<table>
<thead>
<tr>
<th>NUTRIENT</th>
<th>PRINCIPAL SOURCES</th>
<th>FUNCTIONS</th>
<th>EFFECTS OF DEFICIENCY AND TOXICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folate (folic acid)</td>
<td>Fresh green leafy vegetables, fruits, organ meats (eg, liver), enriched cereals and breads</td>
<td>Maturation of RBCs, Synthesis of purines, pyrimidines, and methionine, Development of fetal nervous system</td>
<td>Deficiency: Megaloblastic anemia, neural tube birth defects, mental confusion</td>
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<tr>
<td>Niacin (nicotinic acid, nicotinamide)</td>
<td>Liver, red meat, fish, poultry, legumes, whole-grain or enriched cereals and breads</td>
<td>Oxidation-reduction reactions, Carbohydrate and cell metabolism</td>
<td>Deficiency: Pellagra (dermatitis, glossitis, GI and CNS dysfunction), Toxicity: Flushing</td>
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<tr>
<td>Riboflavin (vitamin B2)</td>
<td>Milk, cheese, liver, meat, eggs, enriched cereal products</td>
<td>Many aspects of carbohydrate and protein metabolism, Integrity of mucous membranes</td>
<td>Deficiency: Cheilosis, angular stomatitis, corneal vascularization</td>
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<tr>
<td>Thiamin (vitamin B1)</td>
<td>Whole grains, meat (especially pork and liver), enriched cereal products, nuts, legumes, potatoes</td>
<td>Carbohydrate, fat, amino acid, glucose, and alcohol metabolism, Central and peripheral nerve cell function, Myocardial function</td>
<td>Deficiency: Beriberi (peripheral neuropathy, heart failure), Wernicke-Korsakoff syndrome</td>
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<tr>
<td>Vitamin A (retinol)</td>
<td>As preformed vitamin: fish liver oils, liver, egg yolks, butter, vitamin A–fortified dairy products, As provitamin carotenoids: dark green and yellow vegetables, carrots, yellow and orange fruits</td>
<td>Formation of rhodopsin (a photoreceptor pigment in the retina), Integrity of epithelia, Lysosome stability, Glycoprotein synthesis</td>
<td>Deficiency: Night blindness, perifollicular hyperkeratosis, xerophthalmia, keratomalacia, increased morbidity and mortality in young children, Toxicity: Headache, peeling of skin, hepatosplenomegaly, bone thickening, intracranial hypertension, papilledema</td>
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<tr>
<td>Vitamin B6 group (pyridoxine, pyridoxal, pyridoxamine)</td>
<td>Organ meats (eg, liver), whole-grain cereals, fish, legumes</td>
<td>Many aspects of nitrogen metabolism (eg, transaminations, porphyrin and heme synthesis, tryptophan conversion to niacin), Nucleic acid biosynthesis, Fatty acid, lipid, and amino acid metabolism</td>
<td>Deficiency: Seizures, anemia, neuropathies, seborrheic dermatitis, Toxicity: Peripheral neuropathy</td>
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<tr>
<td>Vitamin B12 (cobalamin)</td>
<td>Meats (especially beef, pork, and organ meats [eg, liver]), poultry, eggs, fortified cereals, milk and milk products</td>
<td>Maturation of RBCs, neural function, DNA synthesis, myelin synthesis and repair</td>
<td>Deficiency: Megaloblastic anemia, neurologic deficits (confusion, paresthesias, ataxia)</td>
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</tbody>
</table>
do not protect against coronary artery disease or stroke (by lowering homocysteine levels); their role in reducing the risk of various cancers is unclear. The upper limit for folate intake is 1000 µg; higher doses (up to 5 mg) are recommended for women who have had a baby with a neural tube defect. Folate is essentially nontoxic.

Folate Deficiency

Folate deficiency is common. It may result from inadequate intake, malabsorption, or use of various drugs. Deficiency causes megaloblastic anemia (indistinguishable from that due to vitamin B12 deficiency). Maternal deficiency increases the risk of neural tube birth defects. Diagnosis requires laboratory testing to confirm. Measurement of neutrophil hypersegmentation is sensitive and readily available. Treatment with oral folate is usually successful.

Etiology and Pathophysiology

The most common causes are inadequate intake (usually in patients with undernutrition or alcoholism), increased demand (eg, due to pregnancy or breastfeeding), and impaired absorption (eg, in tropical sprue, due to certain drugs). Deficiency can also result from inadequate bioavailability and increased excretion (see Table 4–4).

Prolonged cooking destroys folate, predisposing to inadequate intake. Intake is sometimes barely adequate (eg, in alcoholics). Liver stores provide only a several-month supply. Alcohol interferes with folate absorption, metabolism, renal excretion, and enterohepatic reabsorption, as well as intake. 5-Fluorouracil, metformin, methotrexate, phenobarbital, phenytoin, sulfasalazine, triamterene, and trimethoprim impair folate metabolism.

In the US, many dietary staples (eg, cereals, grain products) are routinely enriched with folate, tending to reduce risk of deficiency.

### Vitamin C

*Citrus fruits, tomatoes, potatoes, broccoli, strawberries, sweet peppers*

**Functions**: Collagen formation, Bone and blood vessel health, Carnitine, hormone, and amino acid formation, Wound healing

**Deficiency**: Scurvy (hemorrhages, loose teeth, gingivitis, bone defects)

### Vitamin D

*Direct ultraviolet B irradiation of the skin (main source), fortified dairy products (main dietary source), fish liver oils, fatty fish, liver*

**Functions**: Ca and phosphate absorption, Mineralization and repair of bone, Tubular reabsorption of Ca, Insulin and thyroid function, improvement of immune function, reduction of autoimmune disease

**Deficiency**: Rickets (sometimes with tetany), osteomalacia

**Toxicity**: Hypercalcemia, anorexia, renal failure, metastatic calcifications

### Vitamin E group

*Vegetable oils, nuts, legumes*

**Functions**: Intracellular antioxidant Scavenger of free radicals in biologic membranes

**Deficiency**: RBC hemolysis, neurologic deficits

**Toxicity**: Tendency to bleed

### Vitamin K group

*Green leafy vegetables (especially collards, spinach, and salad greens), soy beans, vegetable oils, Bacteria in the GI tract after neonatal period*

**Functions**: Formation of prothrombin, other coagulation factors, and bone proteins

**Deficiency**: Bleeding due to deficiency of prothrombin and other factors, osteopenia

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