The Vitamins and Minerals 101 *Cliff Notes*

by Chris Masterjohn, PhD

These cliff notes represent the distillation of the most practical points from the 29 lessons on the essential vitamins, minerals, and fatty acids that make up part two out of my upcoming three-part book, *Vitamins and Minerals 101: How to Get the Nutrients You Need on Any Diet*.

Amounts listed within these cliff notes are for adults, unless otherwise stated. Targets listed here are sometimes the same as the FDA's Daily Values or the United States Recommended Dietary Allowances (RDAs), and when the RDA is used it is stated clearly here. When my target deviates from the RDA, as is often the case, it will be explained and referenced fully in the upcoming book. If the cliff notes don't make a specific recommendation for children, by default I would suggest dividing the amount stated in half and multiplying it by each 1000 Calories per day the child consumes.

Disclaimer: This resource is educational in nature and does not constitute medical or nutrition advice, nor is it a substitute for the assistance or advice of a physician or dietitian. I have a PhD in Nutritional Sciences and am not licensed as a physician or dietitian. Please consult a qualified health care practitioner before acting on any of the educational material found herein.

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Vitamin A

- Vitamin A deficiency can cause dry eyes, night blindness, poor immune function, bumpy or crusty skin, poor sleep, resistance to syncing your daily rhythms with sunlight, kidney stones, autoimmune disease, asthma, allergies, food intolerances, low sex hormones, and, when extremely severe, irreversible blindness.
- Animal foods contain retinol, the form of vitamin A we need in our bodies to prevent deficiency, while red, orange, yellow, and green vegetables contain carotenoids, known as “provitamin A,” which can be turned into retinol.
- Liver and cod liver oil are the best sources of retinol, while dairy fat, egg yolks, and to a lesser extent meats contain smaller amounts of retinol.
- Many things can hurt our ability to derive vitamin A from plant foods, including things we can change, such as too much fiber, or deficiencies of vitamin E, protein, iron, or zinc; things that we may not know are impacting us and may be difficult to change, such as toxic metals, toxic compounds our bodies produce during disease states, parasites, or hypothyroidism; and things we have no control over at all, such as genetics. As a result, while plant foods can meet the vitamin A requirement for many people, animal foods are a more reliable source of vitamin A.
- Consuming colorful plant foods with traditional fats such as butter, olive oil, palm oil, or animal fat, cooking or pureeing them, and consuming them within a meal rich in vitamin E all help to improve our ability to get vitamin A from plant foods.
- An average intake of 3000-5000 IU of vitamin A per day is best for most people. Great dietary practices to achieve this include eating 4-8 ounces of liver per week, up to three whole eggs or egg yolks per day, up to three servings of full-fat dairy per day, 3-4 cups of colorful vegetables per day, and use of grass-fed butter or sustainably harvested red palm oil as your main added fats. The liver itself will meet the requirement but the other practices should be used together if not eating liver.
- People on low-fat diets can protect themselves against inadequate vitamin A by tripling the targets in the last bullet point, and vegans would do well to use red palm oil as liberally as they can stand. In either case it makes sense to supplement if there are any signs of deficiency.
- Cod liver oil is the best natural supplement, and any supplement is safe if it provides 3000-5000 IU per day or 10,000 IU twice per week.
- If you exceed these doses, match each additional 5000 IU of vitamin A with 1700 IU of vitamin D, 5 IU of vitamin E, and 100 micrograms of vitamin K, (preferably as a blend that includes vitamin K1, MK-4, and MK-7). Work with a health care practitioner to monitor your status and make sure you steer clear of any toxicity.
- Vitamin A toxicity can cause poor bone health; birth defects; fatigue; hair loss; upset stomach, nausea, or vomiting; dry, peeling, or itchy skin; cracked lips; or headache. Keeping supplements within the limits described above unless working with a health care practitioner to frequently test vitamin A status is the best way to avoid any risk of vitamin A toxicity.

Vitamin B1 (Thiamin)

- Thiamin is the carb-burner, and doing poorly on high-carb diets might be a sign you need more thiamin.
- Thiamin is needed to build many of the building blocks of life, detoxify substances, recycle vitamin K and folate, and provide antioxidant defense, which protects our tissues from wear and tear as we age. It also supports mental and physical health through a process known as methylation.
- Thiamin deficiency can cause glucose intolerance; tingly, weak, numb, or painful hands and feet; twitching, weakness, or paralysis of the muscles around the eye; elevated heart rate or other heart trouble; difficulty controlling body movements; weakness, confusion, or apathy; in the most severe cases, amnesia, false or distorted memories, seizures, paralysis, and death.
- Get thiamin from nutritional yeast, legumes, or whole grains if you tolerate these well.
- Get it from huge volumes of vegetables and spices, if not.
- Fixing your gut might help, but we don't know exactly how.
- When all else fails, a carefully designed low-carbohydrate diet or thiamin supplements may help.
- When supplementing, using 100 milligrams multiple times a day is safe!
- We only get 1-2 milligrams from food, so expensive forms that provide, say, 10 milligrams may be perfectly effective.
- Try the cheap stuff (thiamin hydrochloride) first if you're concerned with money. Try the others (benfotiamine, TPP, TTFD) to see if you get better results. There are no convincing high-quality human trials demonstrating the superiority of any particular form of thiamin.
- You don't need to eat fat, or even food at all to absorb it. Still, you will retain and activate more if you take it with food and spread the dose across your meals.
- If you have signs of deficiency, or respond well to supplements, see if there are sources of antagonists you could clean up, like raw fish and shellfish, ferns, sulfites, or gut problems.

Vitamin B2 (Riboflavin)

- Riboflavin is the fat-burner, and doing poorly on high-fat diets may be a sign you need more riboflavin.
- Riboflavin prevents iron-deficiency anemia, provides antioxidant support, prevents cataracts, protects pregnant mothers from preeclampsia, lowers homocysteine, supports many aspects of mental and physical health through a process known as methylation, supports healthy blood pressure, and helps with energy levels and migraines.
- Severe deficiency causes red, crusty, or cracking skin at the outer edges of your lips and the corners of your mouth; red, bloody, or swollen tissues inside the mouth; red, scaly, itchy, greasy, painful, candida-infected skin around your nostrils, ears, eyelids, smile lines, and genitals; and unusual sensitivity in the hands and feet to touch, heat, or pain.
- Ideally, eat a half ounce to an ounce of liver every day, or 3-8 oz per week; eat a few foods from tier 2 (kidney, heart, and almonds) or tier 3 (red meat, cheese, eggs, salmon, mushrooms, seaweed, sesame, wheat germ and bran) every day, and minimize sugar.

- Vegans need to avoid sugar *and* fat, and emphasize the tier 2 and 3 foods available to them.
- High-fat diets, cardio, weight loss, tanning, and low-MTHFR genes require doubling or tripling down on the superfoods.
- Various disease states, alcoholism, anorexia, and thyroid and adrenal problems are all red flags.
- When foods won't cut it, supplement. Free riboflavin is best for most people (rather than riboflavin 5'-phosphate), taken with meals and spread out evenly across those meals.
- Low doses of 2-5 mg/d are best for most people, but some people require high doses (200-400 mg/d), especially for migraines (common) and genetic disorders (rare).

Vitamin B3 (Niacin)

- Niacin is especially important to your mind, gut, and skin. It is used to break things down, build them up, detoxify, recycle vitamin K and folate, provide antioxidant support, utilize neurotransmitters to allow your brain and nerve cells to communicate with one another, lengthen telomeres to allow more healthy aging, and to repair DNA. Inadequate niacin leads to accelerated aging, and increases the risk of inflammation of the esophagus, cancer of the esophagus or skin, and leukemia.
- Severe deficiency causes pellagra, which leads to the three Ds: dementia (starting as depression and in the worse cases schizophrenia), dermatitis (scaling and dark skin in response to sunlight), and diarrhea (caused by malabsorption that looks similar to celiac disease). If untreated, it causes the fourth D: death.
- Stress and injury as innocent as simple sunlight or as serious as dangerous diseases all increase niacin needs.
- 3 tbsp of unfortified nutritional yeast and 0.5-1 ounce of liver gives you all your vitamin A, thiamin, riboflavin, and niacin.
- If you don't use the superfoods, select your foods carefully based on the 5-tier distribution found in the full version of Vitamins and Minerals 101 or using a nutritional database to make sure you get at least 20 milligrams per day.
- If you use niacin to lower cholesterol, avoid snacking on carbs 3-6 hours post-dose and pair it with glycine and trimethylglycine (TMG). Nicotinic acid is the appropriate form and roughly 50 mg of glycine and 100 mg of TMG should be used for every 100 mg niacin. TMG has "glycine" in its name but is different and the dosing of each of these are independent of the other.
- If you use niacin for anti-aging, use nicotinamide riboside (NR), nicotinamide mononucleotide (NMN), or nicotinamide, and pair it with TMG. There are arguments for why NR or NMN might be best but the science on this is iffy right now. Doses between 150 mg and 2000 mg have been recommended but there is little science to support any particular dose. 100 mg TMG should be used for every 100 mg nicotinamide, and 50 mg TMG should be used for every 100 mg of NR or NMN.
- If you use multivitamins or B complexes, look for forms of nicotinamide (such as niacinamide, nicotinamide, NR, or NMN) as the ideal ingredients over forms of nicotinic acid or any form of nicotinate (including, for example, inositol hexanicotinate).

Vitamin B5 (Pantothenic Acid)

- Pantothenic acid deficiency causes fatigue, and loss of energy and enthusiasm.
- More severe deficiency causes poor mood, childish behavior, numbness or tingling in the hands and feet, insomnia, elevated heart rate in response to minor exertion, and gut problems such as abdominal cramps, gas, nausea, and vomiting.
- Acne, high cholesterol, anemia, and poor wound healing might be helped by B5.
- Shoot for 10 mg/d. The easiest way to meet this is with two heaping teaspoons of unfortified nutritional yeast. Other foods would require two or three servings, and these include organ meats, caviar, sunflower seeds, shiitake mushrooms, and grape leaves.
- Vitamin B5 occurs in food in complexes that are not found in supplements, and there are reasons to believe food B5 is superior to supplements. However, pantothenic acid, mineral salts labeled as pantothenate, and pantethine are effective for most people.
- 1000-10,000 mg/d of pantothenic acid with 4-6 daily applications of a topical cream containing 20% B5 in the form of dexpanthenol has been safely used to treat acne. 5% dexpanthenol creams improve skin quality and may accelerate wound healing. 600-1200 mg of pantethine lowers cholesterol.
- B5 has no toxicity, but large amounts can interfere with the absorption of biotin and lipoic acid. It is best to take B5 away from foods rich in these two nutrients and if taking high doses multiple times a day it is wise to supplement with 100-300 micrograms of biotin and 100 mg of R-lipoic acid taken at least 3 hours apart from the nearest dose of B5.

Vitamin B6

- B6 takes the building blocks of protein, known as amino acids, and turns them into neurotransmitters, different amino acids, or glucose; it helps break down excess amino acids and clean up the ammonia that is left over as a result; and it releases stored carbohydrate to fuel intense exercise or keep blood sugar stable. B6 also prevents anemia, lowers homocysteine and histamine, and prevents collagen from turning into oxalate, a compound that can cause kidney stones.
- Insomnia, problems with mood or mental health, and anemia are the biggest clues of needing more B6.
- High estrogen, high-protein diets, inflammation, certain drugs, and sulfites are the biggest reasons to need more.
- Men should get 3 mg B6 per 100 grams of protein in their diet, and women should get 3.5 mg B6 per 100 grams of protein.
- B6 is found as pyridoxine in plant foods and a mix of pyridoxal and pyridoxamine in animal foods. Pyridoxine is often bound to sugars within plant foods that make it poorly absorbed and utilized. In order to become functional, pyridoxine has to be converted to pyridoxal within our livers using an enzyme that depends on riboflavin. About 15% of people have genetic impairments in making this conversion, and have a higher risk of schizophrenia as a result. As with vitamin A, the B6 requirement can be met with plant foods, but animal foods are more reliable.
- Taking 4 mg as a daily target, the target could be met with 2.5 heaping teaspoons of unfortified nutritional yeast, or six 100-gram servings of many meats, fish, and organ meats.

- Bananas are a good source of B6 as they are known to have a very low amount of the sugar-bound form, but one would have to eat two pounds of them to meet the target if relying on bananas alone.
- Pyridoxal 5'-phosphate (P5P) is the best supplement. Pyridoxine hydrochloride doesn't have the problematic sugar-bound form that plants have, but it still needs to be converted to pyridoxal, and high doses of pyridoxine may actually interfere with the function of pyridoxal within our cells. Some people object to P5P on the basis that the phosphate is broken off during digestion, but the reason it is better is that it is pyridoxal rather than pyridoxine, not that it has phosphate attached.
- 500 mg per day of pyridoxine has caused neurological problems that completely reverse upon withdrawal. Using 100 mg/d as a maximal dose provides a window of safety. Some people report neurological problems precipitated by low doses, but this appears to be a rare hypersensitivity whose causes are unknown. For the vast majority of people, supplements up to 100 mg/d are safe.

Vitamin B7 (Biotin)

- Biotin is needed to burn any fuel for energy, and is especially important in burning protein for energy. It is also used to synthesize new fatty acids or make them longer, which helps lubricate and protect our skin. Biotin is needed to free up vitamin B5 to do its job, and if we lose enough biotin we will begin losing the supportive functions of B5 as well.
- While strong energy and healthy skin and hair require optimal biotin status, severe deficiency causes the following: red, scaly, candida-infected skin on the face and genitals; hair falling out, including the eyelashes and eyebrows; depression and tiredness; tingling, numbness, or a sense of something crawling on the skin; in the most severe cases it causes loss of control over body movements, hallucinations, and seizures.
- One-third of mothers become biotin-deficient during pregnancy, and this increases the risk of birth defects.
- Dialysis, digestive disorders, and alcoholism are red flags for deficiency. Egg whites are dangerous if they aren't boiled, but including the yolks makes them fine. Egg whites that are raw, or cooked by any method other than boiling, risk causing biotin deficiency when the yolks are thrown out.
- Biotin intake should be 100 micrograms per day for every 100 grams per day of protein. Egg yolks and liver are the best sources, but 100 micrograms of biotin would require almost ten eggs if relying on eggs alone. Compared to eggs, beef liver has twice as much, chicken liver has nine times as much, peanuts have 80% as much, sunflower seeds 36%, almonds and most meats about 20%, walnuts 12%, pecans and mushrooms 10%, broccoli and avocado 4%. Many foods haven't been measured.
- Vegans should seek biotin from nuts, seeds, fruits, and vegetables, but should look out for deficiency and consider a supplement.
- High doses of biotin in the range of thousands of micrograms per day have no toxicity. However, they can interfere with the absorption of B5 and lipoic acid. It is best to take biotin away from foods rich in these two nutrients and if taking high doses multiple times

a day it is wise to supplement with 10 milligrams of B5 and 100 mg of R-lipoic acid taken at least 3 hours apart from the nearest dose of biotin.
- High-dose biotin can cause incorrect readings on some labs. It is best to stop biotin supplements four days before getting lab work just to be on the safe side.

Vitamin B9 (Folate)

- By supporting a process known as methylation, folate contributes to mental flexibility (which may help with obsessive compulsive disorder and rumination, and in some people may help with anxiety and depression), clearance of histamine (which may help with anxiety, allergies, and excess stomach acid), the synthesis of creatine (supporting muscular strength among many other things), the synthesis of choline (supporting focused concentration, relaxation, muscular strength, and liver and gallbladder health), and many other aspects of mental and physical health. Folate contributes to DNA synthesis, which helps prevent anemia and birth defects.
- The folate requirement can be met with 2-3 100-gram servings of liver, legumes, or leafy greens, measured raw.
- Add one more serving for pregnancy or lactation; add one more if you always cook your plant foods; and add another if you always throw out the cooking water when you cook your plant foods.
- Don't wash veggies after cutting and don't trust frozen veggies or canned beans.
- Cutting out enriched flour can hurt folate status. The synthetic folic acid in enriched flour is not ideal, but it still contributes to your folate intake.
- Sunlight, tanning, smoking, alcohol, digestive disorders, various drugs, cancer, and rare genetic disorders hurt folate status.
- Variations in folate-related genes can make it harder to use synthetic folic acid, or lead to low production of a specific form of folate known as methylfolate. The genes affecting folic acid utilization are not well characterized. Those that hurt methylfolate production increase riboflavin requirements up to 5 mg/d and choline requirements up to 1200 mg/d, and can be helped by 2-5 g/d creatine and 3-20 g/d glycine. You can identify these genes by running a 23andMe or Ancestry raw data file through the free choline calculator listed under “tools” at chrismasterjohnphd.com.

Vitamin B12

- B12 has all the benefits of folate in methylation and the prevention of anemia AND it prevents irreversible nervous system degeneration.
- High intakes of folate can mask B12 deficiency and possibly even provoke its neurological problems.
- Just eight grams of liver, clams, oysters, and nori allow you to get a day's worth into a meal, which can slowly build a 30-year storage supply if using them multiple times a day.
- Meat, milk, cheese, chanterelle, black trumpet, and shiitake mushrooms allow you to break even when you eat 2-3 100-gram servings per day.
- Eggs aren't a good source. The non-animal sources listed above should be regarded with caution. If relying completely on them, it is good to get B12 status tested.

- Vegetarians and vegans are at high risk of deficiency and should be proactive about testing or supplementing.
- Elderly are at high risk due to poor absorption.
- High-dose supplements are safe and usually effective even in cases of poor absorption.
- Hydroxycobalamin is the preferred default supplement, and methylcobalamin can be used to tinker with the methylation system. Adenosylcobalamin probably does not survive digestion intact.
- Someone with a healthy digestive system only needs 3 micrograms per day, and doses higher than this per meal are absorbed very inefficiently. Getting 3 micrograms per meal will be absorbed very efficiently and will help build up a long-term reserve. About 15-40% of older adults have poor absorption and need 40 micrograms per day. Pernicious anemia affects 2% of older adults and can be effectively treated with 1000 micrograms per day.

Choline

- Choline supports all the methylation functions of folate and B12, and helps them focus on other tasks like preventing anemia and supporting the nervous system.
- Choline itself protects against fatty liver, and supports fat digestion, gall bladder health, muscular power, focused concentration, and relaxation.
- To support methylation, choline is first converted to betaine, also known as trimethylglycine (TMG). Betaine also occurs naturally in foods and it is found in supplements labeled as TMG. Meaningful amounts of betaine are found in far fewer foods than choline.
- Egg yolks and liver are the best choline sources; meat, fish, nuts, seeds, and beans follow. The best sources of betaine are quinoa, wheat germ and bran, lambsquarters, beets, dark rye flour, spinach, whole wheat flour, and kamut. Use my free choline database for a more detailed view of what foods provide.
- The choline requirement may vary between 550 and 1200 mg per day. The major factors are the genes discussed above in the folate section. You can identify these genes by running a 23andMe or Ancestry raw data file through the free choline calculator listed under “tools” at chrismasterjohnphd.com.
- Alpha-GPC is the best supplement for brain health, calming, and muscle strength. Alpha-GPC is 40% choline. When using it to meet the choline requirement, multiply the labeled dose by 0.4, or multiply the choline requirement you are trying to meet by 2.5.
- Trimethylglycine (TMG) is the best supplement for methylation. You do not need to adjust the dose.
- Betaine HCl is a supplement used to support digestion by increasing stomach acidity. It is 76% betaine. If using it to support digestion, multiply the dose by 0.76 to see how much betaine you are getting.
- Phosphatidylcholine is the best supplement for liver health and fat digestion. It should also be the default for replacing food because it is the main form found in food. Phosphatidylcholine is only 13% choline. When using it to meet the choline requirement, multiply the labeled dose by 0.13 or multiply the choline requirement you are trying to meet by 7.7. Lecithin has an off-taste but is easier for some people to mix tablespoons of into sauces or smoothies if they don’t want to take lots of capsules.

- Choline salts such as choline bitartrate are more likely to be converted by intestinal bacteria into a compound known as TMAO, which currently is under investigation for a possible role in heart disease. They provide no specific advantages apart from cost or convenience. While I am skeptical of the TMAO issue, until it is fully resolved I do not think it is wise to use choline supplements other than the three I listed above.
- Limit to 1200 mg/d and spread the doses out evenly across meals.

Vitamin C

- Vitamin C prevents scurvy, which causes bleeding gums, bruise-like marks that occur without any trauma, and corkscrew patterns in the hair. It can also have more serious consequences, such as a heart attack, a dysfunction in the rhythm of the heartbeat, and internal bleeding.
- Vitamin C plays many other roles. For example, it is needed to make adrenaline and the pigments of our hair and skin. It activates half of the neuropeptides, including those that govern the production of thyroid hormone, adrenal hormones, and sex hormones; some that regulate appetite and libido; oxytocin, the so-called love hormone; and antidiuretic hormone, which, among other things, is what prevents us from waking up in the middle of the night to pee. Finally, vitamin C is a critical part of our antioxidant system, which protects against chronic disease and helps us age more gracefully.
- This means that, beyond preventing scurvy, we need vitamin C for strong bones, robust immunity, resistance to illness and toxic stress, brain power, sex drive, love and affection, energy, healthy skin, and gray-resistant hair.
- Scurvy can be prevented with a consistent intake of 10 mg/d or more. At intakes only moderately below this, it can take many years to develop scurvy. After high intakes of vitamin C, it can take 6-8 months to develop scurvy on a zero-C diet, and after low intakes of C it can take only a month to develop scurvy on a zero-C diet. It is best to steer widely clear of any chance of developing scurvy, because serious consequences like a heart attack could be the first sign and appear suddenly without warning.
- 100-140 mg/d provides the blood levels associated with the lowest risk of cancer and heart disease. 250 mg/d may be needed to prevent colds in people who engage in high volumes of intense exercise or who are under extreme stress. 400 mg/d when spaced apart into two doses of 200 mg provides the highest achievable blood levels. 1000 mg/d or more can raise levels of uric acid and oxalate, which could increase the risk of gout or kidney stones in some susceptible people. Higher doses can cause diarrhea, and the amounts required to produce diarrhea differ from person to person.
- A diet rich in fresh fruits and vegetables, especially raw, provides the most. Organ meats and non-grain starches provide decent amounts. Fresh meat and fish, especially shellfish, provide a little but not enough. If you can't hit 100-140 mg/d with food, you should supplement. One or two doses per day of 100-200 mg are best.
- Water and heat destroy vitamin C, while acidity protects it. If you mix supplements with water or blend C-rich foods into a smoothie, drink them right away. A source of acid such as vinegar preserves C during cooking and the natural acids in citrus fruits help preserve vitamin C in their juice while stored in the refrigerator.
- While food sources are better than supplements because of the other food components provided in the background, vitamin C itself is ascorbic acid, and there is no evidence

that anything other than pure ascorbic acid is more effective in providing vitamin C's biological activity. Some people may find that a buffered vitamin C is better on their gut or that liposomal vitamin C is more effective at preventing colds, and there is no harm in experimenting.
- People with a history of kidney stones, hemochromatosis, or glucose 6-phosphate dehydrogenase deficiency should be careful with vitamin C supplements.

Vitamin D, Calcium, and Phosphorus

- Deficiencies of all three lead to low bone mineral content and to rickets in children or osteomalacia in adults, which causes painful, deformed bones. Deficiencies of calcium or vitamin D can lead to tetany, which involves neuromuscular dysfunction ranging from tremors to confusion and even seizures.
- Calcium protects against kidney stones within healthy dietary ranges.
- Toxicities of all three nutrients cause soft tissue calcification (such as kidney stones or calcified blood vessels).
- Toxicities of vitamin D or phosphorus cause weak, porous bones; calcium toxicity causes hard, brittle bones.
- Most of us lie in the middle, outside of deficiency or toxicity, where calcium and vitamin D are on one team and phosphorus is on the other.
- Each team needs to be balanced with the other: the more calcium you get, the less vitamin D you need; the more phosphorus you get, the more calcium or vitamin D you need.
- In this middle area, calcium and vitamin D protect against osteopenia and osteoporosis; phosphorus makes these diseases worse. These diseases involve low bone mineral content and worsen the risk of fracture.
- We also want "team calcium and vitamin D" for blood pressure, asthma, allergies, colds and flu, autoimmunity, insomnia, hormones, heart disease, and cancer.
- Our best sources of vitamin D are sunshine, pastured egg yolks, cod liver oil, certain fish, or certain mushrooms (the mushrooms contain D2, possibly less effective than D3).
- Sunshine is best mid-day, and this matters most outside of the summer and far from the equator. You get the least D from the sun when you are well-clothed and standing up; you get the most D from the sun when you are wearing minimal clothes and are lying down. The darker your skin, the more time you need in the sun, or the more you should focus on exposing more skin and lying down. You can estimate how much D your sun exposure gives you with the D Minder app.
- Most people should aim for their vitamin D status to be 30-40 ng/mL, though some people may need more. Most people can maintain this level with 1700 IU of dietary vitamin D per day, and the average person requires 900 IU/d. Testing your blood level is the best way to know how your diet, supplements, and sunshine are all working together to maintain your vitamin D status.
- If using more D than this, balance each additional 1700 IU with 3000 IU vitamin A, 5 IU vitamin E, and 100 micrograms of vitamin K, (preferably as a blend that includes vitamin K1, MK-4, and MK-7).
- The RDA for calcium is, while not without controversy, among the RDAs best supported by evidence. It is 1000 milligrams per day (mg/d) for most people over the age of 3. It

increases to 1300 for children aged 9-18 to account for increased growth, and to 1200 for women over the age of 50 and men over the age of 70. The RDA is 200 mg/d during the first six months of life, 260 during the next six, and 700 mg between the ages of 1-3.

- Calcium absorption from different foods is widely variable, with some veggies being better than milk and others being far worse. When considering absorbability, the best sources are dairy, bones, napa cabbage, Chinese mustard greens, bok choy, and high-calcium mineral water, such as Gerolsteiner and Ferrarelle. Mix and match two servings for young kids, three for most adults, or four for women over 50, men over 70, or adolescents.
- Try to meet your targets with food first, and use supplements to fill the gaps. Bone meal from a lead-tested product is the best by default. Calcium citrate is best for those who need to avoid phosphorus or collagen, or who are at high-risk of kidney stones.
- Phosphorus deficiency is mainly a risk of mostly fat diets, refeeding after starvation, anorexia, or other eating disorders that have led to a long-term decrease in food intake, or sudden treatment of a disorder causing low bone mineral content. These latter cases are called refeeding syndrome and hungry bone syndrome. Hungry bone syndrome lowers calcium levels as well as phosphorus. Meat and eggs are great for refeeding syndrome and dairy is great for hungry bone syndrome.
- Keto carnivore is at the greatest risk of phosphorus deficiency but can avoid it with enough dairy, eggs, or meat. Regular keto can use veggies too.
- We can avoid getting too much phosphorus by avoiding processed foods, which have large amounts of phosphorus additives that are not listed on the label.
- Remember that vitamin D requirements go down when you get enough calcium and go up when you get too much phosphorus. Before concluding you need more D than recommended in the lessons, check your calcium/phosphorus balance.
- Conversely, you may need less calcium than the RDA when your vitamin D status is above-average.
- Details on using blood tests to assess the balance of these three nutrients are found in Testing Nutritional Status: The Ultimate Cheat Sheet.
- Magnesium deficiency can compromise the function of calcium and vitamin D, and can cause difficulty in interpreting blood tests related to them. See the magnesium section for tips on ensuring against deficiency in order to get the best results out of this section.

Vitamin E

- Vitamin E is needed to protect our tissues from wear and tear as we age. It is especially important to our brain health and our fertility, and helps protect us from chronic, degenerative diseases like heart disease and cancer.
- The ratio of vitamin E to PUFA is more important than the absolute amount of vitamin E.
- We should seek a high ratio and avoid excess total PUFA regardless of E.
- High-PUFA whole foods are good when they supply needed nutrients but the oils should be avoided.
- Grass-fed animal products and fresh whole plant foods should be the main sources of dietary vitamin E. Cruelty-free red palm oil is the best source of additional E.
- Most people don't need a vitamin E supplement, but if you switch from high-PUFA oils to low-PUFA oils, it would be wise to supplement for about four years.

- Avoid synthetic vitamin E, also known as all-rac- or DL-alpha-tocopherol. This mixes effective vitamin E with ineffective forms that don't exist in nature. D-alpha-tocopherol is natural and acceptable. However, high doses of alpha-tocopherol can hurt the status of other forms of vitamin E such as gamma-tocopherol or the tocotrienols, which may have important benefits that are not yet well understood.
- The best default supplement is one that provides close to 15 mg or 20 IU of natural alpha-tocopherol in a background of mixed tocopherols and tocotrienols.
- Try a low-dose natural alpha-tocopherol without the other forms if the default does not give you the results you are looking for.
- There is some evidence that 145 IU of natural alpha-tocopherol helps prevent the age-related decline in immune function that otherwise occurs in older adults, while 200 IU or more may increase the risk of hemorrhagic stroke, especially when not balanced by vitamin K.
- If taking doses substantially higher than 20 IU of alpha-tocopherol, use a source that includes mixed tocopherols and tocotrienols, and balance each additional 20 IU of alpha-tocopherol with 3000 IU A, 900 IU D, and 200 micrograms of vitamin K, (preferably as a blend that includes vitamin K1, MK-4, and MK-7).
- There is no well-substantiated reason to exceed 20 IU for most people or to exceed 145 IU for those over the age of 65, except very rare genetic disorders or diseases of fat malabsorption, where doses high enough to normalize blood levels are used under the guidance of a health care practitioner.
- High-dose tocotrienols are technically a form of vitamin E but have drug-like effects that are separate from the natural nutritional functions of vitamin E. Their best use is to raise HDL-cholesterol, which requires doses of 200-600 mg/d.

Vitamin K

- Vitamin K is needed for blood clotting, and its deficiency can cause bruising or hemorrhage.
- Vitamin K is also needed to keep calcium out of blood vessels, where it can contribute to heart disease; out of kidneys, where it can cause kidney stones; out of cartilage, where it can hurt the growth of children; and to shuttle it into bones, making them healthy and strong.
- Vitamin K supports healthy blood sugar, optimal sex hormones, and exercise performance; and it protects against cancer.
- Although K supports clotting, too much vitamin K does not cause the blood to clot too much. The only people who need to worry about vitamin K increasing clotting are those who are on warfarin or other 4-hydroxycoumarins, which decrease blood clotting by causing a functional vitamin K deficiency. If you are on one of these drugs it is important to discuss any change in the K content of your diet or any vitamin K supplements you take with your doctor before making the change; your doctor may need to adjust the dose of your medication because of it.
- Vitamin K refers to a number of compounds including vitamin K1, found in unfermented plant foods, mainly in leafy greens, and vitamin K2, found in animal foods and in fermented foods regardless of whether they are of plant or animal origin. Fermented foods contain many forms of vitamin K2 labeled MK-n, where "n" can be any number

from 4 through 13. Animal foods are specifically rich in MK-4, though egg yolks and dairy fat also have some K1, and liver contains many of the other MKs.

- Supplements usually provide K1, MK-4, or MK-7.
- MK-4 has specific roles within our bodies that other forms of K cannot fulfill. When we eat vitamin K, we convert all forms to MK-4 to some degree. The ability to make this conversion is low and variable, making dietary MK-4 the most reliable source of MK-4.
- K1 and MK-7 both support blood clotting, whereas MK-4 does not support it well. K2 supports most other functions much better than K1, but MK-4 and MK-7 supplements have not been compared directly to one another to see which one is better for most of these functions.
- Consuming green vegetables can easily provide 100 micrograms per day of K1. We should aim for an additional 100-200 micrograms per day of K2, preferably as a mix that includes both MK-4 and MK-7.
- 100 mcg of K2 can be obtained from 3-4 grams of natto, 8 grams of emu oil, 9 grams of goose liver, 28 grams of free-range duck fat, 32 grams of beef liver, 45 grams of hard cheese, 2.5 egg yolks, 57 grams of dark chicken meat, 60 grams of soft cheese, 97 grams of ghee from pasture-raised cows, 110 grams of goose leg, 160 grams of butter or lard, 225 grams of chicken liver or heart, or 425 g soured whole milk, light chicken meat, and many cuts of other meats. More details can be found in the Vitamin K2 Database of The Ultimate Vitamin K2 Resource.
- Carnivores can get a lot of MK-4 from a mainly meat diet, but should include fermented foods and organ meats to diversify the forms of vitamin K. Vegans can get a lot of K1 from green plants, but should include natto to obtain K2 and should consider supplementing with MK-4.
- Patients with chronic kidney disease need at least 480 micrograms per day (which has been studied) and may need 3-4 milligrams per day (which hasn't been studied yet) of K2. This has only been studied with MK-7.
- Statins and osteoporosis drugs known as bisphosphonates hurt the conversion of other K forms to MK-4. People on these drugs should supplement with MK-4.
- Anything that causes fat malabsorption, low-fat diets, deficiencies of thiamin, niacin, and riboflavin, extreme carbohydrate restriction, and impaired glucose 6-phosphate dehydrogenase or VKOR (impaired VKOR would show up on a genetic report as "increased sensitivity to warfarin") all have the potential to hurt vitamin K status.
- Vitamin K injections are given to newborns to prevent hemorrhaging that otherwise occurs in 1 out of 10,000 babies. This is rare and can be fatal, and there is no way to completely rule it out without the injections. Nursing moms who want the best natural way to give their babies protection from hemorrhage should aim to get 400 micrograms per day of MK-7 and two milligrams per day of K1 (obtainable from several cups of green veggies), which will provide the baby with vitamin K through the breastmilk. This will protect most babies but those with rare cases of malabsorption may still be at risk without the shot.
- If supplementing with more than 500 mcg/d (excluding the natural K found in your food), balance each additional 500 mcg with 3000 IU vitamin A, 900 IU vitamin D, and 5 IU vitamin E.
- 45 milligrams per day of MK-4 is used to treat osteoporosis, but this should be seen as a drug, and the balancing of other vitamins and monitoring of vitamin status should be done under the guidance of a health care practitioner.

Essential Fatty Acids: Omega-6

- Polyunsaturated fatty acids (PUFAs), found most abundantly in oils that remain liquid even in the refrigerator, can be divided into two categories: omega-6 and omega-3.
- What is classically described as “essential fatty acid deficiency” (EFA deficiency) is a deficiency of omega-6 fatty acids.
- EFA deficiency causes dandruff; inflamed, scaly skin; hair loss; low sex drive and infertility; low sex hormones; a blunted stress response in males and an exaggerated stress response in females.
- EFA deficiency is cured by linoleic acid or arachidonic acid, both of which are omega-6 PUFAs.
- Arachidonic acid is what's needed. Linoleic acid is just a precursor.
- Arachidonic acid is also needed for stomach health, preventing food intolerances, defending against infection, resolution of chronic inflammation, and the confidence to explore the world without anxiety.
- EFA deficiency is mainly a concern for growing children, pregnant or nursing mothers, bodybuilders in a gaining phase, and those dealing with chronic diseases or recovering from disease or injury.
- One gram of linoleic acid or 133 mg arachidonic acid for every 2000 Calories are sufficient in most cases.
- Any diet of natural, whole foods will provide one gram of linoleic acid, but 133 mg arachidonic acid requires 2 egg yolks or 100 grams of liver.
- Arachidonic acid supplements are derived from the mushroom Mortierella alpina and not from animal products, but vegans with strict ethical standards should inquire with the manufacturer of any supplement they choose to see if the production methods fully meet their ethical requirements.
- Meeting the target for arachidonic acid is an insurance policy against poor conversion from linoleic acid.
- Poor conversion can be caused by genetics; diabetes; insulin resistance; inadequate protein, calories, or carbs; inadequate biotin, B6, riboflavin, calcium, or zinc; sugar; or reheated vegetable oils. Additionally, a high intake of total PUFA can reduce conversion, which means that consuming too many omega-3, described below, could hurt the conversion of omega-6.
- Activation of arachidonic acid can be hurt by non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen, natural anti-inflammatories from foods or herbs, or EPA from fish or fish oil.
- Anyone at any life stage should be concerned with activation and the solution to symptoms of deficiency that may result from poor activation is to reduce the things impairing activation.
- Adjust your approach for increasing intakes of linoleic acid or arachidonic acid, or removing factors that impair the activation of arachidonic acid, according to what helps improve anything that seems like EFA deficiency symptoms. Since all PUFAs raise the need for vitamin E yet cannot be fully protected by it, don't use more EFAs than you come across by way of seeking other vitamins and minerals from natural foods, than you need to meet the targets described above, or than you need to resolve signs and symptoms that appear to be related to deficiency.

Essential Fatty Acids: Omega-3

- The three major omega-3 fatty acids are alpha-linolenic acid (ALA, not to be confused with alpha-lipoic acid, which is also abbreviated ALA), EPA, and DHA.
- DHA is the fatty acid that must be in our tissues to prevent deficiency. When deficiency becomes very extreme, it can lead to blurry vision, numbness and pain that begins in the feet and spreads up to the hips, and brief episodes of being unable to walk. This level of deficiency has only been observed in someone fed intravenously for many months, whose sole source of fat was the omega-6-rich safflower oil.
- More moderate deficits of DHA are likely to hurt learning and memory, visual acuity, and the resolution of chronic inflammation.
- EPA is essential to fish, but does not appear to be essential to mammals. It can be converted into DHA, and at high doses it can act as an anti-inflammatory drug. High-dose EPA appears to benefit depression better than DHA, and high-dose EPA can be used to reduce triglyceride levels in the blood.
- While EPA can act as an “anti-inflammatory” by blocking the beginning of inflammation, DHA helps resolve existing inflammation. EPA can only help resolve existing inflammation when someone is taking aspirin.
- When comparing the omega-3 fatty acids to the omega-6 fatty acids, ALA is like linoleic acid, and DHA is like arachidonic acid. The main value of ALA is its conversion to DHA.
- Consuming DHA directly is an insurance policy against poor conversion.
- The factors that hurt the conversion of ALA to DHA are the exact same factors that hurt the conversion of linoleic acid to arachidonic acid described above: genetics; diabetes; insulin resistance; inadequate protein, calories, or carbs; inadequate biotin, B6, riboflavin, calcium, or zinc; sugar; or reheated vegetable oils. Additionally, a high intake of total PUFA can reduce the conversion, which means that consuming too many omega-6 could hurt the conversion of omega-3.
- DHA and EPA are rich in fish, fish oils, and fish liver oils. Small amounts of DHA are found in egg yolks when chickens eat bugs. Vegan DHA supplements are available that are derived from algae. ALA is especially rich in flax seed oil, but is also found in meaningful amounts in many other plant oils. Some plant oils, however, such as corn, cottonseed, safflower, and sunflower oils are very low in omega-3.
- Pregnant and nursing moms should aim for 2 grams per day of EPA and DHA, with an emphasis on DHA, to enrich the baby’s brain in DHA via the placenta during pregnancy and via breast milk when nursing. This will lead to long-lasting improvements in intelligence.
- Kids should be breast-fed as long as practical, and should be weaned on to a diet containing as much DHA-rich food as they're willing to eat, up to age 4.
- Most adults should be fine with 150 mg/d DHA, which can be obtained from five pasture-raised egg yolks per day or from one serving of fatty fish per week.
- In the cases of ADHD, autism, age-associated memory loss, migraines, depression, or atrial fibrillation, 2 grams of EPA and DHA may be warranted. In most cases, err on the side of getting more DHA, but with depression try getting more EPA.
- In the case of stubbornly high triglycerides, 4-5 grams per day of EPA may be warranted.
- Fish oil or cod liver oil can be used to meet these requirements. They vary in their DHA and EPA content, so check the label. Cod liver oil has the benefit of extra A and D.

- Vegans as well as those who do not eat any egg yolks, liver, or fish present a special case. Most of the talk on the internet about the omega-6-to-omega-3 ratio doesn't apply to people who are getting arachidonic acid and DHA, because the ratio mainly affects the ability to get these fatty acids from plant oils. Individuals who rely entirely on plant oils should aim for an omega-6-to-omega-3 ratio of no more than 4:1, and ideally close to 1:1. This still doesn't fix the poor conversion problem, however. It is better to hit the targets with arachidonic acid supplements from the fungus Mortierella alpina and with DHA supplements from algal oil.
- As with omega-6, since all PUFAs raise the need for vitamin E yet cannot be fully protected by it, you should never eat more omega-3 than you come across by way of seeking other vitamins and minerals from natural foods, than you need to meet the targets described above, or than you need to resolve signs and symptoms that appear to be related to deficiency.

Copper

- Copper deficiency causes anemia, low white blood cells (especially low neutrophils), osteoporosis, gray hair, loss of color in the skin, heart disease, and maybe high cholesterol and high blood sugar.
- Copper protects against allergies, histamine intolerance, insomnia, anxiety, acid reflux, brain fog, low sex drive, fatigue, poor stress-coping, overeating, hypothyroidism, waking up in the middle of the night to pee or peeing too much in general, poor motivation, easy distraction, excessive fear avoidance, and faster aging.
- Copper toxicity damages the liver, eyes, and brain, and may contribute to age-related dementia.
- Copper levels are extremely variable in foods, but using average values we can say that you can get 1 milligram of copper from any one of the following food choices: 10 grams of (g) beef liver, 12.5 g oysters (less than one oyster) or goose liver, 14 g lamb liver, 17 g dried spirulina or duck liver, 20 g shiitake mushrooms, or 25 g sesame seeds or cocoa powder. If eating chocolate, divide 25 grams by the percent chocolate you are eating to find the amount of chocolate you need to eat.
- 1 mg/d copper satisfies the requirements for most people, but breastfeeding moms should shoot for 1.3 mg/d.
- Zinc supplements can cause copper deficiency. Avoid zinc supplements over 50 mg/d unless you have a strong reason to use higher doses, and if supplementing with zinc use a zinc-to-copper ratio between 2:1 and 15:1.
- Digestive disorders, antacids, proton pump inhibitors, gastric bypass surgery, dialysis, and severe burns can all cause copper deficiency.
- Use up to 7 mg/d of any copper supplement for 2 months to correct a severe deficiency.
- As an insurance policy, try 1 mg/d of copper from MitoSynergy MitoActivator Extra Strength, if you wish to take a long-term supplement.
- If you are a woman on supplemental estrogen, keep total copper under 5 mg/d and copper supplements to a maximum of 1 mg/d.
- Filter your water if it's contaminated with copper, or find another source.
- Be cautious about copper IUDs as birth control.

Iodine

- Fatigue, brain fog, high cholesterol, low sex hormones, period problems, thinning hair and loss of eyebrows and lashes, puffiness, feeling cold (especially in the hands and feet), digestive troubles, depression or mood problems, getting sick often, and pain or discomfort in the muscles, joints, and breasts can all be signs of hypothyroidism. Most people with hypothyroidism only have some of these signs, not all of them.
- Iodine deficiency causes hypothyroidism in anyone, but during pregnancy and the first few years of life it can cause cretinism, with permanent developmental effects.
- The most reliable sources of iodine are commercial milk, iodized salt, fish, shellfish, and seaweed.
- The best natural way to get enough iodine is to use seaweed providing a daily average that meets the RDA. The RDA is 150 micrograms per day (mcg/d) for most people over the age of 14, 220 for pregnancy, and 290 for lactation. In infants, it is 100 for the first six months and 130 for the next six months. It is 90 for children up to age 8, and 120 for children 9-13 years old.
- There's a long list of goitrogenic foods (cruciferous vegetables are the ones most common in modern diets), related supplements (sulforaphane), and fluoride, chlorine, and bromine that can all interfere with iodine function.
- Restricting salt or switching from iodized salt to natural sea salt can hurt your iodine status.
- Keep crucifers moderate (1-3 servings/day), be aware that if you take sulforaphane you may need more iodine, and be mindful that altering your salt might require making up for lost iodine.
- If you feel like you might be iodine deficient, try increasing iodine from foods or supplements, or decreasing antagonists. In these cases, use up to 1000 mcg/d. Talk to your doctor before using more.
- 5,000 mcg/d may be needed for fibrocystic breast disease, under medical supervision.
- Don't go higher than 15,000 mcg/d without a strong reason, and do so only under medical supervision.
- If you have Grave's or Hashimoto's, have your doctor carefully monitor your response to any change in iodine intake. I believe that in the context of these autoimmune conditions it is best to run testing for all antioxidant-related nutrients as described in Testing Nutritional Status: The Ultimate Cheat Sheet and optimizing all these nutrients before starting any iodine supplementation.

Iron

- Feeling tired, fatigued, dizzy, or depressed, or your hair falling out, could indicate too little or too much iron.
- Iron deficiency is more likely to make your skin pale, while iron overload is more likely to make it darker or discolored.
- An irregular heart beat, muscle cramps, poor digestion, feeling cold, and hypothyroidism could all be signs of iron deficiency.
- Pain in the joints, chest, or abdomen; sexual or menstrual problems; high cholesterol; and diabetes could all indicate iron overload.

- Iron overload is mainly a genetic condition and should be treated primarily with phlebotomy or blood donation.
- In its extreme state, iron overload leads to diagnosable hemochromatosis, but many people without this condition may still suffer many of the problems listed above for iron overload.
- On average, men are more likely to get iron overload and women are more likely to get iron deficiency anemia because women lose blood through menstruation. However, men can become anemic and women can develop iron overload or even hemochromatosis.
- Menstruating women have higher needs for iron than men, and those needs increase with heavier menstrual flow, lactation, and especially pregnancy.
- Heme iron from meat and egg yolks is more absorbable and more reliably absorbed than non-heme iron from plant foods and dairy.
- Whole grains, nuts, seeds, and legumes should be soaked, sprouted, fermented, or soured to free the iron.
- Consuming plant foods with meat, vitamin C, citrus fruit, and lacto-fermented foods will help enhance iron absorption.
- The best sources of iron are organ meats; shellfish; red meat; properly prepared legumes, nuts, seeds, and whole grains; and many specific vegetables listed in the 5-tier distribution found in the full version of Vitamins and Minerals 101 or using a nutritional database.
- The best supplement to use, if needed, is iron bisglycinate. Ferrous sulfate is more common but can cause gastrointestinal side effects and alter gut bacteria in negative ways.
- Iron-saturated lactoferrin taken 100 mg before a meal twice a day can help improve iron status in women with chronic inflammation by suppressing the inflammation. This is sold in Italy as Lattoglobina. Most other lactoferrin products are not iron-saturated and may not be effective. The best way to get 200 mg of iron-saturated lactoferrin for those who do not have access to the Italian product is to take one or two scoops (20-40 grams) of whey protein.
- Keeping inflammation low and getting plenty of copper and riboflavin (and to a lesser extent other B vitamins such as B5, B6, B12, and folate) are necessary to use iron properly.
- Whenever possible, it is best to avoid treating iron overload by restricting dietary iron, because that will lead to other nutrient deficiencies.

Magnesium

- Magnesium is needed to support protein synthesis and energy use, which in turn supports EVERYTHING.
- It maintains good energy levels, relaxation, and calmness.
- It prevents twitching, spasming, muscle tension, cramping, and irregular heartbeats.
- It helps build healthy bones and teeth, and prevents soft tissue calcification.
- It helps with exercise performance, healthy sleep, asthma, pain, glutamate sensitivity, noise-induced hearing loss, depression, PMS, pregnancy complications, diabetes, and migraines.

- The RDA is 400 mg/d for adult men and 310 mg/d for adult women, with 10 mg/d added for being over the age of 30, and 40 mg/d added for being pregnant, but nothing added for nursing. For infants, it is 30 mg/d for the first six months and 75 mg/d for the next six months. For children, it increases from 80 mg/d for ages 1-3, to 130 mg/d for ages 4-8, to 240 mg/d for ages 9-13. Finally, for kids aged 14-18, it increases to 410 mg/d for boys and 360 mg/d for girls.
- There are very few studies showing benefits of magnesium intakes higher than the RDA. However, helping migraines may require 600 mg/d, lowering blood blood pressure may require 700 mg/d, and patients with chronic kidney disease may require 720 mg/d.
- The best sources are cocoa powder and chocolate, legumes, nuts and seeds, with seafood, seaweed, and cheeses coming next. Hitting the targets will require significant volumes of diverse foods. Designing your diet to hit magnesium targets would best be done using the 5-tier distribution found in the full version of Vitamins and Minerals 101 or using a nutritional database.
- Higher protein intakes and lower fiber intakes help with absorption. When obtaining magnesium from whole grains, nuts, seeds, or legumes, it will be more absorbable if these foods are prepared with soaking, sprouting, fermenting, or souring. Magnesium from mineral water is especially well absorbed.
- Carnivore, keto, high-fat, AIP, and junk food are the dietary patterns where magnesium deficiency becomes risky.
- Alcoholism, diabetes, sweating, antacids, certain prescription drugs, acute or chronic digestive problems, rare genetic disorders, and anything that increases urination can increase magnesium needs.
- If you can't meet the RDA consistently, supplement with a low dose that will help you meet it. Consider the special doses described above for migraines, blood pressure, and chronic kidney disease. If you have reasons to believe you are deficient, work up slowly from the RDA to find the dose that best seems to help.
- Magnesium in food is not known to cause any side effects, but supplemental doses higher than 350 mg/d may cause gastrointestinal effects in some people, especially softened stools or diarrhea.
- Aspartate, glycinate, gluconate, lactate, malate, and citrate are all well absorbed forms, and glycinate may have the lowest risk of gastrointestinal side effects. Avoid oxide, chloride, and sulfate. Limited research suggests magnesium threonate might be the best supplement for the nervous system.
- Take it with food and spread it out across meals to avoid the risk of loosening stools and to maximize absorption, and cut back on the dose if you do loosen your stools.
- Cut back on the dose and have your doctor measure your blood levels if you develop excessively low blood pressure, a faster or slower heart rate, twitches, or spasms.

Manganese

- Manganese protects your mitochondria's ability to burn clean energy, protects your tissues from wear and tear as you age, helps you tolerate protein, keeps your blood sugar up, protects against glutamate sensitivity, keeps your blood vessels free of plaque, keeps your joints well-oiled, makes your bones strong, and helps your wounds heal faster.

- Severe manganese deficiency causes low cholesterol, and a bubbly or scaly dermatitis.
- Manganese is likely helpful for optimizing hormones, for preventing osteoporosis, and for improving symptoms of PMS.
- We appear to need 2.5-3 milligrams per day of manganese.
- The simplest way to get enough manganese is to eat a 100-gram serving of mussels every day. Short of that, the best way is to eat at least five servings per day of whole plant foods, and to prepare whole grains, nuts, seeds, and legumes by soaking, sprouting, fermenting, or souring them.
- If you hate eating large volumes of plants, 6-10 grams per day of certain spices can rescue you, especially cloves, ginger, saffron, cardamom, turmeric, and cinnamon.
- Carnivores are vulnerable to manganese deficiency and should focus first on mussels and second on Pacific oysters and these specific fish: fresh-water bass, trout, walleye pike, burbot, drum, perch, rainbow smelt, sunfish, and sucker. Carnivores who hate or can't have seafoods should strongly consider supplementing.
- Supplements shouldn't be given to infants or taken by people with chronic liver disease or iron deficiency.
- Reasonable doses to try for manganese are anywhere from 500 micrograms per day to a maximum of 3 milligrams per day. The form does not seem to matter much, but manganese from supplements is twice as absorbable as manganese from vegetables and four times more absorbable than manganese from whole grains, nuts, seeds, and legumes.
- Industrial exposure to inhaled manganese causes neurological toxicity. There is limited and conflicting evidence that manganese-contaminated drinking water can cause lower-level toxicity leading to weak or weakly controlled body movements. Staying beneath a total of 11 mg/d from food and supplements steers clear of any toxicity risk.

Molybdenum

- Severe deficiencies of molybdenum cause fast breathing and heart rate, headache, night blindness, nausea, vomiting, blurry vision, sluggishness, disorientation, and coma.
- Genetic disorders of molybdenum metabolism cause seizures, mental retardation, widespread nervous system degeneration, and dislocation of the lenses within the eyes.
- Moderate deficiencies of molybdenum may contribute to insomnia, problems with mood, motivation, or stress-coping, sensitivities to sulfites or glutamate, chronic pain, fatigue, morning sickness in pregnancy, and deficiencies of thiamin or vitamin B6.
- The molybdenum requirement can be raised by a high intake of animal protein; a high exposure to sulfites as additives to processed foods, medications, and cosmetics; a high intake of onions, garlic, and cruciferous veggies; use of sulfur-containing nutritional supplements or medications; pregnancy, estrogen spikes during the menstrual cycle, or use of supplemental estrogen in birth control or hormone replacement therapy; or an overgrowth of sulfur-metabolizing bacteria in the gut.
- The daily requirement for molybdenum is 45-50 micrograms per day. The best sources of molybdenum are liver, legumes, and, to a lesser extent, grains. 35 grams (g) of liver per day, or 1.25 ounces, the equivalent of nine ounces per week, is sufficient on its own to meet the requirement. 8 ounces of liver per week is adequate, given that small amounts of molybdenum will be found in other foods. Without liver, meeting the target

requires using at least one thing from this list every day: 5 g lima beans, 10 g small white beans, 20 g yellow split peas, 23 g red beans, 25 g oats, 35 g green beans, 38 g black-eyed peas, 45 g pinto beans, 75 g string beans, 120 g pasta, 155 g rice, 225 g asparagus, 321 g dry cornmeal, or 500 g cheese or whole eggs.
- Diets rich in animal protein and poor in legumes are at risk of deficiency. Carnivore, paleo, keto, low-carb, and high-protein diets all fall into this category. 8 ounces of liver per week is the best insurance against deficiency.
- For molybdenum supplements, the form doesn't matter, and doses up to 2000 mcg/d are safe. Cut back if you experience joint pain. If you experience symptoms of copper deficiency, either cut back or boost your copper intake.
- Supplements containing sulfate should be taken separately from your best food sources of molybdenum and your molybdenum supplements.

Salt and Potassium

- Salt and potassium are hydrating. Rather than drinking plain water between meals, put a tiny pinch of salt and a little bit of lemon juice in your water, or have small amounts of water with food.
- Salt mainly hydrates the *outside* of your cells, while potassium mainly hydrates the *inside* of your cells.
- Without adequate potassium, salt could leave your cells dehydrated, raise your blood pressure, and increase swelling.
- Salt is extremely important to the digestive process, from releasing saliva, stomach acid, and bile acids, to directly absorbing glucose, amino acids, and many vitamins and minerals.
- Salt is involved in retaining nutrients, transporting them into cells and between tissues, and in transporting many other essential substances, such as creatine.
- Salt is important to controlling the proper level of acidity in the body as a whole and in individual tissues and compartments within cells.
- Salt and potassium allow neurons to respond to neurotransmitters or other signals, and to transmit signals to other neurons or to muscle cells.
- Salt and potassium clear neurotransmitters, preventing them from having more of an effect than intended. Lack of these minerals in the brain could contribute to glutamate sensitivity, as an example.
- Potassium activates a number of enzymes involved in energy metabolism, antioxidant defense, and repair.
- Although the evidence is weaker than it is for blood pressure, balancing salt with potassium may be important to bone health and kidney health as well.
- Our ancient hunter-gatherer ancestors lived in an environment where they naturally got more potassium than they needed while trying to get adequate calories, and where they had to work hard to get enough salt. We therefore have a tendency to crave salt but no such craving for potassium.
- Today, we live in an environment where it is easy to get salt and calories and we have to work harder to get potassium. Our cravings can easily push us towards consuming too much salt and not enough potassium.

- The National Academy of Medicine recently revised the adequate intake for potassium downward, not because of evidence that less is needed, but because of changes in the criteria used to evaluate research.
- The adequate intake (AI) for potassium is 2300 mg/d for adult women, 3400 mg/d for adult men, revised downward for children based on energy requirements and revised upward by 2-300 mg/d for pregnant and lactating women.
- The Academy established an AI for sodium of 1500 mg/d and a chronic risk reduction intake that aims to reduce sodium intakes to 2300 mg/d or below to reduce the risk of cardiovascular disease. These figures are revised downward for children according to energy requirements.
- The recommendations for sodium only apply to people who don't sweat heavily as a result of temperature or high-intensity activity, and don't take into account the need to balance sodium and potassium. People who fall into these categories may need more salt and are best off obeying their taste for salt.
- I suggest the potassium AI be considered a minimum target, and an optimal target in the range of 4700-11,000 mg/d for both sexes. This is based on the amount of potassium needed to prevent the rise in blood pressure caused in some people by salt (4700 mg/d), and the estimated intakes of our hunter-gatherer ancestors (11,000 mg/d).
- If you consume potassium within the optimal range, you should salt your food to taste and can likely eat as much salt as tastes good to you without negative effects on your health. If you consume potassium close to the minimum target, you may need to reduce your sodium intake to between 1500 and 2300 mg/d if you find that higher salt intakes raise your blood pressure. Achieving this balance may also be necessary for optimal bone and kidney health.
- Signs you need more potassium include high blood pressure, water retention and swelling, bone loss, kidney stones, fatigue, muscle weakness and cramps, bloating, constipation, and abdominal pain.
- There are three ways to get adequate potassium: 1) eat lots of fruits and vegetables, 2) eat lots of legumes and starchy tubers such as potatoes, while limiting fat and grains, and strictly avoiding refined grains and sugars; 3) eat lots of lean protein foods, while limiting fat and consuming all of the juices in sauces and stews.
- Desserts made from whole grains and completely unrefined sweeteners can be decent sources of potassium, but treats made from refined grains and sugars are poor in potassium.
- Those eating keto or low-carb high-fat need to eat large volumes of high-potassium, low-carb veggies, while carnivores need to keep fat low and consume all the juices released from their meats during cooking. I created two tools to help with diet design in these cases, Getting Potassium on Low-Carb Diets: The Database, and Getting Potassium on Carnivore Diets: The Database.
- Potassium supplements are safe for healthy people if the total intake from food and supplements is kept under 15 grams per day (with little if any need to go above 11 grams per day), spread evenly across meals, and always taken with food. Potassium citrate is the best form to take. Potassium chloride found in salt substitutes should be regarded as a way of reducing salt intake but not the ideal way to get potassium. Slow-release forms should be avoided since they can damage the lining of the stomach.
- People with diabetes, insulin resistance, impaired kidney function, or who are using ACE inhibitors, angiotensin receptor blockers, potassium-sparing diuretics, alpha- or beta-blockers, digitalis, heparin, the antimicrobial drugs Bactrim and pentamidine or

nonsteroidal anti-inflammatory drugs (NSAIDs, such as aspirin and ibuprofen) should not take potassium supplements at all unless authorized by their doctor.

- If potassium supplementation causes your heart rate to increase, skip beats or flutter, or if you experience confusion, tingling, numbness, weakness, or the feeling of something crawling on your skin, stop the supplement and tell your doctor.
- Signs you may not be getting enough sodium include low blood pressure, including orthostatic hypotension (which causes you to feel dizzy when standing up), fatigue, weakness, dizziness, diarrhea, poor mental function, poor digestion, poor absorption of nutrients, and in extreme cases headaches, nausea, vomiting, muscle cramps, disorientation, and fainting.
- Signs you may be getting too much sodium include headaches, high blood pressure, water retention, and swelling.
- Keeping potassium in the 4700-11,000 mg/d range will allow most people to consume as much salt as they like.
- It is hard to get enough salt from most natural foods, and if you don't eat any processed foods (including fermented foods, cheese, bread, and sausages) then you will need to salt your food to get enough.
- Most salt comes from processed foods, and only 5-6% comes from adding salt at the table. If you need to reduce sodium, cut out processed foods, not added salt.
- As a general rule, limit all processed foods (including fermented foods, bread, cheese, and sausages, as well as deli meats, fast foods, and packaged snacks and deserts) to 20% of the diet (you can use weight or volume, since this is a rough measure), and add salt to all of your meals, never adding more than needed to make it taste good. If you still crave salt doing this, feel free to add additional fermented foods, cheese, or high-quality salty snacks.
- If you are out of touch with your salt needs, try a "salt reset" (go to the opposite extreme of your usual habits, such as zero processed foods and added salt, or extra-salty food, for a month to help reset your taste for salt in accordance with your need).

Selenium

- Selenium creates resilience to stress. It is especially important for protecting us from viruses, and it's deficiency makes us more vulnerable to infections, toxins, and other nutrient deficiencies.
- Selenium is an important part of the antioxidant system, protects us from wear and tear as we age, is important to nearly every aspect of thyroid health, and protects against heart disease and cancer.
- Severe deficiency causes damage to the liver and heart and causes the fingernails to fall out. Streaks and white spots in the nails may be a sign of more moderate deficiency.
- Toxicity causes brittle nails with streaks and white spots that may fall out, hair loss, liver damage, and tingling in the hands and feet.
- Moderate excesses of selenium may raise the risk of diabetes and cancer.
- The difference between the maximally beneficial amount of selenium and the amount where the risk of diabetes and cancer starts increasing is small. This emphasizes the need to measure blood levels. This is all the more important because selenium status is largely driven by soil variation, and it is hard to judge our selenium intake from our food

choices alone. The optimal plasma selenium level is 90-140 ng/mL, with a sweet spot of 100-120.

- The optimal target for selenium intake from food and supplements combined is 100-120 mcg/d for most adults.
- Selenium is largely about the soil, but animal foods are more consistent than plant foods: animal foods vary 2-5-fold, while plant foods vary up to 100-fold.
- For animal foods, kidneys are the best source, can meet the target in one serving per day, and are so high that they should be limited to two servings per day. 4-8 ounces of liver per week are a useful contribution. 1-2 pounds per day of eggs, cheese, seafood, and meat can, together, meet the target.
- For plant foods, Brazil nuts are the best source, but Brazil nuts and all other plant foods are extremely variable. Unless you verify the exact selenium content of a given Brazil nut product, I recommend limiting them to two nuts per day. Diversifying several pounds of food across legumes, whole grains, nuts, and seeds offers the highest likelihood of hitting the selenium target with plants.
- If you choose to supplement, use selenomethionine. If you aren't treating a specific issue, use about 50 mcg/d or 200 mcg twice a week.
- Hashimoto's, Graves', or HIV are conditions where supplementation may be especially helpful, and while most studies have used 200 mcg/d, it would be wise to measure blood levels and use the dose that stabilizes them at 120 ng/mL if using doses higher than 50 mcg/d.
- Doctors caring for critically ill patients with systemic inflammatory response syndrome (SIRS), sepsis, or septic shock should consider intravenous use of selenium.
- Vitamin B6, methylation nutrients (especially folate, B12, and choline), protein, iodine, vitamins E and C, zinc, copper, manganese, and iron are all important to utilizing selenium effectively.
- Because the soil variation is so great, it is best to focus on keeping blood levels between 90 and 140 ng/mL, with the sweet spot being 100-120.

Zinc

- Zinc deficiency causes patches of dry skin, acne, other skin problems, and frequent infection involving sore throat and diarrhea. When it gets really bad, you may lose lean body mass. When it happens early enough in life, it could impair growth and sexual development.
- Zinc supplements decrease infection, inflammation, and oxidative stress, improve blood sugar, and reduce the incidence of age-related macular degeneration, a major cause of blindness in the elderly.
- Zinc supports the functions of vitamins A and D, thyroid hormones, sex hormones, and stress hormones, supports blood pressure and sexual function, and protects against heavy metal toxicity.
- Most people will have enough zinc if they get 12 milligrams per day.
- Oysters and red meat are the best sources of zinc. Two or three oysters, 3-4 ounces of calf's liver, or 8-12 ounces of red meat, can each meet the daily target on their own.

Lean cuts of most meats, dark cuts of poultry meat, egg yolks (but not whites), and cheese are rich in zinc.

- Meat protein and whey protein, but not cheese protein, enhance zinc absorption. Sour acids from fermented foods and fruits also enhance absorption. Phytate from whole grains, nuts, and seeds hurts absorption, as does coffee.
- Avoiding phytate-rich foods, or soaking, sprouting, or fermenting them to reduce phytate content, is important to support zinc status. However, it is also wise to consume at least one zinc-rich food per day in the context of an otherwise empty stomach or a phytate-free meal.
- Vegetarians and vegans have limited options for top-tier, low-phytate foods, and should consider supplementing if they find it hard to follow the recommendations above for managing phytate. On a phytate-rich diet, zinc needs may be at least 18 milligrams per day.
- Sugar displaces zinc in the diet. Moderating sweets and using honey (OK), molasses (decent), or maple sugar (excellent) can help.
- Fat also displaces zinc in the diet. On a high-fat diet, focus on top-tier zinc foods, such as oysters, calf's liver, and red meat.
- Chronic diarrhea, persistent vomiting, heavy metal toxicity, oxidative stress, inflammation, psychological or emotional stress, disorders that hurt digestion or cause hemolysis, chelation therapy, impaired methylation, alcoholism, diabetes, and rare genetic defects can all contribute to zinc deficiency.
- You may benefit from a supplement if you have signs of zinc deficiency, have a dietary pattern or some other risk factor associated with deficiency, or are hoping to benefit from anything it supports.
- Zinc sulfate, gluconate, acetate, and citrate are the best studied forms of zinc and work well. Zinc methionine, glycinate, and orotate appear to also work very well. Zinc carnosine is used for digestive issues but appears to nourish zinc status as well. Zinc oxide and picolinate should not be used generally speaking, although there is some evidence zinc picolinate can help with taste disorders.
- Take zinc supplements on an empty stomach with a full glass of water, or with a phytate-free meal with meat and/or fruit. The ideal dose is 7-15 mg. If you need more, take this dose multiple times a day separated by five hours. Don't take more than 50 mg/d, and make sure you are getting enough copper in your diet and supplements to maintain a zinc-to-copper ratio between 15-to-1 and 2-to-1.
- Life Extension Enhanced Zinc Lozenges can kill a cold if used correctly at the first sign. Suck, but don't chew, on one at the first sneeze or other symptom and use them continuously until the symptoms abate, then use them once every two hours until the bottle finishes or the illness is clearly gone for good.
- While high-dose zinc is best-studied as a cause of copper deficiency, there is also some evidence it can contribute to iron deficiency and there is reason to believe it may contribute to deficiencies of many other minerals. It is best, therefore, to use only what you need, and to avoid high doses if you are currently suffering from a deficiency of iron or any other mineral.

Additional Resources

The lessons these cliff notes are derived from can be taken as a once-a-day 29-day class for free by joining the Vitamins and Minerals 101 class using email or Facebook Messenger. You can get all 29 lessons immediately as downloadable PDFs, along with a dashboard where you can keep all the lessons neatly organized, search across them, and comment on them with other members, by joining Vitamins and Minerals 101 Premium, which currently is free with a pre-order of the book.

The Vitamins and Minerals 101 book will be a much more expansive resource available in paperback, Kindle, Audible, and fully referenced. The 29 lessons will form the core of part 2, while part 1 will make the case for a food-first approach and outline why many of the RDAs are inadequate, and part 3 will cover all practical aspects of diet design. The release date is not established, but I *hope* to have it ready before the end of the spring.

If you pre-order it now, you can immediately request a rebate for the $2.99 you paid for these cliff notes, making them a free gift. To do so, first place your pre-order. Then, forward *both* your email order confirmation for these cliff notes *and* your email order confirmation for the book pre-order to support@chrismasterjohnphd.com with the subject line of *both* changed to “Cliff Notes/Pre-Order Rebate Request.” My support team will then refund your $2.99 within one to two days, which may take up to 5-10 days to show up on your bank or card statement.

Testing Nutritional Status: The Ultimate Cheat Sheet is my comprehensive system for using nutrition tracking, blood and urine tests, and sign and symptom inventory to manage nutritional status. If you want to start optimizing or solving problems with lab work, this is exactly what you are looking for.

If you need help using these tools to manage your nutrition, I am available for consultations. You can book a call with me here.