FOOD, NUTRITION AND DIET THERAPY

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of the same consistency but of higher linoleic acid content may be prepared by mixing a portion of almost completely hydrogenated fat with some of the original oil. This procedure is used for some margarines. Table 5–2 shows the distribution of saturated and unsaturated fatty acids in some common natural and hydrogenated food fats.

Rancidity When fats and oils are exposed to warm, moist air over a period of time, chemical changes occur which produce unpalatable flavors and disagreeable odors. Hydrolysis of butter fat in the presence of oxygen, airborne bacteria and heat releases butyric acid and other products with very strong taste. The oxygen of the air can attack the double bonds of the polyunsaturated fatty acids, forming peroxides which may be toxic in large amount. Rancid fat has a toxic effect on rats given low-fat diets.

The oxidative process destroys vitamin A and vitamin E. Vitamin E is present in rather large amount in vegetable fats. It is an antioxidant and protects against rancidity but in the process is, itself, inactivated. Fortification of fats or fatty foods with antioxidants extends the storage time and protects essential nutrients. Precautions should be taken to lessen the danger of rancidity by storage of fat-containing foods at low temperature and limiting the storage time of susceptible foods such as butter and lard.

FUNCTIONS OF TRIGLYCERIDES IN THE BODY

ENERGY Fats serve as a concentrated source of energy. Each gram of fat supplies 9 kcalories, which is more than twice the amount of energy supplied by each gram of carbohydrate. The main source of this energy is the fatty acids which supply 40 to 50 carbon atoms for oxidation as compared with 3 from glycerol. Because of the high energy density and low solubility of fats, they are used as a store of energy. Not only ingested fat but carbohydrate and amino acids not immediately used by the tissues are converted to fat and stored in the adipose tissue. Up to two-thirds of the total energy of the cells may be supplied by triglyceride rather than carbohydrate. Fat spares protein for tissue synthesis.

OTHER FUNCTIONS Adipose tissue helps to hold the body organs and nerves in position and to protect them against traumatic stomach, providing a pleasant feeling of satiety after a meal. Fats also retard the rapid development of hunger which occurs after a carbohydrate meal. Fats add to the palatability of food as well as to the flavor of the diet.

ESSENTIAL FATTY ACID (EFA) Three polyunsaturated fatty acids, namely, linoleic, linolenic and arachidonic acids, are necessary for growth. They have important roles in fat transport and metabolism and in maintaining the function and integrity of cellular membranes. They also are a part of the fatty acids of cholesterol esters and phospholipids in plasma lipoproteins and mitochondrial lipoproteins.[3] Fatty acids with EFA activity are also precursors of a group of compounds, prostaglandins, which participate in the regulation of blood pressure, heart rate, lipolysis and the central nervous system.[4] In the presence of a dietary source of linoleic acid (along with Vitamin B_6) the body can synthesize arachidonic and linolenic acids, but no conversion of the other acids to linoleic acid occurs. Linoleic acid was shown to be a dietary essential for infants by Hansen, Wiese and associates,[5] who found that linoleic acid would prevent or cure a characteristic dermatitis (eczema) observed in infants fed a fat-free diet (Fig. 5–1). Only linoleic acid is considered to be an essential component of human dietaries.

EFA deficiency in animals produces not only poor growth and dermatitis but a poor reproductive capacity, lowered efficiency of energy utilization, decreased resistance to certain stresses such as x-ray and ultraviolet light, impairment of lipid transport and changes in the polyunsaturated fatty acid content of tissues.

The dietary requirement of linoleic acid for infants has been estimated to be between 1 and 3 per cent of the total calories.[6] The requirement for the adult is relatively low. The minimum human requirement would appear to be near 2 per cent of the calorie intake.[7] The tissue storage of linoleic acid in the adult with the average dietary is high. An excess amount in the diet may be harmful. Excessive

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[3]Report: Dietary fat and human health. Washington, D.C., National Academy of Sciences, National Research Council, Pub. No. 1147, 1966.

[4]Dairy Council Digest: Current research on dietary fatty acids. National Dairy Council. Chicago. *41*: No. 3, May-

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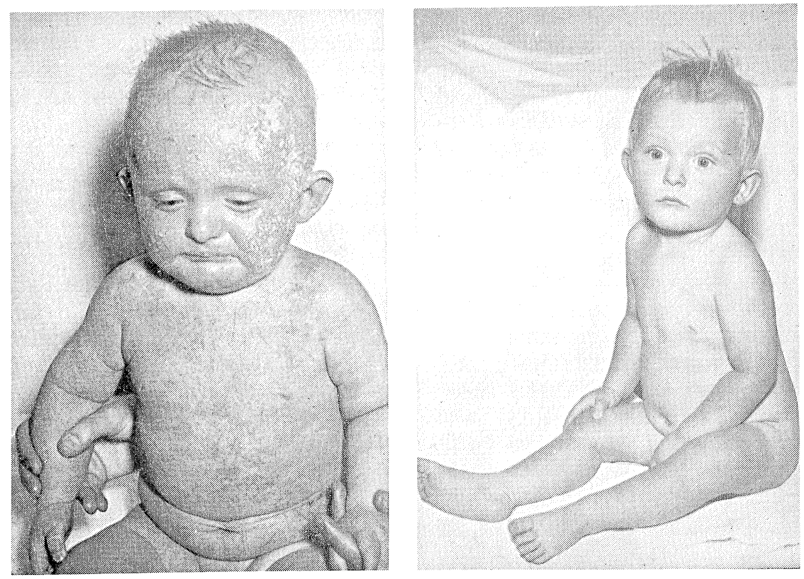

Figure 5–1 Certain fatty acids, found in fats of low melting point, must be furnished in the food. Skin troubles result when these essential fatty acids (linoleic and arachidonic acids) are lacking. Left, 6-month-old infant with very resistant eczema since 2½ months of age. Right, same child 6 months later, after lard had been included in the diet. (Courtesy of Dr. A. E. Hansen.)

amounts of polyunsaturated fatty acids have been observed to reduce the vitamin E level in animal tissues to a dangerously low level, resulting in encephalomalacia in chicks, creatinuria in rats and sterility in male chicks.[8] Vegetable oils supplying the linoleic content in a diet high in the EFA have a natural vitamin E content, which serves as a lipid antioxidant.

LIPIDS WITH SPECIAL FUNCTIONS

PHOSPHOLIPIDS Any lipid containing phosphorus is included in this classification. They are the next largest lipid component of the body after the triglycerides. Phospholipids are formed in essentially all cells of the body, although a greater portion that enter the blood are formed in the liver cells and the intestinal mucosa. Phospholipids have a strong affinity for both water-soluble and fat-soluble substances in the molecule. The phospholipids function in maintaining the structural integrity of the cells rather than as fat stores. Large concentrations of phospholipids are found in combination with protein in cell membranes where they act as a liaison be-... membrane. Despite the loss of body fat that occurs in extreme starvation the phospholipid content remains fairly constant, thus maintaining the integrity of tissue cells.

The lecithins contain glycerol and fatty acids as well as phosphoric acid and the nitrogen-containing base choline. They are the most widely distributed of the phospholipids. Traces are present in liver and egg yolk and in raw vegetable oils such as corn oil. Lecithin is added to food products such as cheese, margarine and confections to aid in emulsification.

Phospholipids such as cephalins (which are similar in structure to lecithins), lipontols (which contain inositol, a compound with vitamin-like activity) and sphingomyelins (which contain no glycerol but a complex amino alcohol) are found in rather high concentrations in nerve tissue. A cephalin is needed to form thromboplastin for the blood clotting process. Sphingomyelin is found in the brain and other nerve tissue as a component of the myelin sheath. This substance acts as an insulator around the nerve fibers. Egg yolk and liver are good sources of these phospholipids.

As a rule, the invisible and not the visible bones and teeth, the remaining 1 per cent of the body's calcium is found in the body fluids and soft tissues. This calcium, present principally in ionic form has important metabolic functions. It is essential for the activity of certain enzymes, notably adenosine triphosphatase in the release of energy for muscular contraction.

In the blood clotting process, calcium must be present to initiate the changes needed for the formation of the clot, fibrin. The ionized calcium stimulates the release of thromboplastin from the blood platelets. Thromboplastin catalyzes the conversion of prothrombin to thrombin. Thrombin aids in the polymerization of fibrinogen to fibrin.

In the control of the passage of fluids to cell walls, calcium controls the permeability of the cell membrane to various nutrients. It regulates the uptake of nutrients by the cell. It is closely bound to lecithin in the cell membrane.

In normal nerve transmission and regulation of the heartbeat, calcium is required. Calcium ion concentrations together with correct amounts of sodium, potassium and magnesium maintain muscle tone and control muscle irritability.

ABSORPTION AND UTILIZATION Calcium absorption in humans is very inefficient. Usually only 20 to 30 per cent of the ingested calcium is absorbed and sometimes it is as low as 10 per cent. About 70 per cent is unabsorbed and is excreted in the feces. Calcium is absorbed in the duodenum in an acid medium, and its absorption ceases in the lower part of the intestinal tract when the food content becomes alkaline. Calcium is absorbed by active transport requiring energy. The amount absorbed depends largely upon the nature of the diet, for unless it is present in a water-soluble form in the intestine and is not precipitated by another dietary constituent, it will not be absorbed.

Many factors influence the actual amount of calcium absorbed. The body absorbs calcium more effectively when in need. The greater the need and the smaller the dietary supply the more efficient the absorption. During periods of rapid growth, the absorption of calcium is increased. The factors favoring calcium absorption are as follows:

Vitamin D This is required for the efficient absorption of calcium. In the presence [illegible]

secreted in the stomach provides the acid medium of the contents of the digestive tract in the small intestine.

Lactose In the presence of lactose, calcium absorption is improved. A relatively high ratio of lactose to calcium to form a sugar-calcium complex in the intestine keeps the calcium in the form in which it can be transported to and across the intestinal mucosa. The lactose-calcium complex also prevents the precipitation of calcium in an insoluble complex as the contents of the intestinal tract change from acid to alkaline.

Fat Fat content in moderate amounts, moving slowly through the digestive tract, tends to facilitate calcium absorption.

Protein Intake When the intake of protein is high, a greater percentage of calcium is absorbed than when the intake of protein is low. The action of certain amino acids upon intestinal pH and upon the formation of the soluble complex with calcium facilitates calcium absorption.

On the other hand, there are many factors which depress the absorption of calcium:

Vitamin D Deficiency Lack of or insufficient amount of vitamin D decreases or prevents the absorption of calcium and thus it is not available to the body.

Fats An excessive intake of dietary fats or poor absorption of fats results in an excess of free fatty acids which unite with calcium to form insoluble soaps. The calcium soaps are excreted in the feces.

Oxalic Acid The calcium content and availability in some fruits and vegetables depend upon the oxalic acid they contain. Oxalic acid combines in the digestive tract with calcium to form an insoluble compound, calcium oxalate. The calcium is not absorbed. Rhubarb, spinach, chard and beet greens contain oxalic acid in appreciable amounts.

Phytic Acid Phytic acid, a phosphorus-containing compound found principally in the outer husks of cereal grains (especially oatmeal) combines with calcium to form calcium phytate which is insoluble and is not absorbed from the intestines.

Alkaline Medium In an alkaline medium, calcium (and phosphorus) will form insoluble and non-absorbable calcium phosphate.

Gastrointestinal Motility When the food passes through the intestinal tract too rapidly, calcium absorption is decreased.

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of calcium is required to maintain calcium equilibrium.

CALCIUM-PHOSPHORUS RATIO The ratio of calcium to phosphorus in the dietary is important in the absorption of both elements. Adults require an intake of phosphorus in the ratio of 1½ to 1 of calcium. The ratio in the dietary of children and of females during pregnancy and lactation is 1 to 1. An excess of either one in the dietary causes poor absorption of both and increased excretion of one or the other.

Calcium is transported by the blood to the fluids bathing the tissues of the body and to the cells and is used wherever needed. Most of the calcium is used in the bones. The calcium in the bone is in equilibrium with calcium in the blood. The parathyroid hormone, parathormone, and calcitonin, secreted chiefly by the thyroid gland, keep the blood calcium at a normal concentration of about 10 mg. per 100 ml. of blood serum. When it falls below this level, parathormone transfers exchangeable calcium from the bone into the blood. At the same time the parathyroid causes the kidney to reabsorb calcium which normally might be excreted in the urine and it stimulates more absorption of calcium from the intestines. When the blood calcium level is above normal, calcitonin acts to lower it and calcium is thus excreted by the kidney.

EXCRETION Normally, most of the calcium (65 to 75 per cent) is excreted in the feces and the rest in the urine. Some is excreted in the perspiration, which may become significant in environmental and physiological conditions producing active sweating.[2] Most of the calcium in the feces is unabsorbed food calcium, which is variable. Despite wide variation in calcium intake, under normal conditions the amount excreted in the urine remains rather constant at about 100–150 mg./day.

DIETARY SOURCES Calcium is assimilated better from some foods than from others. The calcium in milk is assimilated readily. Milk and milk products are the best sources of calcium. Dark green leafy vegetables such as kale, turnip greens, mustard greens and broccoli, and sardines, clams and oysters are good sources of calcium. It is difficult to have an adequate intake of calcium without milk or milk products. Eight ounces of milk (whole or non-fat) daily would supply

fourths of the recommended daily amounts of calcium would be provided for an adult.

Infants can easily meet the calcium intake requirement of milk, since this is their chief food. Children can best meet the requirement by including the amount of milk recommended for each age group (Table 17–1), or its equivalent, daily. Appendix Table 7 shows the foods high in calcium content.

RECOMMENDED DIETARY ALLOWANCE Most of the data regarding calcium requirements for man have been obtained from calcium balance studies. (A controversy exists regarding the interpretation of the data and the use of the balance studies as a basis for requirements.) These studies measure the intake and output of calcium over periods of time. To determine the minimum calcium requirement, the calcium intake is reduced until the person can no longer remain in balance (i.e., his excretion becomes greater than his intake). It is evident from these studies that man, if given time to adjust to changes in levels, can remain in calcium balance over a very wide range of calcium intakes.

The 1968 revision of Recommended Dietary Allowances of the National Research Council states that the normal adult male and female should receive 800 mg. of calcium daily. This amount covers basic needs and allows for a margin of safety. These allowances are greater than those recommended by the FAO/WHO Expert Group.[3] This report concludes that intakes of 400 to 500 mg. per day would represent a suggested practical allowance for adults. They feel that this level can more readily be achieved by a larger segment of the world's population. Sources of calcium are limited in the national food supply of many countries.

The Food and Nutrition Board, National Research Council justify their allowance of 800 mg. on the basis that calcium losses in metabolism amount to approximately 320 mg. per day. Since only 20–30 per cent of the dietary calcium is absorbed, 800 mg. would be required to maintain balance. Food sources of calcium are readily available to the population of the United States. Cognizance was also taken of the relatively high prevalence of osteoporosis in older persons and the possibility that minimal or moderate inadequacy in calcium intake over a period of years may contribute to the occurrence or accentuation

An increase in calcium is needed for the calcification of fetal bones and teeth and for the storage of calcium by the mother to meet the demands of lactation. The National Research Council has recommended an additional 400 mg. of calcium daily to meet the demands of the fetus and mother. Indications are that the pregnant woman may absorb up to 40 per cent of dietary calcium, depending on the need.

The amount needed by the lactating mother is 500 mg. daily over normal requirements in order to provide adequate calcium in milk without causing depletion of the mother's calcium reserve or decrease in milk production.

During these periods of increased dietary needs for calcium the growing fetus or nursing child will satisfy his need for calcium at the mother's expense. If her dietary intake is deficient, presumably the mother will lose bone calcium.

The calcium requirement of the infant is not precisely known. A breast-fed infant receives about 60 mg. of calcium per kilo body weight and retains about two-thirds of this amount. An infant fed a standard cow's milk formula receives about three times this amount of calcium per kilo body weight, and retains 35 per cent to 50 per cent. The National Research Council states that their recommended calcium intakes are from 0.4 to 0.6 grams per day in infants up to one year of age and are based on the infant fed cow's milk formula.

It is assumed that the calcium needs of the breast-fed infant have been met even though calcium intake is considerably less than that obtained on a cow's milk diet.

Children from ages 1 to 10 years need 0.7 to 1.0 grams of calcium daily. From 10 to 18 years of age the recommendation for males is 1.2 to 1.4 grams and for the female 1.2 to 1.3 grams of calcium daily.

Obviously an adequate intake of calcium is not enough. The conditions influencing the absorption and metabolism of calcium must be considered and the nutrients involved must be provided in the daily food intake.

CALCIUM DEFICIENCIES These aspects will be considered in more detail in Chapter 34. Suffice it to state here that calcium deficiency in children may lead to *rickets* with retarded growth or, more likely, continued body growth, but with abnormal development of bones resulting in bowed legs and other bone deformities. (See Figs. 8–1 and 34–15). Deficiency of calcium in adults may result in osteomalacia (sometimes referred to as adult rickets), a failure to mineralize the bone matrix, resulting in a reduction in the mineral content of the bone. Usually, rickets and osteomalacia are associated with a concurrent lack of vitamin D and imbalance in calcium-phosphorus intake. In scurvy, the lack of ascorbic acid prevents the formation of bone matrix and normal mineralization does not occur.

Osteoporosis develops when the dietary intake of calcium is low over an extended period of time or when dietary needs are abnormally high because of poor absorption. Bone resorption occurs at an accelerated rate to maintain normal calcium blood levels. The bone is of normal composition but a reduced amount of bone is present.

Extremely low levels of calcium in the blood may increase the irritability of nerve fibers and nerve centers and result in muscle spasms such as leg cramps. This condition is known as tetany. It sometimes occurs in pregnant women who have received too little calcium in their diets or who have received too much phosphorus. (The latter is responsible for hastening the excretion of calcium during pregnancy.) The rise in serum phosphorus causes a compensatory decrease in serum calcium. It sometimes occurs in newborn infants fed undiluted cow's milk, which contains more phosphorus than calcium. The kidneys of the infants cannot clear the phosphate.

Calcium rigor occurs when the calcium levels are well above normal causing tonic contractions of the muscle. Both of these conditions are due to abnormal functioning of the parathyroid.

A high intake of calcium and the presence of a high intake of vitamin D such as may occur in children is a potential source of hypercalcemia (elevated blood calcium lev-

Figure 8–1 Skeletons of twin albino rats showing influence of calcium content of the diet on the

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els). This may lead to widespread excessive calcification not only in bone but in the soft tissues such as kidneys.

PHOSPHORUS

The metabolism of phosphorus is intimately related to that of calcium. It is second to calcium in abundance forming 22 per cent of the total minerals. Most of it (about 80 per cent) is in the form of insoluble calcium phosphate (apatite) crystals that give strength and rigidity to the bones and teeth. The remaining phosphorus is distributed in every cell of the body and in the extracellular fluid in combination with carbohydrates, lipids, proteins and a variety of other compounds.

FUNCTION Phosphorus has numerous functions in the body beyond its important part in the structure of bones and teeth; more than any other mineral element. It is an essential component of the nucleic acids. Phosphorylation is the first step in the metabolism of glucose and in many other phases of the metabolic processes. ATP and creatine phosphate serve to store the energy liberated by oxidation. Many of the B vitamins function as coenzymes only when in combination with phosphate. Phosphorus is a member of certain conjugated proteins of which casein in milk is a good example. Phospholipids are important in the structure of cell membranes. The phosphate buffer system is important particularly in intracellular fluid where its concentration is much higher than in extracellular fluid and in the tubular fluids of the kidney.

ABSORPTION Normally, about 70 per cent of the phosphorus ingested in foods is absorbed. Most favorable absorption takes place when calcium and phosphorus are ingested in approximately equal amounts. As with calcium, the presence of vitamin D increases absorption. Simple phosphates such as calcium phosphate or potassium sodium phosphate are absorbed as such in the small intestine. In the digestion of phosphoprotein and nucleoprotein, phosphate is split off and absorbed. The factors that aid or deter the absorption of calcium act essentially in the same manner with regard to the absorption of phosphate. Phosphorus present as phytic acid in some cereals and flour is not well absorbed and may depress absorption of calcium and iron.

DIETARY SOURCES Meat, poultry, fish and eggs are excellent sources of phosphorus. Milk and milk products are good sources, as are nuts and legumes. Cereals are good sources but the availability of the phosphorus (especially in bran) is somewhat doubtful due to the phytic acid, as explained previously. Table 8–2 shows the phosphorus content of average servings of various foods. Note that the good sources of protein are also good sources of phosphorus.

RECOMMENDED DIETARY ALLOWANCE The Food and Nutrition Board recommends that the daily intake of phosphorus at least equal that of calcium for all age groups except the young infant. The phosphorus allowances for young infants to one year of age are slightly less than those for calcium. (See Table 11–1.) Because phosphorus is so liberally distributed in foods, there is little possibility of a dietary inadequacy if the food intake contains adequate protein and calcium.

TABLE 8–2 PHOSPHORUS CONTENT OF FOODS

FOOD	AVERAGE SERVING: APPROXIMATE MEASURE	AVERAGE SERVING: WEIGHT GRAMS	MILLIGRAMS OF PHOSPHORUS*
Peanuts, roasted, with skins	2/3 cup	100	407
Turkey, roasted, flesh only	3 1/3 oz.	100	251
Fish (halibut, broiled)	3 1/3 oz.	100	248
Pork loin, broiled, med. fat	3 1/3 oz.	100	268
Milk, nonfat (skim), fluid	1 glass (8 oz.)	246	232
Milk, whole, fluid	1 glass (8 oz.)	244	227
Chicken, roasted	3 1/3 oz.	100	220
Loin lamb chop, broiled	3 1/3 oz.	100	179
Beef, hamburger, cooked (regular ground)	3 1/3 oz.	100	194
Oysters, raw	6 oysters	100	143

IRON

Iron is present in the body in relatively small amounts, 3 to 5 grams. Normally an adult male has 40 to 50 mg. of iron per kilogram of body weight and the female 35 to 50 mg. per kilogram of body weight. Sixty to 70 per cent is classified as essential and 30 to 40 per cent as storage or non-essential. Most of the essential iron is in the red blood cells (hemoglobin). Approximately 5 per cent of the essential iron is in muscles (myoglobin), and a small amount (less than 1 per cent) is found in the body cells as a constituent of certain enzymes that catalyze oxidation-reduction processes in the cell. Approximately 20 per cent is stored in the liver, bone marrow and spleen as ferritin and hemosiderin. It is present in the transport form, bound to protein (transferrin), in the blood plasma.

FUNCTIONS Iron plays an essential role in the body in transport of oxygen from the lungs to the tissues and in the processes of cellular respiration. The first of these functions is accomplished by hemoglobin in the erythrocytes. Hemoglobin is a metalloprotein with heme, an iron-porphyrin attached to the protein moiety. The iron combines with oxygen in the lungs where the concentration is high and releases it in the tissues where it is needed. Myoglobin and the cytochromes are also heme-containing proteins. Myoglobin, within the muscle cell, has a function similar to that of hemoglobin. The cytochromes do not combine with oxygen but function in the respiratory chain in transfer of electrons through alternate oxidation and reduction of the iron ($Fe^{++} \rightleftarrows Fe^{+++}$). The enzymes catalase and peroxidase have a heme component.

In fetal life the red blood cells or erythrocytes are manufactured principally in the liver and in the spleen. In the adult they are formed chiefly in the bone marrow. The red blood cells begin as immature cells (erythroblasts). As they mature in the bone marrow the porphyrin ring of heme is synthesized from simple units (glycine and intermediates of the Krebs cycle) and combined with the globin. The presence of copper is essential for the synthesis of hemoglobin. The average life span of the red blood cell is about 120 days. As the cells age they become more fragile and rupture; they are disintegrated in the reticulo-endothelial system. The iron is released from the porphyrin and returned to occur more rapidly in the presence of ascorbic acid and vitamin E deficiencies.

ABSORPTION Inorganic forms of iron ($FeSO_4$) are readily absorbed by the mucosa of the small intestine. The ferrous (Fe^{++}) salts appear to be more readily absorbed than are the ferric (Fe^{+++}) salts. The greatest absorption occurs in the upper duodenum. The rate of iron absorption seems to be controlled by the intestinal mucosa in response to the body's requirement for iron. The iron is attached to the plasma protein, transferrin, and carried to the storage depots where it combines with apoferritin to form ferritin. Normally about 30 per cent of the transferrin is combined with iron. As the apoferritin stores become saturated, the amount of iron remaining attached to the transferrin increases and there is less absorbed from the mucosal cells. As the level of ferritin in the mucosa increases, it is exfoliated and excreted in the feces. If there is need for iron these processes are reversed. Greater absorption takes place when there is an increased rate of blood formation as needed in pregnancy, during growth and as a result of loss of blood. Children may absorb iron at a rate twice that of adults.

It is estimated that only 5 to 15 per cent of the iron in food is absorbed by normal adults. From 2 to 10 per cent of iron in vegetables and from 10 to 30 per cent of iron in animal protein can be absorbed. Animal protein improves iron absorption. Ascorbic acid enhances iron absorption by helping to reduce ferric to ferrous iron. The degree of gastric acidity influences solubility and availability of the iron in food. The presence of an adequate amount of calcium helps to bind and remove phosphate, oxalate and phytate that otherwise would combine with iron and inhibit its absorption.

The lack of hydrochloric acid in the stomach; the administration of alkalis; a high intake of cellulose; the presence of insoluble iron complexes such as phytates, oxalates and phosphates; increased intestinal motility and steatorrhea interfere with iron absorption.

When abnormally large amounts of iron are present as a result of long-term ingestion of extremely high amounts or excessive blood transfusions, the apoferritin becomes saturated and hemosiderin appears in large quantities. It is similar to ferritin but contains more iron and is very insoluble. Also