Nutrients for Radiation Protection

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Introduction and Summary

Many, many supplements and foods offer radiation protection and are non-toxic. These nutrients have been researched in scientific studies easily accessible to anyone on the website of the United States' National Library of Medicine, also known as PubMed.

Here is my short list of the most important radiation-protecting supplements, compiled from a review of this research: Vitamins C and E (particularly mixed tocopherols and succinate forms); the essential fatty acid DHA; the minerals selenium, calcium, and iodine; probiotics; the hormonal supplement melatonin; the herbs mint, lemon balm, curcumin, ginseng, ginger, rosemary, and gotu kola; and the detoxifiers laminaria (seaweed) or its extract sodium alginate, sodium bicarbonate, apple pectin, and possibly vitamin D. Certainly no one would wish to i ngest all the herbs on this list. I document several herbs for your information. Suggested amounts of each supplement are given in Appendix I.

Certain foods also offer demonstrated radiation protection: beets, spinach, grapefruit, apricots, mustard greens, black grapes, Indian gooseberry or aamla, and Amaranthus gangeticus ("Elephant ears," eaten as salad greens).

Q-her herbs may protect from radiation damage, but the evidence supporti ng their use is less compelling. These are listed here in descending order from most to least corroborating evidence: rhodiola, grape seed extract, spiru lina, lycopene, cat's claw, chlorella, gymnema, and aloe vera. The evidence for the radiation protection qualities of these less-studied supplements is contained in Appendix III.

Several supplements are promoted on the Internet as offering protection from radiation, but many of these claims are not backed by published research, or the published research is negative or troubling for other reasons. These questionable supplements include glutathione (as an oral supplement), bentonite clay, liquid zeo lite, miso, alpha lipoic acid, and N-acetyl-cysteine. My reasons for excluding these items from my short list appear in section XI. Of course, the lack of pub lished evidence is not evidence of ineffectiveness.

Vitamins, minerals and herbs may interact with prescription drugs. Consult y our doctor or pharmacist before taking supplements if you are already taki ng drugs. The issue of whether persons currently undergoing chemotherapy or radiation for

cancer can safely take antioxidant supplements is discussed briefly in Appendix II. Cancer patients should consult a nutritional-oriented oncologist.

I. Why might I need to take supplements for radiation protection?

Some radiation researchers say that there is a threshold below which radiation damage does not occur. Others postulate that there is no such threshold and that any amount of radiation is unhealthy.

Part of the reason for the disagreement is something called the "adaptive response" to low-dose radiation. Low dose radiation can trigger DNA repair mechanisms, possibly within a few hour of irradiation.[1] This small dose thus preconditions the cell to a protective response to a successive and possibly higher dose. The genes controlling DNA repair have already been activated, so that mutations are slower to develop at the next dose. Thus, some radiation researchers conclude that this low dose is not only safe but also protective.

Other researchers[2] note that the effects of radiation extend beyond these initial genetic mutations. Low-level radiation causes an inflammatory response in cells that is not easily measured in its early stages and is not measured by assessments of mutation damage.[3] Measuring radiation damage solely by DNA damage means that other damage is ignored.

Moreover, in real life the response of the organism to low-dose radiation is affected by other environmental exposures. The combination of these exposures may cause more cancer-causing mutations than do the individual exposures experienced separately. For example, X-rays enhance **ninefold** the mutations caused by chemical carcinogens (cancer-causing chemicals). [4] A low dose of radiation that

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[1] Joiner, M. et al. Hypersensitivity to very-low single radiation doses: its relationship to the adaptive response and induced radioresistance. *Mutation Research* 1996 November 4; 358(2): 171-183.

[2] The points and examples in the next four paragraphs are drawn from Prasad, N. Rationale for using ultiple antioxidants in protecting humans against low doses of ionizing radiation. *British Journal of Radiology* 2005; 78: 485-492.

[3] Guan, J. et al. Effects of dietary supplements on space radiation-induced oxidative stress in Sprague-Dawley rats. *Radiation research* 2004 November; 162(5): 572-579.

[4] DiPaulo, j., Donovan, P., and Popescu, N. Kinetics of Syrian hamster cells during x-irradiation enhancement of transformation in vitro by chemical carcinogens. *Radiation Research* 1976; 66:; 310-325.

does not produce detectable mutation nevertheless causes mutations in the presence of caffeine, a substance inhibits DNA repair mechanisms. [5]

Cells vary in their sensitivity to radiation damage. Gonadal cells and fetal cells are particularly vulnerable. An increase in cancer risk is directly proportionate to the number of X-rays received *in utero.*[6] An increased cancer risk of 1.2- to 2-fold is seen even among children whose mothers received diagnostic X-rays **before becoming pregnant.** [7]

Mutations that are not repaired can accumulate and can cause genetic damage that affects the health of future generations.

And **very** low doses do not activate the DNA repair genes. Also at very low doses the response of the tissue is the same whether one cell or many cells have been irradiated. [8] The combination of these two factors means that at very low doses many cells may suffer inflammatory radiation damage, but none of the cells mount a DNA repair response.

At some point the individual organism's ability to cope may become exhausted. Members of the WHO Liaison Institute for Radiation Accident Management reported that at a daily exposure of about 10 to 100mSv, humans are capable of coping with the stem-cell death among the cells that create blood cells—for weeks or even many months. At some point, however, too many cells will have been killed. "Once the stem-cell pool is approaching an exhaustion level, a 'turbulence region' is reached. Then it takes a very little additional stress for the system to fail."[9]

For all these reasons, Dr. Prasad of the Department of Radiology at the University of Colorado's Medical School concludes that "it is very prudent to continue to support the well-established radiobiological concept **that no radiation dose can be considered completely safe** [emphasis added]. " He recommends that radiation workers, airplane attendants, frequent flyers, persons living in areas with higher background radiation levels, persons receiving diagnostic X-rays, and those affected

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[5] Puck, T. et al. Caffeine enhanced measurement of mutagenesis by low levels of gamma-irradiation in human lymphocytes. *Somatic Cell and Molecular Genetics* 1993; 19: 423-429.

[6] Newcombe, H. and McGregor, J. Childhood cancer following obstetric radiography. *Lancet* 1971; 2: 1151-1152.

[7] Stewart, A. and Kneale, G. Radiation dose effects in relation to obstetric x-rays and childhood cancers. *Lancet* 1970; 1:1185-1188.

[8] Rothkamm. K. and Lobrich, M. Evidence for a lack of DNA double strand break repair in human cells exposed to very low x-ray doses. *Proceedings of the National Academy of Sciences* 2003; 100: 5057-5062.

[9] Fliedner, T. and Graessle, D. (the data on blood-creating cells is from chronic irradiation studies of dogs at the Argonne National Laboratory in the U.S.

by nuclear accidents all take antioxidant supplements to prevent cumulative radiation damage. [10]

II. What sort of evidence supports the radiation protection ability of nutrients and herbs?

Several different types of researchers are looking for non-toxic radiation protection agents. The U.S. Army's Walter Reed Institute, beginning in the 1950's, synthesized and tested more than 4000 compounds to try to find an effective radiation protection agent. The most promising compound, amifostine, later was discovered to have very severe side effects. The dose that may be safely taken does not produce maximal protection. [11] As one military researcher commented, perhaps wryly, radiation protection agents should not "affect the ability of military personnel to perform tasks." [12]

A second group of researchers is concerned with the victims of nuclear accidents, and have researched methods, for example, to detoxify children living near Chernobyl. A third group of researchers is concerned with alleviating collateral damage to healthy tissue caused by radiation therapy for cancer. Again, the toxicity of the approved drugs for this purpose limits their clinical usefulness, so researchers seek non-toxic, food-based agents. [13]

Researchers offer several types of evidence for the efficacy of these supplements and herbs. I describe these types of evidence here in order of the complexity and costs (monetary and human) of the research. First are cell culture studies, in which human or animal cells (such as healthy liver cells or blood cells) are subjected to radiation. Before or after the radiation, some cells are bathed in the nutrient or herb

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[10] Prasad, op cit, page 489.

[11] Shirazi, A., Ghobadi, G., and Ghazi-Khansari, M. A radiobiological review on melatonin: a novel radioprotector. *Journal of Radiation Research* 2007; 48(4): 263-272. The drug is sometimes used in effectiveness comparison studies of non-toxic herbs.

[12] Kumar, K. et al. Nutritional approaches for radioprotection: vitamin E. *Military Medicine* 2002 Feb; 167(2 Suppl.): 57-59. The authors are from the Radiation Casualty Management Team, Department of Radiation Medicine, U.S. Armed Forces Radiobiology Research Institute.

[13] "[M]ost of the synthetic radioprotective compounds studied have shown inadequate clinical application owing to their inherent toxicity and high cost. These observations necessitated a search for alternative agents that are less toxic and highly effective." Baliga, M., and Rao, S. Radioprotective potential of mint: a brief review. *Journal of Cancer Research and Therapy* 2010 July-September; 6(3): 255-262.

being tested; others are not. The radiation damage to both cell groups is then assessed and compared.

Second are animal studies, in which animals are subjected to lethal or non-lethal doses of radiation, again with or without the supplement. The rates of death are recorded, and the tissues of the autopsied animals are tested for cellular, genetic, and biochemical damage.

Third are studies of human patients who are undergoing radiation therapy. Radiation-induced chronic diarrhea, for example, is common among patients receiving radiation of the pelvic region. Similarly, patients receiving radiation for head and neck cancer suffer radiation damage to the oral cavity and esophagus. Radiation is particularly damaging to lining cells, such as those lining the gastro-intestinal tract or the esophagus or the lungs. Supplements are given to some cancer patients who are undergoing radiation treatments to see whether nearby tissues are better protected from the radiation, as compared to the same tissues in radiation patients not receiving the supplement.

Fourth are studies of the victims of accidental radiation damage, such as the children of Chernobyl or, in one study, the X-ray technicians at a hospital. Again, supplements are administered to these individuals and then their damaged blood cells or their radioactive excretion levels are compared with those of controls not given the supplements.

III. Why is the list of recommended supplements so long?

A range of supplements can address a range of radiation issues.

1. Free radical damage. Radiation causes free radical damage in living tissues, both directly and indirectly. When the radiation striking a cell has enough energy to dislodge one or more electrons from an atom in the cell, the loss of the electron turns that atom into a "free radical. " (A "free radical" is an atom that is missing one electron from a pair on its outermost electron "shell.") The free radical will immediately react with any biomolecule in the vicinity, seeking to grab an electron to complete a pair. The process that creates a free radical is also called "oxidation" (even if oxygen did not cause the free radical).

When radiation interacts with water molecules in the cell, it can create highly reactive free radicals such as peroxide, hydroxide, or superoxide. Free radicals that contain oxygen are collectively called "reactive oxygen species" or ROS.

This electron-grabbing by free radicals or ROS changes chemicals in the cell, disrupts cell function, and may kill cells. Moreover, after the insult of radiation, cells

may continue to produce large amounts of free radicals for weeks or even months.[14] Free radicals can activate a vicious cycle of oxidation damage: the molecule damaged by oxidation causes a biological response that produces more free radicals, perpetuating the cycle.[15] Researchers are now realizing that these oxidative processes are partly responsible for atherosclerosis, diabetes, autoimmune disease, and aging. [16] Reactive oxygen species can also both initiate and promote cancer. [17]

Indirect free radical damage from radiation occurs when the damaged cell sends chemical messages to other cells, which sets off another cascade of reactions. Radiation easily damages these "bystander" cells. [18]

2. Free radical damage to fats within the cell. The free radicals may damage lipids (fats) within the cell. Damage can affect the cellular membranes, which are composed almost entirely of fats. These membranes include the membrane that encases every cell, the membranes that protect the nucleus, and membranes that enclose other organelles inside the cell. The mitochondria (the cells' energy factories) create energy literally on their membranes, so damage to these

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[14] Lemon, J. Rollo, C., and Boreham, D. Elevated DNA damage in a mouse model of oxidative stress: impacts of ionizing radiation and a protective dietary supplement. *Mutageesis* 2008 July; 23(6): 473-482, 474.; Spitz, D. R., Azzam, E. I., Jian, L. J. and Gius, D. Metabolic oxidation/reduction reactions and cellular responses to ionizing radiation: a unifying concept in stress response biology. *Cancer Metastasis Rev*. 2004; Aug-Dec; 23 (3-4): 311–322.

[15] NADPH oxidase on the cellular membrane, for example, both produces and is activated by free radicals. This can cause chronic free radical production. Cai, H. NADPH oxidase-dependent self-propagation of hydrogen peroxide and vascular disease. *Circ. Research* 2005; 66: 10377-10383.
Similarly, peroxinitrite activates a vicious cycle of peroxinitrite production. Pall, M. High-dose therapy with ascorbate, niacin, folate, and B12: Pauling was right, but for the wrong reason. *Journal of Orthomolecular Therapy* 2010; 25(3): 148-156.
Recent research indicates that this peroxinitrite cycle is activated by radiation damage to the mitochondrial membrane. Zabbarova, I. and Kanai, A. Targeted delivery of radioprotective agents to mitochondria. *Molecular Interventions.* 2008 December; 8(6): 294-302. See also Leach, J. et al. Ionizing radiation-induced, mitochondria-dependent generation of reactive oxygen/nitrogen. *Cancer Research* 2001 May 15; 61(10): 3894-3901. So far, however, prevention of the peroxinitrite cycle has not been studied among the radiation researchers.

[16] Lemon, et al. op cit.

[17] See, for example, Guis, D. and Spitz, D. Redox signaling in cancer biology. *Antioxidants and Redox Signaling* 2006 July-August; 8(7-8): 1249-1252; Valko, M. et al. Free radicals, metals, and antioxidants in oxidative stress-induced cancer. *Chem. Biol. Interact.* 2006 March 10; 160(1): 1-40.

[18] Shirazi, *Journal of Radiation Research* 2007, op. cit.

membranes interferes with the cell's ability to create energy. Free-radical damage to lipids (fats) is called "lipid peroxidation."

Understanding these free radical mechanisms enables researchers to assay the damage done by radiation and the ability of supplements or herbs to prevent such damage. For example, one measure of radiation damage is the number of reactive oxygen species or ROS in the damaged cells or tissues. A second measure is the amount of lipid peroxidation, usually assessed by the amount of certain biochemical by-products produced by lipid-damaged cells. A third measure is the number of cells or animals that have been killed by the radiation. (Not every measure is used in every study.)

3. Free radical damage to DNA. About 60% of the DNA damage from ionizing radiation is believed to be caused by the peroxide free radical, which is formed when the radiation strikes the water in the cell. [19] DNA damage can lead to cancer and to genome instability—both are caused by accumulated mutations.

One measure of DNA damage is the number of single- and double-strand breaks found in the DNA. Although the cell readily repairs single-strand breaks, double-strand breaks are not easily repaired. Double-strand breaks are considered one of the primary causes of cellular death. [20] Another measurable damage is the amount of oxidized guanine. Guanine is one of the nucleic acid bases that form DNA, so damage to guanine signifies damage to the DNA. (Oxidized guanine is also a biomarker for cancer. [21]) Other measures of DNA damage are chromosome aberrations and the presence of micronuclei. Micronuclei are small extra nuclei in cells, formed from chromosome fragments that break off during faulty DNA replication. The strand breakage, chromosome aberrations, and micronuclei can be seen through a microscope.

4. Damage to lining cells and bone marrow. In addition to looking for signs of free radicals and DNA damage, researchers examine two types of cells that are uniquely vulnerable to radiation: epithelial or lining cells and bone marrow cells. The cells that line the gastro-intestinal system, for example, are easily damaged by radiation. [22] This damage to the gastro-intestinal lining cells in turn can cause

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[19] Shirazi, op cit., page 265.

[20] Elia, M. , DeLuca, J., and Bradley, M. Significance and measurement of DNA double strand breaks in mammalian cells. *Pharmacol. Therapy* 1991; 51:291-327.

[21] Floyd, R. The role of 8-hydroxydeoxyguanosine in carcinogenesis. *Carcinogenesis* 1990; 11: 1447-1450.

[22] In one animal study, a single dose of radiation that did not cause death produced "profound changes" in the intestinal lining, including decreased numbers of macrophages, neutrophils, and B and T lymphocytes, which persisted for 3 weeks. Garg, S. et al. Influence of sublethal total-body irradiation on immune cell populations in the intestinal mucosa. *Radiation Research* 2010 April; 173(4): 469-478.

nausea, vomiting, weight loss, and death from dehydration in severe cases. The cells lining the lungs are also vulnerable to radiation damage, which may in turn cause respiratory illness.[23]

The cells of the bone marrow produce blood cells. Damage to bone marrow cells may cause damage to blood cells, or a reduction in the amounts of blood cells. [24]

In animal studies of lethal radiation, the dose of radiation is often calculated to be LD (lethal dose) 50/30, meaning the dose that kills 50% of the animals in 30 days. In studies using an LD 50/30 dose of radiation, death from destruction of the gastro-intestinal lining ordinarily occurs at days 7 to 10. Death from damage to the bone marrow comes at day 30. These known patterns help researchers to measure the radiation protective effects of nutrients and herbs.

5. **Damage to the immune system.** The oxidative damage also triggers an inflammatory response. One way of measuring inflammation is to measure levels of pro-inflammatory cytokines (chemical messengers), such as tumor necrosis factor alpha. TNF alpha signals an acute inflammatory reaction, causing fever and wasting. It stimulates the release of stress hormones. In the liver TNF alpha causes an increase in C-reactive protein, one measure of the risk of heart attack. TNF alpha is also associated with arthritis, cancer, and Alzheimer's disease. [25]

Another measure of damage to the immune system is nuclear factor kappa beta (NFkB), a messenger chemical that directs DNA transcription. NFkB is naturally present in the cell in an inactive state, to be activated when needed. NFkB in turn activates more than 400 genes that control the body's immune system and its inflammatory system. Reactive oxygen species can cause NFkB to become chronically active. Chronically active NFkB can cause inflammatory diseases such as arthritis, cardiovascular disease, and diabetes. NFkB also activates genes that promote cancer. [26] Radiation researchers look for elevated NFkB and elevated tumor necrosis factor alpha as measures of radiation damage to the immune system.

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[23] Pikas, O. [Fatty acid lipid spectrum in the expired air condensate of persons exposed to moderate-dosage ionizing radiation at the CXhernobyl atomic power station]. [Article in Russian]. *Probl. Tuberk* 2002; (3): 48-50.

[24] Dainiak, N. Henatologic consequences of exposure to ionizing radiation. *Experimental Hematology* 2002 June; 30(6): 13-28. The article also discusses the possibility of developing leukemia and bone marrow cancer (multiple myeloma) from low-dose radiation from nuclear power plant accidents.

[25] Loksley, R., Killeen, N., and Leonardo, J. The TNF and TNF receptor superfamilies: integrating mammalian biology. *Cell* 2001 February; 104(4): 487-501; Swardfager, W. et al. A meta-analysis of cytokines in Alzneimer's disease. *Biological Psychiatry* 2010 November; 68(10): 930-941.

[26] Julius Goepp, MD, has written an excellent summary of these processes with extensive footnotes to the relevant research. What is nuclear factor-kappa beta? *Life*

6. Dose response factor (DRF), also called dose modification factor (DMF). These numbers are tools for communicating the level of radiation protection of a given substance. For example, a DRF or DMF of 2 means essentially that if a given dose of radiation were doubled while the animal was given a protective supplement, the amount of radiation damage to the animal would remain the same as with the initial dose.[27]

7. Repair of oxidative damage. Researchers also examine herbs and nutrients for their ability to repair and not just prevent all these sorts of damage. The cell has its own DNA repair mechanisms, for example, and certain nutrients are essential for this process. Similarly, the cell has internal processes that prevent and repair oxidation damage, such as the glutathione system. (Glutathione is a protein created by the body to serve as an anti-oxidant and as a metal transporter.) Again, specific nutrients are required for these processes. Radiation depletes certain vitamins, and appropriate supplementation restores these missing nutrients. Damage to the cellular membranes can only be healed if the appropriate building blocks, primarily fatty acids, are available in the diet.

8. Prevention of absorption of particles and their removal from the body. Finally, researchers have looked for ways to prevent absorption of radioactive particles and to remove these particles from the body if absorbed. Radioactive particles from the Japanese reactor may include radioactive cesium, iodine, plutonium, strontium, or uranium. If lodged in body tissues, these radioactive particles would be an internal source for ionizing radiation throughout the lifespan, because these radioactive elements have half-lives ranging from 30 years to millions of years.

IV. Antioxidants: Vitamin C, Vitamin E, and Selenium

The obvious first choices to prevent free radical damage from radiation are **vitamins C and E.** Each of these nutrients is already well known as an *antioxidant.* An antioxidant is a molecule that donates an electron to the free radical, stopping the free radical cascade of damage. Vitamins C and E have prevented oxidative damage from radiation, in human, animal, and cell studies. They have also

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Extension Magazine July 2006.
http://www.lef.org/magazine/mag2006/jul2006_report_nuclear_03.htm

[27] However, disagreement exists as to whether this number allows meaningful comparisons between radioprotective substances. Beck-Bornholdt, H. Quantification of relative biological effectiveness, dose modification factor and therapeutic gain factor. *Strahlenther Onkol.* 1993 January; 169(1): 42-47.

prevented damage to DNA. And they are safe.[28] Each has been studied separately and in combination for radiation protection.

Here are some examples of studies using vitamin C for radiation protection. Vitamin C protected the testes of mice against the effect of chronic irradiation via radioactive particles incorporated into the tissue. [29] In fact, this study calculated a dose modification factor of 2.3, the highest radiation protection level reached in all the studies of nutrients and herbs that I have found.

In other animal studies, vitamin C prevented activation of the NF-kappa beta pathway (which, unchecked, can lead to chronic inflammation and to cancer). In the same study the vitamin C inhibited several pro-inflammatory genes in kidneys in mice. [30] Vitamin C given to mice (at 100 mg per kilogram of weight), prior to abdominal radiation, protected intestinal lining cells.[31] Vitamin C administered to mice prior to whole-body gamma radiation reduced the lipid peroxide damage from radiation in the liver, as compared to that in controls not given the supplement.[32] Mice treated with 250 mg of vitamin C per kilogram of body weight prior to lethal whole-body gamma radiation had 33% greater survival at 30 days as compared to controls without the vitamin C. In a separate experiment by the same researchers, mice were wounded, and then treated with radiation or with radiation and vitamin C. Those receiving 250 mg per kilogram of vitamin C had the fastest wound healing.[33]

In a cellular study vitamin C prevented damage to proteins in human blood plasma subjected to gamma radiation. In the absence of vitamin C, twice as many oxidized

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[28] Garewal, H and Diplock, A. How "safe" are antioxidant vitamins? *Drug Safety* 1995 July; 13(1): 8-14: alpha-tocopherol and ascorbic acid "are remarkably well tolerated and free from toxicity."

[29] Narra, V. et al. Vitamins as radioprotectors in vivo. I. Protection by vitamin C against internal radionuclides in mouse testes: implications to the mechanism of damage caused by the Auger effect. *Radiation Research* 1994 March; 137(3): 394-399.

[30] This study is especially germane to humans because these SMP30 mice were genetically unable to make their own vitamin C. Chung, S. et al. Molecular delineation of gamma-ray-induced NF-kappaB activation and pro-inflammatory genes in SMP30 knockout mice. *Radiation Research 2010 May; 173(5): 629-634.*

[31] Kanter, M. and Akpolat, M. Vitamin C protects against ionizing radiation damage to goblet cells of the ileum in rats. *Acta HIstochem.* 2008; 110(6): 481-90.

[32] Matthew, D. et al. Ascorbic aid monoglucoside as antioxidant and radioprotector. *Journal of Radiation Research (Tokyo)* 2007 September; 48(5): 369-376.

[33] Jagetia, G. et al. Augmentation of wound healing by ascorbic acid treatment in mice exposed to gamma-radiation. *Int. J. Radiation Biology* 2004 May; 80(5): 347-354. See also Jagetia, G. et al. Ascorbic acid increases healing of excision wounds of mice whole body exposed to different doses of gamma-radiation. *Burns* 2007 June; 33(4): 484-494.

proteins were created by the radiation. [34] Vitamin C reduced radiation damage to calf thymus cells by 30% to 50%. [35] Vitamin C was effective in protecting human epithelial (lining) cells from the effects of X-rays, gamma-rays, protons, and high energy particles. [36]

Vitamin E also offers radiation protection. Vitamin E at 400 IU protected against lethal doses of cobalt-6 radiation in mice.[37] Vitamin E reduced inflammation in the brains of irradiated rats, as measured by reductions in tumor necrosis factor alpha and interleukin-1B. [38] (The brain, a high-fat organ, is particularly susceptible to lipid [fat] peroxidation damage.)

A water-soluble form of E reduced deaths of embryos by 75% when administered prior to radiation of the pregnant mice. The same study also found that vitamin E is a "potent free-radical scavenger": E protected mitochondrial membranes from peroxidation and protected DNA from strand breaks. [39] A study by the same researchers using mice with tumors found that although the vitamin E protected the normal tissues from DNA damage caused by radiation, vitamin E did not protect the tumor cells from radiation.[40] This result suggests that Vitamin E may be safely given to persons with existing cancers. (See Appendix III for a discussion of this issue.)

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[34] Zbikowska, H., Nowak, P., and Wachowicz, B. Protein modification caused by a high dose of gamma irradiation in cryo-sterilized plasma: protective effect of ascorbate. *Free Radical Biology and Medicine* 2006 Feb. 1; 40(3): 536-542.

[35] Cai, L., Koropatnick, J., and Cherian, M. Roles of vitamin C in radiation-induced DNA damage in presence and absence of copper. *Chem. Biol. Interact.* 2001 July 31; 137(1): 75-88. In the presence of copper, however, the vitamin C induced DMA damage.

[36] Wan, X. et al. Protection against radiation-induced oxidative stress in cultured human epithelial cells by treatment with antioxidant agents. *International Journal of Radiation Oncology Biology Physics* 2006 Apr. 1; 64(5): 1475-1481.

[37] Kumar, K. et al. Nutritional approaches to radioprotection: vitamin E. *Military Medicine* 2002 Feb.; 167(2 Suppl.): 57-59. A dose of 400 IU (in mice) was "a good radioprotectant against lethal doses of cobalt-60 radiation."

[38] Abd-El-Fattah, A. et al. Possible role of vitamin E, coenzyme Q10, and rutin in protection against cerebral ischemia/reperfusion injury in irradiated rats. *International Journal of Radiation Biology* 2010 December; 86(12): 1070-1078. Rutin also reduced levels of TNF and IL-1B, whereas Co-Q10 had no effect.

[39] Nair, C. et al. Water soluble vitamin E (TMG) [tocopherol monoglucoside] as a radioprotector. *Indian Journal of Experimental Biology* 2003 Dec; 41(12): 1365-71.

[40] Nair, C. et al. Relevance of radioprotectors in radiotherapy: studies with tocopherol monoglucoside. *Journal of Environmental Pathology, Toxicology, and Oncology* 2004; 23(2): 153-160.

In fact, there are more studies showing the radioprotective effect of vitamin E than I can readily summarize here. Others are footnoted here, listed in order of publication.[41]

Some researchers use the water-soluble alpha tocopherol-succinate form in studying radiation protection. A study focusing on bone marrow cells in irradiated mice found that the tocopherol succinate inhibited the expression of genes that promote cancer and also protected the naturally occurring antioxidant enzymes.[42]

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[41] Singh, V., Brown, D., and Kao, T. Alpha-tocopherol succinate protects ice from gamma-radiation by induction of granulocyte-colony stimulating factor. *International Journal of Radiation Biology* 2010 January; 86(1):12-21. (significantly fewer deaths in irradiated mice given alpha-tocopherol succinate); Singh, V., Brown, D., and Kao, T. Tocopherol succinate: a promising radiationcountermeasure *International Immuopharmacology,* 2009 November; 9(12): 1423-1430 (tocopherol succinate protected mice against lethal doses of cobalt-60 radiation with a DRF of 1.28; "TS may be developed as a radioprotectant for humans against the potentially lethal effects of radiation exposure.") Alcaraz, M. et al. Liposoluble antioxidants provide an effective radioprotective barrier. *British Journal of Radiology* 2009 July; 82(979): 805-809 (water-soluble vitamin E scavenges the peroxide and superoxide radicals in human lyphocytes; only fat-soluble vitamin E, administered as E as delta tocopherol in this study, also prevents lipid peroxidation); Singh, V. et al. Induction of cytokines by radioprotective tocopherol analogs. *Experimental and Molecular Pathology* 2006 August; 81(1): 55-61 (alpha tocopherol, alpha tocopherol succinate, and gamma-tocotrienol significantly protected mice against lethal gamma radiation and also increased peripheral blood cell recovery). Cherdyntseva, N. et al. Effect of tocopherol-monoglucoside (TMG), a water-soluble glycosylated derivate of vitamin E, on hematopoietic recovery in irradiated mice. *Journal of Radiation Research (Tokyo)* 2005 March; 46(1): 37-41 (mice subjected to whole-body radiation and given tocopherol monoglucoside had enhanced recovery of bone marrow cells as compared to controls). Weiss, J. and Landauer, M. Protection against ionizing radiation by antioxidant nutrients and phytochemicals [review article]. *Toxicology* 2003 July; 15; 189(1-2): 1-20 ("vitamin E and selenium compounds" are "protective against lethality and other radiation effects" and "have the advantage of low toxicity"). Paranich, A. et al. [The role of fat-soluble vitamins A and E in preventing the biological effects of ionizing radiation in rat tissues.] *Radiobiologia* 1992 September-October; 32(5): 743-50 (Vitamin E more radioprotective than vitamin A [synthetic] particularly in the brain; vitamin A seemed to promote oxidation).

[42] Singh, V. et al. Tocopherol succinate: modulation of antioxidant enzymes and oncogene expression, and hematopoietic recovery. *International Journal of Radiation Oncology Biology Physics* 2011 February 1; 79(2): 571-578.

Recently researchers have begun studying gamma-tocotrienol, an analogue of vitamin E, for its radiation protection effects. [43]

Gamma tocotrienol has been described as "a potent radioprotector and mitigator."[44] For example, a recent study found that gamma tocotrienol increased the number of mice surviving lethal total-body radiation, reduced oxidative stress in blood vessels, enhanced recovery of bone marrow cells, and reduced intestinal injury. [45] Another animal study of total-body radiation found that gamma tocotrienol at a dose of 200 mg per kilogram of weight had a dose response factor of 1.29. The vitamin also accelerated the recovery of total numbers of white blood cells as well as specific types of white blood cells. [46]

Vitamin C is water-soluble and therefore may be most protective of molecules that are also water-soluble, such as proteins. By contrast, E is fat-soluble, and therefore possibly more protective of lipids (although C also reduces lipid peroxidation).

Many radiation researchers, therefore, have studied C and E in combination.

Researchers at the Garden State Cancer Center in New Jersey studied mice to determine whether vitamins C and E could extend the amount of radiation that can be tolerated in radiation treatments by protecting normal tissues from radiation. Together, the vitamins increased the maximum tolerated dose of radiation by 42%. The vitamins also reduced the weight loss from radiation, which is caused by damage to the gastrointestinal lining. Most important to these researchers, the antioxidants did not cause existing tumors to grow. This study and others suggest that antioxidant vitamins are safe for those who are undergoing radiation treatment for existing cancers. (See discussion of this issue in Appendix III.)

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[43] Vitamin E has been defined by the FDA as being composed solely of alpha tocopherol. Associated with alpha tocopherol in palm oil and other natural sources are 3 other tocopherols and 4 tocotrienols, all of which are similar in structure to alpha tocopherol. Some researchers refer to all 8 forms as "natural vitamin E," but technically only alpha tocopherol is "vitamin E."

[44] Berbee, M. et al. Pentoxifylliine enhances the radioprotective properties of gamma-tocotrienol: differential effects on the hematopoietic, gastrointestinal and vascular systems. *Radiation Research* 2011 March; 175(3): 297-306. See also Kulkami, S. Hematological targets of radiation damage. *Current Drug Targets* 2010 November; 11(1): 1375-85 (review of the mechanisms by which gamma tocotrienol protects bone marrow cells).

[45] Berbee, M. et al. Gamma-tocotrienol ameliorates intestinal radiation injury and reduces vascular oxidative stress after total-body irradiation by an HMG-CoA reductase-dependent mechanism. *Radiation Research* 2009 May; 171(5): 596-605.

[46] Ghosh, S. et al. Gamma-tocotrienol, a tocol antioxidant as a potent radioprotector. *International Journal of Radiation Research* 2009 July; 85(7): 598-606.

In a study of mice given C and E and exposed to whole-body radiation, researchers examined bone marrow cells to determine assess radiation damage. Both C and E reduced the frequencies of micronuclei and chromosomal aberrations. [47]

In a study of rats subjected to electromagnetic radiation from mobile phones 9not the same as ionizing radiation), researchers chose to examine cells of the endometrium (uterine lining). Vitamins C and E in combination protected the endometrium from cell death, oxidation products, and lipid peroxidation from radiation damage. The two vitamins also increased the activities of natural oxidation-repair processes, including the glutathione system, superoxide dismutase, and catalase, all of which had been diminished by the electromagnetic radiation. [48]

Selenium is another antioxidant nutrient that has been shown to offer protection from radiation damage.

In fact, researchers have discovered that a selenium deficiency encourages radiation damage in the form of micronuclei. The mechanism is that the glutathione antioxidant system, which prevents radiation damage to DNA, requires selenium.. [49]

Selenium (as sodium selenite) was given to rats at a dose of 1.5 mg per kilogram each day, while being exposed to radiation for 60 minutes per day, for 30 days. The selenium significantly reduced lipid peroxidation and also increased the activity of the glutathione antioxidant system. [50] In another rat study, selenomethionine

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[47] Sarma, L. and Kesavan, P. Protective effects of vitamins C and E against gamm-ray-induced chromosomal damage in mouse. *International Journal of Radiation Biology* 1993 June; 63(7): 759-764. In this study E was found more effective than C, and the combination of E and C was not more effective than E alone in preventing radiation damage to chromosomes. The doses are not specified in the abstract.

[48] Guney, M. et al. 900 MHz radiofrequency-induced histopathologic changes and oxidative stress in rat endometrium: protection by vitamins E and C. *Toxicology and Industrial Health* 2007 August; 23(7): 411-420.

[49] Baliga, M. et al. Selenoprotein deficiency enhances radiation-induced micronuclei formation. *Molecular Nutrition and Food Research* 2008 November; 52(11): 1300-1304.

[50] Turker, Y. Selenium and L-carnitiine reduce oxidative stress in the heart of rat induced by s.45-GHz radiation from wireless devices. *Biological Trace Element Research* 2011 March 1 [Epub ahead of print]. The L-carnitine decreased lipid peroxidation but did not affect glutathione.

protected rats from radiation damage due to oxidative stress and DNA damage.[51] In a mouse study, a selenium compound improved the 30-day survival rate by 35%.[52]

Selenium as selenocystine reduced radiation DNA damage in liver tissue and enhanced the rate of DNA repair, in mice exposed to a sublethal dose of gamma radiation. The selenium also inhibited the radiation damage of lipid peroxidation, protected the glutathione anti-oxidant system, and protected bone marrow cells from radiation damage to DNA, as measured by the numbers of cells with micronuclei.[53]

Selenomethionine had a "dramatic effect" in preventing alterations of gene expression caused by high LET radiation in human thyroid cells in test tube culture.[54] In a similar study, the same researchers found that selenium prevented alterations in 77 of the 196 genes (39%)that had been damaged at one level of radiation, and protected 336 out of 610 genes (55%) that had been damaged by a higher level of radiation. Some of the genes that were protected by selenium are those known to be mutated in cancer cells.[55]

Combined with vitamin E, selenium protected rats from radiation-caused lipid peroxidation and cell death in the liver.[56]

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[51] Kennedy, A. et al. Selenomethionine protects against adverse biological effects induced by space radiation. *Free Radical Biology and Medicine* 2004 January 15; 36(2): 259-266.

[52] Kunwar, A. et al. In vivo radioprotection studies of 3,3'=diselenodiproprionic acid, a selenocysteine derivative. *Free Radicals in Biology ad Medicine* 2010 February 1; 48(3): 399-410.

[53] Kunwar, A. Protective effects of selenocystine against gamma-radiation-induced genotoxicity in Swiss albino mice. *Radiation and Environmental Biophysics* 2011 January 23. [Epub ahead of print]

[54] Stewart, J. L-selenomethionine modulates high LET radiation-induced alterations of gene expression in cultured human thyroid cells. *Oncology Research* 2006 September; 16(3): 569-574. High LET (linear energy transfer) refers to the rate whereby radiation deposits energy as it passes through tissue. Higher levels of deposited energy cause more cells to be killed by a given dose of radiation therapy. Different types of radiation have different levels of LET. For example, neutrons, prions, and heavy ions are high LET radiation, whereas gamma and X-rays are low-LET radiation. High LET radiation is a therapy available at only a few US hospitals because the equipment to produce it is extremely expensive.

[55] Stewart, J. et al. Protective effects of L-selenomethionine on space radiation induced changes in gene expression. *Radiation and Environmental Biophysics* 2007 June; 46(2): 161-165.

[56] Gencel, O. et al. Selenium and vitamin E modulates radiation-induced liver toxicity in pregnant and nonpregnant rat: effects of colemanite and hematite shielding. *Biological Trace Element Research* 2010 June; 135(1-3): 253-63.

Selenium has also been found to enhance the effects of radiation therapy in killing prostate-tumor cells in test tubes, without affecting normal intestinal lining cells. Researchers concluded that selenium could safely be used to increase radiation doses for the treatment of prostate cancer. [57] These results suggest that selenium also may safely be used by persons who are undergoing radiation therapy for existing cancers.

All three nutrients, in various combinations with other vitamins and minerals, offer demonstrated radiation protection.

Researchers in Egypt gave a mixture of antioxidants to women with cervical cancer who were undergoing radiation treatments. The women who received C, E, A, and selenium three times per day during and after radiation therapy had significantly reduced levels of lipid peroxides, reduced numbers of micronuclei, and reduced apoptosis (cell death) in non-cancerous cells, as compared to controls. [58]

The amounts of the vitamins exceeded the American "recommended dietary allowance" for three of these vitamins. (The U.S. "recommended dietary allowances" are "estimated average requirements" for specific vitamins and minerals, set by the Food and Nutrition Board of the Institute of Medicine.[59]) In this study the women were given 180 mg of C, 30 mg of vitamin E, 150 mcg of selenium, and 3000 IU of vitamin A, daily. The U.S. recommendations for these vitamins are 75 mg of vitamin C per day for women, 14 mg of vitamin E, 45 micrograms of selenium, and 400 IU of Vitamin A for women. The increased doses used in this successful study are in line with the recommendations of many researchers that a dose designed to heal specific conditions must be larger than the dose needed merely to prevent deficiency of conditions recognized many decades ago, as the reference daily intakes are designed to do.

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[57] Tian, J, Ning, S., and Know, S. Sodium selenite radiosensitizes hormone-refractory prostate cancer xenograft tumors but not intestinal crypt cells in vivo.

[58] Ismail, M., et al. Effect of antioxidants on markers of apoptosis in postoperative radiotherapy of cancer cervix. *Gulf Journal of Oncology* 2010 January; 7:8-13. The women given the antioxidants also had reduced levels of Fas, the cell-death receptor.

[59] Panel on Dietary Antioxidants and Related Compounds, Food and Nutrition Board, Institute of Medicine, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids,* National Academies Press, 2000, page 149; Food and Nutrition Board, Institute of Medicine, Dietary Reference Intakes, updated as of 2011. http://www.iom.edu/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/New%20Material/5DRI%20Values%20SummaryTables%2014.pdf

> "When used for disease prevention, the doses given are several-fold greater than the Recommended Dietary Allowance, the latter being based on amounts necessary for the prevention of classic deficiency conditions recognized decades ago. Alpha-tocopherol, [and] ascorbic acid [vitamin C] … are remarkably well tolerated and free from toxicity. Consequently, they are well suited for testing as preventive agents, since their use does not require any toxicity monitoring except under unusual circumstances."[60]

For this reason, researchers at the University of Pennsylvania's medical school oncology department set out to determine the radiation protection effect of what they believed to be *maximal* amounts of these nutrients. [61]

> "The antioxidant combination was formulated to provide the equivalent [in human terms] of 2000 mg/day [C], 1000 mg/day [E], and 400ug/day [selenium], which represent the upper limits of the RDA ["recommended daily allowance", a prior term for reference daily intake] for vitamin C, vitamin E succinate and selenium, respectively. Although there is no published RDA for NAC [N-acetyl cysteine] or alpha-lipoic acid, these thiol supplements were formulated according to effective doses determined previously for humans, 2400 mg/day and 1200 mg/day, respectively."

In their study, the researchers gave this maximal supplement combination to groups of mice prior to and after total-body radiation. Controls were given the mouse equivalent of the human RDI amounts of the selected nutrients (for men, 90 mg of vitamin C, 15 IU of vitamin E, and 55 mcg of selenium). [62]

This supposed maximal antioxidant supplement increased the 30-day survival time of the mice as compared to controls, whether the supplement was given before or after radiation. The survival rate was of mice receiving supplements was more than 50% greater than that of mice who did not receive the supplements. The antioxidant combination had a stunning dose-reduction factor of 1.6.

Maximal supplementation also protected bone marrow cells from cell death, prevented depletion of white blood cells, and improved recovery of the blood cells

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[60] Garewal, H. and Diplock, A. How "safe" are antioxidant vitamins? *Drug Safety* 1995 July; 13(1): 8-14 .

[61] Wambi, C. et al. Protective effects of dietary antioxidants on proton total-body irradiation-mediated hematopoietic cell and animal survival. *Radiation Research* 2009 Aug; 172(2): 175-86. The supplement also increased survival of cells in the bone marrow that produce red blood cells.

[62] The article states 60 *milligrams* of selenium, but I assume that this is a typographical error.

after radiation, as compared to controls.[63] A more recent study by the same group confirmed that the antioxidant supplement also offered radiation protection by disabling the expression of apoptosis-related (cell death) genes in bone marrow cells. [64]

The need to use higher doses for radiation protection than is offered by American RDI amounts was underscored by a study of multiple vitamin supplements used by airline pilots. Pilots are subject to radiation damage from cosmic radiation, which is not shielded in aircraft. Consequently, pilots have damage to DNA, measured in this study as the frequency of chromosome translocations (parts of the chromosome that have moved to other chromosomes, a condition common in cancer).

By questionnaire, the researchers determined the frequency of fruit and vegetable consumption and the use of multivitamin pills. Whereas consumption of fruits and vegetables above the median was associated with decreased chromosomal damage from radiation, the vitamin supplements did not affect the radiation damage. The likely explanation is that the vitamin pills offered only the RDI amounts of vitamins C and E (75 to 90 mg of C and 14 IU of E), not enough to cause a noticeable difference in chromosomal damage from radiation. [65]

Several other animal studies have had good results, using various mixtures and doses of vitamins for radiation protection.[66]

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[63] Ibid. See also the researchers' earlier study: Wambi, C. et al. Dietary antioxidants protect hematopoietic cells and improve animal survival after total-body irradiation. *Radiation Research* 2008 April; 169(4): 384-396.

[64]Sanzani, J. et al. Antioxidant dietary supplementation of mice exposed to proton radiation attenuates expression of programmed cell death-associated genes. *Radiation Research* 2011 March 28 [Epub ahead of print].

[65] Yong, L. et al. High dietary antioxidant intakes are associated with decreased chromosome translocation frequency in airline pilots. *American Journal of Clinical Nutrition* 2009 November; 90(5): 1402-1410. Moreover, vitamin C is a water-soluble vitamin that needs to be ingested several times daily to keep serum levels high. Most persons taka a multi-vitamin once per day. Recall that the successful stury with cervical cancer patients administered the supplements three times daily. See also discussion of high intakes necessary for radiation protection in Prasad, K. Rationale for using high-dose multiple dietary antioxidants as an adjunct to radiation therapy and chemotherapy. *Journal of Nutrition* 2004 November; 134: 31825-31835 (although low doses of antioxidants may protect cancer cells, higher doses inhibit proliferation of cancer cells in vitro and in vivo).

[66] Sarma, L. and Kesavan, P. Protective effects of vitamins C and E against gamma-ray-induced chromosomal damage in mouse. *International Journal of Radiation Biology* 1993 Jun; 63(6): 759-764.

In one study, supplementing mice with vitamin C, selenium, vitamin E succinate, Co-Q10, along with N-acetyl-cysteine and alpha lipoic acid, reduced death rates in mice receiving lethal doses of total-body irradiation. Of 18 mice who got the antioxidant supplement 24 hours after radiation, 14 survived, as compared to only 4 survivors of 14 mice who did not get the supplement. Or in other words, 77% of the supplement treated mice survived, as compared to 28% of the controls.[67]

The best radiation protection with antioxidants was achieved when researchers used a combination of many nutrients in addition to antioxidants. Vitamins B2, B5 (folate) and pantothenic acid have all been shown necessary for radiation protection.[68] Zinc offered radiation protection to mice;[69] and zinc metallothionein protected mice from DNA damage caused by radiation.[70] (Metallothioneins are proteins that transport metals in cells. Zinc helps to activate transcription, allowing genes to assemble proteins. After the zinc has left the metallothionein, the residue molecule can scavenge oxidative free radicals, such as the superoxide and hyroxyl radicals. These two of the many functions of zinc may explain zinc's protective effect against radiation.) Another animal study found that combinations of spirulina with zinc and with zinc and vitamin C offered more radiation protection than spirulina by itself. [71]

Researchers at McMaster University in Canada assembled a supplement composed of multiple nutrients, including the B vitamins and zinc as described above, as well as several herbs, many of which have also been shown to offer radiation protection,

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[67] Brown, S. et al. Antioxidant diet supplementation starting 24 hours after exposure reduces radiation lethality. *Radiation Research* 2010 April; 173(4): 462-468. An anomaly of this experiment was that mice receiving the supplementation immediately after radiation did not fare as well as those getting it 24 hours later.

[68] See for example Endoh, K. et al. Low folate status increases chromosomal damage by X-ray irradiation. *International Journal of Radiation* Biology 2006 April; 82(4): 223-230, and Fuga, L. et al. VitaminB2 (riboflavin) and a mixture of vitamin B2 and C affects MMC efficiency in aerated media under irradiation. *Anticancer Research* 2004 November-December; 24(6): 4031-4034. Schittl, H. and Getoff, N. Radiation-induced antitumor properties of vitamin B5 (pantothenic acid) and its effect on mitomycin C activity: experiments in vitro. *Oncology Research* 2007; 16(8): 389-394.

[69] Huang, M. et al. Effects of zinc compound on body weight and recovery of bone marrow in mice treated with total body irradiation. *Kachsiung Journal of Medical Science* 2007 September; 23(9): 453-462.

[70] Cai, L. and Cherian, M. Zinc-metalothionein protects from DNA damage induced by radiation better than glutathione and copper- or cadmium-metallothioneins. *Toxicology Letters* 2003 January 13; 136(3): 193-198.

[71] Dartsch, P. Antioxidant potential of selected spirulina platensis preparations. *Phytotherapy Research* 2008 May; 22(5): 627-633.

as I will describe below. [72] Using this supplement with mice bred to be prone to DNA damage, researchers achieved a **6-fold reduction** in chromosomal aberrations in supplemented mice as compared to controls. The supplement also prevented double-strand breaks and oxidative base damage to DNA. Researchers concluded that the supplement "appeared to scavenge free radicals before they could cause damage" and offered "unprecedented radioprotection by a dietary supplement comprised of ingredients available to the general public. " [73]

Studies of cells in culture also found radiation protection from mixtures of antioxidant vitamins.

These results are summarized in the footnote. [74]

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[72] Lemon, J., Rollo, C., and Boreham, D. Elevated DNA damage in a mouse model of oxidative stress: impacts of ionizing radiation and a protective dietary supplement. *Mutagenesis* 2008 November; 23(6): 473-482. [Free online text.] The supplement included B1, B3, B12, and folate; vitamins, C, D, and E; alpha lipoic acid, acetyl-L-carnitine, bioflavonoids, rutin, L-glutathione, N-acetyl-cysteine, cod liver oil, CoQ10, and flax seed oil; the minerals chromium, magnesium, potassium, selenium, and zinc; plant extracts garlic, ginger, ginkgo, ginseng, and green tea extract, and melatonin.

[73] Ibid.

[74] Kennedy, A. Protection against adverse biological effects induced by space radiation by the Bowman-Birk inhibiter and antioxidants. *Radiation Research* 2006 August; 166(2): 327-332 (the Bowman-Birk inhibiter is an artificial antioxidant derived from soy; the antioxidants used were ascorbic acid, CoQ10 L-selenomethionine, and vitamin E succinate; tissue was human breast epithelial cells); Wan, X. et al. Protection against radiation-induced oxidative stress in cultured human epithelial cells by treatment with antioxidant agents. *International Journal of Radiation Oncology Biology Physics* 2006 April 1; 64(5): 1475-1481 (nutrients were ascorbic acid, sodium ascorbate, CoQ10, alpha lipoic acid, selenomethionine, and vitamin E succinate; cells were human breast epithelial cells). Konopacka, M. and Rzeszowska-Wolny, J. Antioxidant vitamins C, E, and beta-carotene reduce DNA damage before as well as after gamma-ray irradiation of human lymphocytes in vitro. *Mutation Research* 2001 April 5; 491(1-2): 1-7 (vitamin C prevented micronuclei; vitamin E and beta-carotene diminished numbers of micronuclei). Konopacka, M. et al. Modifying effect of vitamins C, E, and beta-carotene against gamma-ray-induced DNA damage in mouse cells. *Mutation Research* 1998 September 11; 417(2-3): 85-94 (cells were bone marrow polychromatic erythrocytes and exfoliated bladder cells; mixture was more effective, than nutrients used separately, in reducing numbers of micronuclei).

IV. Protection against Nutrient Depletion from Radiation: Depletion of Antioxidants and Fatty Acids

Supplementation is also useful to replace nutrients depleted by radiation. The research shows interesting relationships among various nutrients in the context of radiation damage. Taken together, the studies indicate that many different nutrients are needed to protect the body from radiation damage.

The Role of Antioxidants:

A study of 20 X-ray technicians found that their blood levels of copper, zinc, and selenium were depleted by radiation, as compared to those of 30 healthy matched controls. Supplementation with vitamins C and E for 5 weeks caused recovery of the copper, zinc and selenium levels. [75]

An animal study found that radiation reduces levels of vitamins A, C, and E in the heart tissue of rats. The researchers also found that and that supplementation with selenium reduced this radiation-induced depletion of A, C, and E.[76] Similarly, a cell study found that supplementation with lycopene, a member of the carotene family, increased levels of A, C, and E in irradiated rat liver cells. [77] Presumably selenium and lycopene spare the antioxidant vitamins by activating other antioxidant pathways in the cell.

Another animal study found that radiation depleted vitamins C and E in mice bone marrow, although the blood plasma levels of these vitamins were not affected, even at lethal doses of radiation. [78] The same study found that folate levels in both plasma and bone marrow decreased in a dose-dependent manner with irradiation. Another animal study found that irradiation of mice depleted another B vitamin, pantothenic acid. [79]

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[75] Kayan, M., Naziroglu, M., and Barak, C. Effects of vitamins C and E combination on element levels in blood of smoker and nonsmoker radiology X-ray technicians. *Biological Trace Element Research* 2010 August; 136(2): 140-148.

[76] Turker, Y. et al. Seleniumm and L-carnitine reduce oxidative stress in the heart of rat induced by 2.45-GHz radiation from wireless devices. *Biological Trace Element Research* 2011 March 1. [Epub ahead of print].

[77] Srinvasan, M. et al. Lycopene as a natural protector against gamma-radiation induced DNA damage, lipid peroxidation, and antioxidant status in primary culture of isolated rat hepatocytes in vitro. *Biochimica, Biophysica Acta* 2007 April; 1770(4): 659-665.

[78] Endoh, K., Murakami, M., and Umegaki, K. Vulnerability of folate in plasma and bone marrow to total body irradiation in mice. *International Journal of Radiation Biology* 2007 January; 83(1): 65-71.

[79] Slyshenkov, V. et al. Protection by pantothenol and beta carotene against liver damage produced by low-dose gamma radiation. *Acta Biochim Pol.* 1999; 46(2): 239-248.

Vitamin E was depleted in bone-marrow cells in a dose-response manner in irradiated mice, and lipid peroxidation levels in bone-marrow cells rose accordingly.[80]

In another animal study, the level of vitamin C in bone marrow was decreased by 80% after a minimal X-ray exposure, whereas vitamin E required double that exposure for depletion to reach significance. No depletions were observed in serum or intestinal cells. The researchers concluded: "the bone marrow is more highly susceptible to oxidative damage by radiation and that ascorbic acid [vitamin C] plays an important defense role against it." [81]

These studies corroborate the findings that combinations of antioxidants, along with other nutrients, provide the best radiation protection.

The Role of Fatty Acids:

Lipid peroxidation damage to the fatty acids in cellular membranes is a hallmark of radiation injury. These fatty-acid building blocks are needed for repair of the cells and of the organelles within the cells: intake of fatty acids will allow the body to replace the damaged fatty acids.

The omega-3 and omega-6 fatty acids are more likely to be damaged by oxidation than saturated fatty acids. The longer-chain fatty acids such as DHA are more vulnerable than the shorter chains. [82] DHA is particularly important as a component of brain tissue. Radiation damage to DHA in the brain, from lipid peroxidation, causes cognitive decline. [83]

Thus, DHA is probably the most important fatty acid to replace. DHA is also known to suppress cancer, [84] and DHA supplementation inhibits lipid peroxidation. [85]

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[80] Umegaki, K. and Ichikawa, T. Decrease in vitamin E levels in the bone marrow of mice receiving whole-body X-ray irradiation. *Free Radical Biology and Medicine* 1994 November; 17(5): 439-444.

[81] Umegaki, K., Acki, S., and Esashi, T. Whole body X-ray irradiation to mice decreases ascorbic acid concentration in bone marrow: comparison between ascorbic acid and vitamin E. *Free Radical Biology and Medicine* 1995 October; 19(4): 493-497.

[82] Gregory, M. et al. Development of a fish cell culture model to investigate the impact of fish oil replacement on lipid peroxidation. *Lipids* 2011 April 29 [Epub ahead of print].

[83] Manda, K., Ueno, M., Anzai, K. Memory impairment, oxidative damage, and apoptosis induced by space radiation: ameliorative potential of alpha-lipoic acid. *Behavioural Brain Research* 2008 Mach 5; 187(2): 387-395.

[84] See for example Patterson, R. et al. Marine fatty acid intake is associated with breast cancer prognosis. *Journal of Nutrition* 2011 February; 141(2): 201-206;

Rats were given omega-3 fatty acids (including DHA) prior to abdominal radiation treatment. Injuries to cells in the stomach and intestinal tissue were reduced among the rats given the fatty acids, as compared to control rats fed a standard diet. Moreover, bacterial colony counts in the intestines and associated lymph nodes were lower in the rats given the fatty acids as compared to controls. [86] Thus, the supplementation demonstrably repaired the lining cells, making them better able to suppress and sequester bacteria.

VI. Melatonin

Melatonin is a hormone secreted by the pineal gland. Melatonin regulates sleep and wake cycles. Bone marrow cells also secrete melatonin. [87] Melatonin as a supplement is used therapeutically chiefly for insomnia.

Recently researchers have fond a link between exposure to light at night and increased risk of cancer. [88] Melatonin appears to prevent cancer in part by inhibiting a metabolic pathway that promotes cell proliferation.[89] Melatonin also blocks tumor cells from taking in a fatty acid that is metabolized into a tumor-promoting agent. [90] Melatonin is used therapeutically for cancer. An analysis of 10

Altenberg, J. et al. A synergistic antiproliferation effect of curcumin and DHA in SK-BR-3 breast cancer cells: unique signaling not explained by the effects of either compound alone. *BMC Cancer* 2001 April 21; 11(1): 149; Corsetto, P. et al. Effects of n-3 PUFAs on breast cancer cells through their incorporation in plasma membrane. *Lipids in Health and Disease* 2011 May 12; 10(1): 73; Cavazos, D. et al. DHA selectively induces human prostate cancer sensitivity to oxidative stress through modulation of NFkB. *Prostate* 2011 February 25. Epub ahead of print.]

[85] Takahashi,, M. et al. Fish oil feeding alters live gene expression to defend against PPAR-activation and ROS production [and NFkB production]. *American Journal of Physiology: Gastrointestinal and Liver Physiology* 2002; 282 G338-G448.

[86] Atasoy, B. et al. Prophylactic feeding with immune-enhanced diet ameliorates chemoradiation-induced gastrointestinal injury in rats. *International Journal of Radiation Biology* 2010 October; 86(10): 867-879.

[87] Conti, A. et al. Evidence for melatonin synthesis in mouse and human bone marrow cells *Pineal Research* 2000 May; 28(4): 193-202.

[88] A summary of the evidence linking light at night and cancer appears in Davis, S. and Mirick, D. Circadian disruption, shift work, and the risk of cancer: a summary of the evidence and studies in Seattle. *Cancer Causes and Control* 2006 May; 17(4): 539-545.

[89] Mao, L. et al. Inhibition of breast cancer cell invasion by melatonin is mediated through regulation of the p38 mitogen-activated protein kinase signaling pathway. *Breast Cancer Research* 2010; 12(6): R107.

[90] Blask, et al. Melatonin uptake and growth prevention in rat hepatoma 7288CTC in response to dietary melatonin: melatonin receptor-mediated inhibition of tumor

randomized controlled trials found among 643 patients with tumors found that melatonin reduced the risk of death at 1 year by 66%.[91] Melatonin also diminishes nerve damage in the limbs that is caused by certain cancer drugs.[92]

Hundreds of studies have documented that melatonin combats oxidation from ionizing radiation.[93] One group of Japanese researchers declared "by virtue of melatonin's radioprotective and anticancer effects, it is time to use it as a radioprotector both for radiation workers and patients suffering from cancer."[94]

Melatonin's chief means of preventing radiation damage, it is assumed, is that it is one of the most potent scavengers of free radicals. It can scavenge the hydroxyl, peroxyl, peroxinitrite, and singlet oxygen radicals. Moreover, it also stimulates glutathione in the brain, and may be the only antioxidant to do so in the brain.[95] (Glutathione is the body's natural anti-oxidant.) In one rat study, treatment with melatonin for 4 days prior to radiation "abolished" the lipid peroxidation and damage to proteins that were seen in controls not given the melatonin. [96] In another

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linoleic acid metabolism to the growth signaling molecule 13-hydroxyoctadecadienoic acid and the potential role of phytomelatonin.. *Carcinogenesis* 2004 June; 25(6): 951-960. See also Blask, D. et al. Circadian stage-dependent inhibition of human breast cancer metabolism and growth by the nocturnal melatonin signal: consequences of its disruption by light at night in rats and women. *Integrative Cancer Therapies* 2009 December; 8(4): 347-353.

[91] Mills, E., et al. Melatonin in the treatment of cancer: a systematic review of randomized controlled trials and meta-analysis. *Journal of Pineal Research* 2005 November; 39(4): 360-366.

[92] Zhanleh, Z. Melatonin, a promising role in taxane-rekated neuropathy. *Clinical Medical Insights: Oncology* 2010; 4: 35-41. Free full text at *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2883241/?tool=pubmed*

[93] See the review articles: Shirazi, A., Ghobadi, G., Ghazi-Khansari, M. A radiobiological review on melatonin: a novel radioprotector. *Radiation Research (Tokyo)* 2007 July; 48(4): 263-272. Vijayalaxmi, et al. Melatonin as a radioprotective agent: a review. *International Journal of Radiation Oncology Biology Physics* 2004 July 1; 59(3):639-653. Karbownik, M. and Reiter, R. Antioxidative effects of melatonin in protection against cellular damage caused by ionizing radiation. *Proceedings of the society of Experimental Biology and Medicine* 2000 October; 225(1): 9-22.

[94] Shirazi, op cit.

[95] Shirazi, op cit

[96] El-Missiry, M. et al. Ameliorative effect of melatonin against gamma-irradiation oxidative stress and tissue injury. *Ecotoxicology and Environmental Safety* 2007 February; 66(2): 278-286.

rat study, pretreatment with melatonin reduced DNA strand breaks and lipid peroxidation in the brain.[97]

In a 1994 mouse study, melatonin increased survival of irradiated mice. All those not treated with melatonin died within 12 days, whereas 43% of those given melatonin were still alive 30 days after irradiation.[98]

Melatonin also prevents damage to DNA. In human lymphocytes exposed to radiation, melatonin reduced the numbers of genetically damaged cells by up to 62%, depending on the dose of melatonin. [99] Melatonin concentrates in the nucleus of the cell. Researchers at the University of Texas Department of Radiology theorize that melatonin activates enzymes that repair DNA and/or activates genes that create proteins that repair DNA. [100]

VII. Probiotics

Beneficial bacteria in the intestines strengthen the mucous membrane barrier, which protects the intestinal cells from pathogens and their toxic byproducts. Without this strong barrier, infection and toxicity develop in the intestines, and bacterial contamination may migrate from the intestines to other tissues. Moreover, the beneficial bacteria influence the expression of genes that regulate the lining cells. These genes govern the lining cells' metabolism, their maturation, and the development of blood vessels that nourish them. [101]

Radiation damages both the lining cells and the beneficial bacteria. From the 6 weeks to 10 years following irradiation, chronic intestinal damage may gradually develop, usually experienced as diarrhea. Nausea and vomiting may also occur, because radiation damages the rhythm of natural contractions in the intestines, so that a backwards peristalsis may develop. These chronic changes in the irradiated intestine develop in the majority of patients who have received abdominal radiation

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[97] Undeger, U. et al. Protective effects of melatonin on the ionizing radiation induced DNA damage in the rat brain. *Experimental and Toxicologic Pathology* 2004 March; 55(5)" 379-384.

[98] Blickenstaff, R. et al. Potential radioprotective agents. 1. Homologs of melatonin *Journal of Pharmacy Science* 1994 February; 83(2): 216-218, cited inShirazi, op cit, p 267.

[99] Vijayalaxmi, et al. Marked reduction of radiation-induced micronuclei in human blood lymphocytes pretreated with melatonin. *Radiation Research* 1995 July; 143(1): 102-106. The 62% figure was quoted in Shirazi, op cit, p. 267.

[100] Vijayalami, et al. Melatonin: possible mechanisms involved in its "radioprotective" effect. *Mutation Research* 1998 August 3; 404(1-2): 187-189.

[101] See summary in Blanarova, C., Galovicova, A., and Petrasova, D. Use of probiotics for prevention of radiation induced diarrhea. *Bratislave Medical Journal* 2009; 110(2): 98-104. Free full text online at http://www.bmj.sk/2009/11002-07.pdf

therapy. Of those who develop radiation damage to the intestines, 15% will require surgery and another 5% will die from the intestinal damage.[102]

Ingestion of probiotics, or beneficial strains of intestinal bacteria, can prevent and repair damage to intestinal tissues.

In a double-blind, placebo controlled study of nearly 500 persons who had received abdominal radiation therapy, the incidence of diarrhea among those receiving a probiotic supplement was only 60% that of controls. The supplement included the strains L.casei, L. plantarum, L. acidophilus, and L. Bulgaricus, in a product called VSL#3. [103]

For rats given a single large dose of radiation to the abdomen, the probiotic strains L. acidophilus, L. helveticus, and bifidobacterium protected the intestinal mucous membrane from radiation damage. The group given probiotics had significantly less toxicity from bacteria, as compared to controls. In addition, high bacteria counts occurred in the lymph nodes and the portal blood system among the non-supplemented rats, whereas the group getting probiotics had less bacterial contamination. [104] In a similar study, the probiotic L .Bulgaricus protected the intestinal lining cells from radiation damage in rats undergoing radiotherapy. [105]

VIII. Radiation Protection from Herbs

A. Radiation Protection from Mint

Mint has the highest dose modification rating among the herbs and the greatest number of animal studies confirming radiation protection. [106]

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[102] Ibid.

[103] Ibid.

[104] Seal, M. et al. Experimental radiotherapy-induced enteritis: a probiotic interventional study. *Journal of Digestive Disease* 2007 August; 8(3): 143-147.

[105] Demirer, S. Effects of probiotics on radiation-induced intestinal injury in rats. *Nutrition* 2006 February; 22(2): 179-186. See also the review article by Ciorba, M. and Stenson, W. Probiotic therapy in radiation-induced intestinal injury and repair. *Annals of the New York Academy of Science* 2009 May; 1165: 190-194. See also discussion in Ciorba, M. and Stenson, W. Probiotic therapy in radiation-induced intestinal injury and repair. *Annals of the New York Academy of Science* 2009 May; 1165: 190-194.

[106] An excellent review of the research on the mechanisms of mint, see Baliga, M. and Rao, S. Radioprotective potential of mint: a brief review. *Journal of Cancer Research and Therapeutics* 2010 July-September; 6(3): 255-262.

The radiation protection from mint may have many mechanisms, including "free radical scavenging, antioxidant, metal chelating, anti-inflamatory, antimutagenic [mechanisms], and enhancement of the DNA repair processes."[107]

Mint prevented lipid peroxidation and weight loss in the testes of irradiated mice and it protected the germ cells, whereas the controls had severe testicular atrophy, with degeneration of the germ cells. [108] Mint protected gastrointestinal cells in rats[109] and protected bone marrow cells of irradiated mice from oxidative damage and DNA damage from radiation.[110]

In a study of lethal radiation, 80 to 100 percent of the mice survived, depending on the timing of the mint administration. The dose used was 10 milligrams per kilogram of body weight. In the same study mint was found to be non-toxic up to 1 gram per kilogram of body weight, the highest dose that researchers could test. [111]

In other animal research mint increased the glutathione system and decreased lipid peroxidation in irradiated mice. The mint also increased blood counts, hemoglobin concentration and hematocrit values, as compared to controls. The dose reduction factor was calculated to be 1.78, the highest found for any herb that protects from radiation damage. At the highest doses of radiation, 42% of the mice given mint died, as contrasted to 100% of the controls. [112]

B. Radiation Protection from Lemon Balm

Only one study shows lemon balm as radioprotective. But because the study is compelling and use of lemon balm is safe, easy, and cheap, I draw it to your attention. A clinical trial of lemon balm tea (drunk twice a day for 30 days) by 55

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[107] Baliga, M. and Rao, S. Radioprotective potential of mint: a brief review. *Journal of Cancer Research and Therapeutics* 2010 July-September; 6(3):: 255-262.
[108] Samarth, R. and Samarth, M. Protection against radiation-induced testicular damage in Swiss albino mice by Mentha piperita (Linn.). *Basic Clinical Pharmacology and Toxicology* 2009 April; 104(4): 329-334.
[109] Haksar, A. et al. Mint oil (Mentha spicata Linn.) offers behavioral radioprotection: a radiation-induced conditioned taste aversion study. *Phytotherapy research* 2009 February; 23(2): 293-296.
[110] Samarth, R. Protection against radiation induced hematopoietic damage in bone marrow of Swiss albino mice by Mentha piperita (Linn.). *Journal of Radiation Research (Tokyo)* 2007 November; 48(6): 523-528.
[111] Jagetia, G. and Baliga, M. Influence of the leaf extract of Mentha arvensis Lin. (mint) on the survival of mice exposed to different doses of gamma radiation. *Strahlenther Onkol.* 2002 February; 178(2): 91-98.
[112] Samarth, R. and Kumar, A. Radioprotection of Swiss albino mice by plant exract Mentha piperita (Linn.). *Journal of Radiation Research (Tokyo)* 2003 June; 44(2): 101-109.

radiology staff members concluded that the lemon balm markedly improved their plasma levels of the antioxidant enzymes catalase, superoxide dismutase, and glutathione peroxidase. The lemon balm also decreased lipid peroxidation and DNA damage.[113]

C. Radiation Protection from Curcumin (extract of the spice Tumeric)

Curcumin has protected liver, kidney, heat, and the oral mucous membranes from radiation-induced toxicity.

Curcumin's radiation protection effects are partly from its ability to scavenge free radicals, including the hydroxyl and peroxide radicals. Curcumin also increases levels of glutathione. It activates nuclear regulating factor 2 (NRF2), which activates the antioxidant response. And curcumin controls inflammatory chemical messengers such as nuclear factor kappa beta (NFkB). Curcumin has been given to cancer patients undergoing cancer treatments, because it sensitizes tumors to radiation and to chemotherapy while it nevertheless protects normal tissue**.** [114]

D. Radiation Protection from Ginseng

Ginseng protected against radiation damage in four animal studies as well as in several cell studies.

In one animal study, ginseng protected from death the cells in the intestine that produce lining cells. [115] In another very recent animal study, ginseng protected the red blood cell levels, hematocrit levels, and hemoglobin levels, as compared to controls. This study also found that the ginseng increased levels of glutathione in

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[113] Zeraatpishe, A. et al. Effects of Melissa officionalis L. on oxidative status and DNA damage in subjects exposed to long-term low-dose ionizing radiation. *Toxicology and Industrial Health* 2011 April; 27(3): 205-212.

[114] See these review articles: Goel, A. and Aggarwal, B. Curcumin, the golden spice from Indian saffron, is a chemosensitizer and radiosensitizer for tumors and chemoprotector and radioprotector for normal organs. *Nutrition and Cancer* 2010; 62(7): 919-930. Anand, P. et al. Curcumin and cancer: an "old-age" disease with an "age-old" solution. *Cancer Letter* 2008 August 18; 267(1): 133-134. Jagetia, G. Radioprotection and radiosensitivity by curcumin. *Advanced Experimental Medical Biology* 2007; 595: 301-320.

[115] Park, E. et al. Acidic polysaccharide of Panax ginseng as a defense against small intestinal damage by whole-body gamma irradiation of mice. *Acta Histochem.* 2011 January; 113(1): 19-23.

serum as well as in the liver, and that the ginseng diminished lipid oxidative damage in the liver.[116]

In an earlier animal study, ginseng protected the testes of mice from lipid peroxide damage.[117] And a study done 2 decades ago found that ginseng protected intestinal lining-generating cells from oxidative damage and also reduced numbers of micronuclei in spleen lymphocytes, as compared to controls. [118] A group of Korean researchers has made several studies of ginseng's effects on irradiated human lymphocytes. The group has concluded that ginseng reduces free radicals, increases the total anti-oxidant capacity of the cells, and prevents the development of micronuclei by 37 to 54 percent, depending on the dose of radiation.[119]

E. Radiation Protection from Ginger

Ginger has been shown to protect against radiation damage in four animal studies.

Two studies of ginger extract at two different doses found that the extract protected against both gastro-intestinal and bone marrow deaths from radiation damage in mice subjected to whole-body radiation. Ginger also protected against lipid peroxidation from radiation damage in a dose/response manner.[120] A dose of 250

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[116] Verma, P. et al. Amelioration of radiation-induced hematological and biochemical alterations in Swiss albino mice by Panax ginseng extract. *Integrative Cancer Therapies* 2011 March; 10(1): 77-84.
[117] Kumar, M. et al. Radioprotective effect of Panax ginseng on the phosphatases and lipid peroxidation level in testes of Swiss albino mice. *Biological and Pharmaceutical Bulletin* 2003 March; 26(3): 308-312.
[118] Kim, S. et al. In vivo radioprotective activity of Panax ginseng and diethyldithiocarbamate. *In Vivo* 1993 September-October; 7(5): 467-470.

[119] Lee, T. et al. Radioprotective effect of American ginseng on human lymphocytes at 90 minutes postirradiation: a study of 40 cases. *Journal of Alternative and Complementary Medicine* 2010 May; 16(5): 561-567. Lee, T. et al. American ginseng modifies Cs-induced DNA damage and oxidative stress in human lymphocytes. *Open Nuclear Medical Journal* 2009 January 1; 1(1): 1-8. Lee, et al. Effect of North American ginseng on 137Cs-induced [cesium 137] micronuclei in human lymphocytes: a comparison with WR-1065 [synthetic radioprotector]. *Phytotherapy Research* 2008 December; 22(12): 1614-1622. Lee, T. et al. Radioprotective potential of ginseng. *Mutagenesis* 2005 July; 20(4): 237-243 (review article).
[120] Jagetia, C. et al. Ginger (Zingiber officinale Rosc.), a dietary supplement protects mie against radiation-induced lethality; mechanism of action. *Cancer Biotherapy and Radiopharmacruticals* 2004 August; 19(4): 422-435. Jagetia, C. et al. Influence of ginger rhizome (Zingiber officinale Rosc) on survival, glutathione and lipid

mg/kg had a dose reduction factor of 1.2, [121] and a dose of 10 mg/kilogram had a DRF of 1.15.[122]

Two studies focused on extracts of ginger for their radiation protection effects. Zingerone normalized intestinal cells in mice subject to whole body irradiation. The zingerone also reduced the numbers of micronucleated cells, increased antioxidant enzymes, and decreased lipid peroxide levels. [123] A second study used dehydrozingerone and achieved similar radiation protection results, calculating the dose reduction factor as 1.09. [124]

F. Radiation Protection from Rosemary

Rosemary has been shown effective against radiation damage in three animal studies.

In one study of mice exposed to lethal gamma radiation, rosemary extract reduced the mortality rate of mice, reduced lipid peroxidation, and increased glutathione in the blood and liver. The most effective dose was 1 gram per kilogram of body weight. [125]

Rosemary extract protected intestinal cells from radiation damage (including cells that generate lining cells. It also reduced lipid peroxidation from radiation damage and increased levels of glutathione in mice exposed to sub-lethal radiation. [126]

In another study of mice subjected to radiation, the same group of researchers found that rosemary extract decreased lipid peroxidation from radiation damage and raised glutathione levels in the liver. The rosemary also normalized glycogen,

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peroxidation in mice after whole-body exposure to gamma radiation. *RadiationResearch* 2003 November; 160(5): 584-592.

[121] Jagetia 2004, op cit.

[122] Jagetia 2003, op cit

[123] Rao, B. et al. Radiomodifying and anticlastogenic effect of Zingerone on Swiss albino mice exposed to whole body gamma radiation. *Mutation Research* 2009 June-July; 677(1-2): 33-41.

[124] Parihar, V. et al. Free radical scavenging and radioprotective activity of dehydrozingerone against whole-body gamma irradiation in Swiss albino mice. *Chemico-Biological Interactions* 2007 October 20; 170(1): 49-58.

[125] Jindal, A. et al. Radioprotective potential of Rosemarinus officinalis against lethal effects of gamma radiation: a preliminary study. *Journal of Environmental Pathology, Toxicology, and Oncology* 2006; 25(4): 633-642.

[126] Jindal, A., Agrawal, A., and Goyal, P. Influence of Rosemarinus officinalis extract on radiation-induced intestinal injury in mice. *Journal of Environmental Pathology, Toxicology and Oncology* 2010; 29(3): 169-179.

pH, and cholesterol levels, whereas control animals did not achieve normal values by 30 days following radiation. [127]

In studies not involving radiation, rosemary has been found to be an anti-inflammatory and to reduce levels of the pro-cancerous nuclear factor-kappa beta. Rosemary consumption in food has been linked with reduced rates of cancer, cardiovascular disease, and diabetes. An extract of rosemary, carnosol, is selectively toxic to cancer cells, without harming normal cells.[128]

G. Radiation Protection from Gotu kola (Centella asiatica)

The Chinese herb gotu kola has been found effective against radiation damage in four animal studies and one cell culture study.

Gotu kola also has demonstrated antimicrobial, antiviral, and immune-stimulating effects in animal studies.[129]

In mice exposed to whole-body gamma radiation, the gotu kola reduced the numbers of deaths from radiation. Gotu kola also reduced lipid peroxidation from radiation and DNA damage in bone marrow cells (the only cells examined).[130] A prior study by the same researchers (cited in the same abstract) found that gotu kola also prevented a radiation-induced decline in levels of antioxidant enzymes.

Another animal study examined gotu kola's ability to protect liver cells in irradiated mice. The dose of 100mg per kilogram of body weight increased the number of

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[127] Soyal, D. et al. Modulation of radiation-induced biochemical alterations in mice by rosemary (Rosemarinus officinalis) extract. *Phytomedicine* 2007 October; 14(10): 701-705.

[128] Johnson, J. Carnosol: a promising anti-cancer and anti-inflammatory agent. *Cancer Letters* 2011 June 1; 305(1): 1-7. Epub March 5, 2011. Lo, A-H. et al. Carnosol, an antioxidant in rosemary, suppresses inducible nitric oxide synthase through down-regulating nuclear factor-kB in mouse macrophages. *Carcinogenesis* 2002 June; 23(6): 983-991. Awney, H. and Sindi, H. The effect of rosemary on the mutagenic activity of heterocyclic amines extracted from common food consumed in Saudi Arabia. *International Journal of Food Science and Nutrition* 2010 March; 61(2): 192-203.

[129] Brinkhaus, B. et al. Chemical, pharmacological, and clinical profile of the East Asian medical plant Centella asiatica. *Phytomedicine* 2000 October; 7(5): 427-448.

[130] Joy, J. and Nair, C. Protection of DNA and membranes from gamma-radiation induced damages by Centella asiatica. *Journal of Pharmacy and Pharmacology* 2009 July; 61(7): 941-947.

normal liver cells and decreased the number of micronuclei in the cells, as compared to liver cells in irradiated controls who were not given the herb. [131]

A prior mouse study by the same researchers determined that a dose of 100 mg per kilogram of body weight was the most effective, against sub-lethal cobalt-60 gamma radiation. The gotu kola increased survival times and diminished weight loss of the irradiated animals, as compared to controls.[132]

Finally, Chinese radiologists found that an ointment containing the most active extract from gotu kolu alleviated skin damage from irradiation in rats, as compared to controls treated with Vaseline. [133] (The ointment was selected for study because of gotu kola's effectiveness in treating wound-healing disturbances in other contexts.[134])

IX. Foods that Protect from Radiation Damage

Several inexpensive and widely used foods offer radiation protection in animal studies: beets, spinach, grapefruit, mustard leaf, and apricots.

Less common foods also show radiation protection: black grapes, Grewia asiatica, Indian gooseberry or aamla, and elephant ears.

An extract of red beets was found to protect against radiation damage in mice. The betalain extract protected spleen and thymus function, protected generation of blood cells, and reduced numbers of micronuclei in bone marrow. [135]

An extract of spinach protected against radiation damage in a study of mice that focused on liver damage from radiation. The spinach extract reduced lipid peroxidation damage and alleviated the radiation-induced depletion in the antioxidant glutathione. The percentage of protection ranged from 23% to 43%.

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[131] Sharma, R. and Sharma, J. Modification of gamma ray induced changes in the mouse hepatocytes by Centella asiatica extract: in vivo studies. *Phytotherapy Research* 2005 July; 19(7): 605-611.
[132] Sharma, J. and Sharma, R. Radioprotection of Swiss albino mouse by Centella asiatica extract. *Phytotherapy Research* 2002 December; 16(6): 785-786.
[133] Chen, Y. et al. The effect of tetrandrine and extracts of Centella asiatica on acute radiation dermatitis in rats. *Biological and Pharmaceutical Bulletin* 1999 July; 2(7): 703-706.
[134] Brinkhaus, op cit.
[135] Lu, X., Wnag, Y., and Zhang, Z. Radioprotective activity of betalains from red beets in mice exposed to gamma radiation. *European Journal of Pharmacology* 2009 August; 615(1-3): 223-227.

Researchers attributed the protection to the carotenoid, flavonoid, and ascorbic acid content of spinach. [136] A review article that did not focus on radiation damage found that spinach has contains a "powerful" antioxidant mixture called NAO that has been found superior in animal and cell studies to the antioxidant activity of green tea, N-acetylcysteine, and vitamin E. NAO is also non-toxic, non-mutagenic, and may be anti-carcinogenic.[137]

A flavonone in grapefruit protected mice from radiation damage to chromosomes in the bone marrow. Treatment of the mice with this flavonone, naringin, at 2 mg per kilogram of body weight reduced chromosomal aberrations and chromatid breaks. The naringin also scavenged hydroxyl and superoxide radicals, scavenging 90% of radicals from sulphonic acid. [138] Naringin is found in the peel of grapefruit and gives grapefruit its bitter flavor. Grapefruit juice is not a good source of the bioflavonoid, because manufacturers use fruits with low naringin content to avoid bitterness. [139] A better source would be a whole grapefruit peeled like an orange, with the inner peel also scraped and consumed. Naringin supplements are also available.

An extract of mustard leaf (brassica campestris) prevented lipid peroxide and chromosomal damage in mice subjected to gamma radiation. The extract also increased the activity of glutathione. The extract was administered at 50 to 250 milligrams per kilogram of body weight. [140]

Apricots were fed to rats at 20% of the caloric intake, and the rats were then subjected to low-dose X-rays. The apricot-rich diet reduced oxidative damage and prevented tissue disintegration in the rats' testes, as compared to the radiation damage suffered by controls.[141]

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[136] Bhatia, A. and Jain, M. Spinacia oleracea L. protects against gamma radiations: a study on glutathione and lipid peroxidation in mouse liver. *Phytomedicine* 2004 November; 11(7-8): 607-615.
[137] Lomnitski, L. et al. Composition, efficacy, and safety of spinach extracts. *Nutrition and Cancer* 2003; 46(2): 222-231.
[138] Jagetia, G., Venkatesha, V., and Reddy, T. Naringin, a citrus flavonone, protects against radiation-induced chromosome damage in mouse bone marrow. *Mutagenesis* 2003 July; 18(4): 337-343.
[139] "Naringin: Nonessential Micronutrient" at Nutros.net http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2703618/ accessed 5/3/11.
[140] Tiku, a. et al. Protective effect of the cruciferous vegetable mustard leaf (Brassica campestris) against in vivo chromosomal damage and oxidative stress induced by gamma-radiation and genotoxic chemicals. *Environmental and Molecular Mutagenesis* 2008 June; 49(5): 335-342.
[141] Ugras, M. et al. Prunus armeniaca L. (apricot) protects rat testes from detrimental effects of low-dose X-rays. *Nutrition Research* 2010 March; 30(3): 200-208.

Black grape juice prevented oxidative damage to liver cells in irradiated rats. The juice also restored the liver's glutathione antioxidant system to levels comparable to those in non-irradiated controls. [142]

The fruit Grewia asiatica (commonly called *phalsa* or f*alsa*), native to southern Asia, has been shown to protect against damage from radiation in three animal studies. In a study of irradiated mice, the Grewia extract (at 700mg per kilogram of body weight) alleviated lipid peroxidation and protected glutathione levels. The fruit also protected DNA and RNA in the testes from radiation damge. Researchers attributed the effects to the ascorbic acid, carotene, and anthocyanin content of the fruit. A cell culture study by the same researchers found that Grewia also protected cellular proteins from oxidative damage due to radiation.[143]

In another study by the same group, the Grewia pulp extract given to irradiated mice inhibited the depletion of glutathione and alleviated lipid peroxidation, which reached normal levels by 30 days after radiation.[144] A third study focusing on brain tissue likewise found protection of glutathione and proteins from radiation damage. [145]

Emblica officinalis (Indian gooseberry or aamla) has been radioprotective in two animal studies. Mice exposed to gamma radiation had significantly increased numbers of white blood cells, red blood cells and levels of hemoglobin, and hematocrit values, as compared to controls. Also, the aamla-ingesting animals had increased glutathione levels and decreased lipid peroxidation, although these levels remained abnormal. [146] In an earlier study, aamla extract at 100 mg per kilogram of body weight reduced weight loss, increased the survival time, and reduced the mortality of irradiated mice.[147]

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[142] Andrade, E. et al. Evaluation of the potential protective effects of ad libitum black grape juice against liver oxidative damage in whole-body acute X-irradiated rats. *Food and Chemical Toxicology* 2001 April; 49(4): 1026-1032.

[143] Sharma, K. and Sisodia, R. Evaluation of the free radical scavenging activity and radioprotective efficacy of grewia asiatica fruit. *Journal of Radiology Protection* 2009 September; 29(3): 429-443.

[144] Sisodia, R. et al. Post treatment effect of Grewia asiatica against radiation-induced biochemical alterations in Swiss albino mice. *Environmental Pathology, Toxicology, and Oncology* 2008; 27(2): 113-121.

[145] Sisodia, R., et al. Modulation of radiation-induced biochemical changes in cerebrum of Swiss albino mice by Grewia Asiatica. *Acta Neurobiologiae Experimentalis (Warsaw)* 2008; 68(1): 32-38.

[146] Singh, I., Soyal, D., Goyal, P. Emblica officinalis (Linn.) fruit extract provides protection against radiation-induced hematological and biochemical alterations in mice. *Journal of Environmental Pathology, Toxicology, and Oncology* 2006; 25(4): 643-654.

[147] Singh, et al. Radioprotection of Swiss albino mice by Emblica officinalis. *Phytotherapy Research* 2005 May; 19(5): 444-446.

A number of other medicinal food extracts offer radiation protection. Each has received a single animal study of radiation protection:

Hippophae rhamnoides (sea buckthorn);[148]
Ocimum (holy basil);[149]
NIgella sative (black seed oil);[150]
Tinospora cordifolia (Guduchi);[151]
Alstonia scholaris (blackboard tree, devil tree);[152]
Cordyceps Sinensis (mushroom);[153]
Salvia miltiorrhiza (Chinese sage).[154]

X. Nutrients that Prevent Absorption of Radioactive Particles

Absorption of radioactive particles creates an internal source of radiation, lasting as long as the particle is radioactive. For radioactive particles from nuclear accidents, the half-life is at least thirty years and may extend for hundreds or millions of years.

Laminara (the seaweed kombu) and its sodium alginate extract inhibit the absorption of radioactive strontium, iodine, cesium. They also may help the body to excrete these radioactive particles, as well as plutonium and radon.

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[148] Shukla, S. Protection from radiation-induced mitochondrial and genomic DNA damage by an extract of Hippophae rhamnoides. *Environmental and Molecular Mutagenesis* 2006 December; 47(9): 647-656. See also Vhawla, R. et al. Radioprotective and antioxidant activity of fractionated extracts of berries of Hippophae rhamnoides. *Medicinal Food* 2007 March; 10(1): 101-109.

[149] Monga, J. et al. Antimelanoma and radioprotective activity of alcoholic aqueous extract of different species of Ocimum in C(57)BL mice. *Pharmaceutical Biology* 2011 April; 49(4): 428-436.

[150] Assayed, M. Radioprotective effects of black seed (Nigella sativa) oil against hemopoietic damage and immunosupression in gamma-irradiated rats. *Immunopharmacology and Immunotoxicology* 2010 June; 32(2): 284-296.

[151] Sharma, P. et al. Radiation-induced testicular injury and its amelioration by Tinospora cordifolia (an Indian medicinal plant). *Evidence Based Complementary and Alternative Medicine* 2011; 2011: 643847.

[152] Gupta, U. et al. Amelioration of radiation-induced hematological and biochemical alterations by Alstonia scholaris (a medicinal plant) extract. *Integrative Cancer Therapies* 2008 September; 7(3): 155-161.

[153] Xun, C. et al. Radiation mitigation effect of cultured mushroom fungus Hirsutella Sinensis (Corimmune) isolated from a Chinese/Tibetan herbal preparation—Cordyceps Sinensis. *International Journal of Radiation Biology* 2008 February; 84(2): 139-149.

[154] Du, H, Qian, Z., and Wang, Z. [Prevention of radiation injury of the lungs by Salvia miltiorrhiza in mice.] [Article in Chinese] *Zhong Xi Yi Jie He Za Zhi* 1990 April; 10(4): 230-231, 198.

A. Radiation Protection from Laminaria.

Russian researchers irradiated rats with radioactive cesium from an external source, and implanted radioactive iodine in the thyroid glands of the mice to serve as an internal source of radiation. The researchers found that laminaria in the diet decreased the incidence of leukemia and malignant tumors among the irradiated mice, as compared to controls. The laminaria also increased the latency period prior to tumor formation.[155]

Laminaria suppresses the thyroid gland's absorption of radioactive iodine.
In one study a significant reduction in uptake of radioactive iodine was observed in mice fed a diet containing 1% to 2% powdered Laminaria religiosa. A second experiment showed that the degree of the suppression of radioactive iodine uptake depended on the amount of iodine in the diet, whether from seaweed or from an inorganic iodine supplement. Researchers concluded that iodine-rich material, such as dietary seaweeds or inorganic iodine supplements, would be effective in preventing radiation damage to the thyroid by preventing absorption of radioactive iodine. [156]

In addition, beta-1,3;1-6-glucan, extracted from Laminaria, stimulated the immune systems of irradiated mice in two Russian studies. In one study, the beta glucan increased the number and activity of immune cells in mice subjected to radiation. [157] In a previous study of mice who were irradiated and infected, the beta glucan reduced the number of microbes found in the spleen and also stimulated the ability of macrophages to ingest and digest microbes. The researchers concluded that the beta glucan was "an effective stimulator of immunity." [158]

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[155] Knizhnikov, V. et al. [The effect of adding Laminaria japonica to food on the ong-term effects when combined with radiation injury.] [Article in Russian] *Gigiena i sanitaritaria* 1993 December; (12): 37-39.
[156] Maruvama, H. and Yamamoto, I. Suppression of 125I-uptake in mouse thyroid by seaweed feeding: possible preventative effect of dietary seaweed on internal radiation injury of the thyroid by radioactive iodine. *Kitasato Arch Exp Med* 1992 December; 65(4): 209-216.
[157] Zaporozhets, T. et al. [The effect of translam {beta glucan} on the immune response of irradiated mice.] [Article in Russian] *Radiats Biol. Radioecol. [Radiatsionnaia biologiia, radioecologiia]* 1995 March-April; 35(2): 260-263.
[158] Kuznetsova, T. et al. [The effect of translam {beta glucan} on the natural resistance indices of the irradiated organism.] [Article in Russian] *Radiats Biol Radioecol.* 1994 March-Aril; 34(2): 236-239. See also Zaporozhets, T. et al. [The effect of translam on the immune response of irradiated mice.] [Article in Russian] *Radiats. Biol. Radioecol.* 1995 March-Aril; 35(2): 260-263.

B. Radiation Protection from Sodium Alginate

A significant amount of research supports the use of sodium alginate, another Laminaria extract, to prevent absorption of radioactive particles. Alginate binds to heavy metals, such as lead, mercury, cadmium, cobalt, and radium, whether or not these metals are radioactive isotopes. Because alginate cannot be broken down by bile or by saliva, it cannot be absorbed by the body. The alginate is secreted along with the metals it contains.[159]

Several studies by Canadian researchers document the ability of both calcium alginate and sodium alginate to prevent the absorption of radioactive strontium. In one study calcium alginate diminished the absorption of radioactive calcium as well as radioactive strontium.[160] In another study, injected sodium alginate reduced the absorption of radioactive strontium in the intestines by 50% to 80% of the amount absorbed by control animals. Blood and bone levels of radioactive strontium were correspondingly reduced. [161] A three-year study found that small constant doses of sodium alginate (at 1.4%, 12%, and 24% of the diet) were sufficient to reduce bone uptake of radioactive strontium from food.[162]

A human study in China replicated these results with a different formulation of sodium alginate. Researchers assessed 23 different preparations of alginate from several species of Laminaria and Sargassum, another seaweed. The researchers concluded that sodium alginate from Sargassum siliquastrum was the more potent agent. This alginate, ingested in bread at 6% of the bread's weight, reduced absorption of stable (non-radioactive) strontium by 78% in human volunteers, without altering calcium, iron, copper, or zinc metabolism, and without gastro-intestinal effects. [163]

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[159] See discussion by Canadian chemical engineers Volesky, B. and Holan, Z. Alginates and detoxification. *Biotechnology Progress* 1995 May-June; 11(3): 235-250.

[160] Paul, T., Skoryna, S., and Waldron-Edward, D. Studies on the inhibition of intestinal absorption of radioactive strontium. V. The effect of administration of calcium alginate. *Canadian Medical Association Journal* 1966 November 5; 95(19): 957-960.

[161] Skoryna, S., Paul, T. and Waldron-Edward, D. Studies on inhibition of intestinal absorption of radioactive strontium. I. Prevention of absorption from ligated intestinal segments. *Canadian Medical Association Journal* 1964 August; 8; 91: 285-288.

[162] Skoryna, S. Paul, T., and Waldron-Edward, D. Studies of inhibition of intestinal absorption of radioactive strontium. IV. Estimation of the suppressant effect of sodium alginate. *Canadian Medical Association Journal* 1965 August 28; 93: 404-407.

[163] Gong, Y et al. Suppression of radioactive strontium absorption by sodium alginate in animals and human subjects. *Biomedical and Environmental Sciences* 1991 September; 4(3): 273-282.

A German study found that sodium alginate, when added to strontium-contaminated milk, prevented human absorption of the radioactive strontium particles. In fact, the absorption of radioactive strontium was reduced by a factor of nine when alginate was added to the milk. [164] A similar Russian study also found that sodium alginate prevented the absorption of radioactive strontium from milk. [165]

In other studies, a combination of algisorb (apparently an alginate product) and riboxin prevented absorption of plutonium in rats.[166]

C. Excretion of Radioactive Particles: Alginates

Alginates also help the body to excrete radioactive particles that have been absorbed.

The mechanism is as follows: A portion of radioactive strontium molecules stored in the bone, for example, are continually being released to the blood stream. Some of the released radioactive strontium enters the large intestine with other fluids. Most of the liquid in the large intestine is re-absorbed, including the radioactive isotopes, which are then redeposited in the bone. Alginate interrupts this redeposition by absorbing strontium in the intestines. The strontium-alginate complex is then released from the body. [167]

The body's release of absorbed strontium has been confirmed in several studies. A study at the Pacific Northwest National Laboratory in Washington State found that alginate "selectively binds ingested strontium" and also reduces skeletal retention of strontium, without changing calcium metabolism. [168]

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[164] Hollriegl, V. et al. Strontium biokinetics in humans: infuence of alginate on the uptake of ingested strontium. *Health Physics* 2004 February; 86(2): 193-196.
[165] Ivannikov, A. Altukhova, G., and Parfenova, I. [Effect of algisorb on decomntamination of milk contaminated with 90Sr [radioactive strontium}]. [Article in Russsian] (addition of algisorb to milk created an insoluble complex of alginate and strontium, preventing absorption) *Radiats Biol. Radioecol.* 1994 July-October; 34(4-5): 713-717.
[166] Vernigorova, L. et al. [Combined prophylactic administration of riboxin and algisorbum at 239Pu intake into gastrointestinal tract of rats.] (Article in Russian] *Radiats Biol.Radioecol.* 2005 March-April; 45(32): 201-206.
[167] This description is from Volesky, B. and Holan, Z. Alginates and detoxification. *Biotechnology Progress* 1995 May-June; 11(3): 235-250.
[168] Levitskaia, T. et al. Biomaterials for the decorporation of (85)Sr in the rat. *Health Physics* 2010 September; 99(3): 394-400. Researchers also found that the removal of strontium was accelerated when alginate was dissolved in a sodium chloride solution containing low molecular weight polyethylene glycol.

Similarly, sodium alginate was found to remove radium from the bone in mice.[169] In a rat study, laminaria ingested at 20 grams per animal reduced the accumulation of cesium and strontium by 77% and 58% respectively. [170]

For persons living in the regions polluted by the Chernobyl release, Laminaria in the human diet (along with calcium carbonate and bone meal) reduced the accumulation of both radioactive strontium and radioactive cesium. [171]

If alginate treatment were delayed, however, alginate would cause the release of radium from the bone without diminishing the risk of bone cancer. [172] (This result was found in a rat study.) The delay in this case was only four days, which indicates the need for immediate prophylactic measures against radioactive particles.

D. Excretion of Radioactive Particles: Pectin

Pectin has also been found to reduce the body's burden of radioactive particles.

Pectins, natural constituents of fruits, are polysaccharides that are used as jelling and thickening agents in foods such as jams and jellies. Apples and carrots contain among the highest amounts of pectin, about 1.5% of the total weight. Dried citrus peels are about 30% pectin.[173]

From 1996 to 2007 a total of 160,000 children from Belarus received pectin supplements for 25 days of treatment, at 5 grams of pectin twice per day, for unspecified numbers of treatments. The levels of cesium-137 in the children's organs decreased after each course of treatment by 30% to 40%. Continued treatment is necessary because consumption of local contaminated foods is unavoidable. The Institute of Radiation Safety in Belarus has concluded that cesium accumulation in Belarusians is three to eight times the official calculation. The Institute recommends the manufacture and consumption of pectin products "under

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[169] Schoeters, G. et al. Sparing of bone marrow stem cells by long-term administration of Na-alginate to 226Ra contaminated mice. 1979 October; 36(4): 379-386.
[170] Korzun, V. et al. [Evaluation of the use of sea products in nutrition of population inhabiting regions under rigid radiation control]. *Vopr. Pitan.* 1993 March-April; (2): 36-38.
[171] Shandala, N. [Alimentary methods for decreasing the radiation load of the body with cesium and strontium radionuclides]. [Article inRussian] *Gig sanit.* 1993 October (10): 51-54.
[172] Schoeters, G., Luz, A., and Vanderborght, O. 226Ra induced bone-cancers: the effects of a delayed Na-alginate treatment. *International Journal of Radiation Biology and Related Studies in Physics and Chemical Medicine* 1983 March; 43(3): 231-247.
[173] Wikipedia: Pectin. http://en.wikipedia.org/wiki/Pectin Accessed 5/3/11

circumstances where consumption of radioactively contaminated food is unavoidable." [174]

Researchers in Belarus gave apple pectin for 16 days to children with moderate and high radioactive cesium loads. The children's' cesium loads were decreased by 39% and 28%, respective. The children's abnormal heart rhythms from radiation damage also improved.[175]

A placebo-controlled study of pectin was done among Belarusian children staying for one month at a "clean" sanatorium. The children who were given radiologically "clean" food and a placebo for one month reduced their cesium levels by 14%,, whereas those given apple pectin along with the clean food reduced their cesium load by 63%. None of the children receiving the clean food and the placebo decreased their cesium levels below the official danger point, whereas all the children on pectin did so. [176]

In additional research on the protective effect of pectin supplements among those subjected to radiation from the Chernobyl accident, pectin-containing fruits and foods enriched with pectin were found to improve antioxidant levels in the blood.[177]

E. Possible Excretion of Radioactive Particles: Vitamin C

Vitamin C seems to assist the body in excreting several heavy metals, including cadmium, lead, gold, and chromium. [178] Thus it may assist with the

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[174] Nesterenko, V. and Nesterenko, A. Decorporation of Chernobyl radionuclides. *Annals of the New York Academy of Sciences* 2009 November; 1181: 303-310.
[175] Bandazhevskaya, G. et al. Relationship between caesium (137Cs) load, cardiovascular symptoms, and source of food in "Chernobyl" children—preliminary observations after intake of oral apple pectin. *Swiss Medical Weekly* 2004 December 18; 134(49-50): 725-729.
[176] Nesterenko, V. et al. Reducing the 137Cs-load in the organism of "Chernobyl" children with apple-pectin. *Swiss Medical Weekly* 2004 January 10; 143(1-2): 24-27.
[177] Bereza, V. et al. [Pectin-containing products in the dietary nutritionof subjects exposed to ionizing radiation as a result of the accident at the Chernobyl Atomic Electric Power Station]. *Lik Sprava.* 1993 July (8): 21-24.
[178] See for example, Pace, V. The importance of vitamins in relation to the presence of heavy metals in food. *Panminerva Med.*1994 June; 36(2): 80-82; Kim, H. et al. Blood cadmium concentrations of male cigarette smokers are inversely associated with fruit [and vitamin C] consumption. *Journal of Nutrition* 2010 June; 140(6): 1133-1138; Cheng, Y. et al. Relation of nutrition to bone lead and blood lead levels in middle-aged to elderly men, the normative aging study. *American Journal of Epidemiology* 1998; 147(12): 1162-1174; Simon, J. and Hudes, E. Relationship of ascorbic acid to blood lead levels. *JAMA* 1999; 28(24): 2289-2293; Dawson, E. et al. The effect of ascorbic acid supplementation on the blood lead levels of smokers. Journal of the American College of Nutrition *1999; 18(2): 166-170*. Summaries of

excretion of radioactive heavy metals, although this effect has not been studies.

F. Radiation Protection from Sodium bicarbonate: Detoxifying Uranium

Sodium Bicarbonate (baking soda) has traditionally been used to detoxify uranium.

Research in this area dates back to 1916, with the publication of an animal study showing that the toxicity of uranium nitrate to the kidneys could be inhibited by sodium bicarbonate. [179] (Uranium nitrate was used to provoke kidney disease in animals, in order to study kidney disease.) Although the original researcher used intravenous administration of the bicarbonate, a later researcher found the same protective effect by administering the bicarbonate solution to dogs through a gastric feeding tube.[180] So absorption through the stomach does not change the efficacy of the bicarbonate for this purpose.

The mechanism of the kidney toxicity and its relief, according to these researchers, is that the uranium causes the kidneys to form the acid products acetone and diacetic acid. These acids in turn cause tissue damage in the microtubules of the kidneys. The bicarbonate, being alkaline, counteracts the toxicity of these acids.

Sodium bicarbonate for detoxifying uranium's effects on the kidneys is still being recommended. [181] A recent study suggests that the bicarbonate may also mobilize uranium from body tissues, but the article's abstract is not clear on this point and I

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earlier studies appear in Stone, Irwin, *Vitamin C against Disease,* Grosset & Dunlap, 1972, pages 152-156.

[179] MacNider, W. The inhibition of the toxicity of uranium nitrate by sodium carbonate, and the protection of the kidney acutely nephropathic from uranium from the toxic action of an anesthetic by sodium carbonate. *Journal of Experimental Medicine* 1916 February 1; 23(2): 171-187. Free full text at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2125401/?tool=pubmed

[180] Goto, K. A study of the acidosis, blood urea, and plasma chlorides in uranium nephritis in the dog, and of the protective action of sodium bicarbonate. *Journal of Experimental Medicine* 1979; 25(5): 693-719. Free full text at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2125507/?tool=pubmed Dr. Goto showed that the sodium bicarbonate administered in this way increased the carbon dioxide content of the plasma, which in turn was associated with reduced kidney toxicity from the uranium.

[181] Fatome, M. [Management of accidental internal exposure]. [Article in French] *Journal of Radiology* 1994 November; 75(11): 571-575 (a writer from the French Center for Research on Army Health recommends sodium bicarbonate for uranium exposure).

was not able to access the article itself.[182] Uranium accumulates in the bone and is toxic to the cells that create new bone.[183] Dr. Apsley recommends bicarbonate in small doses for radiation protection. He apparently believes that sodium bicarbonate does cause excretion of uranium. I quote his recommended dosing schedule for sodium bicarbonate in Appendix I.

G. **Calcium Supplements to Prevent Absorption of Radioactive Strontium[184]**

Researchers in India gave to rats several types of calcium salts (including calcium lactate, calcium carbonate, calcium phosphate, and calcium gluconate) in order to reduce their body burden of radioactive strontium. The calcium salts reduced the animals' retention of radioactive strontium, from 50% to 60% after 24 hours, to 20% to 30% after 15 days. The control rats still retained 50-60% of their absorbed strontium after 15 days. The researchers concluded that calcium salts could replace the use of calcium alginate to reduce the body burden of strontium. They also found that calcium gluconate was the most effective of all the calcium salts tested.[185]

The effectiveness of calcium was confirmed in an American scientist's review of data on persons exposed to radioactive strontium from the Mayak nuclear facility in Russia. In adults, strontium deposition was not affected by age or sex. Instead, "absorption of strontium is reduced if the intake of stable calcium is very high and is enhanced if the intake of calcium is very low." [186]

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[182] Destombes, C., et al. [Reduction of renal uranium uptake by acetazolamide: the importance of urinary elimination of bicarbonate]. [Article in French] *Annales Pharmaceutiques Francaises* 1999 September; 57(5): 397-400. Also, in a separate cell study, sodium bicarbonate produced an alkaline environment in hamster ovary cells, which stimulated the expression of genes responsible for producing metallothioneins. Metallothioneins help to transport metals in cells. This effect on the metallothionein gene expression could be the mechanism for sodium bicarbonate's ability to increase uranium excretion—if that ability in fact exists. Lin, K. et al. Alkaline induces metallothionein gene expression and potentiates cell proliferation in Chinese hamster ovary cells. *Journal of Cell Physiology* 2005 December; 205(3): 428-436.

[183] Milgram, S. et al. Cellular accumulation and distribution of uranium and lead in osteoblastic cdells as a function of their speciation. *Toxicology* 2008 October; 252(1-3): 26-32.

[184] See general description of dilution of radionuclides by stable isotopes or analogous inactive elements in Voigt, G. Chemical methods to reduce the radioactive contamination of animals and their products in agricultural ecosystems. *Science of the Total Environment* 1993 September 24; 137: 205-225.

[185] Jagtap, V. et al. An effective and better strategy for reducing body burden of radiostrontium *Journal of Radiological Protection* 2003 September; 23(3): 317-326.

[186] Apostoaei, A. Absorption of strontium from the gastrointestinal tract into plasma in healthy human adults. *Health Physics* 2002 July; 83(1): 56-65. See also Shandala,

The International Atomic Energy Agency calculated that the lower-than-normal consumption of calcium among persons in most Asian countries "may lead to higher uptake of fission nuclide 90 Sr [radioactive strontium] and could result in perhaps higher internal radiation dose."[187] Asians' daily intakes of iodine (90 micrograms) were also only about 45% of the reference intakes proposed by the International Commission for Radiological Protection. [188]

H. Iodine Supplements to Prevent Absorption of Radioactive Iodine

Radioactive iodine may be absorbed in the thyroid gland and may eventually cause thyroid cancer as well as benign thyroid tumors. The thyroid gland is one of the most radiosensitive human organs. [189] Stable iodine prevents the absorption of radioactive iodine. [190]

The International Agency for Research on Cancer, in Lyon, France, studied the risk of thyroid cancer in Belarus and Russia following the Chernobyl accident. The researchers found a strong dose-response relationship between the radiation dose that the thyroid received in childhood and the risk of thyroid cancer. Moreover, the risk of radiation-related thyroid cancer was three times higher in regions where the soil was deficient in iodine. Use of "potassium iodide as a dietary supplement reduced this risk of radiation related thyroid cancer by a factor of three." [191]

N. [Alimentary methods for decreasing the radiation load of the body with cesium andstrontium radionuclides]. [Article in Russian] *Gig Sanit.* 1993 October; (10): 51-54 (calcium carbonate and bone meal in the diet, along with fish and laminaria, reduced levels of strontium-90 in the population living in regions polluted by the Chernobyl accident).

[187] Iyengar, G. et al. Dietary intakes of seven elements of importance in radiological protection by Asian population: comparison with ICRP [International Commission for Radiological Protection] data. *Health Physics* 2004 June; 86(6): 557-564.

[188] Ibid.

[189] Ron, E. and Brenner, A. Non-malignant thyroid diseases after a wide range of radiation exposures. *Radiation Research* 2010 September 7 [Epub ahead of print].

[190] Iodine from Laminaria or inorganic iodine each reduced uptake of radioactive iodine in the thyroid in mice, in experimental diets consisting of 1% and 2% powdered Laminaria. Maruyama, H. and Yamamoto, I. Suppression of 125I-uptake in mouse thyroid by seaweed feeding: possible preventative effect of dietary seaweed on internal radiation injury of the thyroid by radioactive iodine. *Kitasato Arch Exp. Med.* 1992 December; 65(4): 209-216.

[191] Cardis, et al. Risk of thyroid cancer after exposure to 131I [radioactive iodine] in childhood. *Journal of the National Cancer Institute* 2005 May 18; 97(10): 724-732. Thyroid cancer in children of Belarus began to increase in 1990, following the 1986 accident. Robbins, J. Lessons from Chernobyl: the event, the aftermath fallout: radioactive, political, social. *Thyroid* 1997 April; 7(2): 189-192.

The Norwegian government concluded that iodine supplements protect against the absorption of radioactive iodine isotopes. The government has arranged for the ready availability of iodine supplements for children and pregnant and breastfeeding women in case of nuclear accident, on the grounds that the risk for radiation-related thyroid cancer is much higher for fetuses and children under age 18.[192]

Doctors at Cornell Medical Center in New York concurred that "stable potassium iodide prophylaxis given shortly before or immediately after exposure [to radioactive iodine] can reduce greatly the thyroidal accumulation of radioiodines [radioactive iodine iosotopes]."

In Poland after the Chernobyl accident, 16 million persons received a single large dose of potassium iodide, with only rare side effects and "probably a 40% reduction in the projected thyroid radiation dose." [193]

Supplemental stable iodine also may protect other body tissues from damaging radiation from radioactive iodine. Recent research in humans indicates that the breasts, like the thyroid gland, likewise concentrate iodine. Moreover, iodine may be essential to prevent both fibrocystic breast disease and breast cancer.

The Reference Daily Intake for iodine has been set by the International Commission for Radiological Protection at 200 micrograms. [194] Japanese consumption of iodine (primarily from seaweed) is estimated at 1 to 15 milligrams daily. [195] The U.S. average intake is about 200 to 250 micrograms. Japanese women have among the lowest rates of breast cancer in the world. Americans have the highest rate of breast cancer. [196]

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[192] Jaworska, A. [Iodine prophylaxis following nuclear accicents]. [Article in Norwegian] *Tidsskr. Nor. Laepeforen* 2007 January 4; 127(1): 28-30.
[193] Becker, D. and Zanzonico, P. Potassium iodide for thyroid blockade in a reactor accident: administrative policies that govern its use. *Thyroid* 1997 April; 7(2): 193-197.
[194] Iyengar, op cit. This figure is calculated from the 90 micrograms of consumption in Asia, said to be 45% of the reference intake.
[195] In one study, home-cooked meals ranged from 360 to 1023 micrograms and institutional meals ranged from 47 to 5000 micrograms of iodine per meal. Katamine, S. Iodine content of various meals currently consumed by urban Japanese. *Journal of Nutritional Science and Vitaminology (Tokyo)* 1986 October; 32(5): 487-495. But see Nagataki, S. The average of dietary iodine intake due to the ingestion of seaweeds is 1.2 mg/day in Japan. *Thyroid* 2008 June; 18(6): 667-668 [abstract unavailable].
[196] On the need for iodine in larger amounts than the reference intake, see the following: Abraham, G. The safe and effective implementation of orthoiodosupplementation in medical practice. *Original Internist* 2004; 11:17-36. Flechas, J. Orthoiodosupplementation in a primary care practice. *Original* Internist

XI. Supplements of Questionable Value for Radiation Protection

Several substances have been recommended by supplement companies and nutritionists as offering radiation protection. For the following supplements I have found the evidence to be questionable.

A. First, **glutathione** administered as a supplement appears to have no effect on radiation damage.[197] (However, a special form of fat-soluble glutathione reduced levels of cobalt in rats by 12% to 43%, as compared to controls receiving ordinary glutathione supplements.)[198]

B. Second, **bentonite clay** works as a soil amendment to prevent transfer of radioactive particles to crops. [199] I could find no published evidence that bentonite clay prevents absorption of radioactive particles in the human gastrointestinal system.

C. Third, I could find no published study of **liquid zeolite** preparations, which are currently being sold as heavy metal chelators. (Zeolite is a type of rock that would not readily dissolve in water.)

For **powdered zeolite**, the evidence is mixed.

In a rat study, dry zeolite as a food supplement increased the excretion of radioactive cesium and decreased the deposition of radioactive cesium in the liver and kidneys.[200] A study of broiler chicks found that zeolite significantly reduced radioactive cesium's transfer to the breast meat, liver, and gizzard. [201] Powdered

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2005; 12(2):89-96. Brownstein, D. *Iodine: Why you need it and why you can't live without it.* Medical Alternatives Press, 2004. Derry, D. *Breast Cancer and Iodine.* Trafford Publishing 2002. A good summary of this research is Donald Miller, MD. "Iodine for Health" at http://www.lewrockwell.com/miller/miller20.html

[197] Pujari, G. Sarma, A., and Chatterjee, A. The influence of reduced glutathione on chromosome damage induced by X-rays or heavy ion beams of different LETs and on the interaction of DNAlesions induced by radiations and bleomycoin. *MutationResearch* 2010 February 2; 696(2): 154-159.

[198] Levitskaia, T. Aminothiol receptors for decorporationo f intravenously administered (60)Co in the rat. *Health PhysicsI 2010 January; 98(1): 53-60.*

[199] Vandernhove, H. et al. Effect of K and bentonite additions on Cs-transfer to ryegrass. *Environmental Radioactivity* 2005; 81(2-3): 233-253.

[200] Mizik, P., Hrusovsky, J., and Tokosova, M. [The effect of natural zeolite on the excretion and distribution of radiocesium in rats.] [Article in Slovak] *Vet Med (Praha)* 1989 August; 34(8): 467-474.

[201] Mitrovic, B. et al. AFCF [ammoniumironIII-hexacyanoferrate] and clinoptilolite [a type of zeolite] use in reduction of (137)Cs deposition in several days'

zeolite given to dogs and mice with tumors prolonged the animals' life- spans.[202] Toxicology studies in mice and rats found no evidence of toxicity of powdered zeolite.[203]

On the other hand, zeolite powder is toxic to the lungs when inhaled.[204] Zeolite particles increased the amount of aberrant DNA replication in human lymphocytes.[205] Zeolite affected serotonin receptors in mouse brains. [206] Zeolite given to pregnant dairy cows effectively prevented low calcium levels after calving, but also mildly depleted magnesium levels. [207] These results suggest that zeolite has unpredictable effects on cell function and mineral concentrations. Thus, the safety of human consumption of powered zeolite remains questionable. To me it seems safer to use Laminaria, alginate, or pectin to reduce the body burden of cesium and other radioactive particles.

D. Fourth, scientific studies of miso consumption do not correlate miso with a decrease in human cancer risk from radiation, despite popular belief.

The source of this belief appears to be the book *Macrobiotic Diet*, by Michio Kushi. Kushi writes that Dr. Tatsuichiro Akizuki at St. Francis Hospital in Nagasaki in 1945 saved his staff and patients from radiation sickness by feeding them "a strict macrobiotic diet of brown rice, miso and shoyu [soy sauce] soup, wakame [seaweed] and other sea vegetables, Hokkaido pumpkin, and sea salt," while prohibiting consumption of sugar and other sweets.[208]

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contaminated broiler chicks. *Journal of Environmental Radioactivity* 2007; 95(2-3): 171-177.

[202] Pavelic, K. et al. Natural zeolite clinoptilolite: new adjuvant in anticancer therapy. *Journal of Molecular Medicine* 2001; 78(12): 708-720.

[203] Ibid.

[204] Elmore, A. and the Cosmetic Ingredient Review Expert Panel. Final report on the safety assessment of aluminum silicate … and zeolite. *International Journal of Toxicology* 2003; 22 Suppl. 1:37-102.

[205] Ibid.

[206] Muck-Seler, D. and Pivac, N. The effect of natural clinoptilolite on the serotonergic receptors in the brain of mice with mammary carcinoma. *Life Sciences* 2003 September 5; 73(16): 2059-2069

[207] Thilsing-Hansen,T. et al. The effect of zeolite A supplementation in the dry period on blood mineral status around calving. *Acta Vet. Scand. Suppl* 2003; 97: 87-95..

[208] Kushi, Michio. *Macrobiotic Diet,* Japan Publications, 1993, pages 352-353. A macrobiotic website states that miso was used for leukemia patients following Chernobyl. I can find no record of this use in the medical literature. The same website states that higher consumption of miso soup was associated with a 50% decrease in risk of breast cancer among radiation survivors. This statement compares two insignificant results with one another, misinterpreting the Kay et al study, discussed below, footnote 224. http://www.macrobiotic.org/Miso.htm

I have been unable to find corroboration for this report. (Of course, lack of evidence is not evidence that miso does not work, and the report may exist in Japanese sources not available to me.) In any case, miso was only a small portion of the reported diet. Other aspects of the regime (such as the sea vegetables) may have caused the reduction in radiation illness, if achieved. Kushi's book also refers to American researchers who theorized in the 1990's that miso consumption may have accounted for the low rates of breast cancer in Nagasaki women. However, later research has negated this theory.

The situation is complex because one animal study shows miso as radioprotective. In this study by researchers at Hiroshima University, irradiated mice had significantly increased survival times if fed miso that had been subject to prolonged fermentation. Moreover, the miso protected the intestinal lining-generating cells. [209] (Other animal studies that did not involve radiation showed that miso protects rats from lung cancer[210] and gastric tumors. [211])

On the other hand**, human studies do not show a link between miso consumption and reduced risk of cancer from radiation.**

A study of 34,759 women in Hiroshima and Nagasaki who had been subject to atomic bomb radiation, found that the relative risk of cancer in those consuming miso two to four times per week was greater than that for those consuming miso soup five or more times per week, but the reduction in breast cancer in each group was not significant—the findings could have been from chance. Among 17 other foods examined in this study, only pickled vegetables and dried fish consumption had statistically significant relationships with breast cancer risk in the irradiated population. (Pickled vegetables increased the risk and dried fish reduced the risk.)[212]

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[209] Ohara, M. et al. Radioprotective effects of miso (fermented soy bean paste) against radiation in B6C3F1 mice: increased small intestinal crypt survival, crypt lengths, and prolongation of average time to death. *Hiroshima Journal of Medical Sciences* 2001 December; 50(4): 83-86. A statistical analysis later confirmed that long-term fermentation gave better radioprotection than short-term fermentation Arcana, I. and Ohtaki, M. Multi-target models and their application to data analysis of cellular mortality due to radiation exposure. *Hiroshima Journal of Medical Sciences* 2005 March; 54(1): 9-20.

[210] Shiraki, K. Inhibition of long-term fermented miso of induction of pulmonary adenocarcinoma by diisopropanolnitrosamine in Wistar rats. *Hiroshima Journal of Medical Sciences* 2003 March; 52(1): 9-13.

[211] Ohara, M. et al. Inhibition by long-term fermented miso of induction of gastric tumors by N-methyl-N'-nitrosoguanidine in CD (SD) rats. *Oncology Reports*

[212] "This study showed no significant associations between reported consumption of tofu or miso soup and breast cancer risk. . . . The reduction in risk associated with

If miso were protective against radiation-induced cancers, one would expect to find this protective effect among breast cancer patients, because studies not involving radiation do show a decrease in breast cancer risk from miso soup consumption.[213]

A possible explanation for this anomaly is the composition of miso soup, which in Japan often contains seaweed. Seaweed is a rich source of iodine and the breasts preferentially absorb iodine, which is protective against breast disease.[214] The breast cancer incidence in Hiroshima and Nagasaki is among the lowest in the world, whereas liver cancer in this population is among the highest in the world and continues to rise in incidence. Gastric cancer is the highest in incidence in this population, accounting for 24% of all cancers. The most recent rates of gastric and other cancers in Japan are intermediate to rates in other countries. Only breast cancer has a unique rarity.[215] Thus it seems possible that a food component

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frequent consumption of miso soup was greater after further adjustment for consumption of dried fish and pickles, but was still only of borderline statistical significance." Kay, T. et al. Soya foods and breast cancer risk: a prospective study in Hiroshima and Nagasaki, Japan. *British Journal of Cancer* 1999 December; 81(7): 1248-1256. Free full text online at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2374337/?tool=pubmed

[213] Yamamoto, S. et al. Soy, isoflavones, and breast cancer risk in Japan. *Journal of the National Cancer Institute (Tokyo)* 2003 June18; 95(12): 906-913. Consumption of miso soup and isoflavones but not of other soyfoods was inversely associated with the risk of breast cancer. See also Wu, A. et al. Tofu and risk of breast cancer in Asian Americans. *Cancer Epidemiology, Biomarkers, & Prevention* 1996 November; 5(11): 901-906 (Tofu intake was associated with decreased risk of breast cancer, but researchers cautioned that "we cannot discount the possibility that soy intake is a marker of other protective aspects of Asian diet and/or Asian lifestyle.")

[214] Iodine has induced breast cancer regression in rat models and showed cytotoxic effects in human breast cancer cells. Beneficial effects were observed with iodine supplementation in women with fibrocystic breast disease. Shrivastava, A. et al. Molecular iodine induces caspase-independent apoptosis in human breast carcinoma cells involving the mitochondria-mediated pathway. *Journal of Biological Chemistry* 2006 July; 281: 19762-19771. Free full text at http://www.jbc.org/content/281/28/19762.abstract See also Aceves, C. et al. Antineoplastic effect of iodine in mammary cancer: participation of 6-iodolactone (6-IL) and peroxisome proliferator-activated receptors (PPAR) *Molecular Cancer* 2009; 8:33. Free full text online at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2703618/ See generally Brownstein, David MD. *Iodine: Why You Need It Why You can't Live Without It.* Medical Alternatives Press, Fourth Edition 2009; Derry, David MD. *Breast Cancer and Iodine* Trafford, 2001

[215] Goodman, M. et al. Cancer incidence in Hiroshima and Nagasaki, Japan, 1958-1987. *European Journal of Cancer* 1994; 30A(6): 801-807.

uniquely protective of breast tissue accounts for the relative rarity of this particular cancer among this particular population.

Other human studies of miso and disease risk found that **miso** was associated with **increased** risk of cancer. A study of lung cancer deaths in Japan found that among females, a high intake of miso soup "almost dose-dependently increased the risk."[216]

A meta-analysis of 37 studies that looked at the effects of oy consumption on gastric cancer concluded that high consumption of fermented soy foods (such as miso) was significantly associated with an increased risk in gastric cancer, whereas non-fermented soy foods were significantly associated with a decreased risk.[217] Similarly, a study of atrophic gastritis (chronic inflammation of the gastric mucosal lining) found that among males, high consumption of miso soup increased the risk of the condition.[218]

I conclude that consumption of miso soup to protect oneself from radiation injury is not supported in the scientific literature.

E. Fifth, I think that supplementation with alpha lipoic acid for the purpose of radiation protection should be avoided.

Alpha lipoic acid is an antioxidant. It also increases the body's supply of natural glutathione, an antioxidant that also removes harmful substances from the body. Thus, alpha lipoic acid supplements are often recommended to prevent free radical damage.

Nonetheless, I believe that alpha lipoic acid should not be used for free-radical radiation protection from nuclear accidents, because the radiation damage from a nuclear accident has the added feature of ingested radioactive particles. Despite the increase in glutathione that it encourages, alpha lipoic acid in an animal study did not increase but rather **decreased** the excretion of methylmercury, cadmium, zinc, and copper. [219] In another study alpha lipoic acid could not decrease the mercury content in the brains of rats.[220]

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[216] Ozasa, K. Dietary habits and risk of lung cancer death ina large-scale cohort study (JACC Study) in Japan by sex and smoking habit. *Japanese Journal of Cancer Research* 2001 December; 92(12): 1259-1269

[217] Kim, J. et al. Fermented and non-fermented soy food consumption and gastric cancer in Japanese and Korean populations: a meta-analysis of observational studies. *Cancer Science (Japan)* 2011 January; 102(1): 231-244.

[218] Montani, A. Food/Nutrient intake and risk of atrophic gastritis among the Helicobacter pylori-infected population of northeastern Japan. *Cancer Science (Japan)* 2003 April; 94(4): 372-377.

[219] Gregus, Z. et al. Effect oflipoic acid on biliary excretion of glutathione and metals. *Toxicology and Applied Pharmacology* 1992 May; 114(1): 88-96. Researchers

Most important, studies have shown that lipoic acid redistributes mercury rather than eliminating it. One study found that tissues with high levels of mercury had reduced concentrations of mercury after lipoic acid treatment, but that other tissues had greater concentrations of mercury after the treatment. [221] One researcher concludes: Alpha lipoic acid has "patterns of heavy metal mobilization and transport not yet understood in humans. In the absence of data from human trials, …it can only be suggested that ALA be used as an adjunct to chelation." If lipoic acid re-distributes rather than eliminates mercury, it may do the same for other heavy metals, such as radioactive cesium, strontium, and uranium.

F. Sixth, for similar reasons, I do not recommend the use of N-acetyl cysteine (NAC) for radiation protection.

Like alpha lipoic acid, NAC is an anti-oxidant that increases levels of glutathione (cysteine is one component of glutathione). There is evidence from cell cultures that NAC prevents cancer by preventing damage to DNA. [222] However, like lipoic acid, NAC may redistribute rather than eliminate mercury. [223] Two researchers familiar with chelation of mercury point out that there is "no reference, no toxicology study, no clinical evidence" that NAC will "escort mercury out of the body," even if NAC is shown to attach to mercury in cell studies.

"In fact, NAC, cystine, and cysteine do not detoxify by themselves. But they

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theorized that the lipoic acid carried glutathione to the bile, where it was no longer able to attach the metals.

[220] Aposhian, H. Vitamin C, glutathione, or lipoic acid did not decrease brain or kidney mercury in rats exposed to mercury vapor. *Journal of Toxicology: Clinical Toxicology* 2003; 41(4): 339-347. See also Hultberg, B., Andersson, A. and Isaksson, A. Lipoic acid increases glutathione production and enhances the effect of mercury in human cell lines. *Toxicology* 2002 June 14; 175(1-3): 103-110.

[221] Patrick, L. Mercury toxicity and antioxidants: Part I: Role of Glutathione and alpha-Lipoic acid in the treatment of mercury toxicity. *Alternative Medicine Review* 2002; 7(6): 456-471: Alpha lipoic acid has "patterns of heavy metal mobilization and transport not yet understood in humans. In the absence of data from human trials, …it can only be suggested that ALA be used as an adjunct to chelation with the standard dithiols, DMPS and DMSA." See also Suh, J. et al. Dihydrolipoic acid [the reduced form of alpha lipoic acid] lowers the redox activity of transition metal ions but does not remove them from the active site of enzymes. *Redox Report I2004; 9(1): 57-61.*

[222] See for example De Flora, S. et al. Mechanisms of N-acetylcysteine in the prevention of DNA damage and cancer with special reference to smoking-related end points. *Carcinogenesis* 2001 July; 27(7): 999-1013 (describes NAC's ability to increase glutathione and prevent DNA damage, particularly from cigarette smoke).

[223] Jon Pangborn, PhD and Sidney MacDonald Baker, Md. *Autism: Effective Biomedical Treatments.* Autism Research Institute, 2005, page 299.

> can move mercury around, perhaps spreading the contamination, and their use may make the sequestering of mercury more difficult to undo. It takes another cysteine-like molecule to grab mercury and dispose of it, by carrying it to urine or bile—which is why the body has glutathione….But don't use NAC or cystine by themselves for detoxing; they don't work that way." [224]

Many other supplements increase levels of glutathione in the body and protect the DNA, as I have documented here. It's not necessary to use NAC for these purposes and not worth the risk that radioactive particles may be distributed in our tissues.[225] Moreover, most of us are mercury-compromised, due to exposure from "silver" mercury amalgam fillings, fish consumption, vaccine preservatives, and airborne pollution.[226] Thus, it seems safer to avoid substances that may redistribute our mercury burdens, possibly moving mercury to the brain.

Appendix I

Suggested Amounts of Supplements for Radiation Protection

Note: Scientific studies justifying the use of these supplements for radiation protection are described in other sections of this article.

It is always safest to consult a doctor before taking dietary supplements. This article is for educational purposes only. Supplements can interfere with pharmaceuticals.

However, dietary supplements in general are much safer than drugs. In the past few years there have been no reported deaths in the United States from dietary

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[224] Ibid.

[225] One researcher concluded that NAC generally has not proven useful in clinical practice, despite its long history of positive cell and animal studies. Mirja-Liisa, A. N-acetylcysteine—passe-partout or much ado about nothing? *British Journal of Pharmacology* 2006 January; 61(1): 5-15.

[226] Mercury is the most toxic and third most frequently found toxic substance in the United States, according to the Agency for Toxic Substances and Disease Registry of the U.S. Department of Health and Human Services. Cited in Patrick, L. Mercury Toxicity and Antioxidants: Part I: Role of glutathione and alpha-lipoic acid in the treatment of mercury toxicity. *Alternative Medicine Review* 2002; 7(6): 456-471. The author adds: "Mercury toxicity is a significant clinical entity, as it is ubiquitous in the environment and poses serious risk to human health."

supplements or herbs.[227] By contrast, 106,000 persons die in American hospitals every year from the side effects of correctly prescribed and correctly administered pharmaceuticals. [228]

For a few vitamins and minerals, I am suggesting that you consider amounts that are greater than the U.S. Food and Nutrition Board's "recommended dietary allowances."

> "When used for disease prevention, the doses given are several-fold greater than the Recommended Dietary Allowance, the latter being based on amounts necessary for the prevention of classic deficiency conditions recognized decades ago. Alpha-tocopherol [vitamin E] [and] ascorbic acid [vitamin C] … are remarkably well tolerated and free from toxicity. Consequently, they are well suited for testing as preventive agents, since their use does not require any toxicity monitoring except under unusual circumstances."[229]

Vitamin C:

The U.S. recommended dietary allowance for vitamin C is 75 milligrams for women and 90 milligrams for women.[230] These amounts are probably not adequate for radiation protection.

The successful human study of vitamin C and radiation protection, described in the main article, used 180 milligrams daily, in divided doses (along with vitamin E and selenium). [231] The animal study that achieved a six-fold decrease in DNA damage used the equivalent for humans of 2000 milligrams of vitamin C, along with other vitamins and minerals. [232]

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[227] http://www.orthomolecular.org/resources/omns/v07n01.shtml; http://www.orthomolecular.org/resources/omns/v06n04.shtml; http://www.orthomolecular.org/resources/omns/v03n03.shtml.
[228] Starfield, B. Is US health really the best in the world? *Journal of the American Medical Association* 2000 July; 284(4): 483-485.
[229] Garewal, H. and Diplock, A. How "safe" are antioxidant vitamins? *Drug Safety* 1995 July; 13(1): 8-14 .
[230] Panel on Dietary Antioxidants and Related Compounds, Food and Nutrition Board, Institute of Medicine, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids,* National Academies Press, 2000, page 149.
[231] Ismail, M., et al. Effect of antioxidants on markers of apoptosis in postoperative radiotherapy of cancer cervix. *Gulf Journal of Oncology* 2010 January; 7:8-13.

[232] Wambi, C. et al. Protective effects of dietary antioxidants on proton total-body irradiation-mediated hematopoietic cell and animal survival. *Radiation Research* 2009 Aug; 172(2): 175-86.

Vitamin C is "remarkably well-tolerated and free from toxicity."[233] Intakes of 4000 milligrams daily are well tolerated, according to a review in the journal *Drug Safety*.[234] A study of vitamin C and cold prevention used 1000 milligrams three times daily for a total of 3000 milligrams, with an extra 1000 milligrams each hour for 6 hours if the participant felt symptoms of a cold. (It is important to take vitamin C several times a day because it is a water-soluble vitamin that is very quickly excreted in the urine.) Those on this regime, about 250 persons, had 85% fewer days of colds than did controls, and the vitamin C users had no significant side effects.[235]

The U.S. Food and Nutrition Board established an "upper limit" for vitamin C intake of 2000 milligrams. This limit was not set on the basis of any perceived toxicity from higher amounts of vitamin C. Rather, the limit was set solely on the basis that taking 3000 milligrams at a single time might cause diarrhea or flatulence. The 3000-milligram figure was divided by an uncertainty factor of 1.5 to reach the upper limit of 2000 milligrams. [236]

However, diarrhea from vitamin C is not a sign of toxicity. It is merely a sign that the stomach cannot absorb this much vitamin C at this time.[237] If a person experiences diarrhea, one can simply reduce the amount taken at one time.

For more information on dosing, consult the article by Dr. Robert Cathcart.[238]

Despite the safety record of vitamin C, persons in three groups should exercise caution with higher amounts of vitamin C. First, those with existing kidney disease should be careful with high amounts of vitamin C, because it is possible that vitamin C may increase the risk of kidney stones.[239]

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[233] Garewal, H. and Diplock, A. How "safe" are antioxidant vitamins? *Drug Safety* 1995 July; 13(1): 8-14.
[234] Johnston, C. Biomarkers for establishing a tolerable upper intake level for vitamin C. *Nutrition Review* 1999 March; 57(3): 71-77.
[235] Gorton, H. and Jarvis, K. The effectiveness of vitamin C in preventing and relieving the symptoms of virus-induced respiratory infections. *Journal of Manipulative and Physiological Therapeutics* 1999 October; 22(8): 530-533.
[236] Panel on Dietary Antioxidants and Related Compounds, Food and Nutrition Board, Institute of Medicine, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids,* 2000, pages 161-162.
[237] Robert Cathcart, MD. "Vitamin C, titrating to bowel tolerance, anascorbemia, and acute induced scurvy." *Medical Hypotheses* 7:1359-1376, 1981. http://www.orthomed.com/titrate.htm
[238] Robert Cathcart, MD. "Vitamin C, titrating to bowel tolerance, anascorbemia, and acute induced scurvy." *Medical Hypotheses* 7:1359-1376, 1981. http://www.orthomed.com/titrate.htm
[239] Taylor, E., Stampfer, M., Curhan, G. Dietary factors and the risk of incident kidney stones in men: new insights after 14 years of follow-up. *Journal of the American Society of Nephrology* 2004 December; 15(12): 3225-3232.

Second, caution should be exercised by persons with pre-existing conditions causing red blood cells to be fragile –-conditions such as sickle cell anemia, thalassemia, and glucose-6-phosphate dehydrogenase deficiency. Third, persons with hemachromatosis (excessive iron in the tissues) should use caution because vitamin C may increase the absorption of iron. [240]

The ascorbic acid form of vitamin C is generally the cheapest and is very effective. Persons with sensitive stomachs may prefer a non-acidic mineral ascorbate form, such as sodium ascorbate, calcium ascorbate, magnesium ascorbate, or potassium ascorbate. If one uses the mineral ascorbate forms, one should try to maintain a good ratio of calcium intake to magnesium intake (see discussion of magnesium below).

Vitamin C may be helpful for many other conditions. For example, a 20-year Japanese study of stroke found that those with the highest vitamin C levels had a 40% to 50% decreased risk of stroke. [241] In American men, high levels of vitamin C in the blood were associated with a 35% lower risk of death from all causes[242] and a 30% reduced risk of death from cancer. [243] High vitamin C levels are also associated with decreased risks of stomach cancer;[244] decreased levels of H. pylori (the bacteria that causes ulcers)[245]; decreased risk of gallstones, [246] and decreased risk of hip fracture.[247]

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[240] Panel on Dietary Antioxidants and Related Compounds, Food and Nutrition Board, Institute of Medicine, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids,* 2000, pages 160-161 and 165.

[241] Yokoyama, T. et al. Serum vitamin C concentration was inversely associated with subsequent 20-year incidence of stroke in a Japanese rural community. The Shibata study. *Stroke* 2000 October; 31(10): 2287-2294.

[242] Enstrom, J., Kanim, L. and Klein, M. Vitamin C intake and mortality among a sample of the United States population. *Epidemiology* 1992 May; 3(3): 194-202.

[243] Simon, J., Hudes, E., and Tice, J. Relation of serum ascorbic acid to mortality among US adults. *Journal of the American College of Nutrition* 2001 June; 20(3): 255-263.

[244] Drake, I. et al. Ascorbic acid may protect against human gastric cancer by scavenging mucosal oxygen radicals. *Carcinogenesis* 1996 March; 17(3): 559-562.

[245] Simon, J., Hudes, E., and Perez-Perez, G. Relation of serum ascorbic acid to Helicobacter pylori serology in US adults: the Third National Health and Nutrition Examination Survey. *Journal of the American College of Nutrition* 2003 August; 22(4): 283-289.

[246] Simon, J. and Hudes, E. Serum ascorbic acid and other correlates of gallbladder disease among US adults. *Journal of Public Health* 1998 August; 88(8): 1208-1212.

[247] Sahni, S. et al. Protective effect of total and supplemental vitamin C intake on the risk of hip fracture—a 17-year follow-up from the Framingham Osteoporosis Study. *Osteoporosis International* 2009 November; 20(11): 1853-1851.

Vitamin E analogues:

The successful human study of vitamin E for radiation protection used 30 milligrams of vitamin E as alpha tocopherol. [248] The most successful animal study used the equivalent for humans of 1000 milligrams of alpha tocopherol. [249] (These amounts are equivalent to 66 and 1500 international units (IU), respectively. [250]) The U.S. recommended dietary allowance is 15 milligrams (22.5 IU) of alpha tocopherol. [251] (The other tocopherols have not yet been evaluated by the Food and Nutrition Board.)

One nutritionist who works with cancer patients suggests taking 135 milligrams to 535 milligrams of **mixed tocopherols,** or 200 to 800 IU. [252] Mixed tocopherols are recommended because this supplement will include the alpha and the gamma tocopherol forms, both of which offer radiation protection as discussed in the main article. The U.S. upper limit for natural alpha tocopherol is 1000 milligrams (1500 IU). This upper limit was set on the basis that alpha tocopherol tends to thin the blood and therefore may interfere with blood clotting if taken in amounts greater than 1000 milligrams (1500 IU). [253] For the same reason, persons undergoing surgery are advised to discontinue alpha tocopherol supplements for a few weeks before and after surgery to be sure of proper wound healing.

For best absorption, one should take the mixed tocopherol supplement with a meal, because the fats in the meal will assist absorption of the vitamin.

In addition to this fat-soluble form of vitamin E, some may wish to take the **alpha-tocopherol succinate** form, which offers not only radiation protection but also anti-cancer effects, as described in the main article. The alpha tocopherol succinate form should probably be taken at a different time from the fat-soluble form of

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[248] Ismail, M., et al. Effect of antioxidants on markers of apoptosis in postoperative radiotherapy of cancer cervix. *Gulf Journal of Oncology* 2010 January; 7:8-13.
[249] Wambi, C. et al. Protective effects of dietary antioxidants on proton total-body irradiation-mediated hematopoietic cell and animal survival. *Radiation Research* 2009 Aug; 172(2): 175-86.
[250] http://ods.od.nih.gov/factsheets/vitamine/ This conversion to international units assumes that the study used synthetic vitamin E, which until recently was most often used in scientific studies. If natural vitamin E were used in the study, the 30 milligrams is the equivalent of 44.7 international units.
[251] Panel on Dietary Antioxidants and Related Compounds, Food and Nutrition Board, Institute of Medicine, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids,* National Academies Press, 2000, page 239.
[252] Patrick Quillin, PhD. *Beating Cancer with Nutrition* rev. ed. Nutrition Times Press, 2005, page 224.
[253] Panel on Dietary Antioxidants and Related Compounds, Food and Nutrition Board, Institute of Medicine, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids,* National Academies Press, 2000, pages 252, 258.

vitamin E so that each form has the best absorption. Dr. Russell Blaylock recommends up to 400 IU of the succinate form three times daily for cancer patients.[254]

More expensive are tocotrienol supplements, which also offer radiation protection. A reasonable amount would be 50 milligrams once or twice daily. [255]

Selenium:

The successful human study of radiation protection used 150 micrograms of selenium daily, along with vitamins C and E.[256] The most successful animal study of radiation protection used the equivalent for humans of 400 micrograms per day of selenium, along with other vitamins and minerals. [257] There also is some evidence that selenium helps to prevent cancer and to prevent conditions caused by iodine deficiency. [258]

The U.S. recommended dietary allowance for selenium is 55 micrograms.[259] The organic selenium compounds (such as selenomethionine, selenomethylcysteine, or selenium-enriched yeast) are preferable to inorganic forms of supplemental selenium (such as sodium selenite or sodium selenate). Inorganic forms cause toxicity at much lower doses than organic forms.[260]

The earliest signs of selenium toxicity are hair loss and fingernail brittleness. The Institute of Medicine set a no-observed effect level for selenium at 800 micrograms. This is the amount that, taken regularly, failed to show any signs of selenium toxicity. The Institute of Medicine divided this figure by 2 as an uncertainty factor, and set the tolerable upper limit of selenium intake at 400 micrograms per day.[261]

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[254] Russell Blaylock M.D. *Natural Strategies for Cancer Patients,* Kensington Publishing Corp., 2003, page 248.
[255] Blaylock, op. cit, page 251.
[256] [256] Ismail, M., et al. Effect of antioxidants on markers of apoptosis in postoperative radiotherapy of cancer cervix. *Gulf Journal of Oncology* 2010 January; 7:8-13.
[257] Wambi, C. et al. Protective effects of dietary antioxidants on proton total-body irradiation-mediated hematopoietic cell and animal survival. *Radiation Research* 2009 Aug; 172(2): 175-86.
[258] Office of Dietary Supplements, National Institutes of Health. Dietary Supplement Fact sheet: Selenium. http://ods.od.nih.gov/factsheets/selenium/
[259] Panel on Dietary Antioxidants and Related Compounds, Food and Nutrition Board, Institute of Medicine, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids,* National Academies Press, 2000, page 305.
[260] Ibid. page 312.
[261] Ibid. page 315.

Dr. Russell Blaylock recommends is 200 micrograms daily for cancer patients. [262]

Fatty Acids:

The Japanese diet, high in fish consumption, is also high in the long-chain polyunsaturated fat DHA (docosahexanoic acid). In fact, Japanese intake is about five times the intake in Western nations.[263] However, even in normal times the Japanese are subject to high levels of lipid peroxidation of the DHA in their cellular membranes, probably from insufficient consumption of antioxidants. [264]

Replacement of these oxidation-damaged fatty acids may be difficult in the present situation because of the high level of radiation in the ocean following the nuclear accident. Some persons will be avoiding fish. Those who do eat fish should consume high levels of antioxidant-containing vegetables and supplements, particularly vitamins C and E.

Those who do not eat fish may consume their DHA as a supplement. Reasonable amounts are 500 to 1500 milligrams of DHA. DHA is particularly advantageous for radiation protection because it is also known to suppress cancer.[265]

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[262] Blaylock, op. cit. page 254; Quillin, op. cit. page 266, recommends 200 to 600 micrograms of selenium daily.

[263] Meyer, B. Are we consuming enough long chain omega-3 polyunsaturated fatty acids for optimal health? *Prostaglandins, Leukotrienes, and Essential Fatty Acids* 2011 May 13 [Epub ahead of print].

[264] Ito, Y. et al. Serum concentrations of carotenoids, alpha-tocopherol, fatty acids, and lipid peroxides among Japanese in Japan, and Japanese and Caucasians in the U.S. *International Journal for Vitamin and Nutrition Research* 1999 November; 69(6): 385-395.

[265] See for example, Patterson, R. et al. Marine fatty acid intake is associated with breast cancer prognosis. *Journal of Nutrition;* 2011 February*;* 141(2): 201-206; Cavazos, D. et al. DHA selectively induces human prostate cancer cell sensitivity to oxidative stress through modulation of NF-kB. *Prostate*; 2011 February 25 [Epub ahead of print]; Altenburg, J. et al. A synergistic antirpoliferation effect of curcumin and DHA in SK-BR-3 breast cancer cells: unique signaling not explained by the effects of either compound aloe. *BMC Cancer* 2011 April 21; 11(1): 149; Maillard, V. et al. N-3 and N-6 fatty acids in breast adipose tissue and related risk of breast cancer in a case-control study in Tours, France. *International Journal of Cancer* 2002; 98: 78-83; Rose, D. and Connolly, J. Antiangiogenicity of DHA and its role in suppression of breast cancer cell growth in nude mice. *International Journal of Oncology* 1999; 15: 1011-1015; Connolly, J. et al. Effects of reduced dietary linolenic acid intake, alone or combined with an algal source of DHA, on NMDA-MB-231

A DHA supplement must be accompanied by vitamin E to prevent the oxidation of the DHA. Dr. Blaylock recommends taking at least 1000 IU daily of mixed tocopherols or alpha tocopherol succinate for this purpose.[266]

Two other cellular membrane components that are particularly subject to damage from radiation are phosphatidyl serine and cardiolipin. [267] Supplements of phosphatidyl serine are expensive. However, if one wishes to supplement, a reasonable amount is 100 to 300 milligrams daily. The larger amount (100 milligrams, taken three times daily) is the amount that has been used to improve memory in the elderly.[268]

Cardiolipin, an essential component of the mitochondrial membrane, is partly composed of the omega-6 fatty acid linoleic acid. Linoleic acid is already low in the Japanese diet.[269] This fatty acid may be replenished by eating foods naturally high in linoleic acid, such as walnuts, egg yolks, grape seed oil, rice bran oil, and sesame oil. Consumption of the oils should be accompanied by vitamin E to prevent their oxidation. The oils should be kept refrigerated to prevent their oxidation, and a capsule of fat-soluble vitamin E may be squeezed into the bottle to help preserve the contents from oxidation.

Calcium:

The International Commission for Radiological Protection recommends consumption of at least 1100 mg daily of calcium for protection from radioactive strontium.[270] The U.S. Institute of Medicine recommends 1000 milligrams of

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breast cancer cell growth and apoptosis in nude mice. *Nutrition and Cancer* 1999; 35: 44-49.

[266] Blaylock, *Natural Strategies for Cancer Patients*, page 141.

[267] Tyurina, Y. et al. Oxidative lipidomics of gamma-radiation-induced lung injury: mass spectrometric characterization of cardiolipin and phosphatidylserine peroxidation. *Radiation Research* 2011 May; 175(5): 610-621; Kagan, V. et al. Oxidative lipidomics of apoptosis: redox catalytic interactions of cytochrome c with cardiolipin and phosphatidylserine. *Free Radicals in Biology and Medicine* 2004 December 15; 37(12): 1963-1985.

[268] Kato-Kataoka, A. et al. Soybean-derived phosphatidylserine improves memory function of the elderly Japanese subjects with memory complaints. *Journal of Clinical Biochemistry and Nutrition* 2010 November; 47(3): 246-255.

[269] Ito, Y. et al. Serum concentrations of carotenoids, alpha-tocopherol, fatty acids, and lipid peroxides among Japanese in Japan, and Japanese and Caucasians in the U.S. *International Journal for Vitamin and Nutrition Research* 1999 November; 69(6): 385-395.

[270] Iyengar, G. et al. Dietary intakes of seven elements of importance in radiological protection by Asian population: comparison with ICRP [International Commission for Radiological Protection] data. *Health Physics* 2004 June; 86(6): 557-564.

calcium for adults, and 1100 milligrams for teenagers, for general health. [271] The study that evaluated the radiation protection effects of various types of calcium supplements concluded that all calcium gluconate worked best in preventing absorption of radioactive strontium, although calcium lactate, calcium phosphate, and calcium carbonate also were successful.

Magnesium:

Any increased intake of calcium should be balanced with magnesium to protect the body's electrolyte balance, and to protect against the increased risk of kidney stones from an increased calcium intake.[272] High magnesium intake reduces the risk of kidney stones by about 30%.[273] Moreover, magnesium itself acts as an anti-oxidant and is protective of glutathione. Glutathione levels are lower in cells that are deficient in magnesium.[274] (Low magnesium levels are also associated with heart disease, high blood pressure, and diabetes.[275])

The optimal amount of magnesium in relation to calcium is currently in dispute among nutritionists. The U.S. Institute of Medicine recommends slightly less than half as much magnesium as calcium, that is, 350 milligrams for adult men and 265 for adult women.[276] Other U.S. doctors recommend roughly equal amounts of

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[271] Food and Nutrition Board, Dietary Reference Intakes, Institute of Medicine 2011 http://www.iom.edu/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/New%20Material/5DRI%20Values%20SummaryTables%2014.pdf

[272] Taylor, E., Stampfer, M. and Curhan, G. Cietary factors and the risk of incident kidney stones in men: new insights after 14 years of follow-up. *Journal of the American Society of Nephrology* 2004 December; 15(12): 3225-3232.

[273] Taylor, E., Stampfer, M., and Curhan, G. Dietary factors and the risk of incident kidney stones in men: new insights after 4 years of follow-up. *Journal of the American Society of Nephrology* 2004 December; 15(12): 3225-3232.

[274] Russell Blaylock, M.D. *Health and Nutrition Secrets that can save your life* rev. ed. Health Press, 2006, page 251.

[275] See, for example, Iseri, L. et al. Magnesium deficiency and cardiac disorders. *American Journal of Medicine* 1975; June; 58(6): 837-846; King, D. et al. Dietary magnesium and C-reactive protein levels. *Journal of the American College of Nutrition* 2005; 24(3): 166-171. Huerta, M. et al. Magnesium deficiency is associated with insulin resistance in obese children. *Diabetes Care* 2005 May; 28(15): 175-1181; Paolisso. G. and Barbagall, M. Hypertension, diabetes mellitus, and insulin resistance: the role of intracellular magnesium. *American Journal of Hypertension* 1997 March; 10(3): 346-355.

[276] Food and Nutrition Board, Institute of Medicine, Dietary Reference Intakes, March 2011. http://www.iom.edu/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/New%20Material/5DRI%20Values%20SummaryTables%2014.pdf

magnesium and calcium temporarily, to make up for widespread magnesium deficiency found among Americans.[277]

Magnesium should be taken in small amounts throughout the day to improve absorption. Larger amounts taken at one time may cause diarrhea, from magnesium's relaxing effect on the muscles.

Melatonin:

The optimal dose for radiation protection is between 1 and 20 milligrams of melatonin per day, taken in the evening because melatonin induces sleep. It is probably best to start with 1 milligram and gradually increase the dose, because a few persons inexplicably are stimulated by melatonin.

Melatonin has been safely used in several trials of cancer patients receiving chemotherapy. In these studies the patients took up to 21 milligrams of melatonin, taken in the evening.[278] No serious adverse events were found in trials involving 643 patients.[279] Melatonin has also been tested in humans at 1 gram (1000 milligrams) per day for 30 days, with no negative side effects. [280]

For sleep, melatonin is used in 1 to 5 milligram doses and has been shown safe.[281] A study of melatonin treatment in children with ADHD found no side effects even when taken for more than three years. (The melatonin also improved behavior and mood in about 66% of the children.)[282]

Probiotics:

The strains that have been shown successful in protecting humans from radiation damage to the intestinal tract are lactobacillus Bulgaricus, lactobacillus helveticus,

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[277] Carolyn Dean, MD. *The Magnesium Miracle* Ballantine Books, 2006. Russell Blaylock, MD. *Health and Nutrition Secrets* 2006, pages 250-253. About 70% of Americans consume less than the reference dietary intake. King, D. et al. Dietary magnesium and C-reactive protein levels. *Journal of the American College of Nutrition* 2005; 24(3): 166-171.

[278] Zhanleh, Z. Melatonin, a promising role in taxane-related neuropathy. *Clinical Medical Insights: Oncology* 2010; 4: 35-41. Free full text at *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2883241/?tool=pubmed*

[279] Mills, op cit.

[280] Shiraz, op cit.

[281] Buscemi, et al. The efficacy and safety of exogenous melatonin for primary sleep disorders. *Journal of General Internal Medicine* 2005 December; 20(12): 1151-1158.

[282] Hoebert, M. et al. Long-term follow-up of melatonin treatment in children with ADHD and chronic sleep onset insomnia. *Journal of Pineal Research* 2009 August; 47(1): 1-7.

and lactobacillus acidophilis. In animal studies, the strains lactobacillus casei, lactobacillus Bulgaricus, and biffidobacterium were effective. No serious adverse effects have been seen at doses up to 3600 billion colony-forming units per day of the particular product used in the human study, according to the manufacturer. [283] However, safety studies are not fully reliable because many studies do not have accurate means of investigating potential rare side effects.[284] Bloating may occur for a few days as the body adjusts to the probiotic.

Herbs:

The following herbs have been shown to offer radiation protection, as discussed in the main article. Naturally, one would not wish to consume all of these at once. They are listed here for your information.

Mint

Mint is considered non-toxic by the German commission E. Mint is generally recognized as safe (GRAS) by the U.S. Food and Drug Administration. [285] The German commission's recommended doses are 3 to 6 grams of the dried herb as an encapsulated supplement, or a tea made with these amounts of the dried herb.[286] One study concluded that the water extract of the whole herb (as in tea) gave more effective radiation protection than the oil extract. [287]

Mint should be used cautiously by persons who have reflux and severe liver damage.[288]

Lemon Balm

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[283] http://www.vsl3.com/about-faq.asp#faq-17
[284] Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services, The Safety of Probiotics Used to Reduce Risk and to Prevent or Treat Disease. April 2011. //www.ahrq.gov/clinic/tp/probiotictp.htm
[285] Paula Gardiner, MD. The Longwood Herbal Task Force: Peppermint. http://www.longwoodherbal.org/peppermint/peppermint.pdf
[286] Information from Applied Health: http://www.appliedhealth.com/index.php?option=com_content&view=article&id=108424 . However, very high doses of mint may cause oxidative damage. In one study 200- to 250-gram mice receiving doses of 20 to 40 grams per liter of water experienced oxidative damage to liver cells. Those receiving lower doses were not affected. Akdogan, M. et al. Investigation of biochemical and histopathological effects of Mentha piperitaLabiatae and Mentha spicata Labiatae on liver tissue in rats. *Human and Experimental Toxicology* 2004 January; 23(1): 21-28.
[287] Jagetia and Baliga, op cit.
[288] Paula Gardiner, MD. The Longwood Herbal Task Force: Peppermint. http://www.longwoodherbal.org/peppermint/peppermint.pdf

Lemon balm is generally recognized as safe (GRAS) by the U.S. Food and Drug Administration. [289] Common doses are 300 to 500 mg three times daily as a supplement, 2 to 3 milliliters 3 times daily for tincture, and 1 to 4 grams infused as tea, taken up to 4 times daily.[290] The study of x-ray technicians described in the main article, which found that chromosomes were protected with lemon balm tea, used the equivalent of one tea bag, steeped in water, twice daily.

The only precaution in using lemon balm is that lemon balm is used therapeutically for hyperactive thyroid disease,[291] so persons with poor thyroid function may wish to avoid lemon balm.

Curcumin

In 2010 the European Food Safety Authority conducted an extensive review of curcumin, because food manufacturers had petitioned to be able to use curcumin as a natural food coloring. The European Food Safety Authority concluded that curcumin caused no adverse effects in amounts as high as 250 milligrams per kilogram of body weight.[292] A reasonable dose is suggested by Dr. Russell Blaylock, who recommends that, to resist the spread of tumors, cancer patients take 500 milligrams of curcumin 3 times daily, mixed with olive oil for better absorption of this fat-soluble substance.[293]

Ginseng

Ginseng is relatively safe. It is an anti-oxidant with little pro-oxidant activity. Few side effects have been seen at moderate doses of ginseng. The German Commission E recommends 1 to 2 grams per day, standardized to 4-5% ginsenosides. Larger doses may cause side effects. An uncontrolled study found side effects in about 4% of those consuming up to 15 grams per day. Consumption of more than 15 grams caused confusion and depression. Because ginseng has mild estrogenic effects and

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[289] Gardiner, Paula, MD. The Longwood Herbal Task Force: Lemon Balm. http://www.longwoodherbal.org/lemonbalm/lemonbalm.pdf ; University of Maryland Medical Center: http://www.umm.edu/altmed/articles/lemon-balm-000261.htm

[290] Gardiner, op. cit.

[291] Auf'molk, M. et al. Extracts and auto-oxidized constituents of certain plants inhibit the receptor-binding and the biological activity of Graves' immunoglobulins. *Endocrinology* 1985 May; 116(5): 1687-1693.

[292] European Food Safety Authority, July 9, 2010, reprinted at http://www.flex-news-food.com/console/PageViewer.aspx?page=32058 Accessed 5/1/11.

[293] Blaylock, R. *Natural Strategies for Cancer Patients*. New York, Kensington Publishing Corp., 2003, page 57.

has interfered with neonatal development, it should not be given to infants and children, and it should also be avoided in pregnancy and lactation.[294]

Ginger

Ginger is generally recognized as safe by the U.S. Food and Drug Administration. One study found ginger to be non-toxic up to the very large amount of 1500 mg per kilogram of body weight, the highest testable dose.[295] Estimated use in India is 8 to 10 grams of the root per day. [296] No studies have examined its safety as a supplement for children or during pregnancy and lactation.

Rosemary

According to the German Commission E, rosemary intake should not exceed 4 to 6 grams of the dried herb. Tea may be made at 6 grams steeped in water per day. A tincture of 1:5 may be taken at 2 to 4 milliliters, three times daily, and a 1:1 fluid extract in alcohol may be taken at 1 to 2 milliliters per day. Rosemary supplements should not be given to children under 18, because rosemary's safety has not been studied in children. Pregnant women should not take rosemary supplements because rosemary supplements may cause miscarriage. Rosemary oil should not be ingested, but rosemary oil may be used on the skin and hair. [297]

Gotu Kola

Gotu kola apparently has not been evaluated by either German Commission E or by the U.S. Food and Drug Administration. Safe dosages are 20 to 60 milligrams, 3 times daily, according to the report of the Swedish Medical Center in the U.S. .[298] Persons with liver disease should avoid gotu kola, and its safety has not been studied in children or pregnant women.[299] An herbal combination including gotu kola was

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[294] Information on safety is from the review article by Canadian ginseng researchers Kitts, D. and Hu, C. Efficacy and safety of ginseng. *Public Health Nutrition* 2000 December; 3(4A): 473-485. Full text available at http://journals.cambridge.org/download.php?file=%2FPHN%2FPHN3_4a%2FS1368980000000550a.pdf&code=3c7acc23c6a23d78a467b20ce538f628

[295] Jagetia 2004, op. cit.

[296] Kathi Kemper, MD, MPH. Longwood Herbal Task Force: Ginger. http://www.longwoodherbal.org/ginger/ginger.pdf

[297] University of Maryland Medical Center http://www.umm.edu/altmed/articles/rosemary-000271.htm

[298] Swedish Medical Center (Seattle, Washington) Health Library: Gotu Kola. https://healthlibrary.epnet.com/GetContent.aspx?token=af362d97-4f80-4453-a175-02cc6220a387&chunkiid=21763 Accessed 5/2/11.

[299] Web MD: Find a Vitamin or Supplement: Gotu Kola. http://www.webmd.com/vitamins-supplements/ingredientmono-753-

found non-toxic in acute and non-acute toxicity studies. [300] The Swedish Medical Center (U.S.) states that gotu kola is safe and causes no side effects, except for a possible allergic dermatitis

Sodium Alginate:

Sodium alginate inhibits absorption of radioactive particles. Appropriate amounts, however, have not been well studied. There is an unsubstantiated report that the U.S. Atomic Energy Commission once recommended a minimum of 10 grams of sodium alginate daily for protection from absorption of radioactive strontium. [301] One supplement company in the United States recommends 2 (950-milligram) capsules 3 times daily, taken between meals, along with two full glasses of fruit juice to aid absorption. This dose would amount to about 6 grams of alginate. A naturopathic physician in the early 1980's recommended taking the alginate as a gelatin made from agar-agar flakes. His recommendation: dissolve 10 grams of agar-agar in one half liter of water, boil, then add one cup of juice. Refrigerate. [302]

Pectin:

The amounts of pectin used to decrease absorption of radioactive particles have been 10 grams daily for children and 20 grams daily for adults, in divided doses. Consumption may decrease absorption of beta-carotene, so it may be beneficial to consume the pectin away from meals. Pectin may decrease absorption of statin drugs used to lower cholesterol. [303]

Sodium Bicarbonate:

Here is the recommendation of Dr. John Apsley:

"For adults, up to 7 teaspoons of baking soda daily in divided dosages on an empty stomach may be used short-term (over 6 consecutive days) ... with route & rate of

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GOTU%20KOLA.aspx?activeIngredientId=753&activeIngredientName=GOTU%20KOLA Accessed 5/2/11.

[300] Quinna, N. A new herbal combination, Etana, for enhancing erectile function: an efficacy and safety study in animals. *International Journal of Impotence Research* 2009 September-October; 21(5): 315-320.

[301] Schechter, S. "Radiation" What You Can Do" *Vegetarian Times* December 1981, page 40.
http://books.google.com/books?id=kQgAAAAAMBAJ&pg=PA40&lpg=PA40&dq=John+Hopkins+University+study+about+miso&source=bl&ots=DyAED2znyV&sig=P0m47hHETow4pMFZcRs1EZcobVE&hl=en&ei=4d6PTbTYF4rHgAe-35SfDQ&sa=X&oi=book_result&ct=result&resnum=10&ved=0CE8Q6AEwCQ#v=onepage&q&f=false

[302] Shechter, op cit.

[303] http://www.drugs.com/npp/pectin.html

administration carefully considered by the physician. Another acceptable dosage schedule is to perform the above every other day for two weeks on, then resting for two weeks off of the baking soda schedule." [304]

Iodine:

The research on iodine is complex and contradictory. Some of the contradictions may arise from the differing forms of iodine and types of supplements used in research and epidemiological studies, or from persons' varying levels of other nutrients such as selenium, which is known to interact with iodine.

The International Commission on Radiological Protection recommends 200 micrograms of iodine to prevent the thyroid from absorbing radioactive iodine.[305] (The U.S. dietary reference intake is 95 micrograms, 160 milligrams in pregnancy, and 220 milligrams during lactation.)[306]

The traditional Japanese intake of iodine is high, from large amounts of seaweed in the diet. Estimated amounts of iodine in the traditional Japanese diet range from 1 to 15 grams of iodine daily.[307]

The nuclear accident may affect the production and consumption of seaweed in Japan. Persons subject to radiation who have not been eating seaweed, or who no longer eat seaweed, may wish to take iodine by gargling, or by taking oral iodine/iodide supplements, which are available on the Internet. Tablets of kelp or dulse (another type of seaweed) usually contain about 200 of micrograms of iodine per tablet. There is some evidence that persons who are not accustomed to eating

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[304] http://doctorapsley.com/RadiationTherapy.aspx Accessed 5/5/11.

[305] This figure is calculated from the 90 micrograms of consumption in Asia, said to be 45% of the reference intake. Iyengar, G. et al. Dietary intakes of seven elements of importance in radiological protection by Asian population: comparison with ICRP [International Commission for Radiological Protection] data. *Health Physics* 2004 June; 86(6): 557-564.

[306] Food and Nutrition Board, National Institute of Medicine. Dietary Reference Intakes, modified March 2011. http://www.iom.edu/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/New%20Material/5DRI%20Values%20SummaryTables%2014.pdf

[307] In one study, home-cooked meals ranged from 360 to 1023 micrograms and institutional meals ranged from 47 to 5000 micrograms of iodine per meal. Katamine, S. Iodine content of various meals currently consumed by urban Japanese. *Journal of Nutritional Science and Vitaminology (Tokyo)* 1986 October; 32(5): 487-495. But see Nagataki, S. The average of dietary iodine intake due to the ingestion of seaweeds is 1.2 mg/day in Japan. *Thyroid* 2008 June; 18(6): 667-668 [abstract unavailable].

seaweed lack the digestive enzymes needed to digest it. [308] Iodine can also be absorbed through the skin.

Perhaps the best iodine supplements for radiation protection contain both the iodide form (iodine in an ionic form, as a salt) and the iodine form (molecular iodine or I2). Research indicates that the thyroid concentrates the iodide form, whereas the breast tissue (and perhaps the prostate gland) concentrates the iodine form.[309] Moreover, animal research indicates that the iodine form is active against breast cancer whereas the iodide form is not. [310] However, the use of potassium iodine for radiation protection of the breast has not been studied.

A few doctors in the U.S. are recommending 12 milligrams or more of iodine for persons with low thyroid function, thyroid cancer, fibrocystic breast disease, or breast cancer. [311] These larger amounts should be taken only under a doctor's supervision. Low iodine blood levels cause goiter and may cause severe mental

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[308] Hehemann, J-H et al. Transfer of carbohydrate-active enzymes from marine bacteria to Japanese gut microbiota. *Nature* 2010 April 8; 908-912. Doi:10.1038/nature08937.

[309] Eskin, B. et al. Different tissue responses for iodine and iodide in rat thyroid and mammary glands. *Biological Trace Element Research* 1995 July; 49(1): 9-19.

[310] Aceves, C. et al. Antineoplastic effect of iodine in mammary cancer: participation of 6-iodlactone (6-IL) and peroxisome proliferator-activated receptors (PPAR). *Molecular Cancer* 2009 June 6; 8:33; Anguiano, G. et al. Uptake and gene expression with antitumoral doses of iodine in thyroid and mammary gland: Evidence that chronic administration has no harmful effects. *Thyroid* 2007 September; 17(9): 851-859; Garcia-Solis, P. et al. Inhibition of N-methyl-N-nitrosourea-induced mammary carcinogenesis by molecular iodine (I2) but not by iodide(I-) treatment: evidence that I2 prevents cancer promotion. *Molecular and Cellular Endocrinology* 2005 May 31; 236(1-2): 49-57.

[311] On the potential need for iodine in larger amounts than the reference intake, see the following: Abraham, G. The safe and effective implementation of orthoiodosupplementation in medical practice. *Original Internist* 2004; 11:17-36. Flechas, J. Orthoiodosupplementation in a primary care practice. *Original* Internist 2005; 12(2):89-96. Brownstein, D. *Iodine: Why you need it and why you can't live without it.* Medical Alternatives Press, 2004. Derry, D. *Breast Cancer and Iodine.* Trafford Publishing, 2002. For research on breast cancer and iodine, see http://breastcancerchoices.org/iodineindex.html A good summary of the arguments favoring larger doses of iodine is in an article by Donald Miller, MD, "Iodine for Health" at http://www.lewrockwell.com/miller/miller20.html. A good summary of rebuttal evidence appears in "The Great Iodine Debate" by Sally Fallon at http://www.westonaprice.org/modern-diseases/metabolic-disorders/1662-the-great-iodine-debate?qh=YToyOntpOjA7czo2OiJpb2RpbmUiO2k6MTtzOjEwOiJpb2RpbmF0aW5nIjt9.

retardation in children born to iodine deficient mothers.[312] But high iodine blood levels may cause thyroid disease, and supplementation during pregnancy may also interfere with the child's brain development.[313]

Appendix II

Herbs of Uncertain Value

The following herbs may be effective in reducing radiation damage but the evidence supporting their use is minimal or unpersuasive.

Rhodiola protected mice from lethal total body irradiation in two studies. In the later study, pre-radiation administration of rhodiola at a dose of 350 mg/kg achieved survival rates of 83% (for water extract) and 90% for a water-alcohol extract.. the maximum tolerate dose of rhodiola determined to be between 1100 or and 1300 mg/kg .[314] In the earlier study, 400 mg/kg achieved 83% survival of lethal total-body irradiation. In a cell culture study reported in the same article, rhodiola at 100 micrograms per milliliter scavenged over 90% of superoxide radicals and at 80 micrograms per milliliter reduced lipid peroxidation by 60%.[315] These results are remarkable.

Nevertheless, I did not put rhodiola on the short list because the effective dose used in this study is about one-third of the maximum tolerated dose, which gives the rhodiola dose an unacceptable margin of safety. There is no evidence that a smaller dose would offer radiation protection in humans, although it may do so.

Grape seed extract is considered a powerful antioxidant. [316] In an animal study of rats subject to whole-body irradiation, the grape seed extract at 100 mg/kg body

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[312] De Escobar, G., Obregon, M., and Del Ray, F. Iodine deficiency and brain development in the first half of pregnancy. *Public Health Nutrition* 2007 December; 10(12A): 1554-570.

[313] Murcia, M. Effect of iodine supplementation during pregnancy on infant neurodevelopment at 1 year of age. *American Journal of Epidemiology* 2011 April 1; 173(7): 804-812.

[314] Goel, H. et al. Radioprotection by Rhodiola imbricata in mice against whole-body lethal irradiation. *Journal of Medicinal Food* 2006 Summer; 9(2): 154-160.

[315] Arora, R. Evaluation of radioprotective activities Rhodiola imbricate Edgew—a high altitude plant. *Molecular and Cellular* Biochemistry 2005 May; 273(1-2): 209-223.

[316] See for example Hanausek, M. et al. Inhibition of murine skin carcinogenesis by freeze-dried grape powder and other grape-derived major antioxidants. *Nutrition and Cancer* 2011 January; 63(1): 28-38; Chao, C. et al. Grape seed extract ameliorates tumor necrosis factor-alpha-induced inflammatory status of human

weight increased the activity of the antioxidant enzymes superoxide dismutase and catalase to levels approaching those in controls who were not irradiated. Moreover, the grape seed extract reduced the lipid peroxidation to levels **below** those in the animals that were not irradiated. [317] These effects are extremely powerful. I did not put grape seed extract on the short list because I could find only the one study on grape seed extract and radiation damage.

Spirulina appears in four radiation studies: one of cells, two in animals, and one in humans.

In mouse bone-marrow cells, spirulina extract reduced the numbers of micronuclei from radiation damage.[318]

In an animal study, dogs and mice were subjected to cobalt radiation. Spirulina at 12 mg per kilogram increased the levels of red and white blood cells and hemoglobin, and the numbers of nucleated cells in bone marrow. In the mice, spirulina at 30 and 60 mg per kg increased the level of white blood cells and nucleated cells in bone marrow. [319] A study of irradiated rats found that a spirulina extract increased antioxidant markers.[320]

In a human study, 162 clean-up workers from Chernobyl who had the Russian diagnosis "dyscirculatory encephalopathy" were treated with spirulina as well as other herbs and vitamins.[321] Because the mechanisms causing this neurological syndrome as well as the possible mechanisms of the spirulina in alleviating it are not specified in this study, and because the study used a multitude of healing agents, not just spirulina, this study does not offer good evidence of the efficacy of spirulina for radiation illness.

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umbilical vein endothelial cells. *European Journal of Nutrition* 2010 November 28 [Epub ahead of print].

[317] Cetin, A. et al. The effect of grape seed extract on radiation-induced oxidative stress in the rat liver. *Turkish Journal of Gastroenterology* 2008 June; 19(2): 92-98.

[318] Qishen, P., Guo, B. and Kolman, A. Radioprotective effect of extract from Spirulina platensis in mouse bone marrow cells studied by usingthe micronucleus test. *Toxicology Letters* 1989 August; 48(2): 165-169.

[319] Zhang, H. Chemo- ad radio-protective effects of polysaccharide of Spirulina platensis on hemopoietic system of mice and dogs. *Acta Pharmacologica Sinica* 2001 December; 22(12): 1121-1124.

[320] Karpov, L. [The postradiation use of vitamin-containing complexes and a phycocyanin extract in a radiation lesion in rats.] [Article in Russian]. *Radiats. Biol. Radioecol.* 2000 Jay-June; 40(3): 31-314.

[321] Zozulia, I. and Iurchenko, A. [The adaptive potentials of those who worked in the cleanup of the aftermath of the accident at the Chernobyl Atomic Electric Power Station under the influence of different treatment methods]. [Article in Ukrainian] *Lik Sprava* 2000 April-June; (3-4): 18-21.

However, spirulina's antioxidant effects have been recorded in several studies not involving radiation. In one human study, spirulina enhanced immune system markers.[322] In another human study, spirulina reduced lipid peroxidation and enhanced glutathione activity.[323] Several animal studies also show spirulina's antioxidant activity.[324] Moreover, a recent animal study records that spirulina prevents the bioaccumulation of the one of the heavy metals, cadmium.[325] This result suggests that spirulina may prevent accumulation in humans of the radioactive heavy metals.

With all this evidence, why did I not place spirulina on the short list? Spirulina is far less effective as an antioxidant than the much cheaper vitamin C. In one animal study, spirulina was roughly half as effective as vitamin C, on the basis of milligrams per kilogram of body weight.[326] Two cell assays found that spirulina was roughly half as effective as vitamin C in protecting mouse fibroblast cells from death due to free radicals. [327] One of the animal studies involving radiation found that a spirulina extract was roughly as effective as alpha tocopherol as an anti-oxidant, but that a combination on six (unnamed) water-soluble anti-oxidant vitamins was more effective than either the alpha tocopherol or the spirulina.[328]

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[322] Park, H. et al. A randomized double-blind, placebo-controlled study to establish the effects of spirulina in elderly Koreans. *Annals of Nutrition and Metabolism* 2008; 52(4): 322-328.

[323] Kalafati, M. Ergogenic and antioxidant effects of spirulina supplementation in humans. *Medicine and Science in Sports and Exercise* 2010 January; 42(1): 142-151.

[324] Gad, A. et al. Antioxidant activity and hepatoprotective effects of whey protein and spirulina in rats. *Nutrition* 2011 May; 27(5): 582-589; Ponce-Canchihuaman, J. et al. Protective effects of spirulina maxima on hyperlipidemia and oxidative-stress induced by lead acetate in the liver and kidney. *Lipids in Health and Disease* 2010 March 31; 9:35; Kuhad, A. et al. Renoprotective effect of spirulina fusiformis on cisplatin-induced oxidative stress and renal dysfunction in rats. *Renal Failure* 2006; 28(3): 247-54.

[325] Bharavi, K. Prevention of cadmium bioaccumulation by herbal adaptogens. *Indian Journal of Pharmacology* 2011 February; 43(1): 45-49.

[326] Upansi, C., Khera, A., and Galaraman, R. Effect of lead with vitamin E, C, or Spirulina on malondialdehyde, conjugated dienes and hydroperoxides in rats. *Indian Journal of Experimental Biology* 2001January; 39(1): 70-74. In a cell study, spirulina plus the vitamin-C-containing acerola was found to be more effective in reducing oxidative damage than spirulina alone. Dartsch, P. Antioxidant potential of selected Spirulina platensis preparations. *Phytotherapy Research* 2008 May; 22(5): 627-633.

[327] Chu, W. et al. Protective effect of aqueous extract from Spirulina platensis against cell death induced by free radicals. *BMC Complementary and Alternative Medicine* 2010September 21; 10:53.

[328] Karpov, L. et al. [The postradiation use of vitamin-containing complexes and a phycocyannin extract in a radiation lesion in rats. *Radiats. Biol. Radioecol.* 2000 May-June; 40(3): 310-314.

Thus, spirulina is probably useful for radiation protection. It is considered safe,[329] although there is some evidence that it may exacerbate kidney stones. [330] But Vitamin C is more effective and cheaper. Vitamin C may also aid in the excretion of radioactive heavy metals. It has been associated with the elimination of cadmium, lead, gold, chromium, and it reduces the toxic effects of mercury.[331]

Lycopene, one of the carotenes, has only been studied once with animals and once in cultured cells. Lycopene at 5 mg/kg given to rats prior to whole-body sub-lethal radiation improved the antioxidant status, regenerated cells in the small intestine, and improved levels of neurotransmitters dopamine, norepinephrine, and epinephrine, all of which are produced in the small intestine. [332] In irradiated rat liver cells, pretreatment with lycopene reduced lipid peroxidation and DNA damage. Lycopene also increased levels of vitamins A, C, and E in the cells. [333]

Cat's Claw was examined in a single animal study of radiation. Researchers found that both single- and double-strand breaks were significantly reduced 3 hours after radiation in mice that received the cat's claw, as compared to controls. The maximum tolerated daily dose was observed to be greater than 8 grams per kilogram. At doses of 10 to 80 mg/kg for 8 weeks and 160 mg for 4 weeks, no

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[329] Karkos, P. et al. Spirulina in clinical practice: evidence-based human applications [review article]. *Evidence-Based Complementary and Alternative Medicine* 2011 Article ID 531053. *http://www.hindawi.com/journals/ecam/2011/531053/*

[330] Farooq, S. et al. Credentials of spirulina diet on stability and flux related properties on the biominerralization process during oxalate mediated renal calcification in rats. *Clinical Nutrition* 2005 December; 24(6): 932-942.

[331] See for example, Pace, V. The importance of vitamins in relation to the presence of heavy metals in food. *Panminerva Med.*1994 June; 36(2): 80-82; Kim, H. et al. Blood cadmium concentrations of male cigarette smokers are inversely associated with fruit [and vitamin C] consumption. *Journal of Nutrition* 2010 June; 140(6): 1133-1138; Cheng, Y. et al. Relation of nutrition to bond lead and blood lead levels in middle-aged to elderly men, the normative aging study. *American Journal of Epidemiology* 1998; 147(12): 1162-1174; Simon, J. and Hudes, E. Relationship of ascorbic acid to blood lead levels. *JAMA* 1999; 28(24): 2289-2293; Dawson, E. et al. The effect of ascorbic acid supplementation on the blood lead levels of smokers. Journal of the American College of Nutrition *1999; 18(2): 166-170*. Summaries of earlier studies appear in Stone, Irwin, *Vitamin C against Disease,* Grosset & Dunlap, 1972, pages 152-156.

[332] Saada, H., Rezk, R., and Eltahawy, N. Lycopene protects the structure of the small intestine against gamma-radiation-induced oxidative stress. *Phytotherapy Research* 2010 June; 24 Suppl. 2: S204-208.

[333] Srinvasan, M. et al. Lycopene as a natural protector against gamma-radiation induced DNA damage, lipid peroxidation, and antioxidant status in primary culture of isolated rat hepatocytes in vitro. *Biochimica, Biophysica Acta* 2007 April; 1770(4): 659-665.

symptoms of toxicity were observed. Like grape seed extract, cat's claw does not make the short list because I could only find one study on cat's claw and ionizing radiation damage. (One other study concluded that a water-soluble extract protected human skin cells in culture from ultraviolet radiation.[334])

Chlorella was studied in a mouse trial at the Czechoslovak Institute of Biophysics. An aqueous extract from chlorella was administered by injection, and the animals were later irradiated. A larger number of treated animals survived lethal radiation, as compared to irradiated controls that did not receive the injections. The chlorella extract also increased survival of bone marrow cells after the radiation**.** [335]

Although chlorella is widely recommended as a detoxifying agent, I did not place chlorella on the short list because the sum of the published research is not compelling. It is not clear from the abstracts of the published articles whether three mouse studies were done or only one, described three times. At least two of the articles appear to describe the same study, because the publication dates are nearly identical. [336] The third article appears a few months later. Moreover, the results from **injected** chlorella solution cannot be generalized to human ingestion of chlorella. Of course, lack of published evidence is not evidence that chlorella does not work as a radioprotector. In water solutions, chlorella has been demonstrated to bind uranium,[337] but whether this effect would occur in living organisms has not

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[334] Mammone, T. et al. A water soluble extract from Uncaria tomentosa (Cat's claw) is a potent enhancer of DNArepair in primary organ cultures of human skin. *Phytotherapy research* 2006 March; 20(3): 178-183.

[335] Rotkovska, D., Vacek, A., and Bartonickova, A. The radioprotective effects of aqueous extract from chlorococal freshwater algae (Chlorella kesseri) in mice and rats. *Strahlenther Onkol.* 1989 November; 165(11): 813-816.

[336] Another article apparently on the same study appears in Rotkovska, D., Vatsek, A., Bartonichkova, A. [Increase in the radiation resistance of mice using Ivastimul] [Article in Russian] *Radiobiologiia* 1989 September-October; 29(5): 652-654. The third article is Vacek, A., Rotkovska, D., and Bartonickova, A. Radioprotection of hemopoiesis conferred by aqueous extract from chlorococcal algae (Ivastimul) administered to mice before irradiation. *Experimental Hematology* 1990 March; 18(3): 234-237.

A different study by the same researchers combined the chlorella extract with another protective agent. From the abstract it is not certain whether the research design allowed isolation of the effects of chlorella from those of the chemical radioprotective agent. Vacek, A. et al. Amelioration of radiation damage to haemopoiesis by Ivastimul, given after irradiation to mice protected by peroral cystamine. *Folia Biol. (Praha)* 1992; 38(6): 323-331.

[337] Horikoshi, T., Nakajima, A., and Sakaguchi, T. Uptake of uranium by various cell fractions of chlorella regularis. *Radioisotopes* 1979 August; 28(8): 485-488.

been studied. The antioxidant activity of spirulina is about 50% greater than that of chlorella.[338]

Gymnema was examined in a single animal and a single cell study. The study found that lipid peroxidation was diminished and glutathione increased in the mouse brain after lethal radiation. At the same time, researchers found that gymnema in cell culture scavenged superoxide radicals.[339]

Aloe vera extract has shown radiation protection effects in mice and in cell studies.[340] However, the amounts used in the animal studies were extremely large: 1 gram per kilogram. It not known whether a reasonable dose for a human would be radioprotective.

Appendix III

Safety of Antioxidants for Cancer Patients

The issue of the safety of antioxidants for persons currently undergoing chemotherapy or radiation therapy for cancer is complex.

The conventional view among U.S. oncologists is that antioxidants may protect cancer cells from chemotherapy or radiation therapy and therefore should be avoided by patients undergoing these treatments. [341]

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[338] Wu, L. et al. Antioxidant and antiproliferative activities of spirulina and chlorella water extracts. *Journal of Agricultural and Food Chemistry* 2005 May 18; 53(10): 4207-4212.

[339] Sharma, K. et al. Evaluation of evidence-based radioprotective efficacy of Gymnema sylvestre leaves in mice brain. *Journal of Environmental Pathology, Toxicology and Oncology* 2998; 28(4): 311-323.

[340] Goyal, P. Radioprotective effects of aloe vera leaf extract on Swiss albino mice against whole-body gamma irradiation. *Journal of Environmental Pathology, Toxicology, and Oncology* 2009; 28(1): 53-61. Wang, et al. [Radioprotective effect of aloe polysaccharides on three non-tumor cell lines]. [Article in Chinese] *Ai Zheng* 2005 April; 24(4): 438-442(cell survival rates increased by 41 to 89%, depending on the cell line).

[341] See, for example, D'Andrea, G. Use of antioxidants during chemotherapy and radiotherapy should be avoided. *CA: Cancer Journal for Clinicians* 2005; 55:319-321; Bairati, I. et al. Antioxidant vitamins supplementation and mortality: a randomized trial in head and neck cancer patients. *International Journal of Cancer* 2006 November 1; 19(9): 2221-2224; Lawenda, B. et al. Should supplemental antioxidant

On the other hand, a small number of researchers assert that cell culture, animal, and human studies all support the proposition that higher doses of antioxidants selectively kill cancer cells and inhibit their proliferation, while sparing normal cells, under conditions of chemotherapy or radiation. Several human studies have found increased survival rates among those taking antioxidants along with conventional therapy, as compared to controls receiving the conventional therapy but not the antioxidants. [342] Persons undergoing cancer therapies should consult their doctors before taking antioxidants.

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administration be avoided during chemotherapy and radiation therapy? *Journal of the National Cancer Institute* 2008 June 4; 100(11): 773-83.

[342] For the alternate point of view, see Block, K. et al. Impact of antioxidant supplementation on chemotherapeutic toxicity: a systematic review of the evidence from randomized controlled trials. *International Journal of Cancer* 2008 September 15; 123(6): 1227-1239 (24 of 33 trials reported decreased toxicity from concurrent use of antioxidants with chemotherapy; 9 trials reported no differences).

Block, K. et al. Impact of antioxidant supplementation on chemotherapeutic efficacy: a systematic review of the evidence from randomized controlled trials. *Cancer Treatment Review* 2007 August; 33(5): 407-418 (none of the trials reported decreases in efficacy from antioxidant supplementation; many studies reported increased survival times, increased tumor responses, or both, as well as fewer toxicities as compared to controls).

Prasad, K. Rationale for using high-dose multiple dietary antioxidants as an adjunct to radiation therapy and chemotherapy. *Journal of Nutrition* 2004 November; 134:31825-31835 (although low doses of antioxidants may protect cancer cells, higher doses inhibit proliferation of cancer cells in vitro and in vivo).

Prasad, K. Pros and cons of antioxidant use during radiation therapy. *Cancer Treatment Review* 2002 April; 28(2): 79-91 ("high doses of dietary antioxidants [vitamin C, vitamin E succinate and natural beta-carotene] can be used adjunctively with radiation therapy.")

Simone, C.II et al. Antioxidants and other nutrients do not interfere with chemotherapy or radiation therapy and can increase kill and increase survival. Parts I and II. *Alternative Therapies in Health and Medicine* 2007 January-February and March-April; 13(1): 22-28 and 13(2): 40-47.

Simone, C. and Simone C.II. Re: Should supplemental antioxidant administration be avoided during chemotherapy and radiationtherapy? *Journal of the National Cancer Institute* 2882; 100(21): 1558-1559 [reply to Lawenda, op cit.]
Prasad, K. and Cole, W. Antioxidants in cancer therapy. *Journal of Clinical Oncology* 2006 February 20; 24(6): e8-e9 [reply to Bairati, op cit.]

How could antioxidants selectively kill cancer cells? One possible explanation for this effect of vitamin C is that cancer cells appear to concentrate vitamin C. Cancer cells absorb vitamin C by glucose transporter GLUT 1. Vitamin C enters the cancer cell as the vitamin C metabolite called dehydro-ascorbate (the oxidized form of ascorbic acid). Inside the cell the dehydro-ascorbate picks up an electron and is thus "reduced" or reconverted to active ascorbic acid. This process produces hydrogen peroxide in the cell. In a healthy cell, the antioxidant enzyme catalase would convert the peroxide to oxygen and water, which would protect the cell from oxidative damage. But cancer cells have low amounts of catalase. Thus, in a cancer cell the hydrogen peroxide builds up to toxic levels and kills the cell. Radiation enhances this killing effect, while normal cells are protected against free radical damage from the radiation.

For the cancer-specific effect of vitamin E, one possible explanation is that alpha tocopheryl succinate selectively inhibits angiogenesis, the ability of cancer cells to stimulate blood vessel growth to feed the tumor.

Books for general audiences on nutrients and cancer therapy include Russell Blaylock, MD, *Natural Strategies for Cancer Patients*; Patrick Quillin, PhD*, Beating Cancer with Nutrition*; Ralph Moss, MD, *Antioxidants against Cancer.*