| Micronutrients | Minerals needed in larger quantities |
|---|---|
| *Minerals:* | Calcium |
| Boron | Chloride |
| Chromium | Magnesium |
| Cobalt | Phosphorus |
| Copper | Potassium |
| Fluoride | Sodium |
| **Iodine** | Sulfur |
| **Iron** | |
| Manganese | **Boldface** *indicates the nutrients most often lacking in the diets of people with marginal incomes. Deficiencies of these 5 micronutrients affect the health of roughly 1/3 of the world's population.* <br><br> *Of the eleven B vitamins, folate is most likely to be deficient.* |
| Molybdenum | |
| Selenium | |
| **Zinc** | |
| *Vitamins:* | |
| **A (retinol)** | |
| **B complex (folate)** | |
| D | |
| E | |
| K | |

CHAPTER FOUR

# *Leaf Vegetables and Traditional Malnutrition*

Leaf vegetables can potentially contribute significant amounts of most nutrients to a diet, depending on the type of leaf and the way it is prepared. Leaves are not usually good sources of zinc, iodine, or calories and they cannot provide vitamin B-12[1]. Where green leafy vegetables can make a profound nutritional improvement quickly for millions of people is in addressing the global problem of "hidden hunger" or micronutrient malnutrition.

Micronutrients are substances that we require in very small quantities throughout our lives. They include both minerals and vitamins needed for good health, that cannot be synthesized by our bodies, and so must be secured from our diet. Minerals considered to be micronutrients are: Boron, Chromium, Cobalt, Copper, Fluoride, Iodine, Iron, Manganese, Molybdenum, Selenium, and Zinc.

1 Vitamin B-12 is made by bacteria; it is not synthesized by plants or animals. Trace amounts of B-12 in plants comes from contamination with B-12 producing bacteria. Animals, including insects, concentrate B-12 from the food they eat. Bacteria in the digestive system of some grazing animals produce biologically active B-12. Because animal foods are the only reliable food sources for B-12, the use of B-12 supplements (or fortified foods, e.g., nutritional yeast) is recommended for pure vegetarians by most nutrition experts.

Some minerals are essential but are needed in larger amounts and so aren't micronutrients. These are: Calcium, Chloride, Magnesium, Phosphorus, Potassium, Sodium, and Sulfur.

Vitamins, all of which are considered micronutrients, are: vitamin A (retinol); vitamin B complex (biotin, choline, cobalamin, folate, inositol, niacin, pantothenic acid, pyridoxine, riboflavin, thiamin); vitamin D; vitamin E (tocopherol); and vitamin K. (See chart, opposite page.)

While an adequate supply of all the micronutrients is essential to good health, five stand out. These are the minerals iron, iodine, and zinc, along with vitamin A and folate. They are the nutrients most often in short supply in the diets of people with marginal incomes. Deficiencies of these five micronutrients affect the health of roughly one-third of the world's population. These five are the focus of the World Health Organization's micronutrient initiatives.[2] Ensuring that everyone has access to adequate dietary sources of these five micronutrients is the world's top nutritional priority. Green leafy vegetables are potentially the least expensive and most readily available food source for three of these five target micronutrients: iron, vitamin A, and folate.

2 Investing in the future: A United Call to Action on Vitamin and Mineral Deficiencies. GLOBAL REPORT 2009 Micronutrient Initiative, Ottawa, CANADA. ISBN: 978-1-894217-31-6

**Chart 4–1**
**Iron in Selected Leafy Vegetables[1]**

| Iron | Leaf crop | Iron | Leaf crop |
|---|---|---|---|
| MG | 100 G FRESH, EDIBLE PORTION | | |
| 9.5 | Wolfberry[1] | 1.8 | Swiss chard |
| 8.7 | Toona *(Toona sinensis)*[1] | 1.8 | Cilantro |
| 6.7 | Moringa, mature leaf[1] | 1.7 | Kale |
| 6.2 | Parsley | 1.5 | Vine spinach |
| 5.8 | Chaya | 1.5 | Mustard greens |
| 4.0 | Moringa, young leaf[1] | 1.2 | Lambsquarters |
| 4.0 | Winged bean leaves | 1.1 | Turnip greens |
| 3.1 | Dandelion | 1.0 | Sweet potato leaves |
| 2.7 | Spinach | 0.9 | Broccoli leaves |
| 2.3 | Amaranth | 0.8 | Red cabbage |
| 2.3 | Taro leaves | 0.6 | Cabbage |
| 2.2 | Pumpkin leaves | 0.4 | Lettuce, crisp head |
| 2.0 | Purslane | 0.2 | Watercress |
| 1.9 | Cowpea leaves | | |

1 Composition charts show the huge differences in the iron content of leafy vegetables. Especially with leafy vegetables there can be significant differences between analyses of the same food. For example mature moringa leaves had more than double the iron, calcium, and vitamin A of young moringa shoots in the Asian Vegetable Research and Development Center (AVRDC) samples, but the USDA samples didn't specify maturity of the 'leafy tips.' The proportion of stem remaining in the sample could also have a significant effect on the numbers. The composition numbers should thus be considered useful estimates.

## IRON

When a person doesn't get enough iron in their diet they develop iron deficiency anemia. Iron deficiency anemia is the most common nutritional disease in the world. Especially at risk are women of childbearing age, who need extra iron for menstruation, pregnancies, and lactation; and young children, who need extra iron for rapid growth. Whenever blood is lost, as with wounds, hookworm, malaria, internal bleeding from ulcers, menstruation, or childbirth, iron needs go up significantly. UNICEF estimates 50% of the children in developing countries (about 500 million children) and 60% of the pregnant women in these countries suffer from iron deficiency anemia. Several countries, primarily in sub-Saharan Africa, have childhood anemia rates over 80%.[3]

The most universal symptom of anemia is tiredness. Iron is needed to make hemoglobin, the key protein in the red blood cells that carry oxygen to all parts of the body. Not having enough hemoglobin in the blood causes fatigue because not enough oxygen is carried to the body's cells. Every cell requires oxygen to burn food in order to have energy in the same way that a fire needs a supply of oxygen to burn fuel.

In addition to general tiredness, anemia can cause shortness of breath; dizziness, especially when standing up; headache; and chest pain. The heart has to pump harder to circulate the reduced amount of oxygen in the blood. This can lead to a number of heart problems including an enlarged heart and even heart failure. Anemic children are smaller and grow more slowly than those with normal hemoglobin levels. They have poor appetites and less energy for playing or

3 Investing in the future: A United Call to Action on Vitamin and Mineral Deficiencies. GLOBAL REPORT 2009 Micronutrient Initiative, Ottawa, CANADA. ISBN: 978-1-894217-31-6

learning. Their mental development may be retarded and their attention span reduced. Their immune response is depressed, which leaves them more vulnerable to infections.

When women are anemic during their pregnancies, as the majority of women in developing countries are, they are far more likely to die during childbirth, and their babies are far more likely to be born prematurely or underweight. A woman whose diet is marginal in iron intake and who has children closely spaced in years will often suffer from severe anemia. This can make her lethargic and apathetic, and less able to care for her children. Anemic women have babies born with low iron stores in their livers, who often become very anemic before they are old enough to absorb adequate iron from the food they eat. These families have a high risk of severe health problems and should be a top priority in nutrition improvement efforts.

Anemia in adults lowers productivity and capacity to do work. This, of course, affects their ability to earn an adequate income and increases the likelihood that their children will be malnourished. Increasingly we see that anemia is implicated in a vicious cycle of malnutrition and poverty.

### *Iron Absorption*

As with proteins, both the quantity and the quality of iron in the diet are important. Animal-based foods tend to be richer in both the quantity and quality of iron than plant-based foods. However, as is the case with protein, it is definitely possible to get an excellent supply of iron from plant sources if one has a little information.

Even poor diets often contain more iron than the body needs. The problem is that most of the iron is poorly absorbed. Some of the iron in meat, fish, and poultry (heme iron) is relatively well utilized. However, meat products are usually too expensive for poor families in developing countries to buy. The iron in grains, beans, and vegetables, and the remaining iron in animal-based foods (non-heme iron) is in chemical forms that are poorly absorbed by our bodies. The small, but potentially useful, amount of iron that comes from cooking acidic foods in cast iron cookware is also in a poorly absorbed form.

The absorption of non-heme (plant) iron is even worse when a meal contains phytates, which are concentrated in the fibrous parts of grains and nuts. Similarly tannin, which is found in beans (especially dark colored beans), tea, coffee, and several other foods and spices, makes non-heme iron more difficult to absorb. Deficiencies of other nutrients can also aggravate anemia. The most important of these are folate, protein, vitamin A, vitamin B-6, riboflavin, and copper.

There are several ways to address these problems. For instance, the presence of even a small amount of meat in a meal makes the non-heme iron much more usable; but

**Chart 4–2**
**Recommendations for Daily Iron Intake**[1]

| Iron | Stage of life |
|---|---|
| | ***Children*** |
| 11 mg | 6–12 months |
| 7 mg | 1–3 years |
| 10 mg | 4–8 years |
| 8 mg | 8–13 years |
| 11 mg | Boys 14–18 years |
| 15 mg | Girls 14–18 years |
| | ***Women*** |
| 18 mg | 19–50 years |
| 27 mg | Pregnant |

1 Recommended Dietary Allowances (RDAs) are set to meet the needs of almost all (97–98%) individuals in a group. 2004 US National Academy of Sciences.

**WHY THE TROPICS?**

Looking at the problem of malnutrition one is struck almost immediately by the hugely disproportionate number of malnourished people living in the tropics. The tropics refer formally to the part of the earth between the latitudes of 23½ degrees north and 23½ degrees south. Because of the tilt in the polar axis, this part of the earth has the sun directly overhead at least once a year. In popular usage the tropics is the part of the world where it is warm year round and seldom experiences freezes.

At first glance it would seem that being able to grow food year round, rather than just in the summer, would be an enormous advantage; and that tropical people would be less likely to suffer from food shortages. All sorts of anthropological, historical, and even medical explanations have been offered to explain this seeming contradiction. These range from “the heat makes people lazy” to “cold climates force people to plan ahead and get more organized for the winter.” Some have argued that the grim presence of malaria and other tropical diseases takes its toll on productive activities. The explanation that European colonial powers dominated and exploited the tropical societies and left a legacy of endemic poverty has a ring of truth to it. The situation has been exacerbated in many tropical nations by inefficient and often corrupt governments, and by factional warfare.

For the most part, the political and historical explanations are outside the scope of this book. There are, however a few basic geophysical factors that have serious impacts on tropical nutrition that are sometimes overlooked.

1) Tropical soils tend to be thin with very low levels of organic matter. This means they have little ability to hold water or nutrients for growing plants. In warmer climates the nitrogen in rotting organic matter is more quickly lost to the air (volatilized) as ammonia gas than in cooler climates. As a result, less soil nitrogen is available to stimulate plant growth or to be built into proteins. In addition, laterite soils with low levels of essential phosphorus and high levels of toxic aluminum are prevalent in the tropics. This type of soil makes better building material (adobe) than food-growing soil.

2) Rainfall in the warm tropics is lost more quickly from tropical than temperate soils because of the higher evaporation rate. Tropical rains are more often hard rains than drizzles. These are less useful to plants and cause greater soil erosion. Also, because plant growth is year round there is no recharging of ground water over the winter. In contrast temperate zones get rain over the winter but little vegetative growth to transpire it and little heat to evaporate it.

3) The yield of fish in tropical oceans is much lower than in colder waters. Big seasonal temperature changes affect the water’s density and bring an upwelling of nutrients from the deep ocean to surface water, where sunlight can penetrate and make food for fish.

4) There are no hard winter freezes to dampen the populations of insect and microorganism pests.

5) Many important food plants are better adapted to the longer hours of diffused sunlight of temperate summers than to the shorter days and more intense sunlight of the tropics.

as mentioned above, meat is usually too expensive to be eaten by the poor. Ascorbic acid (vitamin C) also makes non-heme iron more useful to the human body. Basically, the absorption of non-heme iron is considered to be about four times as great in a daily diet containing 90 g of meat or 75 mg of vitamin C, as it is in a diet with less than 30 g of meat or 25 mg of vitamin C.

This is a very important consideration. It is often easier, cheaper, and more effective to add vitamin C, than to add more iron to the diet. Roughly speaking, a woman consuming over 75 mg of vitamin C will need only a fourth as much iron as a woman consuming less than 30 mg of vitamin C, if the iron is from non-animal sources. Good sources of vitamin C are guavas, citrus fruits, fresh leafy vegetables, fresh tomatoes, and other fruits and fruit juices. Some leaf vegetables, such as bush okra (*Corchorus olitorius)* are very good sources of vitamin C as well as iron. Some vitamin C is always lost in processing leaf vegetables. With the leaf concentrate the loss is nearly complete, while carefully dried or lightly cooked leaf vegetables typically retain about one-half of their original vitamin C. Beta-carotene has also recently been shown to improve the absorption of non-heme iron.

***How green leaves can help***

Leaf concentrate, which is discussed in Chapter 7, could be the ideal cure for iron deficiency anemia. Just ten grams (about a third of an ounce) of dried leaf concentrate can supply about half the iron requirement of children and adult men, and nearly one-third of the requirement for women of child-bearing age. It is well-absorbed and can be easily mixed with vitamin C–rich foods to further enhance its absorption. The problem with leaf concentrate is that it is not available in many places yet. Until more progress is made in the manufacture and distribution of leaf concentrate, anemic people will need to look elsewhere.

It is unlikely that the price of meat will drop sufficiently to become a dependable source of high quality dietary iron for the vast anemic masses, the majority of whom have $2 a day or less to meet all their expenses. Beans and peas are relatively inexpensive sources of iron, though their tannins limit absorption somewhat. Nuts, dried fruit, and green leafy vegetables are the other iron sources. Like meat, nuts and dried fruit are too expensive. Green leafy vegetables are our best shot at a food that is cheap, widely available and rich enough in iron to actually meet the iron requirements of the world's anemic people. Greens like chaya and parsley that are extremely rich in both iron and vitamin C, even after cooking, are especially promising.

The amount of iron in leafy vegetables varies a great deal, mainly from differences between species, and secondly from differences between varieties or cultivars within a species. The amount of iron in the soil has relatively little impact on the iron content of the leaves. If the soil is deficient in iron the effect is more on the yield and overall health of the plants than on the iron content in the leaves. Soil deficiencies of iron are relatively rare and very little iron is actually needed. Where soils are highly alkaline or have had an excess of soluble phosphorus fertilizer added, the iron is often not readily absorbed by plants. Compost or incorporated cover crops will usually buffer the pH enough and add sufficient iron to resolve this problem on a garden scale.

Obviously, if you are trying to cure or prevent anemia, the leaf vegetables at the top of the chart (Chart 4–1 on page 24) will be much more useful than those at the bottom.

***Strategies for eliminating anemia***

Most of the world's estimated 2 billion people with iron deficiency anemia are already getting *most* of their iron needs met from their diets. The vast majority of anemic people are mildly or moderately anemic. Unlike the very small percentage of people with severe anemia, what they need is a few milligrams of extra iron every day to cover the shortfall. The US recommendations for daily iron intake for key groups are indicated in Chart 4–2 on page 25.

Eliminating anemia will necessitate getting low-cost, iron rich foods to women and children in the tropics as well as improving the bioavailability of the iron in those foods. Solar-dried, high-iron leaf


Bush okra *(Corchorus olitorius)*

crops could easily become the cheapest source of dietary iron in most communities. Unlike some vitamins, iron is not lost when leaf crops are solar dried.

The bioavailability of the iron in solar-dried leaf vegetables can be improved in several ways. Studies at the Asian Vegetable Research and Development Center (AVRDC) showed that simple cooking improved the bioavailability of the iron in dried moringa leaves three-fold over uncooked dried leaves. This likely holds true for other dried leaves as well. Adding foods rich in vitamin C greatly improves the absorption of the non-heme iron in any dried leaf. Very fine grinding increases the iron absorption rate by providing more surface area to contact with digestive enzymes.

Vitamin A is essential to iron absorption and a large proportion of anemic people also have inadequate or marginal amounts of vitamin A in their diets. Adding a small amount of oil or fat to dried leaf dishes increases the body's absorption of vitamin A. Folate is also helpful in utilizing non-heme iron. Fortunately most of the leaves that are good iron sources are also good sources of both folate and vitamin A.

If we estimate that most anemic people are getting 75% of the iron that they need from their diet, we need a strategy to provide the missing 25%. To provide 25% of the recommended iron for all the high risk anemia groups (except for pregnant women) would only require 4.5 milligrams per day, per person. Pregnant women would need about 7 milligrams to meet one-fourth of their recommendation. Three tablespoons of finely ground dried leaf powder from any of the top twelve leaf crops listed in Chart 4–1 on page 24 would provide 4.5 milligrams of iron. A system to grow the leaves, dry, and grind them can be set up cheaply and relatively quickly almost anywhere. Once in place it could provide a dependable and inexpensive local source of dietary iron, and significantly improve the quality of life.

Reversing anemia is a sound investment. A study in Indonesia, reported in the American Journal of Clinical Nutrition[4], showed than an iron supplement to anemic workers improved productivity an average of 15–25%. This meant a return of $260 for each dollar spent on the supplements. Similarly, more educational benefit can often be had with one dollar of additional iron in the children's diets than with $100 of new school construction. Using local green leaf crops as the source of lacking iron is an investment with several multiplier effects.

## VITAMIN A

It is estimated that one-third of the children under five years old in developing countries are deficient in vitamin A. In some countries, such as India with 62% and Kenya with 84%, the percentage of children suffering from vitamin A deficiency is a public health catastrophe.[5] This micronutrient is essential for everyone, but children are especially vulnerable when it is not adequately supplied in the diet.

Vitamin A participates in dozens of important activities in the human body. It is critical to vision and helps us especially to see in dim light. It maintains the integrity of the epithelial cells that line the interior surfaces of our respiratory and digestive systems. It stimulates the production of white blood cells, takes part in repairing damaged bone, aids in the making of hemoglobin, and regulates cell growth and division.

4 SS Basta, Soekirman , D Karyadi, and NS Scrimshaw. Iron deficiency anemia and the productivity of adult males in Indonesia. Am. J. Clinical Nutrition, Apr 1979; 32: 916–925

5 Investing in the future: A United Call to Action on Vitamin and Mineral Deficiencies. GLOBAL REPORT 2009 Micronutrient Initiative, Ottawa, CANADA. ISBN: 978-1-894217-31-6

What happens when vitamin A is in short supply? The deficiency is often first recognized as night blindness, when dusk settles in and some children can't see well enough to play. A relatively common symptom is xeropthalmia, a drying of the cornea of the eye which greatly impairs vision. A severe lack of vitamin A can cause permanent blindness, as it does with thousands of children.

As horrible as children losing some or all of their sight is, the greatest price exacted by the failure to supply children with an adequate supply of this micronutrient is their reduced resistance to infection. Both the innate and the adaptive immune systems of children with insufficient vitamin A are suppressed, leaving them much more susceptible to infectious diseases, especially diarrhea, respiratory infections, and measles.[6]

Vitamin A deficient children get more infections, the infections are more severe, and they recuperate more slowly than

6 There are two basic branches of the human immune system: innate and adaptive. Innate, or inborn, immunity provides very rapid identification and response to common microbial threats. All living beings have some form of this ancient protective system. The other component is the adaptive immune system. This evolved much later and is shared only with other vertebrates. The adaptive immune system allows us to identify and remember new threats and to create specific antibodies that will attack them. It is the adaptive immune system that enables vaccines to work by offering weakened versions of pathogens that trigger the creation of specific antibodies.

**RED PALM OIL**

The wild card in vitamin A nutrition is red palm oil. The oil from the tropical palm (*Elaeis guineensis*) has been used for centuries in its native West Africa. The relatively unprocessed form of the oil is orange-reddish in color due to extremely high beta-carotene content. With about 3,000 mcg RAE per 100 g red palm oil is the richest commonly available source of this nutrient. The carotene is well absorbed because of the oil matrix, and it is being enthusiastically proposed as a solution to vitamin A deficiencies in many tropical countries, especially India.

There is also considerable resistance to palm oil, both for nutritional and for environmental reasons. Nutritionally, the minimally processed red palm oil traditionally used in West Africa has little in common with the refined, bleached, and deodorized palm oil of global commerce. Significantly, industrial palm oil has no beta-carotene. However it is cheap and stable with a long shelf life. Because of these attributes it is increasingly entering international commerce as a source of fat in processed margarines, cookies, crackers, and snack foods.

This combination of high levels of saturated fat and zero beta-carotene hasn't won over many nutritionists. In fact, the World Health Organization and several other nutrition advisory groups have recommended limiting consumption of palm oil. Their recommendations cite recent research showing that the saturated fats in palm oil may contribute to heart problems if eaten in large quantities. It is worth noting that the amount of traditional red palm oil that would be needed to amend a dietary shortfall of vitamin A would not be enough to increase the risk of heart disease.

Many environmental groups advise against consuming palm oil because the bulk of it is now grown in vast monocultures that are replacing diverse tropical forests, especially in Indonesia, Malaysia, and Brazil. Oil palm monocultures are being blamed for loss of habitat for critically endangered orangutans and other wildlife. The problem is intensifying because of rapidly growing demand for bio-diesel made from the palm oil to replace gasoline as a vehicular fuel.

The problems with palm oil are really the generalized problems of monocultures and industrialized foods. In fact, palms can be easily grown in environmentally stable polycultures and the oil can be lightly processed by local businesses. Red palm oil could greatly reduce vitamin A deficiency in the tropics without serious collateral health or environmental problems.

**Chart 4–3**
**Vitamin A in Selected Leafy Vegetables**

| Vitamin A MCG RAE | Leaf crop 100 G FRESH, EDIBLE PORTION | Vitamin A MCG RAE | Leaf crop 100 G FRESH, EDIBLE PORTION |
|---|---|---|---|
| 1550 | Toona (*Toona sinensis*) | 337 | Cilantro |
| 1376 | Grape Leaves | 306 | Swiss chard |
| 800 | Broccoli Leaves | 241 | Taro leaves |
| 769 | Kale | 223 | Bok choy (Chinese Cabbage) |
| 590 | Molokhaya (*Corchorus olitorius*) | 200 | Dock |
| 580 | Lambsquarters | 160 | Watercress |
| 579 | Turnip Greens | 150 | Spanish needles (*Bidens pilosa)* |
| 525 | Mustard Greens | 146 | Amaranth |
| 508 | Dandelion | 97 | Pumpkin Leaves |
| 469 | Spinach | 87 | Bitter gourd leaves |
| 421 | Parsley | 66 | Purslane |
| 405 | Winged bean leaves | 56 | Red cabbage |
| 400 | Vine spinach | 51 | Sweet Potato leaves |
| 378 | Moringa | 36 | Cowpea leaves |
| 375 | Red Leaf Lettuce | 25 | Lettuce, crisp head |
| 375 | Garland chrysanthemum | 6 | Cabbage |

children with adequate vitamin A in their diet. As a result, lack of vitamin A in the diet causes the death of about 670,000 children under the age of five every year.[7] Around one-fourth of all the deaths of children less than five years old can be attributed to low levels of vitamin A.

Pregnant women are also vulnerable to vitamin A deficiency. Like children, they have an increased demand because they are rapidly building new tissue, and additional vitamin A is needed for regulating cell division. Women with low stores of vitamin A in their livers have much higher rates of complications during childbirth. Over half a million women die from complications in childbirth every year. Vitamin A deficiency is one of the most common factors in these unnecessary deaths. Furthermore, pregnant women with low levels of vitamin A give birth to children who also have low levels, putting them at great risk for fatal infections in their first two years.

***Getting enough vitamin A***

Because vitamin A is stored in our livers we don't need to eat it every day if we are getting an adequate amount. The recommended dietary allowances are based on maintaining a four day supply. In our bodies vitamin A is in the form of retinal or retinol, two fat soluble compounds. When we get vitamin A from plants what we actually are getting is carotenoids (sometimes called pro-vitamin A) that can be converted to vitamin A in our bodies. When we get vitamin A from animal sources, such as meat, milk, and eggs (sometimes called pre-formed vitamin A), the animals have carried out the process of converting the plant carotenoids to vitamin A for us, and so it is more readily usable. Beta-carotene is the most commonly occurring and best absorbed of the pro-vitamin A compounds. The other carotenoids that can be converted

7 Black, RE et al., Maternal and child undernutrition: global and regional exposures and health consequences. The Lancet 2008, 371 (9608) p. 253.

to vitamin A are usually found in association with beta-carotene. Because of this, nutritionists often consider only beta-carotene when speaking of pro-vitamin A.[8]

As with iron, people who eat meat and other animal products normally get enough vitamin A, but people with very low incomes can't afford meat and other animal products. People who can't afford meat are the people whose children become deficient and the people who would most benefit from lower cost sources of vitamin A. The focus should be on getting more beta-carotene in the diet and on finding ways to improve its bioavailability so that the conversion rate to retinol is far better than 12 to 1.

Beta-carotene is a very common compound in nature. It is a pigment that colors many foods orange. Carrots, cantaloupe, mangos, pumpkins, papaya, and sweet potatoes are examples of common foods that are orange colored and good sources of beta-carotene. As a rule, the deeper the orange color the more beta-carotene. So sweet potatoes or winter squash with deep orange flesh are better sources than those with a paler color. This is especially important for sweet potatoes because in many cultures there is a marked preference for white or nearly white cultivars. Switching to deep orange varieties would be a major dietary improvement. Some fruits, notably mango, papaya, and cantaloupes are good sources of vitamin A but tend to be too expensive for the most vulnerable families and are available only during certain seasons.

***How green leaves can help***

Ironically the largest source of dietary beta-carotene is not in the orange colored fruits and roots but in green leaves, where the green chlorophyll pigment overwhelms the orange color.[9] Like many other nutrients, the beta-carotene in green leafy vegetables is difficult to absorb because it is trapped in a matrix of fibrous cell walls and other compounds. The beta-carotene in storage organs like roots and fruits is also bound in a matrix of cellulose, starches, and pectins, but it is typically less tightly bound and therefore more easily absorbed than the beta-carotene in green leaves. Especially for

8 In order to make nutritional comparisons and recommendations, vitamin A values are now described as Retinol Activity Equivalents (RAEs). 1 microgram (1/1,000,000 of a gram or 1/28,000,000 of an ounce) of retinol equals 1 RAE. 2 mcg of beta-carotene in oil equals 1RAE but it takes 12 mcg of beta-carotene in food to equal 1 RAE because the matrix of food makes it more difficult to absorb. Two other carotenoids that are often converted to vitamin A in the human body are alpha-carotene and beta-cryptoxanthin. Twenty-four mcg of either of these are required to equal 1 RAE. An older unit of measurement for vitamin A activity that is now discredited as inaccurate, but unfortunately is still sometimes used, is the International Unit (IU).

9 When maple and other deciduous tree leaves change color in the fall, it is because the green chlorophyll pigment that dominated all summer is lost and as a result the orange carotenes and red anthocyanins that were present all along become much more visible.

Italian parsley *(Petroselinum crispum)* children less than 18 months old, the beta-carotene from orange colored fruit is easier to absorb than the beta-carotene from leaf vegetables.

Once again leaf concentrate bypasses most of the problems of poor absorption by separating the fiber from the rest of the leaf. With over 3,800 mcg RAE per 100 g, dried alfalfa leaf concentrate tops even red palm oil as a source of vitamin A. Combining high levels of beta-carotene in a readily absorbed form along with a full spectrum of the other nutrients that are frequently deficient in the diets of vulnerable children makes leaf concentrate an excellent solution to vitamin A deficiency. However, until many more communities have access to leaf concentrate, other low cost sources of vitamin A need to be developed.

Meeting the body's need for vitamin A from inexpensive leafy vegetables requires three things:

1. Choosing species and varieties that are naturally rich in beta-carotene.
2. Growing them in abundance within communities where vitamin A deficiency is prevalent.
3. Preparing them in ways that maximize absorption of beta-carotene.

Chart 4–3 on page 30 lists some of the best leaf sources of vitamin A and shows the importance of choosing ones near the top of the list. It is, of course, far from comprehensive.

After choosing leaf crops with ample beta-carotene there are still several necessary measures to ensure the maximum vitamin A benefit. Typically leaves grown in hot wet weather have more beta-carotene than those grown in cool dry weather. As a rule, leaves harvested in the morning are richer in vitamin A activity than afternoon harvested leaves. Mature leaves usually have more beta-carotene than either immature or senescent (old, senile) leaves.

Post-harvest loss of vitamin A can be minimized by using the leaf as soon as possible after harvest. Refrigerating the leaf vegetables will slow their loss of vitamin A, as will keeping them in a dark place. Losses are much faster when vegetables are sliced or chopped, so wait until the last minute before cooking to cut them up.

Temperatures above 180° C (350° F), such as those used in deep frying or baking, quickly damage beta-carotene. Prolonged exposure to boiling water also destroys much of the beta-carotene. For example, canned grape leaves have only one-fifth the vitamin A activity of raw grape leaves. However, quickly steaming or stir-frying often has the opposite effect, optimizing the vitamin A value in leafy vegetables by softening and rupturing cell walls. This makes almost all the nutrients in the leaf more available. Liquefying leaves in a household blender does an even better job of liberating beta-carotene from fibrous cell walls, effectively doubling the bioavailability of the vitamin A. Chewing accomplishes some of the same cell rupture, and thoroughly chewed greens provide more vitamin A than quickly gulped ones. Absorption of beta-carotene and its conversion to retinol requires some oil. Adding a small amount of cooking oil or fat to green leaves increases the availability of beta-carotene significantly. The addition of ten percent oil or ten grams of oil for 100 grams of leafy greens is thought to be optimal. A teaspoon of oil for a half-cup serving of greens would be a reasonable guideline. This is especially important with low-income families that tend to have low consumption of oils as well as vitamin A. Adding a bit of red palm oil does double duty, improving absorption and supplying additional beta-carotene. The minerals iron and zinc are also essential to vitamin A metabolism. Assuring an adequate intake of iron and zinc is important for this as well as for other reasons.

The greatest payoffs come from combining these techniques. Start with freshly picked carotene rich greens. Steam them lightly, then blend with a bit of oil and add to soups, stews, or sauces. This unleashes the maximum potential of green leaves to prevent or reverse vitamin A deficiency.

Iron deficiency anemia and vitamin A deficiency are very often are found in the same children. Beta-carotene helps with the absorption of non-heme iron. Low iron levels inhibit the release of vitamin A stores from the liver. Low vitamin A levels inhibit the release of iron stores in the liver. In many ways it makes sense to deal with them as a single combined deficiency.[10, 11]

## FOLATE

Folate, folic acid, and folacin are functionally similar compounds sometimes referred to as vitamin B-9. Folate is the form that occurs naturally in foods while folic acid is a synthetic form used in supplements and in fortifying grain products. The term folate derives from the Latin word *folium* for leaf. This is not surprising since it was first isolated in spinach in 1941, and green leafy vegetables are among the best natural sources of the vitamin. Children and adults both need folate to make healthy red and

10 Unfortunately most of the vitamin C in the leaves is destroyed when the leaf juice is heated, so leaf concentrate (LC) contains very little of this vitamin. We can compensate for this, however, by adding lemon juice or other sources of vitamin C. Leaf concentrate lemonade is therefore an extremely useful food for women and children suffering from anemia. The French cooperative France Lucerne compensates for this by adding 60 mg of ascorbic acid per 100 g of dried alfalfa LC.

11 In a five-month-long study of children in Bolivia anemia was quickly reversed with leaf concentrate and even more quickly reversed with leaf concentrate plus vitamin C. The leaf concentrate costs about five cents per serving, or about five dollars per child for the entire twenty weeks. This study shows the value of vitamin C in improving iron absorption. The Effect of a Leaf Concentrate Supplement on Haemoglobin Levels in Malnourished Bolivian Children: A Pilot Study, by Lowe, C.A. 1991. (www.leafforlife.org/PAGES/BOLIVIR.HTM)

### GOLDEN RICE AND VITAMIN A DEFICIENCY

“Golden Rice” is a genetically engineered variety of rice that was developed in Switzerland in 2000. Genes from daffodils and a soil bacterium (*Erwinia uredovora*) give the rice the ability to produce more beta-carotene. The genetically modified rice was trumpeted by the biotechnology industry as a brilliant solution to the persistent problem of vitamin A deficiency.

The cover of the August 2009 issue of Time magazine proclaimed “This rice could save a million kids a year.” Since poor people are eating mainly rice, doesn’t it make sense to put the micronutrients they lack into their rice? Probably not.

When people become deficient in vitamin A it is usually because their diets lack the variety of naturally occurring foods necessary to ensure good health. In much of Asia, low-income families already spend over half their food budget on rice and derive over half their calories from it. This over-dependence on rice is a prime cause of malnutrition. Diversification of the agriculture and diet of cultures overly dependent on rice is necessary to provide for the sustainable health of the people and their natural environments.

The world is full of beta-carotene. In fact, it is made by all green plants to protect chlorophyll from destruction by short wavelength radiation.[1] Introducing patented seed that can’t be reproduced by farmers in order to produce a ubiquitous biological compound is unnecessary at best. To imagine that further reducing that dangerously shrunken agricultural and dietary diversity to focus on a single variety of genetically modified rice seems short-sighted. The brief history of the biotechnology industry does not warrant Time magazine’s level of confidence in Monsanto and Syngenta and their intellectual property rights perspective on the world’s food supply.

1 Carotenoids absorb some of the unusable short wavelength radiation in sunlight and re-emit it at longer wavelengths that can then be absorbed by chlorophyll and converted to usable carbohydrates. They also have several other functions in plants.

Chart 4–4
**Folate in Selected Leafy Vegetables and other foods**

| Folate | Leaf crop | Folate | Leaf crop | Folate | Leaf crop |
|---|---|---|---|---|---|
| mcg | 100 g fresh, edible portion | | | | |
| 260 | Beef liver | 101 | Cowpea leaves | 29 | Kale |
| 194 | Turnip greens | 98 | Walnuts | 29 | Lettuce (iceberg) |
| 194 | Spinach | 85 | Amaranth | 27 | Dandelion |
| 187 | Mustard greens | 80 | Sweet potato leaves | 26 | Pumpkin leaves |
| 166 | Collard greens | 71 | Broccoli leaves | 21 | Hamburger |
| 152 | Parsley | 62 | Cilantro | 18 | Red cabbage |
| 149 | Black beans | 57 | Cabbage | 16 | Winged bean leaves |
| 140 | Vine spinach | 40 | Moringa | 14 | Swiss chard |
| 136 | Lettuce (romaine) | 30 | Lambsquarters | 12 | Purslane |
| 126 | Taro leaves | 30 | Orange juice | 9 | Watercress |

white blood cells and to prevent anemia. Since folate is essential for the creation of new cells it is critically important during pregnancy and during the first years of life when there is rapid cell division and growth.

It is not entirely clear how many people are deficient in folate, but among pregnant women who are the most vulnerable to this micronutrient deficiency, the rates are high. While folate deficiency is not quite as common as that of iron, some estimates suggest that 40–50% of pregnant women may suffer from some degree of deficiency. Folate deficiency has traditionally been strongly linked to poverty, as are most nutritional deficiencies.

A shortage of folate in the first month of pregnancy has been conclusively linked to birth defects involving the neural tube. These are among the most common of birth defects, occurring in about 1 in every 1,000 births. Neural tube problems can cause the brain of a fetus to be underdeveloped, prevent the skull from closing completely, or cause the spine to be malformed. Neural tube defects usually occur in the first month of pregnancy so women need to have a good supply of folate before conception. The gravity of this problem led the US government in 1998 to require all enriched grain products to be fortified with folate in order to increase the intake for women of childbearing age. The governments of many developed countries have taken similar action.

Recent investigations have implicated folate deficiency in a number of other serious health problems as well. The focus of most of this research is the relationship between folate and homocysteine. Homocysteine is an amino acid that circulates in the blood. High homocysteine levels correlate with increased risk of cardiovascular disease, stroke, poor cognitive function, depression, colorectal, and larynx tumors, and osteoporosis. Folate breaks down homocysteine, thereby lowering blood levels. At this point there isn't conclusive proof for some of these connections, but the pile of circumstantial evidence that folate deficiency increases risk of these diseases is just too great to ignore.

In addition to poor dietary intake of folate itself, deficient intake of other B vitamins can contribute to folate deficiency. These vitamins include B-1, B-2, and B-3, which are all involved in folate recycling. Inadequate intake of protein is also a contributing factor in folate deficiency as is heavy use of alcohol, tobacco, and coffee. During pregnancy folate goes preferentially to the fetus which can quickly lead to problems for a mother whose diet is marginal in this micronutrient. Yet another contributor to folate deficiency is tropical sprue. This is a relatively common ailment, probably caused by a bacterial or viral infection that mainly affects people who live in or have recently traveled to the tropics. It attacks the lining of the intestinal walls and causes the poor absorption of several nutrients, including folate.

The US-recommended daily intake of folate for adults not pregnant or lactating is 400 mcg a day. Half an ounce could meet your requirement for one hundred years, so the term micronutrient is accurate. There are many good food sources of folate, including liver, nuts, beans, and orange juice. However, green leafy vegetables are the greatest underutilized source of this micronutrient. Chart 4–4 on page 34 lists many of the best food sources of folate from the highest down. Other than liver, which is usually too expensive for low-income families, the list is dominated by leafy vegetables. Again, the importance of choosing vegetables near the top of the chart is clear.

Folate is water soluble and somewhat sensitive to high temperatures. To get the most folate from your greens they should be eaten raw when appropriate or cooked as briefly as possible. If the greens are boiled the residual water (pot liquor) will retain much of this vitamin and can be consumed to maximize the folate value of the food.

Grapevine *(Vitis vinifera)*

## IODINE

Iodine is present only in foods grown on land with iodine in the soil and from seaweed and seafood. Although very little iodine is needed by the body, deficiencies are still relatively common. While only about one teaspoonful is needed over an average lifetime, your body cannot store it over long periods of time and so needs a regular supply. Deficiency of iodine can cause goiter, a disfiguring thyroid disorder, fetal growth deformities and mental retardation in children. The deficiency is most common in isolated highlands where most food is produced locally, far from any ocean.

There is a growing consensus among international nutritionists that iodine deficiency is best addressed with iodized salt. Fortifying salt is a relatively simple inexpensive option. Still, it is worth knowing that a small amount of seaweed or kelp meal or fish or shrimp waste added to the soil in vegetable gardens could address this problem from an agricultural perspective. Greens, such as spinach and Chinese cabbage, are good at picking up the iodine in the soil and incorporating it into food.

## ZINC

Zinc is an essential mineral that plays a key role in the immune system. Zinc is also required for dozens of enzymes and is essential to wound healing, normal growth, sexual development, and our senses of taste and smell. Children who are deficient in this mineral suffer from more frequent and severe infections, especially diarrhea. Of

course, diarrhea worsens zinc deficiency, so this is a vicious cycle that ends in premature death for many thousands of children in developing nations.

Seafood, red meat and eggs are among the best sources of dietary zinc, while nuts, beans, and peas are relatively good plant sources. Insects are one of the richest potential sources of dietary zinc. They are still utilized as a traditional food in many tropical rural areas, and there is serious interest, especially in China, in systematic breeding and raising of insects for human food.

As with iron, the bioavailability of zinc from animal-based foods is higher than from plant foods. This is largely due to the presence of phytic acid, which hinders absorption of zinc from grains and beans. Enzymes in active yeast break down phytic acid so that yeast breads are much better sources of zinc than unleavened breads. People who can't afford meats, seafood, and eggs are much more prone to zinc deficiency.

Unfortunately green leafy vegetables are generally not good sources of zinc. They can make a modest contribution to our zinc requirements if they are grown on soil with abundant zinc. Usually these are organic soils, as soil zinc that is removed with crops is rarely replaced in commercial agriculture.

## ELIMINATING HIDDEN HUNGER: FOOD OR NUTRIENTS?

Roughly two-thirds of the people in the world don't have micronutrient deficiencies. This is primarily because they eat a diet sufficiently varied to provide the full range of substances that are essential to their health. Ideally hidden hunger would be eliminated by providing malnourished people access to food sufficiently varied to provide the full range of substances that are essential to their health.

Unfortunately the captains of government, industry, and finance seem to have settled on an easier and cheaper means of meeting the basic nutritional needs of the poor. They buy the missing nutrients—mainly iron, vitamin A, vitamin D, B vitamins, iodine, and zinc—in bulk from chemical manufacturers and spike sugar, flour, salt, and oil with these nutrients. A few global chemical companies, notably Hoffman-LaRoche and BASF, are cornering the world market for micronutrients.

Fortification has certainly done a lot of good. Iodine-fortified salt has greatly diminished the incidence of goiters, and folic acid fortification of cereals has helped reduce neural tube birth defects dramatically. There are situations where fortification and supplements are the best solutions, such as in civil wars and natural disasters. It is obviously far better to give a child a vitamin A palmitate capsule than to have him go blind.

Likewise it is also obviously better to develop local systems that provide the vitamin A he needs in the food he eats, than to create an ongoing dependency on the capsules. While fortification can provide relief from the symptoms of micronutrient deficiencies, it often obscures the causes of the problem that are further upstream. This makes fundamental dietary corrections more difficult.

There are several reasons to prefer improving the patterns of eating whole foods to simply fortifying staple foods with the missing nutrients. For instance, researchers repeatedly find a correlation between a diet high in fruits and vegetables and decreased risk of cardiovascular disease and several other diseases. The relationship is much less clear for the many trials looking at single nutrients or even combinations of nutrients rather than dietary patterns. The ecological viewpoint fully accepts that the whole is greater than the sum of its parts. In nutrition this signifies that foods are more than nutrients, and diets are more than foods. There are many beneficial synergies in our complex relationship with food, that are lost in the reductionist approach of identifying a missing nutrient and supplying it as cheaply (or as profitably) as possible.

The case of zinc deficiency illustrates how different a problem might look from a reductionist perspective than from an ecological one. Zinc deficiency is becoming more common. From a reductionist outlook, many well-intentioned agencies and organizations are calling for fortifying staple foods with zinc as the fastest and cheapest—and therefore most realistic—way to keep children from dying from zinc deficiency.

From an ecological analysis, it is hard to not notice that the diet of the poor has become increasingly dominated by rice and corn, because they are cheap. They are cheap because farmers can now grow huge amounts of them, largely because of soluble fertilizers. With yields of 200 bushels of corn an acre replacing yields of 25 or 50 bushels, more soil nutrients such as zinc are removed from the soil with each harvest. Usually only nitrogen, phosphorus, and potassium are replaced. One of the results of this practice is that roughly half of the world's grain-growing land is now zinc deficient. Since grain grown on zinc deficient land has less zinc in it, this contributes to childhood zinc deficiencies. What's more, grains grown with high levels of soluble nitrogen and phosphorus fertilizers tend to have more phytates in them and phytates inhibit our body's ability to absorb zinc.

As grain lands become more deficient in micronutrients, such as zinc or boron, agricultural chemists are beginning to call for "fortifying" industrial fertilizers with the missing micronutrients. This simply echoes the strategy of "fortifying" industrial foods with the missing micronutrients. Rather than recognizing widespread and persistent deficiencies of essential substances in both our food and our soil as warning lights on the dashboard of a dysfunctional food system, they are seen as irritating problems that can best be patched as a sideline business for the chemical industry.

The ecological perspective sees diet as a pattern of eating foods, not a formulation of nutrients. If that pattern of eating foods routinely fails to supply essential nutrients, so that they need to be forever added by fortification, enrichment, or supplements, that diet needs to be revised. By the same token agricultural soil is seen as an essential part of the dietary pattern, not as an industrial substrate for producing food commodities. People stay healthy with good dietary practices, such as eating a variety of fruits and vegetables, whole grains, lean meat, beans, and nuts. Soil stays healthy with good agricultural practices that include replacing all the nutrients removed by harvest or runoff, adding organic matter, growing legumes and rotating crops.

Reductionist nutrition and agriculture are tempting short-term approaches. They get results quickly. In the long run, however, we will be best served by persisting in the struggle for social justice, local control of a diverse food supply, and ecologically sound agriculture. These three together can provide all the nourishment, including micronutrients, that the human race will need long into the future. Our growing understanding of nutrition, agriculture, and ecology and the connections among them are turning this into a struggle that we can win.