MICROALGAE

The World's most important plant

Introduction to Microalgae

"In blue-green algae we find three and one-half billion years of life on this planet encoded in their nucleic acids (RNA/DNA). At the same time, all microalgae supply that fresh burst of primal essence that manifested when life was in its birthing stages. At a moment in history when the survival of the human species is in jeopardy, many people have begun instinctively to turn to these original life forms for nutritional support."

Paul Pitchford, **Healing with Whole Foods, 1993**

Eleven areas of research are reviewed, ranging from algae's ability to enhance brain function to issues of safety. A few common components found within microalgae, such as antioxidants, essential fatty acids, and amino acids, are significant across a range of topics.

Perhaps one of the reasons microalgal nutrients appear to work in so many areas is that nature is conservative in its designs. Solutions that work are retained. For example, chlorophyll, an "invention" that allows organisms to capture sunlight and produce sugars, first appeared in blue-green microalgae billions of years ago and is now used as a survival strategy by all higher plants. Animals in turn depend upon chlorophyll-containing plants, directly or indirectly, as a food source.

Ancient organic molecules

These kinds of threads are repeated countless times throughout nature. Ancient organic molecules, such as amino acids, which were found in blue-green microalgae at the dawn of life, now act as basic building blocks for all of earth?s creatures. Potent antioxidants (e.g., beta-carotene or glutathione) that originated in primitive microalgae are conserved and widely used across nature. Likewise, essential fatty acids (EFAs) are critical structural components of cell membranes and play a foundational role in our brain chemistry. Microalgae are the primary source of EFAs in the food chain! In short, microalgae at the bottom of the food chain provide an ancient biomolecular pharmacopoeia upon which most of cellular life now depends.

Remarkable Nutritive Qualities of Microalgae

“Gram-for-gram microalgae may be the most nutrient dense food on Earth.”

The primitive character of microalgae’s cellular organization gives it a number of advantages over higher plants and animals as a food source. For starters, practically the entire organism can be nutritious, with minimal indigestible structures. By contrast, typically less than half of the dry weight of plants and animals has nutritional value. Primitive blue-green algae are composed almost entirely of nutritionally useful and uniform cells. Furthermore, microalgae exhibit superior photosynthetic efficiency, using light approximately three times more efficiently than higher plants. 2

Microalgae are among the most productive organisms on the planet.

Aphanizomenon flos-aquae, blue-green algae

“Why does Aph. flos-aquae [Aphanizomenon flos-aquae, a blue-green algae]—small and simple as it seems to be—contain more micronutrients than any other known food?…Aph. flos-aquae cells are about 20 to 30 times smaller than the cells within the food we usually eat. Because of this, Aph. flos-aquae contains 20 to 30 times the membrane surface area.” 3Aph. flos-aquae’s smaller cell size means a larger ratio of cell membrane surface compared to the rest of the cell. In the case of blue-green algae, the cell membrane is where some of the most important nutrients are concentrated.

Aph. flos-aquae algae produces more cell membrane material without getting larger by creating a vast system of membrane inpouchings similar to the brain's infoldings. In other words, if the cell membrane were ironed flat, it would be many times the apparent size of the cell.

One of the most remarkable nutritional aspects of microalgae is its high content of usable protein—ranging from 50% to 70%! This is a far higher percentage than the choicest edible parts of any higher plant or animal. Algal protein has shorter and less complex polypeptide chains—making it easier to digest than plant or animal protein. Red meat has a surprisingly low net protein utilization index of 18%, compared to AFA's 75%. The net protein utilization index is a measure of how completely amino acids are assimilated by humans. In fact, some microalgae, such as Aph. flos-aquae, contain all ten essential amino acids that humans require from their diets—in a profile similar to that recommended by the National Academy of Sciences.

Not least, "microalgae are considered to be the primary source of unsaturated fatty acids in the food chain." Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are two relatively rare and valuable fatty acids found in microalgae. The reason that fish oils are so rich in polyunsaturated fatty acids (PUFAs) is that amicroalgae are abundant in their food chain. Unlike seafood, microalgal oils are cholesterol free. The nutritional value and therapeutic merits of PUFAs have been widely documented.

Enhanced Brain Function, Behavior, and Learning

"Blue-green algae and my new diet have helped me focus and concentrate better in school and on my homework. I am more relaxed and I don't have stomachaches anymore. I have more friends now and my mom is happier too."

--Chelsea, 8 years old

The brain contains and uses one of the highest concentrations of nutrients of any organ in the body. Oxygen consumption is the best indicator of "fuel use" -- almost everyone recognizes how vital oxygen is to the brain. Unlike many organs (e.g., the liver) that have cellular fuel reserves, the brain is almost entirely dependent upon a continuous blood supply for fuel. Children's brains are even hungrier, more metabolically active, and proportionally larger than adults' brains. Per pound of body weight, children eat more food, drink more fluids, and breathe more air than adults, thereby increasing their potential exposure to toxins. Also, younger children's blood-brain barriers and intestinal linings are not as developed and are therefore less protective than those of most adults. This means that more incompletely digested foods and toxins can leak into a child's bloodstream and brain.

Beta-carotenes and antioxidants found abundantly in microalgae may contribute to protecting the central nervous system (CNS) from oxidative stress. Lipids, which comprise most of the brain tissue, are especially sensitive to oxidative damage. Researchers in Israel and Japan have demonstrated the protective effects of antioxidants in experimental animal brain trauma models. [43,44] Oxidative stress has been implicated in the pathogenesis of some disorders of the brain; hence antioxidants have become attractive therapeutic agents. [45]Furthermore, brain trauma and injury tends to increase whole-body oxidative stress. [46]

In 1985, Gabriel Cousens published two case studies on the use of AFA blue-green algae in the improvement of Alzheimer's disease. He reported "some significant return of function" such as decreased hand tremors, better balance, and improved short term memory, attention span, judgment, and reasoning in one patient; in the second patient there was no significant return of previously lost function, but there was a halting of the typical "progressive degeneration associated with Alzheimer's" along with a corresponding improvement in the patient's marital relationship. [50]

Andrew Valencia and colleagues at the Neurolab Clinic associated with the University of New Mexico demonstrated that patients suffering from mild brain injury who ate Aph. flos-aquae showed a

25% improvement in about half the time as patients who did not receive algae. [52] According to Valencia, in his study of more than 150 patients over two years, patients who ate AFA algae alone had improvements similar to those in a two-month hospital-based rehabilitation program. However, the best results were achieved when neuro-rehabilitation was combined with eating Aph. flos-aquae algae, better than Aph. flos-aquae alone or the hospital program alone. Valencia's research team hypothesized that Aph. flos-aquae algae seems to promote reparative neuroplasticity - or, in lay terms, rewiring of the circuitry of the brain.

Valencia also conducted electrophysiological studies of brain waves and found that the ingestion of Aph. flos-aquae algae was linked with pronounced improvements in brain function, notably in the ability to focus and discriminate between various auditory signals.

Benefits:

At least six research studies have demonstrated the benefits of Aph. flos-aquae on improving children's cognition, mood, behavior, and academic performance:

Sevilla and Aguiree's study of 1,567 students at the Monseñor Velez School in Nandaime, Nicaragua, demonstrated an 81% increase in the average standardized test scores among malnourished children eating only .5 to 1 gram of Aph. flos-aquae a day over a six-month period. Subjects showed significantly increased classroom attendance and participation, as well as marked improvement in overall health. Academically, the Velez school went from having one of the lowest national scholastic test scores to achieving one of the best. [53]

Claudia Jarratt, family therapist at the Center for Family Wellness in Harvard, Massachusetts, studied 105 children given Aph. flos-aquae and found a significant improvement in behavior as shown by both parent and teacher ratings. The children, who displayed a variety of behavioral problems, consumed between 0.5 and 1 gram of Aph. flos-aquae daily and were observed over a ten-week period. Data from the Achenbach Child Behavior Checklists (parent and teacher versions) and extensive case histories were collected for all participants. Significant improvements were found on all 11 parent rating scales in pre- to post-test behavior. These findings were corroborated by teachers' ratings, which revealed significant improvements in seven of the ten behavioral problem areas measured. The use of an expectancy scale revealed little correlation between parents' initial expectations of treatment benefits and final outcomes. [54] Subsequently, Claudia Jarratt has continued to work with an additional 250 children, using an AFA-based program, with similar positive results. [55]

My own research team studied 26 students with reading difficulties, who participated in a three-month Aph. flos-aquae supplement study. All were enrolled in the Stilwell Learning Center, a reading tutorial program in Sierra Vista, Arizona. Participants included 18 boys and 14 girls, ranging from 6 to 17 years old, with a mean age of 11. The children were randomly assigned to one of two groups, (1) the low-Aph. flos-aquae, 1.5 grams, treatment group (n = 13) or (2) the high-Aph. flos-aquae, 3 grams, treatment group (n = 13). There was also a non Aph. flos-aquae comparison group.

Both Aph. flos-aquae treatment groups showed significant improvements on the following measures over the three-month trial period: attention and concentration indices, a sequential memory index, standardized academic testing, behavioral parent and teacher reports, health symptoms, tutorial attendance records, and decreased toxic levels of aluminum. Regardless of the assigned treatment group (i.e., high or low), both groups demon-strated significant improvements compared to pre-test baseline measures and a small non-supplemented comparison group. [56]

A team of medical researchers headed by Dr. Krylov of the University of Illinois concluded, after examining hundreds of well-documented case histories, that Aph. flos-aquae appears promising for the treatment of depression and AD/HD as well as several other health challenges. [58]

Improved Immune Function

"We may be different in gender, color of hair and skin, religion, and job. But we have a common bond — we are survivors. Our parents survived long enough to conceive us. Grandparents had the same claim for your parents. The thing that made this possible is that precious commodity—the immune system."

--Schmidt, Smith, and Sehnert
Beyond Antibiotics, 1993

School records of children eating AFA blue-green algae showed a dramatic improvement in class attendance in two studies. Both research teams, along with school personnel reports, suggested that the increased attendance of students who ate blue-green algae was related to decreased sick days. 71,72

In a study of 100 children diagnosed with a zinc deficiency and given either zinc sulfate or blue-green algae tablets, those given blue-green algae demonstrated a superior immune response. The zinc found in blue-green algae may be about three times more effective than zinc from mineral sources. 73

Increased antibody production and enhanced immune function

Researchers have found increased antibody production and enhanced immune function in animals supplemented with blue-green algae. 78, 79

Several studies, animal and human, have demonstrated the ability of microalgae to increase macrophage movement. 80-82 The dietary use of blue-green algae is reported to enhance the immune response in laboratory mice, by stimulating macrophage functions, phagocytosis and enhanced interleukin-1 production. 83, 84

Gitte Jensen, Ph.D., an immunologist at McGill University, working with a team of researchers at the Royal Victoria Hospital in Montreal, demonstrated improved trafficking of immune cells to be among the effects of Aph. flos-aquae algae on the human immune system. Many immune cells (e.g., natural killer [NK] cells) do their primary work outside of the bloodstream in the tissues. Aph. flos-aquae algae increased the number of white blood cells that moved from the bloodstream into the tissues to do their search-and-destroy mission.86

In a follow-up double-blind study, Jensen's team replicated the initial results and also found that longer-term consumers of Aph. flos-aquae demonstrated greater benefits than those taking algae for the first time. Yet even short-term consumers showed some benefits. Dr. Jensen's team found that within two hours of eating Aph. flos-aquae there was a significant migration of natural killer cells from the blood into the surrounding tissues. Natural killer cells play a key role in our defense system as they "patrol for invading microbes and infected or transformed precancerous cells." This gentle immune boost was rapid, short-term, and cell-type specific. 87

In a retrospective review of medical cases, researchers found positive evidence that Aph. flos-aquae blue-green algae might be useful in the treatment of chronic fatigue, Epstein Barr infection, fibromyalgia, and AIDS. These diseases all involve significant immune system, and sometimes viral, components. Such anecdotal evidence suggests that at least some autoimmune diseases may respond favorably to blue-green algae. 88

Antiviral, Antibacterial, and Antifungal Effects

"We have given too much attention to the enemy
and have to some extent overlooked our defenses."

—M. Behar, **World Health**,
February-March, 1974

Microorganisms, bacteria, and fungi have been exploited for almost a century to provide useful drugs, antibiotics, and other pharmacologically active compounds. 95

Antibiotics, active against bacteria, fungi, and even viruses, have been isolated from marine algae, especially macroalgae. 96 Microalgae as well as macroalgae are able to produce a wide variety of pharmacologically active compounds.

Beneficial effects of Microalgae

Beneficial effects in leprosy were first observed in the 1940s. "Jorgensen and Convit fed a soup made from concentrated Chlorella to eighty patients at a treatment colony in Venezuela. The improvement in those patients' physical condition was the first documented evidence of the potential of microalgae as a health supplement." 97

Antibacterial, antiviral, and antifungal properties have been found in dozens of micro-algae species. 99-101

Compounds and extracts from blue-green algae, as well as other microalgae, showing HIV inhibitory activity are often active against other retroviruses such as Herpes simplex virus types 1 & 2, simian immunodeficiency virus (SIV), cytomegalovirus, measles virus, mumps virus, and influenza A virus. 113-117

Aph. flos-aquae blue-green algae shows an inhibitory effect on the growth of Salmonella bacterial strains, in amounts greater than 2 mg. 122 A hot water extract of the green alga, Chlorella, given to mice infected with Listeria mono-cytogenes, significantly increased the survival rates of mice, as well as demonstrating an increased immune cellular response.123,124 Unicellular green algae have also been shown to increase resistance against E. coli and cytomegalovirus infections. 125-128

Beta-carotene, which is plentiful in microalgae, may also decrease susceptibility to respiratory infections. As beta-carotene is transformed into vitamin A, deficiencies associated with vitamin A—such as increased risk of respiratory disease—might be reduced. 130,131

Improved Cellular Repair

Paleobiologists, such as J. William Schop, describe how some blue-green algal species have changed little in the last few billion years. Fossils of blue-green algae from central Australia, dating back more than 3.5 billion years, reveal early forms that are quite similar to living species today.

It appears that blue-green algae achieved a sort of biological perfection—with perhaps little need to evolve—accompanied by strong protective mechanisms that minimized genetic mutations. 137

Masters of regeneration

Two studies by Devi and his team demonstrated the ability of algal diets to stimulate the regeneration of blood serum and liver proteins in rats. 140,141

Because microalgal protein is composed of shorter and less complex polypeptide chains—with an abundance of all essential amino acids—it can be more readily utilized at the cellular level. One can think of it as supplying the foundational building blocks for cellular repair in easily usable form.

Might algal diets be able to confer to other cells some aspect of protection from genetic mutations?

Researchers at the Institute of Molecular and Subcellular Biology in Slovakia found that freeze-dried Aph. flos-aquae blue-green algae demonstrated anti-mutagenic effects on bacterial cells exposed to a mutagen [a substance that disrupts DNA/RNA transcription, causing mutations] using the standard Ames test. When the algae powder was added to the cell culture at the same time as the chemical mutagen, there was no benefit. However, if the algae powder was added to the cell culture medium 2 to 24 hours before exposure to the mutagenic agent, a signifi-cant anti-mutagenic effect was evident. 142 The most intense suppression of mutagenic activity was achieved when the algae powder was mixed in the cell culture medium 24 hours before the addition of the mutagen. This suggests that the algal phytochemicals were utilized by the cell culture as a protective cellular influence rather than neutralizing the chemical mutagen directly.

Steve Gagne, a macrobiotic counselor and author of The Energetics of Food (1990), reports that "Algae are the masters of regeneration—they probably are the most highly regenerative foods on the planet." 145

In support of this empirical observation, it is noteworthy that microalgal extracts added to culture mediums dramatically increase human cell survival rates. In 1984, a U.S. Patent (no. 4,468,460) was granted to S. Kumamoto for A Method of Human Cell Culture. Described as follows: "A method of culture of human cells is disclosed which comprises effecting the cultivation in a culture medium containing an extract of microalgae…said method permitting the normal successive cultivation of human cells to be maintained efficiently without any morphological and genetic mutations over a greater number of successive generations than has hitherto been possible." 146

Radiation Protective Effects

"The transfer of energy that is produced by radiation is similar to that caused by other forms of acute injury such as an automobile crash or a bullet wound…The difference between a bullet and an X ray lies principally in the size of the particle. While a bullet destroys tissues and entire organs, a particle of radiation collides with single atoms or molecules deep within the cells." 153

—H. Needleman and P. Landrigan,
Raising Children Toxic Free, 1994

Beta-carotene derived from the microalga Dunaliella demonstrates anti-mutagenic effects on humanlymphocytes, as shown in a Chinese study using in vitro micronucleus and chromosomal aberration tests. The inhibitory effect of microalgae-extracted beta-carotene on mutagenesis induced by both gamma-rays and mitomycin, a known mutagenic agent, was demonstrated. 143

New research provides evidence that dietary flavonoids (i.e., pigments) may help repair a range of free radical damage in DNA and offer protection against strand breaks and base alterations in our cells' genetic material. Scientists at the University of Aukland, New Zealand, demonstrated that antioxidant flavonoids can reduce the incidence of single-strand breaks in irradiated solutions of double-stranded DNA, in vitro. Using advanced pulse radiolysis measurements, scientists found that electron transfer from the flavonoids to free radical attack sites on DNA appears to result in a faster chemical repair, lessening the oxidative damage to DNA. 144

Remarkable Radioprotective Effects

Numerous animal and in vitro studies using microalgae have demonstrated remarkable radioprotective effects. 160-164 When microalgae was administered orally to mice, radio-protective effects of microalgae were shown to occur both before and immediately after exposure to sub-lethal gamma-rays. 165

Beta-carotene and other carotenoids, found abundantly in microalgae, are known to be potent free-radical quenchers and lipid antioxidants. Natural beta-carotene (50 mg/kg diet), obtained from the unicellular alga, Dunaliella, was fed to rats exposed to a single high dose of whole-body radiation (4 Gy). Radiated control animals, not fed algal carotenoids, suffered a significant loss of body weight and decreased liver concentrations of beta-carotene and retinol, compared to algal beta-carotene supplemented rats. Normal increase in body weight and the absence of ill effects were noted in the groups of rats whose diet was supplemented by beta-carotene before and after irradiation. 155

Extracts of phycocyanin (the blue pigment) from blue-green algae helped to restore the efficiency of anti-oxidant defenses, dehydrogenase activity, and energy-rich phosphate levels in rats exposed to X-rays (dose of 5 Gy). 159

Several animal and in vitro studies using microalgae have demonstrated remarkable radioprotective effects. 160-164 When microalgae was administered orally to mice, radio-protective effects of microalgae were shown to occur both before and immediately after exposure to sub-lethal gamma-rays. 165 Significant benefits were observed in the number of bone marrow cells and the spleen weight.

Cancer Protective Effects

"At present we have overwhelming evidence…(that) none of the risk factors for cancer is…more significant than diet and nutrition."

— B. Reddy, Committee on Diet, Nutrition and Cancer, 1992

Dozens of large-scale studies have disclosed evidence that eating vegetables rich in beta-carotene reduces the risks of cancer. 173-176 It is important to note, however, that isolated beta-carotene (sold as a supplement on its own or in multivitamin formulas) does not provide the same benefits. In fact, the large-scale study referred to as "CARET" (Carotenoid and Retinol Efficacy Trial) found that synthetic beta-carotene supplements were correlated with increased—not decreased—morbidity and mortality from cancer. 15

Because microalgae are the foods richest in natural beta-carotene, several species, notably Dunaliella and Spirulina, have been extensively tested for anticancer effects and these effects have been well documented. 177-185

Researchers at the Harvard University School of Dental Medicine demonstrated that algal extracts rich in beta-carotene applied to cancerous tumors in the mouths of hamsters reduced the number and size of tumors or caused them to disappear. 186 In a further study, when an algal extract was administered to 20 hamsters pre-treated to develop mouth cancer, none of the animals developed the disease. By comparison, two pretreatedcontrol groups that did not receive any algal extract (40 animals) all developed mouth cancer. Interestingly, when beta-carotene alone was given (provided by Sigma Chemical Company) fully half the animals developed cancer. 187 This research team has continued to replicate these effects, repeatedly demonstrating the ability of blue-green algal extracts to inhibit and prevent tumor growth and cancer. 188-190

Powerful Anticancer Properties

Beta-carotene is not the only cancer-protective substance to be found in microalgae. Cancer researchers at the University of Hawaii isolated a blue-green algal pigment, called cryptophycin, that demonstrates powerful anticancer properties—especially useful in the chemotherapy of drug-resistant tumors. 192, 193 Other new algal protein compounds have also exhibited "multidrug-resistance reversing activities" that may be useful in the treatment of difficult, drug-resistant tumors. 194-196

In some cases the survival rates of algae-treated mice increased nearly 80% over control groups. 214 Such findings suggest that presurgical treatment with extracts of microalgae might decrease or prevent metastasis or tumor progression. 215

"In research in Japan, phycocyanin (the blue pigment of blue-green algae) was extracted and…[given] orally…[to] mice with liver cancer. The survival rate of the treatment group was significantly higher than the control group not given phycocyanin. After five weeks, 90% of the phycocyanin group survived, but only 25% of the control group were still alive. After eight weeks, 25% of the phycocyanin group still survived, yet none of the control group was alive. This suggests eating phycocyanin may increase the survival rate of cancer stricken organisms." 218

"Whole body irradiation" animal studies suggest there may be a potential benefit for cancer patients given algal beta-carotene before and after radiation treatments to protect against cellular damage caused by free radicals induced from irradiation. 222 Additionally, Japanese researchers using an animal model found that components of unicellular algae may be beneficial in the alleviation of cancer chemotherapy side effects (e.g., immune suppression) while supporting the anti-tumor activity of the chemotherapeutic agents. 223

Detoxification Support

"Since 1950, at least 70,000 new chemical compounds have been invented and dispersed into our environment through new consumer commodities, industrial products, and food. We are by default conducting a massive clinical toxicological trial. And our children and their children are the experimental animals."

—H. Needleman and P. Landrigan,
Raising Children Toxic Free, 1994 222

"Methionine was probably one of the first amino acids available in Earth's ancient primordial seas billions of years ago. This amino acid was (and is still) used by primitive bacteria and blue-green algae to biosynthesize glutathione, possibly Earth's first antioxidant (protection) tripeptide molecule. Methionine in this form has been shown to help humans detoxify lead and copper contamination in the blood." 224

Blue-green algae is one of the richest food sources of detoxifying polypetides, including methionine and glutathione, along with B-vitamin precursors. Once ingested, these molecules are modified as needed. Such polypeptides are essential in the protection of DNA, the family jewels, and are essential in the chemistry of detoxification. 226 Also glutathione, along with ascorbate, may help to protect against polyunsaturated fatty acid (PUFA) oxidation. 227

When microalgal supplementation was given to rats consuming a high fructose (60%) diet, a preventive effect on the liver triglyceride level was observed, along with lowered plasma cholesterol. The researchers reported that the microalgae helped reduce liver fats that were elevated by the excessively fructose-rich diet. 233

Stimulate Liver Function

Chlorophyll, which microalgae contains in abundance, can help to stimulate liver function, increase bile secretion, and protect cellular functions. 234 Also, "chlorophyll appears to promote regeneration of damaged liver cells." 235

Medical researchers have demonstrated that green microalgae increase the detoxification of harmful chemicals like chlordecone, dioxin, and PCBs. 241 In a study of chlordecone poisoned rats, ingested algae decreased the half-life of the chemical toxins from 40 to 19 days. 242

Several grams of Aph. flos-aquae blue-green algae eliminated excessive aluminum from children in a three-month study. Also, parents reported significant decreases in negative health symptoms, suggestive of improved detoxification pathways. 243 Aluminum exposure in humans is unavoidable. Some aluminum absorption occurs with the ingestion of food and medicines. Greater amounts of aluminum are present in antacids. 244 Blue-green algae may be helpful for dialysis patients, who have a greater risk for aluminum accumulation and an increased risk of neurotoxicity.

Blue-green algae have been shown to reduce lead toxicity, as well. 245 The beneficial effects of blue-green algae may be due to the presence of the abundance of antioxidants, including beta-carotene and SOD enzymes. Numerous studies have demonstrated a strong relationship between childhood learning disabilities and body stores of heavy metals, particularly lead. 246, 247

Blue-green algae have multiple liver-protective factors, including amino acids (e.g., methionine, arginine, and isoleucine), chelating trace minerals, and potent antioxi-dants, such as phycocyanins and superoxide dismutase (SOD).

Anti-inflammatory and Antioxidant Effects

"Many of the elderly in the United States—and quite a few of the not-so-elderly— experience terrible pain in their joints. Their fingers may become twisted and swollen, and they may be unable to button a coat without large doses of anti-inflammatory drugs…Many come to feel crippled and useless. By the age of 35, 35% of Americans have diagnosable arthritis in their knees. At least 85% of those over the age of 70 have it, and many have it severely."

- J. Robbins, **Diet for A New America**, 1987

Prokaryotes, organisms without a nuclear membrane (e.g., blue-green algae), display a more diverse array of antioxidant pigments and a broader selection of carotenoids than terrestrial plants and most green algae. Scientists at the University of Wisconsin, Department of Food Microbiology, report that because of the remark-able health benefits of algal and microbial carotenes, there will likely be a substantial increase in the world-wide demand for a full range of these important antioxidants. 252 Carotenoids represent one of the most widely distributed and structurally diverse classes of natural pigments, with important functions in photosynthesis, nutrition, and protection against photo-oxidative damage.

Rats and chickens fed a natural algal form of beta-carotene showed at least a tenfold higher accumulation of overall beta-carotene in their livers than those control animals fed equivalent amounts of synthetic all-trans beta-carotene supplement. The higher accumulation of the natural algal carotenoids, over the synthetic isolated beta-carotene, likely indicates a greater therapeutic value, according to the researchers. 253

Researchers have reported that natural algal beta-carotene is superior to a synthetic beta-carotene supplement in terms of raising lipophilic antioxidants (protecting PUFAs) in human serum. 254 Also, natural algal extracts of 9-cis beta-carotene are shown to have a higher antioxidant potency compared to synthetic all-trans beta-carotene with in vitro experiments.255

Boost the human body's Antioxidant Defenses

Pigments, phytochemicals, vitamins, and trace elements from algae and higher plants can help boost the human body's antioxidant defenses. 256, 257 Aph. flos-aquae has an unusually wide variety of antioxidants, such as tocopherols, beta-carotene, flavonoids, superoxide dismutase, glutathione, taurine, tryptophan, phenolic acid, and vitamins C, E, B5, and B2. Antioxidants are biomolecules that protect organisms from the damaging effects of reactive oxygen species (free radicals) that are constantly formed in biological systems.

Blue-green algae contain a wide range of antioxidants in the form of specific trace minerals, amino acids, vitamins, and especially pigments – an impressive variety of carotenes along with potent green and blue pigments. Depending on the source of blue-green algae, the amount of phycocyanin can range up to 15% of its dry weight.

Replicated studies with a range of experimental animal models have established the potent antioxidant and anti-inflammatory effects of phycocyanin. In rodents, experimentally-induced colitis as well as edemas of the paw and ear all responded positively to C-phycocyanin. 260-264

Gitte Jensen, an immunologist from McGill University, and her team at the Royal Victoria Hospital in Montreal report that Aph. flos-aquae algae may help to inhibit and to reverse inflammatory conditions. The researchers observed that small dilutions of Aph. flos-aquae algae tend to dampen the release of reactive oxygen species from certain phagocytic cells in human blood. 267

Scientists at the University of Padova, Italy, found that diatoms, golden brown unicellular algae, produce anti-inflammatory chemicals that are the main active ingredients in mud-pack treatments. In European health spas the use of mud-packs for the treatment of rheumatic and osteoarthritic patients has a long and relatively successful history. The maturation of thermal mud is dependent upon the full colonization of the mud by ther-mophilic microorganisms, with diatoms producing anti-

inflammatory sulfoglycolipids (SGL), similar to those in blue-green algae. A typical cycle of treatments requires 12 packs of thermal mud.

“On this basis we calculated the amount of SGL taken up by each patient in a cycle of treatments, and found a figure not far from the recommended dose of non-steroid anti-inflammatory drugs utilized for the same pathology. However, unlike pharmaceutical preparations, the amount of SGL taken up by the patients after the mud-packs does not exert any adverse gastrointestinal effect on these patients,” reported the scientists. 268 Additionally, the anti-inflammatory action of SGL is consistent with the decrease of serum interleukin-1 observed in arthrosic patients treated with mud-packs. 269

Overall, evidence suggests that microalgae demonstrates at least four antioxidant properties:

1. Scavenging of reactive oxygen species (free radicals).
2. Regeneration of endogenous antioxidants, such as SOD and glutathione reductase.
3. Chelation of heavy metals.
4. Repair of oxidation-damaged proteins

Improved Circulation and Heart Function

"The human heart so far surpasses all known motors in functional capacity that we can hardly hope to improve on it, even with the most ingenious machine produced by man…It beats 100,000 times per day, approximately 40 million times in a year…It pumps two gallons of blood per minute and 100 gallons per hour, through a vascular system of about 60,000 miles in length—2 1/2 times the circumference of the earth."

—Bircher-Benner, **Nutrition Plan for High Blood Pressure Problems**, 1993

Microalgae’s potent range of antioxidants, in addition to its healthy balance of EFAs, offer top-quality cardio-vascular support. Dietary supplementation with algal beta-carotene may normalize the elevated LDL oxidation in patients with diabetes, and thus delay the onset and further development of artherosclerosis in these patients.275 Aph. flos-aquae algae has high concentrations of polyunsaturated fatty acids (PUFAs) which account for almost 10% of its dry weight. Even more important, it has a high percentage of the omega-3 fatty acids, comparing extremely favorably with most plants, seeds, nuts, and other microalgae. Natural algae-rich beta-carotene supplementation appears to normalize the diabetic- enhanced LDL oxidation levels and consequently may be of importance in delaying the accelerated development of atherosclerosis in these patients. "EFAs have lubricating qualities and increase cell membrane flexibility. They are known to reduce blood cholesterol and thus help to prevent cardiovascular disease…EFAs are especially useful because of the efficiency with which they increase the solubility of cholesterol deposits and wash these deposits away from our artery walls…As the consumption of fish oils or essential fatty acids found in Aph. flos-aquae increases, the tendency for blood platelets to aggregate decreases and blood pressure goes down." 279

Support Heart Function

Algae-derived omega-3 fatty acids may support heart function, reduce blood viscosity, decrease arteriosclerosis (a disease of hardened arterial walls) and lower high blood pressure, according to research of Zvi Cohen at The Laboratory for Micro-algal Biotechnology in Israel and Helen Norman at the United States Department of Agriculture. 280 The flexibility of any cell membrane is directly proportional to the amount and type of polyunsaturated fatty acids (PUFAs) it contains. Research reveals that algae supplementation can significantly reduce high levels of arachidonic acid (AA) in the blood and liver lipids and cause a significant increase in the percentages of the omega-3 polyunsaturated fatty acids (PUFAs). 281

Dr. Rafail Kushak and colleagues demonstrated that Aph. flos-aquae essential fatty acids are more easily assimilated than those of soybean oil and offer superior cardiovascular benefits. While both soybean oil and blue-green algae contain the essential omega-3 fatty acid, alpha-linolenic acid (LNA), the scientists found that rats required triple the amount of soybean oil in their diets to achieve the same level of circulating LNA as rats fed algae. Also, Aph. flos-aquae significantly increased both eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) blood plasma lev-els far more effectively than did soybean oil. 282 Both EPA and DHA are essential for optimal cardiovascular and brain function and can be synthesized in the body from LNA.

Microalgae-derived DHA supplements markedly enhanced the DHA status levels in serum and platelets of healthy vegetarian subjects. Researchers also found a substantial increase of EPA and a lowering of total and LDL-cholesterol: HDL-cholesterol ratios, suggestive of a decreased risk factor for heart disease in the DHA algal sup-plemented group. 283Microalgae supplementation may be especially important for vegetarians who have a limit-ed intake of fish and eggs.

Japanese White rabbits fed on a ten-week load of high-cholesterol diet and powdered Chlorella, showed a significant suppression of total and beta-lipoprotein cholesterol levels, along with less aortic atheromatous lesions. However, rabbits in the control, with no algae in their diet, showed a dramatic increase in serum total cholesterol and beta-lipoprotein cholesterol levels, with resulting symptoms of atherosclerosis. 291

Homocysteine blood levels are a significant predictor for risk of heart attack, the number one killer of adults in America. 296 Importantly, homocysteine can be transformed into the amino acid methionine—its beneficial alter form—with the help of B vitamins; especially folic acid in conjunction with B-6 and B-12. Microalgae con-tain a variety of B-vitamins and methionine.

Hawaiian scientists have developed a way to grow and extract heart-healthy substances from microalgae. Currently a randomized, double-blind trial is underway in association with Michigan State University, to evaluate whether astaxanthin, a natural antioxidant from microalgae, reduces blood serum levels of C-reactive protein (CRP). CRP is an indicator of low-grade arterial inflammation and one of the single strongest predictors of risk of future heart problems in apparently healthy men and women. 298

Allergy and Asthma Relief

"If you are sitting on a tack, it takes a lot of aspirin to make it feel good. If you are sitting on two tacks, removing just one does not result in a 50 percent improvement."

—Sidney Baker, **Detoxification and Healing**, 1997

A daily dose of beta-carotene, from an algae extract, demonstrated a protective effect against exercise-induced asthma.

Two studies have found that the inclusion of blue-green algae in the diet contributes to a reduction of anaphylactic and immune-type allergic reactions in animal studies. Serum histamine levels are significantly inhibited in rats administered Spirulina. These results suggest that blue-green algae may contain compounds that act to inhibit mast cell-mediated, immediate-type allergic reactions. 302, 303

Researchers at Massachusetts General Hospital, affiliated with Harvard Medical School, found that algal oils significantly reduced blood levels of arachidonic acid in rats. 305Arachidonic acid produces molecules (leukotrienes) that trigger allergic reactions and contribute to water retention (edema) and puffiness. These molecules may be 1,000 times more problematic than histamine in contributing to asthmatic bronchial constriction. 306

A daily dose of beta-carotene, from an algae extract, demonstrated a protective effect against exercise-induced asthma. Of thirty-eight patients given 64 mg of algal beta-carotene extract daily for

one week, 53% were protected from exercise-induced asthma. All of the patients in the placebo condition showed a significant post-exercise reduction of breathing in a forced expiratory volume test. 307

Fewer Allergies, Skin Problems, and Asthma

A pilot study that used a survey developed by the National Center for Health Statistics (1996) reported fewer allergies, skin problems, and asthma among Aph. flos-aquae consumers. The algae eaters scored significantly better than average on numerous measures of health, when scores were compared to normative baseline data. 308

In Japan blue-green algae is reported "to forestall pancreatic exhaustion and return balance to the flow of enzymatic secretions." 310 Good digestion requires that the body secrete sufficient hydrochloric acid and pancreatic enzymes into the stomach to process foods. Certain food allergies can be traced to poor digestion combined with "leaky gut syndrome" that allows undigested proteins to enter the blood; the immune system reacts to these large molecules as foreign invaders. " Aph. flos-aquae blue-green algae contains carotenes and chlorophyll, both of which are able to dramatically stimulate specialized cells around the intestinal walls to secrete lubricating material and thus help to prevent this type of allergic reaction." 311 The omega-3 fatty acids are likely to be helpful as well.

Safety Issues

Industrial chemicals and microbial pathogens can contaminate any food. In recent years, the news media have broadcast many stories of illness and death related to bacteria-contaminated poultry, mercury in fish, aflatoxin in moldy peanuts, and viruses in uncooked shellfish. The Food and Drug Administration reports that food-borne infections caused by Salmonella alone are responsible for an estimated 6.5 million cases of human illness and 9,000 deaths annually in the United States. 312

The primary safety concern with wild-grown algae comes from contaminant algal species that, under certain conditions, may grow in the same lake and thus be harvested along with the food algae. Known toxins that could potentially contaminate edible algae are amenable to regulatory assessment, using reliable laboratory analysis for signs of toxins, along with safety guidelines and consumption rates for the food. 313,314 A reputable microalgae company will guarantee that accurate and independent tests are done on each batch of harvested algae to ensure purity and safety.

Freshness is Important

Another concern is how fresh or nutritionally intact the final product is. One of the best freshness indicators for microalgae is the amount and kind of chlorophyll breakdown products it contains. In one comparison of five companies that harvested wild microalgae the percentage of intact chlorophyll ranged from 0 to 65% (average of 21%). 315 Breakdown products of chlorophyll include pheophytins and, potentially, pheophorbides. 3 The latter are known to be toxic. Careful harvesting and avoidance of heat will minimize these breakdown products. The same is true of any species of microalgae and also of all chlorophyll-rich "green" foods.

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