HOW TO IMPROVE THE DIETS OF COLLEGE STUDENTS

By

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This thesis was prepared under the direction of the candidate's thesis advisor Dr. James K. Wetterer and has been approved by the members of his supervisory committee. It was submitted tot eh faculty of The Honors College and was accepted in partial fulfillment of the requirements for the degree of Bachelor of Arts in Liberal Arts and Sciences.

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ABSTRACT

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Abstract:

Numerous studies have found a significant correlation between diet and brain function in humans and other animals, indicating that a healthy diet can greatly enhance cognition and reduce oxidative stress, which impairs brain health. My thesis examines the policies of ten successful university nutrition programs in the United States, with the aim of improving nutrition for students at the Wilkes Honors College, Florida Atlantic University (FAU). I proposed that FAU should establish an on- campus vegetable garden, partner with local fisheries to provide fresh fish to the campus dining room, and mandate that all freshman complete a course in "nutrition for cognition."

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Introduction

Numerous studies have found a significant correlation between diet and brain function in humans and other animals, indicating that a healthy diet can enhance cognition and stave off age-related mental decline (see Attuquayefio & Stevenson 2015). Conversely, an unhealthy diet can have negative effects on the brain and cognition. With the "Western Diet" becoming increasingly prevalent in the United States, Americans are eating more high fat foods that not only influence weight gain, but can also lead to decreased neuronal function. To protect the public from these unnecessary risk factors, modern nutritionists and physicians recommend that the American diet be changed from one including fatty meats, refined sugars and processed foods, to one that includes food sources that have been indicated to protect neuronal function and which may even enhance cognition and delay onset of neurodegenerative diseases. These foods include omega-3 fatty acids which have been indicated to act as anti-inflammatory agents and antioxidants, which appear to play a key role in combatting oxidative stress by their ability to scavenge free radicals form the body. Fish is the primary source of omega-3's; vegetables and fruits, (especially berries), are rich sources of antioxidants. Having identified these food sources as important to the Wilkes' student diet, and because of my research and passion on the topic of nutrition that has the potential to enhance cognition, the purpose of this thesis is:

1. To show scientific support for the value of a diet rich in omerga-3 fatty acids and in antioxidants, for their positive effects on cognition and overall wellness.

2. To propose a "Nutrition for Cognition Program," at Wilkes Honors College including:

a) requirement of a Freshman course in nutrition

b) implementation of a campus farm and small fruit tree orchard, plus the initiation of partnership with a local fishery to supply fresh fish to the campus dining room.

c) identification of proposed funding strategies for the program.

Section 2: U.S. diet analysis- amount of fat and missing essential nutrients

Attquayefio et al. (2015) completed a meta-analysis, with the goal of "understanding which areas of cognition are most susceptible to the effects of diet." Their analysis includes 18 studies, which look at the dietary food supply of 11 countries, the incidence of Alzheimer's Disease in the older populations, and at memory test results given to younger subjects. The data gathered on diet and disease indicates a positive correlation between total caloric intake and saturated fat intake with the risk for developing Alzheimer's disease. The authors thus determine that overall, these studies indicate "a link between diet and neurodegenerative disease." In younger study subjects, saturated fat intake combined with high intake of refined sugar (HFS) is correlated with performance in memory related tasks. The authors cite a specific study done by Gomez-Pinilla, which finds the HFS diet, "associated with impaired performance in hippocampal-dependent memory tests in normal adults and young children." The authors conclude that based on the observed correlations in 18 studies, consumption of saturated fat "may be an

independent risk factor for impaired cognition," and that the "Mediterranean Diet, " low in saturated fats and refined sugars, and high in polyunsaturated fats and monounsaturated fats was associated with a lower risk of neurodegenerative disease, as compared with the high saturated, high refined sugared "Western Diet," so popular in the United States. Many studies indicate that high fat is bad for cognition.

Section 3: Many studies indicate that high fat diet bad for cognition

Freeman et al. (2014) links the effects of unhealthy fatty acids to inflammation that negatively affects brain and cognition. I realized that the Harriet Wilkes Honors College, in the three years that I lived on campus and ate the cafeteria food every day, did not always provide foods that fully fit my healthy lifestyle diet. As a student, to attain the optimum diet, I regularly had to shop and spend additional money on healthy food sources. I knew many students who did the same, because they got tired of not having enough healthy options to stay on their chosen diet. We would regularly go to local shopping markets like Rorabeck's Plants and Produce to get healthy and organic fruits, veggies, eggs, and meats. In an institution where it is so vital that students focus on their work and have the brainpower to get through the day, it is a priority to supply the best brain- boosting foods in the diet. The main reason not to pursue this excellent goal is likely budgetary, but I have identified a way to get around this problem and found that many other colleges are trying the same approach. For example, in pursuit of supplying healthy omega-3 fatty acids, primarily found in fish, I have identified a very interesting

startup program that is being used by some schools in California. The program called "Bay to Tray," uses locally caught "byfish," (fish not destined for supermarkets and marked for disposal due to aesthetics,) for healthy sources of local fresh fish for their students. This program is a great way to supply both the academic and specific food needs of the students. Additionally, on many prestigious United States campuses, college farms act both as outdoor classrooms for education in organic farming methods and areas for the production of healthier food supply for students. The farms differ in size and lay out, but the reason all of them were established in the last decade, was with the dual purpose of providing to the people of the college, an improvement in both academic and food sources. The Harriet L. Wilkes Honors College currently does not present a program such as this, so I propose in this thesis, that the Honors College creates a small farm that provides organic produce to meet the nutritional needs of the students. I propose that the college work with Matt Rorabeck from Rorabeck Farms, a local third generation Floridian farmer, who has agreed to help supply the cafeteria with fresh produce and also help with the farming initiative on campus. Also, I have reached out to Boca Federated Women's Club, which has agreed to donate fruit trees and seeds to the cause.

Freeman et al. (2014) reviews current research derived from rodent and human studies, which indicate a link between the consumption of fatty acids to inflammation, which may contribute to changes in brain cognition. The authors open by declaring that obesity is an "epidemic," in the United States, contributing to serious health damage, and affecting as much as one-third of the population. They point to Americans' consumption of the "Western Diet," (a diet composed of large intake of high fat sources, like red meats, combined with large amounts of refined sugars and grains,) as the main contributing factor

to obesity. They instruct that diets "high in saturated fats (SFAs) and trans-fatty acids (TFAs), compared to (n-3) fatty acids or polyunsaturated fatty acids, are much worse for weight gain and digestion." The major sources of SFAs are identified as "fatty meats, baked goods, cheese, milk, margarine and butter." Trans-fatty acids are found in many processed American foods. Freeman et al. (2014) describes a healthier diet, superior for proper weight maintenance and blood sugar, as one high in fruits, vegetables, lean proteins and fiber.

Noting that research confirming the western diet as a contributor to obesity is well established, the main focus of interest going forward, is on studies performed in the last two decades, which point to a detriment caused by the high fat diet to our brains. Freeman et al. (2014) presents a review of studies, regarding cognitive function, beginning with a rodent study in which rodents placed on a lard based diet performed the worst in a maze exercise, when compared to the performance of rodents fed a standard chow diet, or a diet rich in soybean product. Also reported from both rodent and human studies, were results identifying insulin resistance as "at least one mechanism by which chronic consumption of a high fat diet is linked to cognitive decline." Next reported are results which demonstrate negative effects of a high fat diet on performance of rodent subjects in a maze. The study associates the high fat diet with "reduced hippocampal integrity." The hippocampus is an area that is associated with memory and spatial navigation. *Table 1* of Freeman et al. (2014), provides a summary of the rodent studies from this review, performed in the last decade, which focus on biological mechanisms related to observed cognitive effects of diets high in fat. These studies focus on determining high fat dietary effects on "insulin resistance, developmental disturbances, altered membrane functioning, oxidative stress,

inflammation, and altered vascularization." *Table 2* includes data from all the human studies on the same subject contained in the review.

Table 1 Rodent studies: effect of diet on cognition

Diet composition	Cognitive results	Postulated biological mechanism	References
Lard-based diet (40% calories from fat)	Worse performance on working memory and retention	Not discussed	21
Lard & corn oil (39% energy)	Worse performance on Morris water maze	Oxidative stress, reduced BDNF levels	31
High fat diet (45% calories from fat)	Worse performance on operant-based delayed matching to position task	Insulin resistance	32
High fat, high glucose diet supplemented with high fructose corn syrup	Worse performance on a spatial learning task	Insulin resistance, Reduced BDNF levels	33
High saturated fat and cholesterol	Worse performance on the Water Radial Arm Maze	Inflammation, reduced dendritic integrity in the hippocampus	34
'Western diet' (41% calories from fat) or Lard (60% calories from fat)	Impaired retention on behavioral test for 60% fat but not 'Western diet'	Oxidative stress	35
High fat diet (45% calories from fat) + Metformin	Improved performance on operantbased task	Insulin sensitivity	36

High-fat high-carbohydrate + Vitamin E	Improved performance on Water Radial Arm Maze	Oxidative stress	37
High fat diet (45% calories from fat)	Impaired performance on Fear Conditioning Task	Oxidative stress	38
High fat diet + Sugar	Impaired performance on serial feature negative task	Vascular/adiposity	39

source: Freeman et al. (2014)

Table 2

Human studies: effect of diet on cognition

Diet composition	**Cognitive results**	**Postulated biological mechanism**	**References**
High linoleic acid intake	Worse performance on Mini Mental State Exam	Oxidative stress	14
Poor diet resulting in impaired glucose tolerance	Worse performance on Mini Mental State Exam	Disturbed glucose metabolism	47
Low intake of monounsaturated and saturated fat	Best performance on the Mini-Mental State Examination and Pfeiffer's Mental Status Questionnaire	Oxidative Stress, lack of micronutrients such as vitamin C, folate, zinc	41
Higher intakes of saturated fat and trans-unsaturated fat	Decline in performance on: East Boston Tests of Immediate and Delayed Recall, the Mini-Mental State Examination, and the Symbol Digit Modalities Test	Cholesterol levels – atherogenic	42
High intake of ***n***-3 polyunsaturated fatty acids and docosahexaenoic acid (22:6***n***-3)	Reduced risk of Alzheimer's disease	not discussed	44

Diet composition	Cognitive results	Postulated biological mechanism	References
Increased caloric intake and increased cholesterol intake	Poorer performance on simple reaction time, symbol-digit substitution, and serial digit learning	not discussed	43

source: Freeman et al. (2014)

While Freeman et al.(2014) notes that not enough validating studies have been done in this area of research, it concludes that the available data indicates that "fatty acid consumption, insulin resistance and oxidative stress may be coordinated with inflammatory and vascular alterations to cause overall change in brain function."

Section 4: Additional Studies Indicate high fat diet is bad for cognition

Wu, et al. (2014) investigates the high fat diet as contributing to a mechanism, which affects the brain's cognitive function. Wu concludes," A diet high in saturated fat, (HF) decreases levels of brain-derived neurotropic factor (BDNF) to the extent that it compromises neuroplasticity and cognitive function, and aggravates the outcome of brain insult." The study shows that male rats placed on a high fat diet, experienced severe oxidative stress. " Supplementation of the high fat diet with Vitamin E, "dramatically reduced oxidative damage, normalized levels of BDNF, synapsin I and cyclic AMP-response element-binding protein (CREB), caused by the consumption of the HF diet." In

addition, the antioxidant, Vitamin E, "preserved the process of activation of synapsin I and CREB, and reversed the HF-impaired cognitive function."

Any association between diet and effect on synaptic activity in the brain is concerning. Even as we wait for additional confirming human studies, the indication that memory and learning can be affected by diet, and in the knowledge that we can, at the least, clearly observe the negative effects of excessive weight gain resulting from the high fat diet, it appears that it is wise to avoid the "western diet," and that it is prudent to add foods containing antioxidants to our diets in pursuit of the goal of achieving enhanced cognition. The next logical investigation for this thesis was to search the literature for research confirming and elucidating the beneficial dietary effects of (n-3) fatty acids and antioxidants.

Section 5: Cognition improvement is indicated in omega-3 supplementation

Innis et al. (2007) explores the positive role of (n-3) fatty acids as protective agents against oxidative stress, and reduced cognition, and identifies the best food sources of these agents. After review of the studies, the conclusion is that "(n-3) fatty acids are essential dietary nutrients, and one of their important roles is providing docosahexaneoic acid (DHA) for growth and function of nervous tissue." Innis et al. (2007), notes that "reduced DHA is associated with impairments in cognitive and behavioral performance." The study instructs that the dietary sources of DHA and EPA (eicosapentaenoic acid) alter the brain's membrane lipid levels. The primary sources of the (n-3) fatty acids are fish and seafood, with lesser sources found in poultry and eggs. Innis et al. (2007) explains that

"dietary DHA… is well absorbed and readily incorporated into plasma and blood cell lipids in humans (as shown in many studies relating DHA intake from fish and fish oils to cardiovascular disease risk endpoints and inflammatory mediators,) and several animal studies have shown that dietary DHA is readily incorporated into lipids of the developing brain before and after birth." It is important to address absorption, because often consumers are wary of the effectiveness, based on published data and advertisements that question the real absorption rate of certain artificially produced supplements. Although Innis et al. (2007) states that more human studies are needed to confirm levels of actual intake of DHA into the brain, it is noted that an animal study, restricting dietary DHA, resulted in reduced DHA in the brain, and particularly in rodents, showed poorer performance in learning tasks. Based on data from recent studies, hypotheses have been put forth that relate dietary DHA, absorbed by brain tissue, to impact the speed of signal transduction and neurotransmission, involving the function of "lipid rafts." The studies cited include human subjects, and include analysis of human maternal breast milk, exploring mother-to-fetal transmission and even results gained from human infant autopsy, comparing formula fed infant brain levels of DHA with breast fed infants' levels. Dietary restriction of (n-3) fatty acids were used with rodent subjects in other studies. In summary of the review of a number of studies exploring the effects of dietary DHA in animal and human models, it is noted that "some studies suggest, that children may profit from early and enhanced DHA nutrition in their development of motor skills." It is stated numerous times that more research is needed, and hopes that future definitive studies confirm the indications that dietary (n-3) fatty acids may protect the human brain from oxidative stress, and contribute to faster synaptic speed, perhaps improving memory and

learning skills, because she believes that this realization would be " of considerable public health importance."

Rathod et al. (2013) also looks at omega-3 fatty acid effects, specifically on rodent offspring and this study reports that spatial memory performance was enhanced in rodents whose nursing mothers were fed B-12 plus omega-3 fatty acid vs. the control group (normal B-12 25 ug/kg diet) and a vitamin B 12 supplemented group. Those subjects receiving omega-3 supplementation performed fewer errors while attempting to navigate an eight –arm maze. Rathod et al. (2013) introduction states: "Our results indicate that a combination of an omega-3 fatty acid and vitamin B12 enriched diet may exert beneficial effects on synaptic plasticity and cognition, which may prove beneficial for mental health, particularly in preventing neurocognitive disorders." The authors first offer that "recent animal studies have demonstrated that maternal vitamin B12 deficiency increases oxidative stress and reduces brain omega-3 fatty acids, especially DHA in the offspring at birth," and therefore, the stated purpose of this study was to investigate the effect on brain fatty acids, when the maternal diet was supplemented with omega-3 fatty acid, supplied by fish oil capsules. To test and compare the reference and working memory of the supplemented and non-supplemented subjects, the rodents were placed in an 8-arm maze. The supplemented rodents performed better in working memory and reference memory, and the authors offer, that "this could be due to higher levels of DHA and BDNF (protein and mRNA) in the hippocampus and brain cortex, since both are involved in learning and memory formation." Rathod et al. (2013) states "this present study suggests that omega-3 fatty acids may boost the benefits of vitamin B12 on brain neuroplasticity… and may improve brain development and prevent early cognitive deficits."

With the purpose of discovering a link between (n-3) fatty acids and cognitive function, Bauer et al. (2014), did a human, double-blind study, of eleven participants. This study's subjects took a thirty- minute cognitive test (the Swinburne University Computerized Cognitive Ageing Battery, and underwent an MRI brain scanning session at the Brain Research Center (Austin Hospital, Heidelberg, Australia) Reaction times were recorded for participants as they performed "Stroop and Spatial Working Memory tasks." Participants were tested at baseline, having had no dietary (n-3) fatty acid supplementation, again after a thirty-day supplementation with EPA, and again after a thirty-day DHA supplementation, with a thirty-day washout period in between. Bauer et al. (2014) designs this double-blind study to access evidence on the effects of EPA-rich and DHA rich supplementations on "cognitive performance and functional brain activation." They conclude that with EPA-rich supplementation, participant's brains worked 'less hard' and achieved a better cognitive performance than prior to supplementation. Study results showing cognitive improvement "may therefore indicate a more efficient utilization of neural resources and/or consumption of oxygen and glucose in the brain." The authors point out that although DHA supplementation did not favorably compare with EPA, there may be other limiting factors involved, perhaps indicating different effects related to age, and even individual intelligence quotients. Based on other reported study data involving MRI tests done on subjects suffering from HIV or hypoglycemic patients, who summoned concentrated levels of focus which enhanced their ability to generate brain energy or to "hyperactivate" to complete tasks, the authors reasoned that a "relationship between cognitive performance and brain effort helps us understand why previous reports on the effects of omega-3 supplementation on cognitive

performance has been inconsistent." Simply put," humans tend to modify their brain activity to maintain an acceptable level of brain performance." Authors also offer that in this study, comparison between EPA and DHA results could be affected by somewhat lower amounts of EPA than DHA in the supplementation (590 mg vs. 417 mg, respectively,) and the fact that DHA is "more slowly incorporated into the phospholipids in the inner cellular membranes." Also, even though it was believed that the washout period was sufficient to compensate for the use of a placebo comparative, a placebo value may have better validated a comparison. The final conclusion presented in this article is: " a thirty day EPA-rich supplementation is more successful than a thirty day DHA-rich supplementation in improving neural efficiency during higher order cognitive tasks. " For purposes of this thesis, the take-away is, that a human double-blind study showed cognitive improvement with dietary (n-3) , omega-3 fatty acid intake.

A double-blind human study that was both randomized and placebo- controlled was done over sixteen weeks with forty boys diagnosed with ADHD, 8-14 years of age, (compared to thirty-nine same aged male control subjects,) to determine the effects of dietary omega-3 supplementation (a natural food source,) compared to a pharmacological stimulant approach, (with its side effect profile,) that is often employed to treat the symptoms of ADHD diagnosed children. Bos, et al (2015) concluded that there was support for a hypothesis that "omega-3 supplementation may be an effective augmentation to pharmacological treatments of ADHD." The forty boys were fed 10g of margarine daily, enriched with 650 mg. of EPA, 650 mg. DHA or a placebo. After reviewing previous conflicting studies on the efficacy of the omega-3 effectiveness in treating ADHD, followed by two independent meta-analyses, showing possible benefits, these

authors determined to investigate the effects in a double-blind randomized, placebo controlled study. Their starting hypotheses was that "dietary supplementation with omega-3 PUFAs would improve symptoms of ADHD, increase phospholipids PUFA status as assessed by cheek cell phospholipids composition, and increase the rate of dopamine turnover as assessed by homovanillic acid (HVA) excretion in urine." Additionally, they state that they predict that omega-3 supplementation would "improve cognitive control." Cheek cell samples were collected at baseline and urine samples collected to "measure HVA to creatinine ratio as a proxy for dopamine turnover." The Child Behavior Checklist (CBCL,) filled out by the parents, was collected to measure their children's severity of symptoms. The Normal Behavior scale (SWAN,) collected five times, was used to measure change. The Teacher Report Form (TRF) was sent to participants' teachers or mentors at baseline and at follow up. MRI technology was used, eliminating thirteen ADHD diagnosed children and six controls for movement. To measure behavioral and physiological group differences, independent t-tests or Mann-Whitney U-tests were used. The authors conclude, as a result, that "this study provides new evidence that dietary supplementation, using omega-3 PUFAs, may be an effective augmentation of pharmacological treatments of ADHD," and it was speculated that its action may involve 'attention networks." This and previous studies, cited so far, indicate possible beneficial effects on cognition, learning and memory from dietary (n-3) fatty acids, found in fish and seafood as primary sources. The search for the best complete diet now points to research studies that have found other food sources that appear to benefit cognitive function.

Section 6: Antioxidants play a role in Reduction of Inflammation and Oxidative Stress

One interesting study identified the spice curcumin, highly valued in the diet of India, as a natural food source, which has been indicated as functioning as a protective agent against inflammation, oxidative damage, and spatial memory deficit. Frautschy et al. (2001), compared the effects of the conventional NSAID, ibuprofen, with the spice curcumin to determine their ability to protect against amyloid B-protein induced damage. This amino acid peptide has been suspected to have a central role in the pathogenesis that produces neurotoxicity that leads to oxidative damage and then possibly to development of Alzheimer's Disease (AD). "In vitro, direct AB application to neuronal cells, increases hydrogen peroxide production, leading to AB neurotoxicity that can be prevented by vitamin E and other antioxidants," Frautschy et al (2001). A former study was cited that hypothesized that "because of strong evidence for oxidative damage in the AD brain and because anti-oxidants can protect from in vitro b-amyloid toxicity," they hoped to prove cognitive decline by using antioxidant Vitamin E supplements. However, this experiment was not successful, perhaps because the form of Vitamin E, (the one used in most supplements,) was not an effective scavenger of free radicals which are produced during inflammation. Frautschy et al (2001), researched that the natural polyphenolic antioxidant curcumin, found in the yellow curry spice tumeric, had been reported to be more potent than Vitamin E as a free radical scavenger, and so it was determined to look at curcumin's ability to be effective against oxidative damage. Further investigation was encouraged by the finding that curcumin has a long history of use in India as an herbal medicine, and that in fact, India reports only one-fourth of the incidence of AD found in the United States.

Frautschy et al. (2001) shows the AD risk to be reduced or delayed in persons using anti-inflammatory drugs (NSAIDS), and therefore "we hypothesized that acting as a combined antioxidant and NSAID, dietary curcumin might also have significant preventative activity against AB induced neurotoxicity and cognitive deficits." With the goal of determining better than previous studies, whether curcumin or ibuprofen could block in vivo toxicity, this study used female 19 month old rodents, because "aged females have two known risk factors for AD." Study B used more easily available younger female rodents. The studies used different doses of infused AB protein, and rodents were fed different formulas of curcumin and control chows. Study B rodents were placed in a water maze to determine spatial memory ability. Results show a significant reduction in overall cortical synaptophysin loss in rodents fed curcumin, but not in those receiving ibuprofen. The authors state that curcumin demonstrated significant effects on oxidative damage and neuroprotective effects in rodents with AB infusion. Additional findings were that "synaptophysin loss was shown to result in spatial memory deficits in the water maze," with the hypothesis that these deficits could be prevented by curcumin treatment. The study concludes that "curcumin or another antioxidant/combined NSAID approach may prove useful for AD prevention or treatment." It notes that curcumin has a history of safe use and has a limited or no side effect profile when given in doses reported effective against inflammation, while NSAIDS have negative gastrointestinal side effects. Considering India's low instance of Alzheimer's Disease compared to the United States, and the results of the demonstrated protective effects of curcumin against inflammation and oxidative stress, which may further protect against memory deficit, the results encourage one to enjoy this great tasting yellow curry spice on a routine basis.

A published academic review of current studies on the positive effects of the class of polyphenols on cognition, also confirms the efficacy of curcumin, and offers an interesting tutorial on the process that underlies cognitive function. Pinilla et al. (2012) states "the consumption of diets enriched with polyphenols may present the potential of dietary manipulation as a non-invasive, natural, and inexpensive therapeutic means to support a healthy brain." These authors go further than celebrating the data that supports the effects of polyphenols as protectors against inflammation or stress, and leap forward to discuss the possibility that these antioxidants from plant sources such as fruits and vegetables, can be used as effective and inexpensive agents to combat cognitive and even psychiatric disorders. The authors first discuss the molecular and cellular actions attributed to polyphenols' ability to combat neurological degeneration. "Polyphenols, epigallocatechin gallate (EGCG), found in green tea, and curcumin, found in the turmeric plant, have been strongly associated with higher cognition function, better mood, and protective effects against various brain diseases." The authors take the discussion down to the molecular level. They instruct that eating a food stimulates the metabolic processes in the mitochondria the "main vessels of energy metabolism in the body that break down matter into usable energy." They go on to explain, that the brain consumes the most energy in the body, and the effect of its metabolism, involving molecules like brain-derived neurotropic factor (BDNF), and insulin-like growth factor I, which affect neuronal plasticity. BDNF influences the survival and differentiation of neurons in the regions of the brain most associated with cognition, the hippocampus and the cerebral cortex. Pinilla et al. (2012) states, "BDNF stimulates synaptic plasticity in neurons enhancing learning capacity and memory formation." They further add that high caloric diets can promote

excessive production of oxygen-containing molecules classified as radicals, which can "damage DNA, lipids and proteins and alter key cellular response systems and pathways." The brain produces natural antioxidants to scavenge the free radicals, but if overtaxed, the radicals can out- run the scavengers. Fortunately, the authors note, "foods high in dietary polyphenols, found in colorful fruits, vegetables, spices, teas, and wines are becoming popular with their powerful antioxidant and anti-inflammatory activities." After being ingested, these plant- based foods are hydrolyzed by intestinal enzymes, to be absorbed by the gut to various tissues and organs including the brain. The authors would prefer to see more in vitro studies, however they are excited about one human study of 1000 elderly green tea drinkers in Japan, which showed improved cognition in elderly Asian patients who ate diets rich in curcumin, and a lower incidence in cognitive impairment in those who routinely drank green tea. Pinilla et al. (2014) showed that "chronic curcumin administration reversed stress-induced changes, altering neutrophin levels in a manner comparable to the tricyclic antidepressant imipramine." The review concluded: "Polyphenols, especially berries, pose a positive effect on the brain by modulating synaptic transmission and enhancing cognitive function with their antioxidant properties, engaging signaling pathways that link molecules that act at the interface between cellular metabolism and synaptic plasticity." Polyphenols are here indicated as a smart daily addition to the American diet.

Pinilla (2008) presents a tutorial on the basics of current theory on the pathway from food intake to brain utilization of nutrients, affecting cognitive function. It begins by first proposing that food signals to the brain, which affected energy metabolism, and synaptic plasticity, were important factors in human brain evolution. Since the brain is the

organ that consumes the most energy used by the body, he reasons that it is most likely that following the pathway from food intake to the production of energy, to the transfer of that energy to neurons, will lead us to the discovery of an effect on cognitive processes. He notes "dietary consumption of omega-3 fatty acids is one of the best-studied interactions between food and brain evolution." These studies indicate that DHA fatty acid is present in the brain's cell membranes more than any other omega-3, but since the body is non-efficient at making its own DHA, it is dependent on dietary DHA. Gomez-Pinilla then says that the fact that DHA is an important brain constituent "supports the hypothesis that a shore-based diet high in DHA was indispensible for hominid encephalization," (increase of brain/body-mass ratio.) He then notes that "archeological evidence shows that early hominids adapted to consuming fish and thus gained access to DHA before extensive encephalization occurred." He follows with a comment on the decrease of consumption of DHA fatty acids in our "western diet," and suspects that this may underlie some modern manifestations of brain disorders. In any case, he continues to follow the pathway from human appetite to food intake to brain effects, by the following information regarding the gut absorption of foods. The hormone, ghrelin, is secreted by an empty stomach, and in mice and humans it acts as an appetite stimulant. Ghrelin promotes synaptic action in the hippocampus. Our intestinal cells synthesize GLPI neurons, which stimulate pancreatic insulin and glucose intake by muscle cells. "Infusion of GLPI into the brains of rodents have been shown to improve spatial memory." Insulin, secreted during digestion and absorption of food into the bloodstream, can enter the brain and interact with signal-transduction in the hippocampus. The summary is that "overall, the evidence seems to indicate that the act of feeding can itself modulate cognitive processes on two levels,

through neural circuits that connect the gut and the brain and through the release of gut peptides into the bloodstream." Neuronal energy can affect synaptic plasticity. Synapses affect metabolic energy influencing brain function at a molecular level. BDNF acts as a signaling molecule which can "engage metabolic signals to affect cognitive function." Task learning increases action by BDNF to affect synaptic plasticity, and thus aids memory. Studies indicate that abnormal neuronal secretion of BDNF is associated with abnormal memory processing. It is stated, however, that more studies are needed to determine the parameters of the relationship of BDNF effects on plasticity with modulation of cognitive function. Insulin-like growth factor1 (IGF1), synthesized in the liver, appears to be related to the mechanism of action of BDNF on synaptic plasticity. In rodents, a similar pathway has been observed by IGF1 and BDNFdownstream to the Akt signaling system.

Pinilla (2008) notes, "DHA stimulates neuron plasticity through the Akt pathway, (a specific protein kinase that plays a key role in multiple processes such as glucose metabolism,) suggesting that Akt activation might be crucial for integrating the effects of food-derived signals on brain plasticity." It briefly addresses the effects of flavonoid antioxidants found in cocoa, beans and some fruits, reporting the results of one study which showed that "dietary supplementation with the plant-derived flavanol (-) epicathechin, which has been shown to cross the blood-brain barrier, elevated indices of synaptaic spine density and angiogenesis and increased hippocampus-dependent memory in mice." Pinilla (2008) takes the reader on an interesting molecular journey, beginning with the diet of early, coastal dwelling man, whose diet of omega-3 rich fish, affects actual brain enlargement, moving him up the evolutionary cognitive ladder, to modern man,

whose (n-3) fatty acid intake improves memory and cognition. Although there is a need for more definitive human studies, the molecular activity Pinilla believes to be accurate, is supported by many rodent and human experiments and observation. A convincing argument about positive effects of dietary omega-3s on cognitive function is made.

Investigative studies indicate a positive effect on cognitive function produced by the dietary intake of omega 3 fatty acids primarily sourced from fish, and antioxidants sourced specifically from the spice curcumin and from certain flavanoids. And the most recent nutritional literature is fascinated with polyphenols as a class and particularly, the blueberry. Kesse-Guyor et al. (2011), for example, reports a study on dietary polyphenol intake to determine cognitive performance of a large sample of participants, 2574 middle-aged adults in France, over a 13 year time span! Dietary records were kept by subjects and collected from 1994-1996 as part of a study on supplementation of vitamins and antioxidants study. Thirteen years later, 2574 subjects of this study, which originally included five times as many subjects, were assessed for cognitive performance, using four neuropsychological tests measuring phonemic and semantic fluency, the RI-48 Cued Recall Test, the Trial Making Test and Forward and Backward Digit Span test. Kesse-Guyot et al. (2011) begins by noting that the most consumed polyphenols are flavonoids, with previous studies having shown neuroprotective properties and enhancement of neuronal function as they stimulate brain flow and induce neurogenesis. The resulting hypothesis from these former experiments was that a positive impact on cognition was implied. The aim of this 2574 participant study was to "evaluate the hypothesized positive associations between the midlife level of intake of different types of polyphenols and cognitive function assessed 13 years later." Polyphenol food and drink supplied sources

were coffee, fruits, wine and tea. The mean age was 66 years in the two groups of men (1413,) and women (1161.) Study results indicated, that "high total polyphenol intake was associated with better language and verbal memory." The authors note that their interest in doing this study was based on the fact that presently there is no discovered cure for dementia, and therefore, information regarding a natural dietary source that might prevent against or slow the onset of dementia would be such a contribution to these patients and to society in general as we see more incidence of Alzheimer's and other neurodegenerative diseases, and that this natural dietary, cost-effective approach would be a gift to public health. The good news is that polyphenols are an affordable, antioxidant source are readily available, and delicious.

A star in the polyphenol universe is the blueberry. It is delicious, abundant and indicated as protective against oxidative stress in Duffy et al (2008) which states that "blueberries (BB) contain high levels of polyphenolic flavonoids, ranking them among the foods highest in antioxidant activity." The purpose of this study was "to test the hypotheses that dietary treatment with BB would protect against neurotoxicity caused by central injections of kainic acid (KA) in rodents and that plasma collected from BB fed rodents would protect cells from H2O2 mediated stress." Alzheimer's pathogenesis for example, is thought to be related to oxidative stress leading to neurodegeneration. A complex popular maze task, Stone 14-unit T-maze, was used to assess BB neuroprotective effects on learning in rodents. Rodents were placed on a 2% BB diet for 8 weeks, and received KA infusion into the hippocampus region of the brain. Superior learning performance and less neuronal loss was observed in rodents who received the BB supplementation, when compared with the non-supplemented rodents, in the maze task.

The authors note that the mechanism of protection remains to be specifically defined, observing that in a number of studies, "flavonoids have been reported to inhibit lipid peroxidation in several biological systems." Various studies were mentioned which addressed the observation of this peroxidative inhibition in the mitochondria, microsomes, erythrocytes and in the liver. Authors note that flavonoids also "appear to have the ability to upregulate endogenous antioxidants." And state that other recent studies indicate that flavonoids, as a class, have effects "beyond antioxidant effects," like anti-inflammatory properties, and may aid in positive regulation of signaling, operating on "diverse pathways," possibly affecting straital-dependent learning and memory, and hippocampal-dependent spatial memory, thus producing "beneficial effects on cognition." Multiple rodent models indicate that a blueberry diet provides neuroprotection involving a number of mechanisms. The optimistic end hope expressed in the article, is that a diet enriched in blueberries "might provide an effective strategy for preventing or treating AD, and possible other neurodegenerative disorders."

Another study which related its results to an optimistic finding which may protect against diseases like Alzheimer's, is found in Galli et al. (2006) which "examines whether short-term supplementation with blueberries might enhance the brain's ability to generate a heat shock protein 70 (SP70) mediated neuroprotective response to stress." In an experiment in which aged rodents were fed a blueberry supplemented, or a non-supplemented diet, for 10 weeks, and then subjected to an in vitro inflammatory challenge, followed by an examination for the levels of HSP70 protein levels which occurred in response to that challenge, it appears that the BB diet restores the HSP70 protein levels. Authors conclude that this result "suggests that a short-term blueberry (BB) intervention

may result in improved HSP70 –mediated protection against a number of neurodegenerative processes in the brain." They believe these effects to be resultant from antioxidant anti-inflammatory action to effects on signaling. This conclusion echoed Lau et al. (2005) results that reported "research from our laboratory has shown that nutritional antioxidants, such as the polyphenols found in blueberries, can reverse age-related declines in neuronal signal transduction, as well as cognitive and motor deficits."

In summary, this research, primarily from the last decade, containing results from both rodent and human studies, offers encouraging indications that diets containing omega 3 fatty acids from fish, and antioxidants contained in plant and fruit sources such as the yellow curry spice curcumin from turmeric, green tea and blueberries, will, at the least, not contribute to obesity, and its related challenges to health, and at the most, may enhance brain cognition, memory and motor skills. Most optimistically, these phytonutrients, may even protect against neurodegenerative diseases like Alzheimer's Disease.

Hyman (2014) counsels "What you put at the end of your fork is more powerful medicine than anything you will find at the bottom of a pill bottle…think of your grocery as your pharmacy." Dr. Hyman, a writer and frequent guest consultant on the popular *Doctor OZ* television show, encourages Americans to look at phytonutrients as medicine. Hyman wrote this article just after he returned from a lecture tour on wellness and nutrition in China. There he was fascinated to discover that the very word for taking medicine in Chinese is "chi yao, or eat medicine." He then instructs that phytonutrients are "special molecules that interact with your biology …like switches on your DNA to heal your body." He notes that after twenty years of practicing medicine, he recognizes that one

of the most powerful tools in the tool box against chronic illness is food. Dr. Hyman finds interesting new suggestions for antioxidant food sources like ginko nuts, which "help increase circulation and improve cognitive function," and the "deep green gai lan" or Chinese broccoli, that is believed to prevent cancer. He shares that while in China, he enjoyed a nutritious meal including " fish maw and ginseng soup which "increases energy, helps us adapt to stress and provides easily digested protein and omega-3 fatty acids." He finished that meal with a healing soup containing lotus seeds and quail eggs, sources which he notes have been associated with improvement of blood pressure, and in the reduction of anemia, and heart palpitations. For a beverage, he drank green tea, which he notes, "improves metabolism, enhances detoxification, reduces inflammation and the risk for cancer as well as helps chelate heavy metals in food." Hyman ends his article with "colorful" commentary. That is, he instructs that the colors of fruits and vegetables indicate the family of "healing compounds," which they bring to the table. " He notes: "The vast array of colors in vegetables represent over 25,000 chemicals that are beneficial." He starts with the "Red Group," containing tomatoes, pink grapefruit and watermelon, containing the carotenoid lycopene, indicated in protection against prostate cancer. Just one glass of tomato juice will access fifty per- cent of the recommended intake of lycopene, he notes. Next, is the "Yellow/Green Group," containing the carotenoids lutein and zeaxanthin found in spinach greens, collard greens, mustard greens, turnip greens, yellow corn, green peas, avocadoes and honeydew melons, and believed to benefit ophthalmic health, reducing the risk of the development of age-related cataracts and macular degeneration. The most optimistic hope for lutein is that it may even be indicated to reduce atherosclerosis. Thirdly, the "Orange Group," found in carrots,

mangos, apricots, cantaloupes, pumpkin, acorn squash, winter squash and sweet potatoes, contains alpha carotene, which has been indicated to protect against cancer. These fruits and vegetables also contain beta-carotene, which is converted in digestion to Vitamin A, which protects the skin and is believed to enhance night vision. The fourth group is "Orange/Yellow, including pineapple, orange juice, oranges, tangerines, peaches, papayas and nectarines, containing beta cryotothanxin, "helps cells in the body communicate and may prevent heart disease." Hyman offers that eating just one orange provides 170% of the recommended daily intake of Vitamin C. Next mentioned is the "Red/Purple Group, loaded with antioxidants called anthocyanins, believed to prevent blood clots. This group contains beets, eggplants, purple grapes, red wine, grape juice, prunes, cranberries, blueberries, blackberries, strawberries and red apples. The optimistic indication is that anthocyanins may play a role in delaying the process of aging of the body's cells, and may even delay the onset of Alzheimer's Disease. The "Green Group," containing broccoli, Brussels sprout and kale, contain the chemicals sulforaphane and isocyanate, and indoles, " all of which help ward off cancer by inhibiting carcinogens." Finally, the "White/Green Group," containing leeks, scallions, garlic, onions, celery, pears, white wine endive, and chives, completes the palate of colors. He notes, "the onion family contains allicin, which has anti-tumor properties, and that the other foods listed contain antioxidant flavonoids, indicated in numerous studies to ameliorate oxidative stress, and act as anti-inflammatory agents. Dr. Hyman, who practices medicine at Cleveland Clinic's Center for Functional Medicine, and is the founder of the UltraWellness Center, is the author of books found on the New York Times bestseller list. He reminds us that "2/3 of all drugs come from the

plant world," and challenges us to build a healthful phytonutrient diet containing colorful fruits, vegetables and omega-3 rich fish, which he identifies as medicinal in effect.

Based on the clinical research studies cited, and this tutorial article by the well respected physician, Dr.Mark Hyman, I submit that there is good evidence that a diet high in (n-3) fatty acids, and in antioxidant sources found in fruits and vegetables is the most healthful for our population. There is evidence that these food sources may not only be generally healthful, in that they do not contribute to the disease- related state of obesity, but also act as protective agents against the development of disease. Most encouraging, they are indicated to have properties that perform, in a pathway from digestion to absorption by the brain, to enhance cognition. Proceeding from this premise, I am convinced that the student population should have the benefit of easy access to these important nutrients, for the obvious reason that foods that may benefit learning and memory are uniquely beneficial to this group of individuals whose very purpose is to learn, remember and utilize the knowledge to the benefit of themselves and others in the future.

Section 6: U.S. colleges and schools implement programs to help students with diet

I therefore propose a program to educate the students of my college "Wilkes Honors College," to the value of proper nutrition, and to provide a method to supply fresh nutritious foods to the campus, by requiring a freshman course in nutrition, founding a student farm and orchard on campus, supplemented by local growers, and by forging a partnership with a local fishery. Grubinger (2010) points out that local foods are best

because the "shorter the time between farm and your table, the less likely it is that the nutrients will be lost." He describes the torturous path food travels from initial storage in distant warehouse, days overland in the bed of a truck, returned to a warehouse, and delivered to the consumer. He argues that even the safety of a local food source can be impacted, and is more secure if grown by a farmer who is not anonymous, but who "looks the consumer in the eye," versus being a remote supplier. Ripeness at harvest, may also affect the vitamin and mineral content that actually arrives at the table. The next research indicated, was to see if the idea for a campus farm had been implemented and found workable on other campuses. I was excited to discover that these farms were already up and running at some of the finest university campuses in the United States.

Hyslop (2015) looks at farms established on campuses in each region of the United States. It begins with the Urban farm at the University of Oregon. This farm "is both a place and a process". It features an outdoor class room and acommunity information and networking facility. On an 1.75-acre site, they have sixty fruit trees one hundred garden beds and a greenhouse. Students learn how to grow food and are introduced to sustainable agriculture in the workshops and lectures offered. It is dependent on the University for funding and sustainability. The University of California farm in Santa Cruz has thirty acres of land on which there are food crops, orchards and research plots. A six-month apprenticeship in ecological horticulture is offered with thirty to forty students' participants each year. Produce grown on the farm is sold at a market on campus and to the campus dinning halls. A community based friend group for the farm has helped with funding. The next farm discussed is on the Purdue campus in Indiana. This five-acre farm managed by the students grows its food organically. A course entitled "Small Farms

Experience," is offered to students. Undergraduate staff and full time summer interns work the farm, which grows vegetables, herbs and cut flowers. The harvest from the farm is sold to dining halls and local grocers. A larger organic student farm is on the Michigan State University campus. It uses cold storage and tunnels for operation in all four seasons. Produce is sold to the college dining halls. They boast two heated green houses and also have pigs, cattle, hens, and honey bees as residents. Michigan State farm offers a 9-month organic farmer training program. The Dilmun Hill Student farm at Cornell University is a 12-acre farm that offers opportunity for experimental learning and research for the students and the surrounding community. The farm uses volunteers twice weekly and provides produce to Cornell's dinning halls. The farm receives organic compost from the Farm's Services Department and manure from its animal's facilities. Most of Cornell's funding is from private grants and donations. Hyslop (2015) shares that at the time of the writing of this article in 2015 Pennsylvania State University was in the planning stage of organizing their farm. This farm plan resulted from interest that many students expressed in having a farm on campus. 160 students from thirty-six majors have participated in the planning. 'The Student Sustainable Farm" was established at Rutgers University as a 5-acre student organic farm in 2010. The students receive hands on experience in the management of an organic farm and participate in agricultural research. With the friendly name "Howdy Farm," Texas A&M University farm is a five-acre sustainable farm managed by students and volunteers. The farm includes a green house a compost area, rainwater harvesting system, and a fruit tree garden. It is run out of the horticulture department. It offers a four-credit internship in the summer and fall semesters for students wanting to expand their degrees.

On the University of Georgia, is a campus farm with the stated mission "to build a community of students centered on sustainable food systems." Produce is distributed from the campus kitchen to families in need in the local community. Likewise, Duke University campus in North Carolina also has a mission statement for their one-acre working farm: "to create positive change in the food system". This farm has a green house, an outdoor classroom, demonstration gardens, and beehives. Students may contribute to farm improvements as part of their class projects. This farm also offers educational workshops and tours and works with professors from many departments around the University.

These farms may fulfill the requirements for healthy sources of polyphenols and antioxidants such as blueberries and turmeric curcumin, however they do not provide sources of DHA which are found primarily in fresh fish. Therefore, I researched and identified an interesting school program in Monterey California called "Bay to Tray," in which a local fishery provides fish not destined for markets and unintentionally caught and reroutes them to local schools that could benefit form the fresh fish. The fish may not look good enough for the supermarkets, but because of this, it offers a most cost- efficient way for the school to obtain nutrition rich fish that students love to eat. "Byfish" that can be found locally in Florida include: Jolthead Porgy, Lionfish, and the Striped Mullet.

These species could be used to create tasty byfish- lunches for students in college cafeterias and would be an economical way of delivering this nutritious food source of DHA and other Omega-3 fatty acids, which we have identified as likely enhancers of brain cognition. Research establishes that presently existing campus farms and fish programs are providing valuable food sources and educational opportunities for students across this nation. From 1 to 15 acres, some farms include fruit trees beehives and even livestock.

These working farms and partnerships with fisheries, add real value to their communities and their students' educational experiences.

Section 7: Proposed program for Wilkes Honors College to improve student diet

Therefore, this thesis proposes the following:

1. The requirement of a course for all freshmen students in nutrition
2. The allocation of no less than one-acre on campus to grow organic fruits and vegetables
3. That this produce be used by the student cafeteria to provide fresh sources of antioxidants and polyphenols
4. Based on the research sited on the "Byfish Bay to Tray" program, that the university partner with a local fishing business to provide fresh sources of fish containing DHA and other omega-3 fatty acids to the student population
5. That the University partner with Matt Roraback at his local farm Roraback Farm Markets for additional sources of locally grown supply
6. That the school appoint a group of students to allocate sources of available state funding, grants, and private donations

As a proud and recent graduate of the Wilkes Honors College I will support this effort. I have already begun by obtaining a funding source in the donation of fruit trees form the local Federated Women's Club. Consultants from the University programs cited would be valuable to approach to gain from the experience of the already established working farms. Realizing the value of goals and timetables. I propose that a planning

committee be established with the goal of breaking ground and establish a relationship with a local fish provider by September 2018.

Conclusion

Twenty-first century research into the effects of diet on brain cognition has indicated a positive relationship between consumption of (n-3) omega-3 fatty acids primarily found in fish, and antioxidants found in fruits and vegetables. The studies cited in this thesis, have employed multiple tests on rodents and humans using MRI technology, maze tests, questionnaires, chemical analyses, and autopsy examinations, to look at performances requiring spatial memory, and mechanism of action of molecules metabolized from food sources. The authors in this meta-analysis conclude that dietary omega-3 fatty acids and antioxidants, positively affect cognitive function, as they act as anti-inflammatory agents, and as scavengers of free radicals, to reduce oxidative stress. In the knowledge that many U.S. student diets are missing essential nutrients, as they consume primarily a "Western Diet," high in saturated fats and refined sugars, it is appropriate for institutions of learning to take action to protect student health, and provide food sources, which may enhance cognition. Therefore, this thesis proposes that Wilkes Honors College launch a program, consistent with its goal of providing excellence in the curriculum, which includes a required Freshman course in nutrition, the establishment of a campus farm and fruit tree orchard, and the building of a partnership with a local fishery, to provide fresh sources of omega-3s for students.. It also recommends establishing a relationship with a local fishery to obtain a good source of fresh fish for the campus dining room, to provide omega-3 nutrients. State grants, and local donors should be identified to

help fund this program. The end result is expanding the excellent academic resources of Wilkes Honors College, which will contribute in a real way to the overall health of the students, and may even enhance their cognitive ability.

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