Great Debates in Nutrition

David S. Ludwig, Section Editor

Children and adults should avoid consuming animal products to reduce risk for chronic disease: YES

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ABSTRACT

The consumption of animal products exposes humans to saturated fat, cholesterol, lactose, estrogens, and pathogenic microorganisms, while displacing fiber, complex carbohydrates, antioxidants, and other components needed for health. In the process, consumption of animal products increases the risk for cardiovascular disease, cancer, diabetes, obesity, and other disorders. This dietary pattern also promotes the growth of unhealthful gut bacteria, fostering, among other things, the production of trimethylamine N-oxide, a proinflammatory compound associated with cardiovascular and neurological diseases. When omnivorous individuals change to a plant-based diet, diet quality as measured by the Alternate Healthy Eating Index improves, and the risk of these health problems diminishes. Planning for nutrient adequacy is important with any diet. However, a diet based on vegetables, fruits, whole grains, and legumes, supplemented with vitamin B-12, is nutritionally superior to diets including animal products and is healthful for children and adults. *Am J Clin Nutr* 2020;112:926–930.

Keywords: vegan, vegetarian, meat, dairy, diet, chronic diseases

Main Argument (Barnard)

Hunting animals was difficult for a bipedal hominid whose slow terrestrial pace could not match that of fleeing prey. Only with the development of Stone Age technology such as arrowheads and other implements did striated muscle and organs become easily accessible. Domestication of mammals for dairy products came much later. The addition of muscle, organs, milk, and eggs to our largely herbivorous diet introduced harmful substances, while adding no nutrients that are not available in more healthful products.

Harmful constituents

Saturated fat.

Saturated fat is abundant in animal products. In 100-g servings of lean beef, Chinook salmon, and cheddar cheese, there are 3.4 g, 3.2 g, and nearly 20 g of saturated fat, compared with 0.1 g for black beans or broccoli.

Cholesterol.

The beef, salmon, and cheddar servings mentioned above deliver 83 g, 85 g, and 58 g of cholesterol, respectively. Two large eggs have 362 g. Plant-derived foods have essentially none.

Heme iron.

Roughly half of red meat's iron is heme iron. Unlike nonheme iron, whose absorption changes with iron status and meal composition, heme iron absorption rate is high and less subject to negative homeostatic feedback. Iron overload increases the risk of cardiovascular disease, Alzheimer disease, and cancer, apparently due to iron's tendency to catalyze the formation of free radicals and genotoxic and carcinogenic compounds (1, 2).

Lactose.

Milk's most abundant nutrient, lactose, causes digestive problems, fosters the growth of pathogenic gut bacteria, and liberates galactose, which is associated with ovarian dysfunction and ovarian cancer (3). In adults, lactose is a substrate for the growth of *Enterococcus* species, important causes of multidrug-resistant infections (4).

Estrogens.

Milk products contain 17b-estradiol, estrone, and estriol (5), suspected contributors to breast cancer mortality (6) and male infertility (7). In addition, the abundant fat and lack of fiber in animal products increase circulating estrogen concentrations (8).

Feces.

Fecal matter and associated pathogens are routinely present in muscle products sold at retail. Chicken products comprise a reservoir for *Escherichia coli* that cause urinary tract infections (9). Unhygienic agricultural practices transmit fecal pathogens to fruits and vegetables, which do not harbor them naturally.

The disease toll of animal products

Individuals consuming animal products have considerably higher risk of serious diseases, compared with people who avoid them.

Cancer.

Omnivores have increased risk of common cancers, apparently due to saturated fat, heme iron, carcinogens [e.g., heterocyclic amines and benzo(a)pyrene], lower intakes of fiber and protective micronutrients, and elevated circulating estrogen concentrations (10). Dairy consumption is associated with fatal prostate cancer, presumably due to increased serum insulin-like growth factor I (IGF-I) and interference with vitamin D homeostasis (11). In diagnosed prostate cancer, avoiding animal products may improve prognosis (12). In the Life After Cancer Study, women previously diagnosed with breast cancer consuming ≥1 high-fat dairy servings/d had a 49% higher breast cancer mortality, compared with those consuming <0.5 servings/d, presumably the result of dairy estrogens (6). In contrast, soy consumption is associated with reduced breast cancer incidence and mortality (13, 14).

Cardiovascular disease.

The saturated fat and cholesterol in animal products increase plasma LDL-cholesterol concentrations, a problem exacerbated by the absence of cholesterol-reducing soluble fiber (15). Meat elevates blood pressure, possibly by increasing packed cell volume and plasma viscosity, impairing arterial compliance, and by displacing potassium-rich vegetables and fruits (16, 17). Omnivorous diets foster the growth of gut bacteria that convert dietary L-carnitine, betaine, phosphatidyl choline, and choline to trimethylamine N-oxide (TMAO), a proinflammatory compound associated with cardiovascular and neurological diseases (18). In contrast, plant-based diets reduce LDL cholesterol, blood pressure, and TMAO, and are rich in antioxidants that stabilize LDL particles. In the Prevención con Dieta Mediterránea (PREDIMED) study, the more individuals followed plant-based dietary patterns, the lower their mortality risk (19). Plant-based diets are an integral part of programs to reverse atherosclerosis (20).

Alzheimer disease.

In the Chicago Health and Aging Project, individuals in the highest quintile of saturated fat intake (found mainly in dairy products and meat) had more than double the risk of developing Alzheimer disease, compared with those in the lowest quintile (21). Other studies have reached similar conclusions (22).

Overweight.

Animal products lack fiber and many have high amounts of fat, the most energy-dense macronutrient. In the Adventist Health Study-2, BMI was much higher in regular meat-eaters (in kg/m^2; 28.8), compared with vegans (23.6) (23). In randomized trials, vegan diets reliably cause weight loss, possibly due to reduced energy density and favorable effects on metabolism (24).

Diabetes.

Animal product consumption likely increases diabetes risk. Type 2 diabetes begins with insulin resistance, resulting from lipid accumulation within muscle and liver cells, which blunts insulin signaling (25). This fat comes mainly from the diet. In the Adventist Health Study-2, diabetes prevalence was 7.6% in meat-eaters, but only 2.9% in individuals avoiding animal products (23). In randomized trials, low-fat vegan diets were more effective for glycemic control in type 2 diabetes than conventional portion-controlled diets (26).

A healthful diet

Animal products are deficient in important nutrients, notably fiber, complex carbohydrates, and vitamin C. True carnivores compensate for striated muscle's deficiencies by producing their own vitamin C (which humans cannot) and expelling carcinogenic compounds from their naturally short colons. When omnivores adopt a vegan diet, diet quality, as measured by the Alternate Healthy Eating Index, improves, with increased intake of fiber, B-carotene, vitamins C and K, folate, magnesium, and potassium (27).

A healthful diet is based on vegetables, fruits, whole grains, and legumes, while avoiding oily and overly processed foods. Vegan diets easily meet recommended protein and essential fatty acid intakes (10). Iron intake is typically high among vegetarians, although absorption of nonheme iron is lower than for heme iron, which, over the long term, may be an advantage, as noted above (10). Nonetheless, iron deficiency can occur in both vegetarians and meat-eaters, highlighting the importance of planning for nutrient adequacy (28). Green leafy vegetables and legumes merit emphasis as sources of iron, as well as calcium.

Vitamin B-12 supplementation is essential with vegan diets and is also advisable for omnivores; deficiencies commonly result from aging, reduced stomach acid, medications, *Helicobacter pylori* infection, and parasitism (29). Indeed, supplemental vitamin B-12 is more readily absorbable than that in animal products.

For children, a diet of vegetables, fruits, whole grains, and legumes, supplemented with vitamin B-12, and including iodized salt or sea vegetables, readily supplies all essential nutrients, supporting healthy growth and brain development (10) and

permitting them to grow up without acquiring the omnivorous preferences that lead to premature mortality.

Humans are in the family of *Hominidae*—great apes. When we eat like carnivores, we put ourselves at risk. A return to a diet based upon the plant kingdom gives us the best chance for sustained good health.

Refutation (Leroy)

A valuable and diverse food group, and some of the components contained therein (saturated fat, cholesterol, heme iron, etc.), has been portrayed as intrinsically unnatural and harmful. Although "a return to a diet based upon the plant kingdom" may invoke a certain Eden-like purity, it is incompatible with evolutionary biology. The argument builds on unsubstantiated assumptions related to *1*) damaging effects of normal food components, *2*) extrapolations of the dietary needs of other hominids to that of humans, and *3*) unsupported causal interpretations of some selected observational studies.

Saturated fat is a normal constituent of healthy diets, found in plants and animal foods. Indeed, numerous meta-analyses and systematic reviews tend to argue against the diet–heart hypothesis, with some evidence pointing to an inverse relation with stroke and type 2 diabetes (30). Rather, plasma saturated fatty acids and palmitoleic acid, not dietary intakes, best predict disease risk. This adverse plasma fatty acid profile, in turn, results from carbohydrate overfeeding, not increased dietary fat (31). In postmenopausal women, greater intakes of saturated fat were associated with less atherosclerotic progression, whereas the opposite was found for carbohydrates (32). Similarly, a single-minded focus on lowering cholesterol to the largest possible degree overlooks physiological complexity. Instead, a shift to healthier overall patterns of lipid markers should be targeted, such as higher HDL cholesterol, lower triglycerides, and a decrease in small, dense LDL particles (31–33). Low-carbohydrate diets, typified by large proportions of animal foods, do exactly that in people with metabolic dysfunction, thereby outperforming low-fat diets (33).

Concern for iron overload is also overblown and disregards the homeostatic mechanisms controlling iron balance in healthy people (in contrast to those with metabolic dysfunction and type 2 diabetes). Moreover, high concentrations of serum ferritin are not consistently associated with increased risk of cardiovascular disease; the largest study available showed no increased risk of coronary heart disease (34).

Because of an evolutionary transition to nutrient-dense animal foods and away from fermentative capacity, humans stand apart from all apes with respect to their digestive system and dietary needs (35). While "Man the Fat Hunter" was becoming adapted to (and dependent on) animal food intake, his capability to convert large quantities of fibrous carbohydrates into short-chain fatty acids was sharply reduced (35, 36). When contrasted to such an idiosyncratic evolutionary background, veganism's restrictive approach may lead to lower nutritional robustness and suboptimal or problematic levels of various critical nutrients compared with omnivores (37).

Moreover, the argument that all nutrients can be obtained from nonanimal foods is not true, as shown by the examples of vitamins B-12, taurine, creatine, and carnosine. Some of the essential nutrients can be found as precursors in plants, but with poor conversion to their active forms (e.g., retinol and DHA). Still others display low bioavailability (e.g., iron and zinc) or lower biological value, such as protein (37). If anything, it is the contemporary consumption of large amounts of cereals and nonseasonal, year-round intake of fruits and vegetables that could be considered an aberration from the larger evolutionary perspective. Even if fiber and phytonutrients have inherent benefit on all background diets (the science is not conclusive on this point), it does not follow that animal foods should be avoided. As omnivores, humans have combined plants and animal foods in myriad ways. Omnivores that follow healthy eating patterns will have ample access to such nutrients as vitamin C, folate, magnesium, or potassium. It is precisely the elimination of an entire series of nutrient-rich foods (i.e., eggs, fish, seafood, dairy, muscle meat, organ meats) that undermines nutritional adequacy, not omnivorism.

Furthermore, the hyperbolic assertion that "omnivorous preferences … lead to premature mortality" and chronic disease is based on a partial selection of observational studies, weak associations, poor-quality data (FFQs), and potential confounding by healthy user bias (37). The quality of this evidence is low and cannot support causal claims. Indeed, in view of the protective associations with fish consumption (38), this logic would argue neatly against the premise that animal foods should be entirely avoided.

Many foods from both animal and plant origin can contain unhealthful components or lead to harmful biological effects, dependent on origin, preparation, dose, and general dietary context. Animal foods may have carcinogenic substances formed during heating (heterocyclic amines), microbial pathogens (*E. coli*), and hormones with untoward effects (estrogen). However, plant foods may have neurotoxins (acrylamide in starchy foods), microbial pathogens (*Listeria monocytogenes* in fresh produce), antinutrients (pulses), antigenic substances (gluten, for those with celiac disease), and phytoestrogens (soy). Concern for contamination extends to virtually all foods, regardless of source, including mycotoxin or heavy metal accumulation in grains and legumes. Likewise, an unhealthy gut microbiota, elevated blood pressure, and excessive weight gain relate to overall dietary quality and lifestyle, not plants versus animal foods. Although more research is needed into the biological effects of TMAO, this compound (especially abundant in some fish) may be a disease marker rather than a causative agent (39).

In conclusion, the complexities of human diets and metabolic health are much too great to allow for a binary categorization as "plants are good, animal foods are bad." This simplistic approach lacks a foundation in science and cannot meaningfully inform dietary policy. We cannot safely eliminate a major food source, consumed by *Homo sapiens* throughout evolution, and hope to correct the resulting deficiencies with supplemented nutrients.

Rebuttal (Barnard)

Interesting questions have been raised in this debate. The way to settle them is with randomized controlled trials. Our research team and others have done precisely that. In a 2005 weight-loss trial, overweight adults were randomly assigned to a low-fat vegan diet or a control diet based on National Cholesterol

Education Program Step 2 guidelines. After 14 wk, weight loss was 5.8 kg in the vegan group, compared with 3.8 kg in the control group (40). The between-group weight difference persisted after a 2-y follow-up. The weight-loss effects of vegan diets are clinically important and were summarized in a 2015 meta-analysis (24).

For type 2 diabetes, a study funded by the NIH compared a low-fat vegan diet with a conventional portion-controlled diet. Among participants who kept medications unchanged, the reduction in glycated hemoglobin was 3-fold greater in the vegan group (1.2 absolute percentage points in the vegan group, compared with 0.4 in the portion-control group) (41). The effects of plant-based diets on glycemic control (42), blood pressure (17), and plasma lipids (43) have been summarized in meta-analyses and are predictable, consistent, and clinically important.

There is no longer any question that avoiding animal products is a healthful choice. It has been demonstrated, not only in observational studies but in a robust body of randomized trials. It is not the result of confounding.

Regarding diet quality, none of Dr. Leroy's predictions have come to pass. Clinical trials do not show that adopting a vegan diet leads to deficiencies. The reverse is true; a diet emphasizing plant-based foods helps rectify the deficits of fiber, potassium, and various vitamins that often occur with omnivorous diets. The purpose of dietary guidance, which is the topic of this debate, is to provide basic instruction to individuals seeking to protect their health, including simple planning steps for complete nutrition. Insisting that the individuals retain carnivorous habits does nothing to prevent deficiencies; it aggravates them and increases health risks.

There are, of course, other eating styles that improve one or another health measure. Mediterranean diets modestly reduce cardiovascular risk (and those whose Mediterranean patterns are most plant-based have the least cardiovascular risk) but do little for weight problems. Ketogenic diets can temporarily reduce body weight but frequently worsen LDL cholesterol. Avoiding animal products is the surest way to simultaneously improve body weight, glycemia, LDL cholesterol, and blood pressure.

Because ingestion of striated muscle, animal milk, and eggs increases LDL cholesterol, Dr. Leroy suggests taking comfort in the rise in HDL cholesterol sometimes observed with carnivorous diets. However, the idea that increasing HDL cholesterol reduces cardiovascular risk has been set aside. In a meta-analysis of 108 studies, treatment-induced HDL-cholesterol elevations did not reduce the risk of coronary heart disease events, coronary disease mortality, or total mortality (44).

The arrival of Covid-19 should be a reminder of the long list of infectious and noninfectious diseases caused by the ingestion of animal products and the commercial practices that support it. Curbing the desire to ingest muscle, milk, and eggs is a healthful choice.

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References

1. Bastide NM, Pierre FH, Corpet DE. Heme iron from meat and risk of colorectal cancer: a meta-analysis and a review of the mechanisms involved. Cancer Prev Res 2011;4(2);177–84.
2. Ayton S, Wang Y, Diouf I, Schneider JA, Brockman J, Morris MC, Bush AI. Brain iron is associated with accelerated cognitive decline in people with Alzheimer pathology. Mol Psychiatry. Published online February 18, 2019. doi: 10.1038/s41380-019-0375-7.
3. Larsson SC, Orsini N, Wolk A. Milk, milk products and lactose intake and ovarian cancer risk: a meta-analysis of epidemiological studies. Int J Cancer 2006;118(2):431–41.
4. Stein-Thoeringer CK, Nichols KB, Lazrak A, Docampo MD, Slingerland AE, Slingerland JB, Clurman AG, Armijo G, Gomes ALC, Shono Y, et al. Lactose drives Enterococcus expansion to promote graft-versus-host disease. Science 2019;366:1143–9.
5. Farlow DW, Xu X, Veenstra TD. Quantitative measurement of endogenous estrogen metabolites, risk-factors for development of breast cancer, in commercial milk products by LC-MS/MS. J Chromatogr B 2009;877:1327–34.
6. Kroenke CH, Kwan ML, Sweeney C, Castillo A, Caan BJ. High- and low-fat dairy intake, recurrence, and mortality after breast cancer diagnosis. J Natl Cancer Inst 2013;105:616–23.
7. Afeiche MC, Bridges ND, Williams PL, Gaskins AJ, Tanrikut C, Petrozza JC, Hauser R, Chavarro JE. Dairy intake and semen quality among men attending a fertility clinic. Fertil Steril 2014;101(5):1280–7.
8. Rock CL, Flatt SW, Thomson CA, Stefanick ML, Newman VA, Jones LA, Natarajan L, Ritenbaugh C, Hollenbach KA, Pierce JP, et al. Effects of a high-fiber, low-fat diet intervention on serum concentrations of reproductive steroid hormones in women with a history of breast cancer. J Clin Oncol 2004;12:2379–87.
9. Bergeron CR, Prussing C, Boerlin P, Daignault D, Dutil L, Reid-Smith RJ, Zhanel GG, Manges AR. Chicken as reservoir for extraintestinal pathogenic Escherichia coli in humans, Canada. Emerg Infect Dis 2012;18:415–21.
10. Melina V, Craig W, Levin S. Position of the Academy of Nutrition and Dietetics: vegetarian diets. J Acad Nutr Diet 2016;116:1970–80.
11. Lu W, Chen H, Niu Y, Wu H, Xia D, Wu Y. Dairy products intake and cancer mortality risk: a meta-analysis of 11 population-based cohort studies. Nutr J 2016;15:91.
12. Ornish D, Weidner G, Fair WR, Marlin R, Pettengill EB, Raisin CJ, Dunn-Emke S, Crutchfield L, Jacobs FN, Barnard RJ, et al. Intensive lifestyle changes may affect the progression of prostate cancer. J Urol 2005;174:1065–70.
13. Wu AH, Yu MC, Tseng CC, Pike MC. Epidemiology of soy exposures and breast cancer risk. Br J Cancer 2008;98:9–14.
14. Chi F, Wu R, Zeng YC, Xing R, Liu Y, Xu ZG. Post-diagnosis soy food intake and breast cancer survival: a meta-analysis of cohort studies. Asian Pac J Cancer Prev 2013;14:2407–12.
15. Food and Nutrition Board, Institute of Medicine. Dietary Reference Intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Washington (DC): National Academies Press; 2002/2005.
16. Ernst E, Pietsch L, Matrai A, Eisenberg J. Blood rheology in vegetarians. Br J Nutr 1986;56:555–60.
17. Yokoyama Y, Nishimura K, Barnard ND, Takegami M, Watanabe M, Sekikawa A, Okamura T, Miyamoto Y. Vegetarian diets and blood pressure: a meta-analysis. JAMA Intern Med 2014;174:577–87.
18. Koeth RA, Wang Z, Levison BS, Buffa JA, Org E, Sheehy BT, Britt EB, Fu X, Wu Y, Li L, et al. Intestinal microbiota metabolism of L-carnitine, a nutrient in red meat, promotes atherosclerosis. Nat Med 2013;19:576–85.
19. Martinez-Gonzalez MA, Sanchez-Tainta A, Corella D, Salas-Salvadó J, Ros E, Arós F, Gómez-Gracia E, Fiol M, Lamuela-Raventós RM,

Schröder H, et al. A provegetarian food pattern and reduction in total mortality in the Prevención con Dieta Mediterránea (PREDIMED) study. Am J Clin Nutr 2014;100(Suppl):320S–8S.

20. Ornish D, Scherwitz L, Billings J, Brown SE, Gould KL, Merritt TA, Sparler S, Armstrong WT, Ports TA, Kirkeeide RL, et al. Intensive lifestyle changes for reversal of coronary heart disease: five-year follow-up of the Lifestyle Heart Trial. JAMA 1998;280:2001–7.

21. Morris MC, Evans EA, Bienias JL, Tangney CC, Bennett DA, Aggarwal N, Schneider J, Wilson RS. Dietary fats and the risk of incident Alzheimer's disease. Arch Neurol 2003;60:194–200.

22. Giem P. The incidence of dementia and intake of animal products: preliminary findings from the Adventist Health Study. Neuroepidemiology 1993;12:28–36.

23. Tonstad S, Butler T, Yan R, Fraser GE. Type of vegetarian diet, body weight, and prevalence of type 2 diabetes. Diabetes Care 2009;32:791–6.

24. Barnard ND, Levin SM, Yokoyama Y. A systematic review and meta-analysis of changes in body weight in clinical trials of vegetarian diets. J Acad Nutr Diet 2015;115:954–69.

25. Petersen KF, Dufour S, Befroy D, Garcia R, Shulman GI. Impaired mitochondrial activity in the insulin-resistant offspring of patients with type 2 diabetes. N Engl J Med 2004;350:664–71.

26. Barnard ND, Cohen J, Jenkins DJ, Turner-McGrievy G, Gloede L, Green A, Ferdowsian H. A low-fat vegan diet and a conventional diabetes diet in the treatment of type 2 diabetes: a randomized, controlled, 74-week clinical trial. Am J Clin Nutr 2009;89(suppl):1588S–96S.

27. Turner-McGrievy GM, Barnard ND, Cohen J, Jenkins DJA, Gloede L, Green AA. Changes in nutrient intake and dietary quality among participants with type 2 diabetes following a low-fat vegan diet or a conventional diabetes diet for 22 weeks. J Am Diet Assoc 2008;108:1636–45.

28. Gibson RS, Heath AL, Szymlek-Gay EA. Is iron and zinc nutrition a concern for vegetarian infants and young children in industrialized countries? Am J Clin Nutr 2014;100(Suppl):459S–68S.

29. Allen LH. How common is vitamin B12 deficiency? Am J Clin Nutr 2009;89:693S–6.

30. Gershuni VM. Saturated fat: part of a healthy diet. Curr Nutr Rep 2018;7:85–96.

31. Volk BM, Kunces LJ, Freidenreich DJ, Kupchak BR, Saenz C, Artistizabal JC, Fernandez ML, Bruno RS, Maresh CM, Kraemer WJ, et al. Effects of step-wise increases in dietary carbohydrate on circulating saturated fatty acids and palmitoleic acid in adults with metabolic syndrome. PLoS One 2014;9:e113605.

32. Mozaffarian D, Rimm EB, Herrington DM. Dietary fats, carbohydrate, and progression of coronary atherosclerosis in postmenopausal women. Am J Clin Nutr 2004;80:1175–84.

33. Volek JS, Fernandez ML, Feinman RD, Phinney SD. Dietary carbohydrate restriction induces a unique metabolic state positively affecting atherogenic dyslipidemia, fatty acid partitioning, and metabolic syndrome. Prog Lipid Res 2008;47:307–18.

34. Reyes C, Pons NA, Reñones CR, Gallisà JB, Val VA, Tebé C, Mateo GF. Association between serum ferritin and acute coronary heart disease: a population-based cohort study. Atherosclerosis 2020;293:69–74.

35. Milton K. The critical role played by animal source foods in human (Homo) evolution. J Nutr 2003;133:3886S–92S.

36. Ben-Dor M, Gopher A, Hershkovitz I, Barkai R. Man the Fat Hunter: the demise of Homo erectus and the emergence of a new hominin lineage in the Middle Pleistocene (ca. 400 kyr) Levant. PLoS One 2011;6:e28689.

37. Leroy F, Cofnas N. Should dietary guidelines recommend low red meat intake? Crit Rev Food Sci Nutr. Published online September 5, 2019. doi: 10.1080/10408398.2019.1657063.

38. Zhao L-G, Sun J-W, Yang Y, Ma X, Wang Y-Y, Xiang Y-B. Fish consumption and all-cause mortality: a meta-analysis of cohort studies. Eur J Clin Nutr 2016;70:155–61.

39. Landfald B, Valeur J, Berstad A, Raa J. Microbial trimethylamine-N-oxide as a disease marker: something fishy? Microb Ecol Health Dis 2017;28:1327309.

40. Barnard ND, Scialli AR, Turner-McGrievy G, Lanou AJ, Glass J. The effects of a low-fat, plant-based dietary intervention on body weight, metabolism, and insulin sensitivity. Am J Med 2005;118:991–7.

41. Barnard ND, Cohen J, Jenkins DJ, Turner-McGrievy G, Gloede L, Jaster B, Seidl K, Green AA, Talpers S. A low-fat, vegan diet improves glycemic control and cardiovascular risk factors in a randomized clinical trial in individuals with type 2 diabetes. Diabetes Care 2006;29:1777–83.

42. Yokoyama Y, Barnard ND, Levin SM, Watanabe M. Vegetarian diets and glycemic control in diabetes: a systematic review and meta-analysis. Cardiovasc Diagn Ther 2014;4(5):373–82.

43. Wang F, Zheng J, Yang B, Jiang J, Fu Y, Li D. Effects of vegetarian diets on blood lipids: a systematic review and meta-analysis of randomized controlled trials. J Am Heart Assoc 2015;4:e002408.

44. Briel M, Ferreira-Gonzalez I, You JJ, Karanicolas PJ, Akl EA, Wu P, Blechacz B, Bassler D, Wei X, Sharman A, et al. Association between change in high density lipoprotein cholesterol and cardiovascular disease morbidity and mortality: systematic review and meta-regression analysis. BMJ 2009;338:b92.