

Your Brain on Food: A Nutrient-Rich Diet Can Protect Cognitive Health

As long suspected, the relative abundance of specific nutrients can affect cognitive processes and emotions, and studies confirm that brain health relies on many factors, including nutrients from everyday diet.

Although food has been classically perceived as a means to provide energy and building material to the body, its ability to prevent and protect against disease is starting to be recognized. Research over the past five years has provided exciting evidence for the influence of dietary factors on specific molecular systems and mechanisms that maintain mental function (Gomez-Pinilla, 2008).

As with any organ, the brain requires nutrients to build and maintain its structure, both to function in a harmonious manner and to be protected from diseases and premature aging. For many years it was not fully accepted that food can have an influence on brain structure and its functions, including cognitive, intellectual, and mental. In fact, most micronutrients (vitamins, minerals, trace elements, essential amino acids, and essential fatty acids, including omega-3 polyunsaturated fatty acids) have been directly evaluated in regard to cerebral functioning (Bourre, 2006).

The full genetic potential of a child for physical growth and mental development may be compromised due to deficiency (even sub-clinical) of micronutrients. Children and adolescents

with poor nutritional status are prone to alterations of mental and behavioral functions that can, to a certain extent, be corrected by dietary measures; nutrient composition and meal patterns can exert either immediate or long-term effects, beneficial or adverse. Brain diseases during aging can also be due to failure of protective mechanisms caused by dietary deficiencies of antioxidants and other nutrients such as trace elements, vitamins, and polyphenols that exert

The brain prefers a constant steady supply of glucose.

protection against free radicals (Bourre, 2006).

This article reviews how food may affect mood, energy, and cognition; identifies select foods and nutrients that are particularly beneficial to the brain; and provides nutrition lifestyle tips to support optimal brain health.

The Brain's Energy Requirement

Energy, or calorie intake, is derived from carbohydrate, protein, and fat found in foods and beverages. The human brain is metabolically very

active and uses about 20 percent to 30 percent of a person's energy intake at rest and higher amounts during problem solving. Individuals who do not consume adequate calories from food to meet their energy requirements will experience changes in mental functioning (simply skipping breakfast interferes with cognition and learning) (Pollitt, 1998). The brain prefers a constant steady supply of glucose; glucose metabolism is mediated by insulin. Several researchers have noted a strong correlation between insulin resistance in the brain and early Alzheimer's Disease, suggesting that Alzheimer's might be considered a neuroendocrine disorder of the brain or so-called "Type 3 diabetes" (Seneff, Wainwright, and Mascitelli, 2011).

It is well established that caloric restriction could be used to promote successful brain aging, but Gillette-Guyonnet and Vellas (2008) point out that the long-term effects of caloric restriction in adults must be clarified before engaging

in such preventive strategy; additionally, animal studies must be conducted to test the effects of "multidomain" interventions (caloric restriction plus regular exercise) on age-related cognitive decline. Nevertheless, it seems a reasonable approach to control caloric intake by limiting or avoiding foods with no nutritional value, while increasing the nutrient density of one's diet.

Neurotransmitters impacted by diet

The four neurotransmitters that are manufactured in the brain directly from food components are serotonin, dopamine, norepinephrine, and acetylcholine. The levels and activity of these neurotransmitters are sensitive to food intake, and changes in dietary patterns can have profound effects on behavior, eating patterns, sleep, and energy level (Somer, 1995).

Serotonin is manufactured from the amino acid tryptophan, which is found in protein-rich foods (meats, dairy, eggs, and legumes), assisted



by vitamins B6, B12, and folic acid. Food sources of these B vitamins include spinach, bell peppers, turnip greens, garlic, bananas, and celery (B6); meats, dairy, and eggs (B12); and leafy greens, fruits, and legumes (folate). Ironically, eating a protein-rich meal lowers brain tryptophan and serotonin levels, while eating a carbohydrate-rich meal has the opposite effect. Tryptophan competes with other amino acids for entry into the brain after eating a protein-rich meal, resulting in very little tryptophan getting through the blood–brain barrier, so serotonin levels do not rise appreciably.

In contrast, a carbohydrate-rich meal triggers insulin release. This causes most amino acids to be absorbed from the blood into the body's cells (not the brain's)—all except tryptophan, which allows free entry into the brain, with a resulting rise in serotonin levels. High serotonin levels increase feelings of calmness, improve sleep patterns, increase pain tolerance, and reduce cravings for food (Somer, 1995).

Dopamine and norepinephrine are manufactured from the amino acid tyrosine, assisted by folic acid, magnesium, and vitamin B12. Food sources of magnesium include leafy greens, whole

B vitamins play a critical role in brain function: low intake and levels of B vitamins have been associated with memory and learning dysfunction.

unrefined grains, nuts, seeds, and legumes. Like tryptophan, tyrosine is abundant in protein-rich foods, but unlike tryptophan, tyrosine levels rise after eating a protein-rich meal. This promotes levels of dopamine and norepinephrine to rise, which has the effect of increasing alertness and mental energy (Somer, 1995).

Acetylcholine is manufactured from the fat-like substance choline. Unlike amino acids, which must compete for entry into the brain, choline has no competitors. Acetylcholine is

important in memory and in general mental function. Lowered acetylcholine levels, common with aging, result in memory loss and reduced cognitive function (Somer, 1995).

Selected Nutrients That Affect Mood, Energy, and Cognition

Dietary components such as lipids, antioxidants and certain vitamins affect brain function in various ways.

Brain lipids

The brain is composed of about 60 percent fat, and myelin, the protective sheath that covers communicating nerve and brain cells is about 70 percent fat. Brain lipids such as essential fatty acids and other fats are repositories of chemical energy and structural components of cell membranes

Essential fatty acids

Essential fatty acids (EFAs) play important roles in vision, nervous system function, immune and inflammatory responses, and modulation of gene expression. Humans cannot synthesize EFAs, so they must be consumed through diet to prevent deficiency.

There are two essential fatty acids, both polyunsaturated fats: linoleic acid (LA) is the precursor to omega-6 fatty acid, and alpha-linoleic acid (ALA) is the precursor to omega-3 fatty acid. Humans convert LA to arachidonic acid (AA) and ALA to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The conversion of ALA to AA is typically efficient, while conversion of ALA to DHA and EPA is much less so (Davis and Kris-Etherton, 2003).

Therefore, it is important to consume food sources of DHA/EPA (cold water fish and DHA/EPA-fortified foods) in addition to ALA food sources (walnuts, chia seeds, hempseed, and flaxseed).

Even though omega-6 fatty acids are essential, the Western diet contains an excessive amount of these fatty acids compared to omega-3

A Closer Look at DHA and EPA

DHA and EPA are orthomolecules whose functional sites are exclusively cell membranes, where they interact with other fatty acids to maintain fluidity. They are found in highest concentrations in the most dynamic membranes (e.g., retina, brain, and spermatozoa). Their confirmation as cardiovascular protectants has spurred research into their benefits for the human brain (Kidd, 2007). The broader scientific literature on DHA confirms it is essential for normal neurological development, maintenance of learning and memory, and brain plasticity. Here is a summary of selected studies:

- DHA in neuronal membranes enhances synaptic membrane fluidity and function, regulates gene expression, mediates cell signaling, and enhances the electrical basis for memory formation (Wu, Ying, and Gomez-Pinilla, 2004).
- In laboratory rats subjected to brain injury, prior dietary supplementation of DHA enhanced recovery and boosted brain production of brain-derived neurotrophic factor, a major brain growth factor (Wu and Gomez-Pinilla, 2004).
- Insufficient intake of DHA and low levels of DHA in the hippocampus may have a role in cognitive decline or Alzheimer's Disease in elders (Cunnane et al., 2009).
- Yurko-Mauro et al. (2010) concluded that six-month supplementation with 900 mg algal DHA (Algal-900) improved learning and memory function in healthy older adults with age-related cognitive decline, whereas Quinn et al. (2010) concluded that supplementation with 2g/d algal DHA for eighteen months did not slow the rate of cognitive and functional decline in patients with mild to moderate Alzheimer's. Thus, DHA may have a preventative effect more than a treatment effect.
- Quinn et al. (2010) sub-group analysis suggested a relationship between efficacy of DHA and the presence of the APOE-4 genotype (allelic variant of the APOE gene), which is associated with an increased risk for Alzheimer's Disease.

fatty acids. This major shift is the result of food supply and food choices. Compared to many years ago, consumption of omega-3-rich fish and grass-fed beef has declined, while consumption of foods made with ingredients containing high levels of omega-6 has increased.

Foods high in omega-6 include fried and other processed foods made with large amounts of vegetable oil, especially soybean, corn, and cottonseed, as well as salad oils and margarine. This dietary change is postulated to result in an overall increase in systemic inflammation and higher incidence of allergic and inflammatory disease including asthma, allergies, diabetes, cardiovascular disease, and arthritis (Weaver et al., 2009). This underscores the importance for Americans to consume more dietary sources of omega-3 fatty acids.

Omega-3 fatty acids and diet

Many leading authorities have developed specific dietary recommendations for omega-3 fatty acids for different countries. For example, the U.S. 2010 Dietary Guidelines recommendation is consumption of two 4-ounce servings of seafood weekly for an average intake of 250 mg DHA/EPA per day (USDA, 2010b). The American Dietetic Association recommendation is 500 mg/day long-chain omega-3 polyunsaturated fatty acid intake (Kris-Etherton et al., 2007). The American Heart Association recommendation is to eat fish (particularly fatty fish) at least two times a week, and include oils and foods rich in ALA (Kris-Etherton, Harris, and Appel, 2002).

Food sources of omega-3s include fatty cold water fish (salmon), flax, hemp, and chia seeds (and their oils), and omega-3-fortified foods. A quick, useful resource to determine the DHA/EPA content of foods is provided on the Omega-3 Learning for Health and Medicine website (www.omega3learning.uconn.edu/).

Other fats

While diets high in saturated fat have been demonstrated to exacerbate cognitive decline in

aging (Greenwood and Winocur, 2005), diets high in carbohydrates and low in fats and cholesterol may lead to the development of Alzheimer's Disease (Seneff, Wainwright, and Mascitelli, 2011). Medium-chain triglycerides (MCT) have shown promise in providing an alternate energy source for the brain in Alzheimer's, thus improving cognitive performance in memory-impaired adults (Reger, 2004). Natural food sources rich in MCT include coconut oil and palm oil.

Antioxidants and other nutrients

Antioxidants have been studied for their effectiveness in reducing the deleterious effects of brain aging and behavior in many studies. Research suggests that the combinations of antioxidant/anti-inflammatory polyphenolic compounds found in fruits and vegetables can significantly reduce the risk of developing cognitive impairment, as well as reverse age-related deficits in neuronal and cognitive function (USDA, 2010a).

Diets rich in fruits and vegetables are considered to be an excellent source of antioxidants. Some minerals and vitamins also have a role as antioxidants; these include vitamin C, vitamin E and its isomers (tocopherols and tocotrienols), and selenium.

A partial measure of a food's antioxidant capacity is an ORAC (Oxygen Radical Absorbance Capacity) score. Foods that have some of the highest ORAC scores include cloves, cinnamon, turmeric, acai berries, blueberries, plums, broccoli, red leaf lettuce, asparagus, pecans, walnuts, dark chocolate, and garlic. (USDA, 2010a).

Curcumin is a powerful antioxidant derived from the spice turmeric, which has the fourth highest ORAC score for spices. Curcumin has been shown to counteract the effects of traumatic brain injury on oxidative stress, synaptic plasticity, and cognition (Wu, Ying, and Gomez-Pinilla, 2006). It also shows promise in boosting the immune system's ability to clear amyloid beta

plaques in the brains of patients with Alzheimer's (Zhang et al., 2006).

Luteolin is a flavanoid compound found in many plants including celery, peppers, carrots, olive oil, peppermint, and chamomile. It has recently been shown to reduce age-related inflammation in the brain and related memory deficits by directly inhibiting the release of inflammatory molecules in the brain (Jang, Dilger, and Johnson, 2010).

Nutrition Lifestyle Tips

- Control caloric intake by reducing or eliminating consumption of highly processed and refined foods containing unhealthy fats, refined sugars, and chemical additives.
- Maximize antioxidant and polyphenol intake by eating at least five half-cup servings of vegetables and fruits daily, including those that are all the colors of the rainbow. The following are easy ways to enjoy more vegetables: cook, puree, and freeze vegetables, then add to soups, sauces, meatloaf, smoothies, and baked goods like muffins and pancakes.
- Incorporate whole grains as another source of antioxidants, certain B vitamins, minerals, and fiber.
- Enhance the flavors of foods with spices and herbs, many of which are potent antioxidants.
- Improve your intake of omega-3 fats (reduce the omega-6 to omega-3 ratio) by eating at least two servings per week of fatty fish like salmon. Choose grass-fed meats over those raised conventionally, and consume raw nuts, seeds, and their oils on a regular basis.
- Maximize overall nutrient intake by choosing locally grown organic meats, fruits, and vegetables.
- Balance blood sugar and neurotransmitter function by eating a balance of protein, fat, and carbohydrate at every meal and snack. For greater mental energy and alertness during the day, eat higher amounts of protein at breakfast and lunch.
- Engage in regular physical activity.

B vitamins play a critical role in brain function, and low B vitamin intake, as well as low B vitamin levels, have been associated with memory and learning dysfunction. A recent study has shown that daily tablets of large doses of the B vitamins (folic acid, B12, and B6) can halve the rate of brain atrophy in elderly adults with mild cognitive impairment. Top food sources of B vitamins include meats, dairy products, and eggs (B12); leafy green vegetables, fruits, dried beans, and peas (folate); and spinach, bell peppers, turnip greens, garlic, bananas, and celery (B6).

Vitamin D may have neuroprotective benefits and could be important for preserving cognitive functions via several different mechanisms. Severe vitamin D deficiency (defined by serum 25(OH) D levels less than 10 ng/ml or less than 25 nmol/L) was associated with substantial cognitive decline in the elderly population studied over a six-year period (Llewellyn et al., 2010). Top food sources of vitamin D include cod liver oil, salmon, shrimp, sardines, and mackerel; fortified milk and juices are reasonable sources. Vitamin D is also synthesized in the body during sun exposure.

In a perfect world, food should provide all the necessary nutrients to support optimal brain health.

Vitamin E is a family of eight natural components: four tocopherols (alpha, beta, gamma, delta) and four tocotrienols (alpha, beta, gamma, delta). Mangialasche (2010) found that elderly subjects with higher blood levels of all the vitamin E family forms had a reduced risk of developing Alzheimer's, compared to subjects with lower levels. After adjusting for various confounders, the risk was reduced by 45 percent to 54 percent, depending on the vitamin E component. This opens up the possibility that the balanced presence of different vitamin E forms can have an important neuroprotective

effect on the brain. Top food sources of vitamin E include mustard greens, Swiss chard, spinach, sunflower seeds, turnip greens, and almonds.

Green tea contains polyphenols (that include catechins and their derivatives), which may possess potent neuroprotective activity that can help to ameliorate neurodegenerative diseases such as Alzheimer's and Parkinson's (Kuriyama et al., 2006).

Supplementation in Cases of Demonstrated Need

Supplementation with the following should be considered when dietary intake is insufficient to meet requirements or laboratory evaluation indicates increased need:

- Omega-3 fatty acids, specifically DHA and EPA, can be provided by cod liver oil, fish oils, or algal sources. The previous section on page 102, "Omega-3 fatty acids and diet," lists some recommendations for the general adult population. For individuals with certain conditions, the amount is adjusted upward. The American Heart Association dietary intake recommendation for individuals with coronary heart disease is 1g DHA/EPA per day (Kris-Etherton, Harris, and Appel, 2002). For a complete listing of recommendations for the intake of omega-3 polyunsaturated fatty acids, visit www.omega3learning.uconn.edu/info/what-are-omega-3-fatty-acids/dietary-recommendations-for-omega-3-fatty-acids/.
- A multivitamin/mineral/trace element supplement will provide added assurance that micronutrient requirements are met, in light of the fact that older adults are most vulnerable to micronutrient deficiencies, especially calcium, magnesium, vitamins D, C, E, B6, B12, and folate (Linus Pauling Institute, 2009).
- While the Institute of Medicine (2010) recently recommended tripling the daily vitamin D intake for most children and adults to 600 IU per day, Holick (2011) estimates that children need at least 400 to 1000 IU of vitamin D per day while teenagers and adults need at least 2000 IU of vitamin D per day to satisfy their body's vitamin D requirement.

Choline is required to make certain phospholipids such as phosphatidyl choline and sphingomyelin, which are essential components of all membranes. It is a precursor for biosynthesis of the neurotransmitter acetylcholine and also is an important source of labile methyl groups. Choline supplements administered to rats in utero, or shortly after birth, permanently altered brain function (Zeisel, 1992). Top food sources of choline include egg yolks, soybeans, beef liver, meats, nuts, flaxseeds, wheat germ, and broccoli.

The Role of Supplements

In a perfect world, food should provide all the necessary nutrients to support optimal brain health. Food contains bio-available vitamins, minerals, enzymes, coenzymes, antioxidants, and more—all in one complete package. Choosing whole, unprocessed, unrefined foods is certainly the goal, but very often not the norm. Targeted, therapeutic supplementation of individual vitamins, minerals, trace elements, and other

nutrients may be necessary for some and should be guided by an experienced nutrition professional. Supplemental nutrients should consist of high-quality, bio-available forms and be free of unnecessary filler ingredients.

Brain health relies on a number of factors, including the nutrients taken in from one's diet, so eating nutrient-rich foods can help nourish the brain and support optimal mood, energy, and cognition. Establishing healthy eating habits beginning early and continuing throughout life provides the greatest protection against age-related cognitive decline and other diseases. While several individual nutrients have been found to exert positive effects on cognition, the starting point should always be a balanced diet, with consideration given to supplementation as needed. 

Julia Turner, M.M.Sc., R.D., L.N., has a private nutrition practice based in Montana. She can be reached via e-mail at julia@juliaturnernutrition.com.

References

- Bourre, J. M. 2006. "Effects of Nutrients (in Food) on the Structure and Function of the Nervous System: Update on Dietary Requirements for Brain. Part 1: Micronutrients. Part 2: Macronutrients." *Journal of Nutrition, Health & Aging* 10(5): 377–99.
- Cunnane, S. C., et al. 2009. "Fish, Docosahexanoic Acid and Alzheimer's Disease." *Progress in Lipid Research* 48: 239–56.
- Davis, B. C., and Kris-Etherton, P. M. 2003. "Achieving Optimal Essential Fatty Acid Status in Vegetarians: Current Knowledge and Practical Implications." *American Journal of Clinical Nutrition* 78(3): 640S–6S.
- Gillette-Guyonnet, S., and Vellas, B. 2008. "Caloric Restriction and Brain Function." *Current Opinion in Clinical Nutrition & Metabolic Care* 11(6): 686–92.
- Gomez-Pinilla, F. 2008. "Brain Foods: The Effects of Nutrients on Brain Function." *Nature Reviews Neuroscience* 9(7): 568–78.
- Greenwood, C. E., and Winocur, G. 2005. "High-fat Diets, Insulin Resistance and Declining Cognitive Function." *Neurobiology of Aging* 26(1; Supp 1): 42–5.
- Holick, M. F. 2011. "Vitamin D: Evolutionary, Physiological and Health Perspectives." *Current Drug Targets* 12(1): 4–18.
- Institute of Medicine. 2010. "Dietary Reference Intakes for Calcium and Vitamin D." www.iom.edu/Reports/2010/Dietary-Reference-Intakes-for-Calcium-and-Vitamin-D.aspx. Retrieved July 21, 2011.
- International Omega-3 Learning and Education Consortium for Health and Medicine. "Omega-3 Learning for Health and Medicine." www.omega3learning.uconn.edu/. Retrieved July 21, 2011.
- Jang, S., Dilger, R. N., and Johnson, R. W. 2010. "Luteolin Inhibits Microglia and Alters Hippocampal-Dependent Spatial Working Memory in Aged Mice." *Journal of Nutrition* 140(10): 1892–8.

- Kidd, P. M. 2007. "Omega-3 DHA and EPA for Cognition, Behavior, and Mood: Clinical Findings and Structural-Functional Synergies with Cell Membrane Phospholipids." *Alternative Medicine Review* 12(3): 207–27.
- Kris-Etherton, P. M., et al. 2000. "Polyunsaturated Fatty Acids in the Food Chain in the United States." *American Journal of Clinical Nutrition* 71: 179S–88S.
- Kris-Etherton, P. M., et al. 2007. "Position of the American Dietetic Association and Dietitians of Canada: Dietary Fatty Acids." *Journal of the American Dietetic Association* 107: 1599–1611.
- Kris-Etherton, P. M., Harris, W. S., and Appel, L. J. 2002. "Fish Consumption, Fish Oil, Omega-3 Fatty Acids, and Cardiovascular Disease." *Circulation* 106: 2747–57.
- Kuriyama, S. et al. 2006. "Green Tea Consumption and Cognitive Function: A Cross-Sectional Study from the Tsurugaya Project 1." *American Journal of Clinical Nutrition* 83(2): 355–61.
- Linus Pauling Institute. 2009. "Micronutrients for Older Adults." <http://lpi.oregonstate.edu/fw08/olderadults.html>. Retrieved April 25, 2011.
- Llewellyn, D. J., et al. 2010. "Vitamin D and Risk of Cognitive Decline in Elderly Persons." *Archives of Internal Medicine* 170: 1135–41.
- Mangialasche, F., et al. 2010. "High Plasma Levels of Vitamin E Forms and Reduced Alzheimer's Disease Risk in Advanced Age." *Journal of Alzheimer's Disease* 20(4): 1029–37.
- Pollitt, E., and Mathews, R. 1998. "Breakfast and Cognition: An Integrative Summary." *American Journal of Clinical Nutrition* 67: 804S–13S.
- Quinn, J. F., et al. 2010. "Docosahexaenoic Acid Supplementation and Cognitive Decline in Alzheimer Disease: A Randomized Trial." *Journal of the American Medical Association* 304(17): 1903–11.
- Reger, M. A., et al., 2004. "Effects of Beta-Hydroxybutyrate on Cognition in Memory-Impaired Adults." *Neurobiology of Aging* 25(3): 311–14.
- Seneff, S., Wainwright, G., and Mascitelli, L. 2011. "Nutrition and Alzheimer's Disease: The Detrimental Role of a High Carbohydrate Diet." *European Journal of Internal Medicine* 22: 134–40.
- Somer, E. 1995. *Food and Mood: The Complete Guide to Eating Well and Feeling Your Best*. New York: Henry Holt.
- United States Department of Agriculture (USDA). 2010a. "Database for the Oxygen Radical Absorbance Capacity (ORAC) of Selected Foods, Release 2." www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/ORAC/ORAC_R2.pdf. Retrieved July 21, 2011.
- USDA. 2010b. "Dietary Guidelines for Americans." www.cnpp.usda.gov/DGAs2010-PolicyDocument.htm. Retrieved July 21, 2011.
- Weaver, K., et al. 2009. "Effect of Dietary Fatty Acids on Inflammatory Gene Expression in Healthy Humans." *Journal of Biological Chemistry* 284(23): 15400–7.
- Wu, A., Ying, Z., and Gomez-Pinilla, F. 2004. "Dietary Omega-3 Fatty Acids Normalize BDNF Levels, Reduce Oxidative Damage, and Counteract Learning Disability After Traumatic Brain Injury in Rats." *Journal of Neurotrauma* 21: 1457–67.
- Wu, A., Ying, Z., and Gomez-Pinilla, F. 2006. "Dietary Curcumin Counteracts the Outcome of Traumatic Brain Injury on Oxidative Stress, Synaptic Plasticity and Cognition." *Experimental Neurology* 197(2): 309–17.
- Yurko-Mauro, K., et al. 2010. "Beneficial Effects of Docosahexaenoic Acid on Cognition in Age-Related Cognitive Decline." *Alzheimers and Dementia* 6(6): 456–64.
- Zeisel, S. H. 1992. "Choline: An Important nutrient in Brain Development, Liver Function and Carcinogenesis." *Journal of the American College of Nutrition* 11(5): 473–81.
- Zhang, L., et al. 2006. "Curcuminoids Enhance Amyloid-Uptake by Macrophages of Alzheimer's Disease Patients." *Journal of Alzheimer's Disease* 10(1): 1–7.

Copyright of Generations is the property of American Society on Aging and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.