Brewer's yeast, meat products, cheeses	Protein calorie malnutrition, elderly	Plasma chromium, glucose tolerance
Copper	Constituent of proteins and enzymes, some of which are essential for the proper utilization of iron; immunity; skeletal development	Anemia (hemolytic), neutropenia, bone disease	Excess accumulation in the liver, brain, kidney, cornea; anemia, diarrhea	Oysters, nuts, liver, kidney, corn oil margarine, dried legumes	Menke's kinky hair syndrome. Excess: Wilson's disease	Plasma copper, plasma ceruloplasmin (ferrochelatase), liver biopsy concentration, superoxide dismutase activity
Fluoride	The main target organs of fluoride in man are the enamel of teeth and bones, where fluoride is incorporated into the crystalline structure of hydroxyapatite and produces increased carie resistance	Poor dentition, caries, osteoporosis	Mottling, brown staining of teeth (in excess of 4 ppm); fluorosis occurs after prolonged (10–20 yr) ingestion of 20–80 mg/d	Fluoridated water; depends on the geochemical environment and therefore amount in food varies widely	Unfluoridated water, bottled water	
Iodine	Component of thyroid hormones triiodothyronine and thyroxine; important in regulation of cellular oxidation and growth	Goiter, depressed thyroid function, cretinism	Thyroid suppression (thyrotoxicosis)	Iodized table salt, salt water, fish, shellfish (content of most other foods geographically dependent), breast milk, infant formula	Endemic goiter in low iodine areas	Thyroid hormones, TSH, urinary iodide/creatinine ratio
Iron	Part of hemoglobin molecule; prevents nutritional anemia and fatigue; increases resistance to infection; functions as part of enzymes involved in tissue respiration	Anemia, malabsorption, irritability, anorexia, pallor, lethargy	Hemosiderosis, hemochromatosis	Red meats, liver, dried beans and peas, enriched farina, breast milk, infant formula, infant cereal	Protein losing enteropathy, malabsorption, acute or chronic blood loss. Excess: hemochromatosis	Plasma iron and ferritin, total iron-binding capacity, hemoglobin/hematocrit, red cell indices, RBC zinc protoporphyrin:heme ratio, bone marrow aspirate stain

(Continued)

Table I-9 Clinical Examination in Nutritional Deficiencies and Excesses (Continued)

	Major Physiologic Functions	Deficiency Signs	Excess Signs	Important Food Sources	Potential Causes of Deficiency	Status Assessment
Manganese	Essential part of several enzyme systems involved in protein and energy metabolism and in the formation of mucopolysaccharide	Impaired growth, skeletal abnormalities, lowered reproductive function, neonatal ataxia	In extremely high exposure of contamination: severe psychiatric and neurologic disorders	Nuts, whole grains, dried fruits, fruits, leafy vegetables		Plasma level, whole blood level, mitochondrial superoxide dismutase
Molybdenum	Essential for the function of flavin-dependent enzymes involved in the production of uric acid and in the oxidation of aldehydes and sulfites	Not described in man	Acts as an antagonist to the essential element copper; goutlike syndrome associated with elevated blood levels of molybdenum, uric acid and xanthin oxidase	Varies considerably, depending on growing environment; main contributions come from meat, grains, and legumes		
Selenium	Functions as a part of the enzyme glutathione peroxidase, which protects cellular component from oxidative damage	Cardiomyopathy, probably secondary to oxidative damage	In animals: blindness, abdominal pain	Seafoods, kidney, liver meat, grains (depending on growing environment)	Cystic fibrosis	Plasma concentration, glutathione peroxidase activity, nail/hair selenium
Zinc	Constituent of enzymes involved in most major metabolic pathways (specifically nucleic acid synthesis for growth and repair)	Growth failure, skin changes, delayed wound healing, hypogeusia, sexual immaturity, hair loss, diarrhea	Acute gastrointestinal upset, vomiting, sweating, dizziness, copper deficiency	Whole grains, legumes, beef, lamb, pork, poultry, nuts, seeds, shellfish, eggs, some cheeses, breast milk, infant formula	Malabsorption, chronic diarrhea, liver disease, sickle cell disease	Plasma concentration, alkaline phosphatase activity, urinary excretion, leukocyte concentration