Vegetarianism and Nutrient Deficiencies

By Chris Masterjohn

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I decided to go vegetarian when I was 18 and vegan soon after, believing I would save the animals, the environment and my health. I thought that my low intake of saturated fat would protect me from heart disease and that my low intake of animal protein and high intake of soy isoflavones would protect me from tooth decay and bone loss. Instead, over the next two years my health took a series of blows: my digestion fell apart; fatigue set in; anxiety took hold; and tooth decay overran my entire mouth—a single visit to the dentist yielded a treatment plan that would take the following year to complete. I was a mess, and I didn't know why.

When I read Weston Price's *Nutrition and Physical Degeneration* about three years after first removing animal products from my diet, I finally understood why my health had fallen apart. I had always associated nutrition with fruits and vegetables. Meat was for protein; milk for calcium; but vitamins were something you got from plant products. Yet the groups that Price studied had a very different idea of nutrition. They valued foods like liver, shellfish and deeply colored butter for their life-promoting qualities. Price used cod liver oil, butter oil and organ meats to supply the fat-soluble vitamins to his patients. These were mostly foods I had never eaten, and the foods with only small amounts of important animal-based nutrients—meat, eggs, and milk—were precisely the ones I had banished from my diet.

Not all vegetarians develop overt health problems in such a short length of time from abandoning animal foods and some—especially those who eat eggs, milk, or occasional fish and shellfish—may maintain good health for decades. A strictly vegetarian diet, however, clearly lacks nutritional qualities that an omnivorous diet possesses. If the people most sensitive to deficiencies of these nutrients suffer the types of problems that I did, those who are less sensitive and not suffering obvious problems may nevertheless fail to achieve optimal health without optimal levels of nutrients from animal sources.

This article will discuss those nutrients, their functions and their sources, starting at the beginning of the alphabet with vitamin A.

VITAMIN A

The roles of vitamin A in vision, growth, immunity, reproduction and the differentiation of cells and tissues are well known.[1] Vitamin A also plays a number of lesser known functions: it is a powerful antioxidant in cell membranes,[2,3,4] protects against environmental toxins,[5] contributes to the regulation of bone growth,[6] protects against asthma and allergies,[7,8] prevents the formation of kidney stones,[9] and protects against fatty liver disease.[10]

"Fat-soluble A" originally referred to the ability of butter or egg yolks to support weight gain and prevent mortality in laboratory rats. One of the discoverers of vitamin A, Elmer Verner McCollum, initially attributed the ability of cod liver oil to treat both the eye disease xerophthalmia and the bone disease rickets to its content of this vitamin. Eventually, researchers recognized vitamins A and D as two different vitamins because heating cod liver oil destroyed its ability to cure xerophthalmia but not its ability to cure rickets. Although they would determine over time the fact that the vitamin D content of butter depends on the season and the condition of the cows producing it, the observation that both cod liver oil and butter could cure xerophthalmia but only cod liver oil could cure rickets also contributed to the differentiation of vitamins A and D.[11] Vitamin A, then, was originally discovered because of the life-promoting properties of three animal fats.

Research conducted soon after, however, showed that the yellow lipid fraction extracted from yellow-orange vegetables possessed the same activity.[12] These vegetables contain beta-carotene and other carotenoids that humans and animals can convert into retinol, the functional form of vitamin A found in animal products. In 1949, Hume and Krebs induced vitamin A deficiency in three human subjects; they treated one with retinol and treated the other two with a concentrated dose of beta-carotene dissolved in oil. They concluded that 3.8 units of carotene are required to produce one unit of retinol. A similar experiment conducted in 1974 established a conversion factor of two and several others established conversion factors between two and four.[13]

In 1967, the United Nations Food and Agriculture Organization (FAO) and World Health Organization (WHO) released a joint recommendation stipulating that six units of beta-carotene and twelve units of other carotenoids with vitamin A activity should be considered equivalent to one unit of retinol, a recommendation they renewed unchanged in 1988. This led H.P. Oomen, the prominent researcher who first highlighted the problem of vitamin A deficiency in the Third World, to write, "The whole procedure of vitamin distribution would be wholly superfluous if adequate carotene were present in the children's diet." Oomen believed that just 30 grams per day of dark green leafy vegetables would be sufficient in and of itself to provide adequate vitamin A to undernourished children.[14]

Yet in the 1990s, this view began to change. In 1994, Suharno and others observed that pregnant Indonesian women were consuming enough carotenes to yield three times the recommended amount of vitamin A based on the WHO's conversion factor, yet large numbers of them were suffering from marginal vitamin A deficiency. Subsequent intervention studies aimed at Indonesian school children and breastfeeding women in Vietnam found that the conversion factor for carotenes to vitamin A in vegetables was 26 and 28 respectively, and 12 when the carotenes were consumed in fruit. In 2002, the U.S. Institute of Medicine (IOM) established a conversion factor of 12 for beta-carotene, 24 for other carotenoids with vitamin A activity, and two for beta-carotene dissolved in oil. West and others criticized the selective use of studies employed by the IOM,

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and suggested that beta-carotene from fruits and vegetables in a mixed diet has a conversion factor closer to 21.[14]

In 2003, Tang and colleagues showed that even the efficiency of beta-carotene dissolved in oil had been grossly overestimated. The researchers gave a concentrated dose of radio-labeled beta-carotene dissolved in oil to 22 adult volunteers and traced its conversion to vitamin A both in the intestine and after intestinal absorption. The mean total conversion rate for the oil-soluble carotene in this experiment was 9.1, and individual rates varied from 2.4 to 20.2.[13]

Figure 1 compares the vegetables richest in carotenes to the animal foods richest in vitamin A. Eating liver once a week or taking a half teaspoon of high-vitamin cod liver oil per day provides the RDA of 3,000 IU. To obtain the same amount with plant foods, one would have to consume two cups of carrots, one cup of sweet potatoes, or two cups of cooked kale every day. The presumed conversion rate, however, is just an average—by definition, many people will convert carotenes more efficiently than the average and many will convert them less efficiently than the average. People who convert carotenes poorly may suffer from vitamin A deficiency even if they are careful to eat large amounts of carotene-rich foods every day.

Many traditional diets contained much more vitamin A than our government recommends. In 1953, for example, Greenland Inuit subsisting on traditional foods consumed an average of 30,000 IU per day.[15] Since researchers are still discovering new roles for vitamin A and still poorly understand many of those already discovered, it would be prudent to assume that the ten-fold increase over the RDA found in traditional diets may have some benefit—providing it is accompanied by a rich array of other fat-soluble vitamins, especially vitamin D, which protects against its toxicity.[16]

It would be virtually impossible to obtain this amount of vitamin A from plant foods without either juicing or using supplemental beta-carotene. Even these methods may be insufficient, however, since larger doses of carotenes are converted less efficiently than smaller ones.[13] Massive doses of beta-carotene, moreover, increase levels of oxidative stress and stimulate the production of enzymes that degrade true vitamin A. By inducing a cellular vitamin A deficiency, large doses of beta-carotene cause cancerous changes in lung tissue even worse than those seen from cigarette smoking. For this reason, high-dose beta-carotene supplementation led to increases in cancer mortality and total mortality in two human trials.[17] Although no studies have demonstrated this type of harm from juicing, carrot juice has the potential to raise blood levels of beta-carotene to the extremely high levels found in the aforementioned trials and large amounts of it may theoretically pose a risk.[18] By contrast, the amount of beta-carotene found in a diet rich in vegetables protects against oxidative stress and cancer.[17]

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FIGURE 1. VITAMIN A YIELD OF PLANT AND ANIMAL FOODS.

All values are derived from the USDA National Nutrient Database for Standard Release 17, except cod liver oil, which is derived from the information provided by commercial manufacturers. All values of vitamin A yield are expressed per 100 grams of food, except cod liver oil, which is expressed per teaspoon. Vitamin A yield values follow West et al. (2002) in assuming that the retinol activity equivalent (RAE) figures for vegetables overestimate the true conversion by 75 percent. These values, however, represent an average conversion factor from a mixed diet and therefore do not represent differences in bioavailability between specific foods—the carotenoids in carrots, for example, are five times more bioavailable than those in spinach.

PLANT FOODS	Vitamin A Yield IU per 100 g	ANIMAL FOODS	Vitamin A IU per 100 g
Sweet Potatoes	1,500	Turkey Giblets	35,800
Carrots	1,145	Beef Liver	25,800
Kale	1,295	High-Vitamin Cod Liver Oil (1 tsp)	5,750
Spinach	997	Commercial Eggs	570
Collard Greens	770	Commercial Butter	330

The best plant source of vitamin A is red palm oil. Its oily matrix makes its carotenes more readily converted to vitamin A and its high content of vitamin E and low content of the polyunsaturated linoleic acid further augment the convertibility of its carotenes and also protect against their potentially destructive effects. It is pure speculation, however, to suppose palm oil can be considered functionally equivalent to vitamin A-rich foods such as liver and liver oils. Vegetarians should use red palm oil, but those who are willing to include liver or liver oils in their diet would be better off for doing so.

VITAMIN D

Vitamin D is best known for its relation to calcium metabolism. By supporting the absorption of calcium from food, it prevents and cures the childhood bone disease rickets and its adult counterpart osteomalacia. It also protects against tetany, convulsions and heart failure in newborns, helps prevent osteoporosis in the elderly, prevents the development of type 1 diabetes, and is believed by some researchers to have additional roles in protecting against cancer, heart disease, high blood pressure, obesity, arthritis, multiple sclerosis and various other diseases.[19]

Vitamin D was originally associated with cod liver oil and exposure to ultraviolet light. It is found in the highest amounts in fish livers, the flesh of fatty fish, and the blood of land animals; and in smaller amounts in butter and lard from animals raised with plenty of exposure to sunshine. Skin contains a precursor to cholesterol called 7-dehydrocholesterol that converts to vitamin D upon exposure to sunlight in the UV-B range, which is available year-round in the tropics but absent during an increasing portion of the year with increasing distance from the equator.[19]

While humans and animals synthesize vitamin D_3, a second form of the vitamin called vitamin D_2 is found in some vegetarian foods, especially mushrooms that have been exposed to ultraviolet light. Although the relative safety and efficacy of the two forms is still controversial, vitamin D_2 appears to be five to ten times less effective at supporting long-term nutritional status.[19]

The RDA for vitamin D is 200 IU for infants and adults through the age of 50, 400 IU for adults between the ages of 50 and 70, and 600 IU for adults over the age of 70. Evidence strongly suggests, however, that the true requirement is far higher. Supplements of 2,000 IU per day in infants under the age of one nearly obliterate the life-long risk of type 1 diabetes while supplements of 800 IU or higher are required to reduce the risk of fracture in the elderly. Nebraskans need to supplement with 1,000 IU per day during the coldest six months of the year to achieve blood levels that maximize calcium absorption and with almost 5,000 IU per day during the same period of time to achieve blood levels similar to those achieved in sun-rich living conditions without supplementation. These amounts of vitamin D should only be consumed in the context of a diet rich in vitamin A and vitamin K_2 for maximal efficacy and safety.[19]

Figure 2 shows the distribution of vitamin D in foods. The easiest way to obtain dietary vitamin D is to eat fatty fish or supplement with high-vitamin cod liver oil. Obscure mushroom products can provide large amounts of vitamin D_2, but the safety and efficacy of this form is

FIGURE 2. VITAMIN D CONTENT OF SELECTED FOODS

These figures are obtained from Reinhold Vieth's chapter in the second edition of the textbook, *Vitamin D,* edited by Feldman and others, except cod liver oil, which is taken from information provided by commercial manufacturers, and pork or bovine blood, which is estimated based on blood concentrations expected in a sun-rich environment. All values are assumed to be vitamin D_3 unless otherwise specified.

FOOD (100 g unless otherwise specified)	Vitamin D (IU)	FOOD (100 g unless otherwise specified)	Vitamin D (IU)
Dried Woody Ear or Silver Ear Fungus	16,000 (D_2)	Grunt and Rainbow Trout	600
Anglerfish Liver	4,400	Eel	200 - 560
Summer Pork or Bovine Blood (1 cup)	4,000	Cultured Red Sea Bream	520
High-Vitamin Cod Liver Oil (1 tbsp)	3,450	Mackerel	345 - 440
Indo-Pacific Marlin	1,400	Salmon	360
Chum Salmon	1,300	Canned Sardines	270
Standard Cod Liver Oil (1 tbsp.)	1,200	Chicken Egg	120
Herring	1,100	Common Mushroom	100 (D_2)
Cultured Bastard Halibut	720	Pork Liver	50
Fatty Bluefin Tuna	720	Unfortified Summer Milk (1 liter)	40
Duck Egg	720	Beef Liver	30
Dried Shitake Mushroom	640 (D_2)	Pork	28

questionable. For most people living outside 35 degrees latitude from the equator, animal foods supply needed vitamin D in the diet.

VITAMIN K_2

Vitamin K is the king of the fat-soluble vitamins. Vitamins A and D cooperate to tell cells which proteins to make; vitamin K is responsible for activating these proteins and making them functional by conferring upon them the ability to bind calcium. In addition to its classically understood role in blood clotting, vitamin K is necessary for the deposition and organization of calcium salts in bones and teeth; the protection of blood vessels, kidneys and other soft tissues from abnormal calcification; and the synthesis of important lipids involved in brain metabolism.[20]

Vitamin K comes in two forms: K_1 and K_2. Vitamin K_1 is found in green plants, while vitamin K_2 is found in animal fats and fermented foods. Vitamin K_1 is preferentially used for the activation of blood clotting factors, while vitamin K_2 is preferentially used for all of vitamin K's other functions. The two K vitamins are therefore not interchangeable. The clearest demonstration of this is the fact that only vitamin K_2 is associated with a reduced risk of heart disease. In the Rotterdam Study, subjects consumed nearly ten times more K_1 than K_2; a high intake of K_2 reduced the risk of severe arterial calcification by 52 percent and reduced heart disease mortality by 57 percent, while a high intake of K_1 had no effect.[21]

Figure 3 shows vitamin K_2 contents of selected foods. Animal products dominate the list—especially goose liver and goose meat, cheeses and egg yolks—but natto, a strong-tasting fermented soy food common in Eastern Japan, actually has the highest amount. Natto contains a specific form of vitamin K_2 called menaquinone (MK-7), rather than MK-4, the form found in animal products; the relative efficacy of these two forms is currently unknown. It is therefore possible for a vegetarian diet to be rich in vitamin K_2. Most vegetarians do not consume natto, however, and most vitamin K_2 consumed by participants in the Rotterdam Study came from meat, eggs and cheese.

VITAMIN B_{12}

Vitamin B_{12} is required for the synthesis of new DNA, the degradation of certain amino acids, the production of energy, the formation of red blood cells and the formation of myelin, the sheath that insulates neurons. Its deficiency occurs in four stages, beginning with declining blood levels of the vitamin (stage I), progressing to low cellular concentrations of the vitamin (stage II), an increased blood level of homocysteine and a decreased rate of DNA synthesis (stage III), and finally, pernicious anemia (stage IV). Irreversible nervous system degeneration also occurs in cases of severe deficiency.[24]

Pernicious anemia is a condition in which red blood cells are immature, oversized and cannot function properly. Because DNA synthesis is compromised, the cells do not divide as they should. The disease was first identified in 1824 and was considered incurably fatal until the 1930s when physicians discovered that it could be treated with liver. Soon after, they found that stomach juice could be used in conjunction with the liver to enhance its effect.[25]

Conventional nutritional wisdom considers vitamin B_{12} as the one vitamin found exclusively in animal products. There are some bacteria in the small intestine that synthesize absorbable B_{12}, but their presence is unreliable and they face competition from bacteria that synthesize inactive analogues that compete with B_{12} for absorption.[26] Most supplements supply cyanocobalamin, in which each molecule of B_{12} is attached to a molecule of cyanide. Since vitamin B_{12} detoxifies cyanide by binding it

FIGURE 3. VITAMIN K_2 CONTENT OF SELECTED FOODS

Values taken from references 22 and 23. MK-4 is the type of vitamin K_2 synthesized by animal bodies from vitamin K_1. Whether it has special value apart from other forms of vitamin K_2 has yet to be determined.

FOOD	Vitamin K_2 (mcg/100g)	
Natto	1103.4	(0% MK-4)
Goose Liver Paste	369.0	(100% MK-4)
Hard Cheeses	76.3	(6% MK-4)
Soft Cheeses	56.5	(6.5% MK-4)
Egg Yolk (Netherlands)	32.1	(98% MK-4)
Goose Leg	31.0	(100% MK-4)
Curd Cheeses	24.8	(1.6% MK-4)
Egg Yolk (US)	15.5	(100% MK-4)
Butter	15.0	(100% MK-4)
Chicken Liver	14.1	(100% MK-4)
Salami	9.0	(100% MK-4)
Chicken Breast	8.9	(100% MK-4)
Chicken Leg	8.5	(100% MK-4)
Ground Beef (Medium Fat)	8.1	(100% MK-4)
Bacon	5.6	(100% MK-4)
Calf Liver	5.0	(100% MK-4)
Sauerkraut	4.8	(8% MK-4)
Salmon	0.5	(100% MK-4)
Mackerel	0.4	(100% MK-4)

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and causing its excretion in the urine, this form might have very poor bioavailability in many people. Cyanide can also be detoxified in the liver by the enzyme rhodanese or by the amino acid cysteine,[27] so people with a low activity of this enzyme or a low intake of animal protein to supply the cysteine might be especially unable to derive any benefit from cyanocobalamin. Thus, even vegetarians who supplement with standard B_{12} supplements could be at risk for deficiency. Those needing B_{12} supplements should take methylcobalamin, dibencozide or hydroxycobalamin, forms that are more easily utilized by the body; additionally, some people with certain genetic defects or heavy metal toxicity may require methylcobalamin sepcifically.

The role of vitamin B_{12} in DNA synthesis and red blood cell production is primarily to recycle folate. A high intake of folate, however, can compensate for insufficient folate recycling. Unfortunately, this means that a high-folate diet can forestall the development of anemia, which is easily detectable with a simple blood test, while potentially irreversible nervous system degeneration progresses without warning. Vegetarians who consume large amounts of folate-rich green leafy vegetables could therefore be at risk for a form of vitamin B_{12} deficiency that is not considered severe until it is too late.[24]

A recent study using a biochemical blood test for B_{12} deficiency—a test that is not vulnerable to the confounding effect of a high-folate diet—found that 16 percent of the elderly, 43 percent of lacto-ovo vegetarians and 64 percent of vegans are deficient in B_{12}.[28] Since deficiency can take decades to fully develop, the proportions of vegans and vegetarians who develop deficiency over time if they stick with the diet is probably close to 100 percent.

Some vegetarians and vegans maintain that these diets must be *raw* in order to be truly healthy. But raw foodists are no better off. The only large-scale study of raw foodists to date examined the B_{12} status of over 200 men and women. Although 58 percent of the subjects consumed some meat and fish and only 21 percent were lacto-ovo-vegetarian and only 21 percent were vegan, a full 97 percent of all foods consumed were plant products. Those eating a mixed diet were thus eating very little animal food. Nevertheless, vegetarians were 3.1 times as likely and vegans were 5.4 times as likely to have deficient blood levels of B_{12}. Twelve percent of the subjects, all of whom were vegans, had stage IV B_{12} deficiency.[29] Even though the average length of time the subjects had followed the raw food diet was only 3.6 years, over half the vegans were developing pernicious anemia; if many of them were eating folate-rich diets, the proportion of vegans developing irreversible nervous system degeneration might have been even higher than the proportion the study suggested were suffering from severe deficiency. Clearly, animal foods must be used if even in small amounts to prevent the worst form of B_{12} deficiency from destroying a person's mental and physical health.

FIGURE 4. VITAMIN B_2 CONTENTS OF SELECTED FOODS

Vitamin B_2 is necessary for the conversion of pyridoxine found in plant foods to pyridoxal, the active form of B_6, which is found preformed in animal foods. Data from the USDA National Nutrient Database for Standard Release 17.

FOOD	Riboflavin (mg/100g)
Baker's Yeast	5.47
Beef Liver	3.42
Chicken Liver	1.99
Pork Liver Sausage	1.53
Turkey Giblets	1.50
Chicken Giblets	1.05
Fried Shrimp	0.55
Enriched White Flour	0.51
Eggs	0.48
Roasted Duck	0.47
Clams	0.43
Pork Ribs	0.38
Veal	0.35
Boiled Mushrooms	0.30
Boiled Beet Greens	0.29
Boiled Soy Beans	0.28
Boiled Spinach	0.24
Skim Milk Yogurt	0.23
Ricotta Cheese	0.20
Milk	0.18
Salmon	0.17
Tomato Paste	0.15

VITAMIN B_6

Vitamin B_6 contributes to myriad functions within the body. It is necessary for the production of histamine, which is involved in inflammation in most of the body but is essential to alertness in the brain; the production of dopamine, which is a precursor to adrenaline and noradrenaline in the adrenals, a precursor to melanin in pigmented tissues, and is involved in memory, attention, and problem-solving in the brain; the storage of carbohydrate as glycogen; the production of the elongated versions of essential fatty acids such as arachidonic acid (AA) and docosohexaenoic acid (DHA); the synthesis of cysteine, the precursor to glutathione, which is the master antioxidant of the cell; the synthesis of glycine, which is involved in detoxification in the liver; the synthesis of heme, which carries oxygen throughout the body in hemoglobin and is a component of drug- and steroid-metabolizing, energy-producing, and antioxidant enzymes; the synthesis of carnitine, which helps burn fat for energy; and the synthesis of taurine, which plays important roles in the brain and eye and assists the digestion of fat and assimilation of fat-soluble vitamins in the intestines. The requirement for B_6 is directly proportional to the intake of protein and increases with the use of oral contraceptives and under conditions of hyperthyroidism, liver disease, trauma and stress.[24]

Vitamin B_6 occurs in three forms: pyridoxine, pyridoxamine and pyridoxal. Plant foods contain pyridoxine, while animal foods contain a mix of pyridoxal and pyridoxamine. Most reactions within the human body require pyridoxal but some require pyridoxamine. Pyridoxine, by contrast, plays no role in the body whatsoever but can be converted into the other two forms in the liver using vitamin B_2.[24]

The plant form of vitamin B_6 has three strikes against it, making it inferior to the form found in animal foods: its conversion to the active form depends on B_2 status, and vitamin B_2 levels tend to be higher in animal foods; most plant foods simply contain much less B_6 than most animal foods; and most plant foods contain much of their B_6 bound up with sugars that make it difficult or impossible to absorb. Figure 4 shows some of the foods richest in vitamin B_2. Supplementation with baker's yeast and the use of enriched white flour can boost B_2 intake, but the level found in natural plant foods is much lower compared to the levels in many animal foods. Figure 5 compares the plant foods richest

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FIGURE 5. VITAMIN B_6 CONTENT OF SELECTED FOODS

The richest animal foods tend to be about twice as rich as the richest plant foods. Although not shown in the table, the plant foods contain pyridoxine rather than pyridoxal and pyridoxamine, which must be converted to the active forms in the liver, and contain it in varying amounts bound up to sugars, making it unavailable. Data taken from the USDA National Nutrient Database for Standard Release 17.

PLANT FOODS	B_6 mcg/100g	ANIMAL FOODS	B_6 mcg/100g
Buckwheat Flour	582	Fresh Tuna (Dry Cooked)	1,038
Roasted Chestnuts	497	Beef Liver (Pan Fried)	1,027
Canned Chickpeas	473	Beef Top Sirloin (Broiled)	631
Hash Browns	472	Pork Chops (Bone In)	513
Banana (Raw)	367	Pacific Cod (Dry Cooked)	462
Whole Wheat Flour	340	Roasted Turkey	460
Sweet Red Peppers	291	Roasted Ham	449
Brussells Sprouts	289	Halibut (Dry-Cooked)	435
Spinach (Boiled)	242	Rainbow Trout (Dry-Cooked)	435
Soy Beans (Boiled)	234	Chicken Breast With Skin	430
Pinto Beans	229	Swordfish (Dry-Cooked)	381
Prune Juice	218	Haddock (Dry Cooked)	346
Carrot Juice (Canned)	217	Pacific Rockfish (Dry Cooked)	270
Tomato Paste	216	Roasted Duck	250

One striking comparison between lactating Nepalese vegetarian women and their American omnivore counterparts illustrates the low bioavailability of B_6 from plant foods.

in B_6 to the animal foods richest in the vitamin. Tuna and liver are the best sources, and, in general, animal foods contain twice as much as plant foods. Figure 6 shows the proportion of pyridoxine bound to sugars in various plant foods, which ranges from zero percent in almonds to 82 percent in cauliflower.

The sugars that bind to pyridoxine can be broken down by microbial enzymes and the mammalian intestine appears to produce a limited quantity of the enzyme as well.[30] Studies conducted with humans suggest that the sugar-bound form has at most fifty percent bioavailability and at worst, none at all. One study conducted in men with a purified form of glucose-bound pyridoxine, for example, examined the urinary output of a B_6 breakdown product and found that roughly half of the pyridoxine was absorbed. A more realistic study conducted in women using whole plant foods, however, examined not only the urinary output of breakdown products, but also the concentration of the active form in red blood cells and the activity of enzymes dependent on it. This study suggested that the portion of plant-based B_6 in the diets bound to sugars had no activity at all.[30]

Heating destroys vitamin B_6. The effect is rather mild, leading to only five percent loss in scrambled eggs, ten percent loss after heating of milk for ten minutes and 45 percent loss after heating milk for one hour.[31] The true effect on the biological activity of B_6, however, is much greater because heat-damaged B_6 can interfere with true B_6 and when fed in purified form can actually accelerate the symptoms of deficiency.[32] Cooking most animal foods leads to a 25-30 percent decrease in activity while cooking soybeans leads to a 40 percent decrease in activity.[33] Many plant foods require more extensive cooking than animal products, which could further decrease the yield of active B_6 in vegetarian diets.

One striking comparison between lactating Nepalese vegetarian women and their American omnivore counterparts illustrates the low bioavailability of B_6 from plant foods. The Nepalese women in this comparison were consuming twelve percent more B_6 but had 35 percent lower serum levels of the active form after three months of lactation and 77 percent lower levels after six months. Their breast milk had the same amount of B_6 as that of American women, but a large proportion of it was glucose-bound pyridoxine. Despite the fact that the Nepalese vegetarians were consuming more B_6 in the diet and had

FIGURE 6. PERCENTAGE OF VITAMIN B_6 IN PLANT FOODS THAT EXISTS AS PYRIDOXINE GLUCOSIDE.

Pyridoxine glucoside is the sugar-bound form that has little if any bioavailability in humans. Data taken from reference 33.

FOOD	Percent glucoside	FOOD	Percent glucoside
Cauliflower, frozen	63-82	Peanut butter	18
Carrots	51-75	Whole wheat bread	17
Orange juice, fresh	37-69	Bananas	3-16
Soy beans, cooked	57-67	Peas, frozen	15
Broccoli, frozen	65	Apricots, dried	14
Raisins	65	Rice (white), cooked	14
Green beans, canned	28-58	Whole wheat flour	11
Broccoli, raw	35-57	Green beans, raw	10
Orange juice, concentrate	47-53	Corn, frozen	6
Cabbage	46	White bread	6
Navy beans, cooked	42	Fortified wheat flakes cereal	5
Wheat bran	27-36	Cauliflower, raw	5
Spinach	35	Rice bran	4
Tomato juice	32	Filberts, raw	4
Shredded wheat cereal	28-31	Avocados, fresh	3
Dark rye bread	23	Walnuts	1
Peaches, canned	21	Almonds, raw	0

equivalent levels in their breast milk, their infants had 83 percent lower levels of the active form at four months and 87 percent lower levels at six months.[33]

Vegetarians should select plant foods that have the least amount of their pyridoxine bound up in sugar complexes. Bananas are an excellent source because the sugar-bound form is low, their total content is comparable to many meats, and they are typically eaten raw. Most plant foods are relatively poor sources, however, and B_6 intake would be much higher on a mixed diet including muscle meats, seafood and organ meats.

ZINC

Zinc is a cofactor for literally hundreds of enzymes. It is an essential structural component of all nuclear hormone receptors as well as some hormones themselves, such as insulin. It acts as an antioxidant in cell membranes by displacing pro-oxidant metals like iron and mercury and is also a cofactor for the antioxidant enzyme superoxide dismutase. A small sample of its biological functions include cell and tissue growth, cell replication, bone formation, skin integrity, immunity, digestion, glucose tolerance, maintenance of a high basal metabolic rate and taste acuity.[24]

Figure 7 shows the distribution of zinc in foods. Although present in grains, legumes, fruits and vegetables, it is found in much lower amounts compared to animal foods and is much less bioavailable. Oysters contain between four and twenty times as much zinc as beef, while beef contains two to four times as much as other meats, four times as much as eggs, ten times as much as milk and four or more times as much as virtually all plant products. Moreover, zinc absorption is inhibited by plant compounds such as phytate, oxalate, polyphenols and fiber, and enhanced by compounds present in meat. Its absorption is greater than 50 percent in the absence of inhibitors but less than 15 percent in the context of a high-phytate meal.[34] While a well planned vegetarian diet may escape overt zinc deficiency, it would be virtually impossible to maintain a truly robust zinc status without the inclusion of animal foods.

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ESSENTIAL FATTY ACIDS

The essential fatty acids as a group are a double-edged sword. On the one hand, small amounts of them are required for the synthesis of various biologically important hormones and hormone-like molecules; on the other hand, they are highly unsaturated and their multiple double-bonds are highly vulnerable to oxidation. Even fresh, non-oxidized DHA, eicosapentaenoic acid (EPA), and omega-3-rich perilla oil increase

FIGURE 7. ZINC CONTENT OF SELECTED FOODS

The zinc content of animal foods is not only much more bioavailable than that of plant foods, but also much higher. Data taken from reference 24.

FOOD	Zinc (mg/100g)
Seafood	
Oysters	17.0-91.0
Crabmeat	3.8 - 4.3
Shrimp	1.1
Tuna	0.5 - 0.8
Meat and Poultry	
Liver	3.1 - 3.9
Chicken	1.0 - 2.0
Ground Beef	3.9 - 4.1
Veal	3.1 - 3.2
Pork	1.6 - 2.1
Eggs and Dairy	
Eggs	1.1
Milk	0.4
Cheeses	2.8 - 3.2
Legumes (cooked)	
All	0.6-1.0
Grains and Cereals	
Rice and Pasta (cooked)	0.3-0.6
Whole Wheat Bread	1.0
White Bread	0.6-0.8
Vegetables	
All	0.1-0.7
Fruits	
All	<0.1

There are a number of amino acids and related compounds that are not technically essential, but are useful in the diet, possibly essential under certain conditions, and found exclusively or almost exclusively in animal products.

oxidative stress markers when fed to rats.[35]

Since it is the elongated forms of the essential fatty acids that are especially important—including AA, DHA, EPA, and dihomo-gamma-linolenic acid (DGLA)—and since the conversion of precursors in plant oils is inefficient, it makes sense to consume small amounts of these fatty acids preformed from animal foods so we can reduce the total amount of polyunsaturated fatty acids (PUFA) we need to obtain them. Moreover, some people with particularly low levels of the enzymes that make these conversions may be vulnerable to an actual deficiency of the elongated forms even while consuming plenty of pro-oxidant PUFA from plant oils.

Vegetarians have 30 percent lower levels of EPA and DHA than omnivores, while vegans have over 50 percent lower EPA and almost 60 percent lower DHA. By contrast, vegetarians have 10 percent higher levels and vegans have over twenty percent higher levels of linoleic acid, the omega-6 precursor fatty acid.[36] If this situation is characteristic of omnivores eating a standard diet high in polyunsaturated oils, we can imagine what the comparison might look like between vegans and vegetarians with a population that avoids PUFA-rich vegetable oils and consumes elongated EFA-rich liver, egg yolks, and small amounts of cod liver oil. The latter diet allows no deficiency of these fatty acids but provides a minimum of total PUFA, and therefore a minimum of oxidative stress and aging-related damage.

CONDITIONALLY ESSENTIAL AMINO ACIDS

There are a number of amino acids and related compounds that are not technically essential, but are useful in the diet, possibly essential under certain conditions, and found exclusively or almost exclusively in animal products. These include carnitine, taurine, creatine and carnosine.[37]

Carnitine shuttles fatty acids into the mitochondria, the so-called "power house of the cell," to be burned for energy, and recycles pantothenic acid, an important B vitamin. Omnivorous diets provide between two and twelve times as much carnitine from meat as the body can produce by endogenous synthesis. Moreover, its synthesis requires vitamins C, B_{12}, and B_6. Vegetarian diets tend to be rich in vitamin C but poor in these B vitamins, so synthesis could be compromised. A reduced rate of synthesis and little or no intake could lead to an impaired ability to utilize fat for energy and a lower pantothenic acid status.[37]

Taurine and glycine are both incorporated into bile acids, but those incorporating taurine are absorbable much further down in the intestines and are therefore much more effective at maximizing the absorption of fat and fat-soluble vitamins. Taurine is also involved in preventing drug-induced cardiac arrhythmia, maintaining the electrical activity of the retina and supporting the development of the brain. The developing brain contains three to four times as high a concentration of taurine as the adult brain, so taurine is particularly important for nursing infants. It is found almost exclusively in animal products and its endogenous synthesis requires vitamin B_6. The serum concentrations of vegans and infants nursing from them are lower than that of their omnivore counterparts, which may compromise the development of the nervous system.[37]

Creatine is necessary for the maintenance of the cellular energy supply, especially during bursts of physical activity, and its supplementation is therefore useful for athletic performance. The endogenous synthesis is one to two grams per day while meat provides one gram per serving, so meat-inclusive diets make a substantial contribution to total creatine status. While vegetarians may not be at risk for an actual creatine deficiency, the additional creatine from meat could be helpful in boosting physical performance.[37]

Carnosine functions as a neurotransmitter and is a powerful inhibitor of a process called glycation, whereby sugars and PUFA bind up with proteins and produce advanced glycation end products (AGEs), which are believed to contribute to the adverse effects of aging. It is found exclusively in animal products, which may be one reason why vegetarians and vegans have higher levels of AGEs than omnivores.[37,38]

CHOLESTEROL

Most people make enough cholesterol to fulfill their body's needs; cholesterol is therefore not considered an essential nutrient. There are, however, millions of people with genetic defects in cholesterol synthesis for whom dietary cholesterol is likely an essential nutrient.

Smith-Lemli-Opitz Syndrome (SLOS) is the best-understood cholesterol deficiency syndrome. It results from a genetic defect in the enzyme that converts 7-dehydrocholesterol (a common precursor of vitamin D and cholesterol) to cholesterol. Most commonly, it results in spontaneous abortion within the first sixteen weeks of gestation so it shows up in only one in 60,000 live births. Children who are born with the defect may suffer from mental retardation, autism, facial and skeletal malformations, visual dysfunctions and failure to thrive. The current treatment is dietary cholesterol.[39]

Because both parents must supply a defective copy of the gene in order for SLOS to manifest, and because most pregnancies that would result in an SLOS birth are spontaneously terminated, the number of people who carry a single copy of the defective gene is far higher than the number of people with the full-blown syndrome. One in a hundred North American Caucasians and as many as one in fifty or even one in thirty Central Europeans carry the defective gene. These people, called "SLOS carriers," have a decreased rate of cholesterol synthesis, but still synthesize enough to escape the severe risks and abnormalities that characterize clinical SLOS.[40]

One small study has examined possible mental health effects in 105 SLOS carriers. Carriers were more than three times as likely to have attempted suicide as those who do not carry the gene, and the methods of committing suicide were more violent. Unfortunately, the study was not statistically powerful enough to conclusively determine whether or not these associations were due to chance, but it was powerful enough to show a conclusive relationship between carrying the gene and having biological relatives who attempted suicide. Carriers were more than four times as likely as controls to have at least one biological relative and almost six times as likely to have a first-degree relative who attempted or committed suicide.[41]

It may be the case, then, that dietary cholesterol is an essential nutrient for one to three percent of the population. There may also be additional genetic defects or variations in cholesterol synthesis that may make dietary cholesterol essential. For these groups, animal foods are absolutely necessary.

THE ESSENTIALITY OF ANIMAL FOODS

When Weston Price traveled to the South Sea Islands of the Pacific, he hoped to find "plants or fruits which together, without the use of animal products, were capable of providing all of the requirements of the body for growth and for maintenance of good health and a high state of physical efficiency." He was disappointed. On the island of Viti Levu, he instead found inland-dwelling groups relying largely on plant products who found it so essential to consume shellfish at least once every few months that they would trade plant foods from the mountains for shellfish with coast-dwelling groups even when these groups were at war with each other.

Shellfish are especially dense in animal-based nutrients. One serving of clams per month provides the same amount of vitamin B_{12} as two servings of salmon per week. One serving of oysters per week likewise provides the same amount of zinc as a quarter pound of beef per day. People who wish to minimize their intake of animal products would do best to consume small amounts of shellfish to obtain these nutrients. For those who do not wish to eat shellfish, the requirement for animal products might be much higher.

Price's research led him to the following conclusion about vegetarianism: "As yet, I have not found a single group of primitive racial stock which was building and maintaining excellent bodies by living entirely on plant foods. I have found in many parts of the world most devout representatives of modern ethical systems advocating restriction of foods to the vegetable products. In every instance where the groups involved had been long under this teaching, I found evidence of degeneration in the form of abnormal dental arches to an extent very much higher than in the primitive groups who were not under this influence."

Thus, we can conclude from Dr Price's studies and a large body of subsequent research that animal foods should be used throughout childhood development, especially those animal foods that are richest in vitamins and minerals, such as liver, shellfish, egg yolks, bone broths, and high-quality dairy products. Depending on their individual constitutions, adults may have varying needs for animal products and those who object to the use of meat should either consume shellfish on a weekly or monthly basis, or high-quality dairy and egg products on a daily basis. Additionally, red palm oil and bananas would respectively be useful sources of carotenoids and vitamin B_6.

Many people may last a long time on a diet that does not contain optimal levels of animal products, while others like myself may develop health problems very quickly. Given all the nutrients that are so much more easily obtained from animal products, it should not be surprising that some people adopting a vegetarian or vegan diet may develop deficiencies very quickly. Each person has to pay careful attention to his or her own body and give it the nutrients it needs—and for many people this will mean giving up on the myths of vegetarianism and consuming the animal products we require by nature.

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