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ARTICLES

NEUROSCIENCE AND NUTRITION: HOW WE PERCEIVE FOOD AND ITS EFFECTS ON THE MIND, BODY, AND BRAIN

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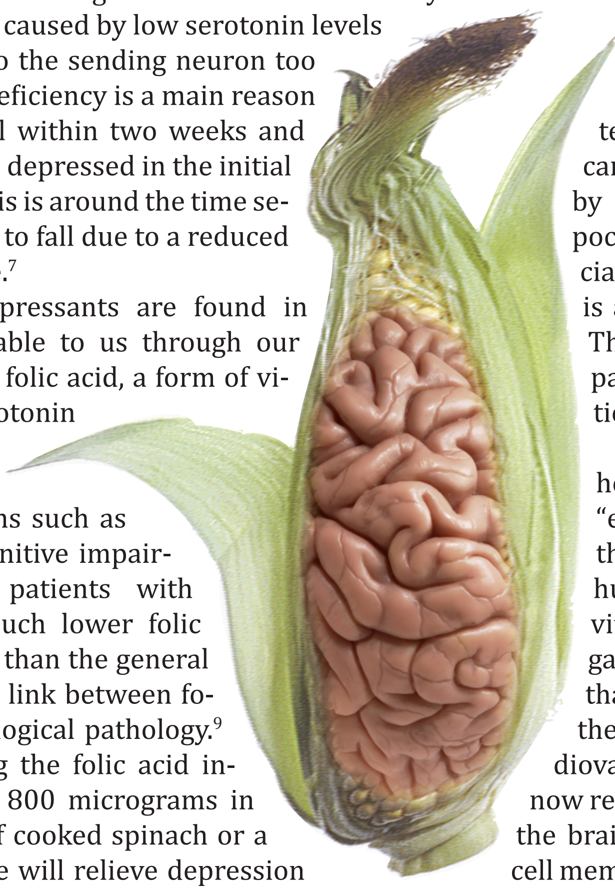
Our need to eat is more primal than our desire to have sex. We must eat several times a day and our survival depends on it. Our choices of what we eat affect our health and the functioning of our mind and body. We have all heard the expression, "you are what you eat," but why do we eat the foods we do? How do they affect us? In fact, there are strong psychological and physiological factors that underscore the dependencies we have on food. Nutrition affects the health of the brain and the body as a whole. We use nutrients obtained from our diets to provide energy to our calorie-demanding brains, which require more energy than any other organ in the body.[1]

Nutrients found in food are the antecedents to neurotransmitters and the amount of nutrients affects the amount of neurotransmitters produced. Since different foods are made up of more than one nutrient it cannot easily be stated that an increase the amount of one nutrient also will increase the production of a specific neurotransmitter in the body. Rather, nutrients interact with each other and differentially affect the production of neurotransmitters.[2] When proteins from foods are digested, they are broken down into their constitutive amino acids. Tyrosine, for example, is one particular amino acid that has been implicated in the increased production of dopamine, norepinephrine and epinephrine. These neurotransmitters are known for increasing alertness and energy. Thus, eating foods that are high in protein like fish, poultry, meat and eggs can temporarily increase mental capacity.[3] In the case of epinephrine and norepinephrine, the release of these two neurotransmitters is triggered during emergency situations when our bodies need to be alert and self-preserving. The epinephrine binds to cell receptors and causes the breakdown of glycogen into glucose for immense amounts of energy.[4]

Carbohydrates are another major biological macromolecule that has a different effect on the brain. The breakdown of carbohydrates triggers the release of insulin into the blood stream, which then causes an increased uptake of amino acids in the extracellular environment of the brain. An exception in this case is tryptophan, which is normally out-competed by other amino acids attempting to cross the blood-brain barrier.[5] However, when other amino acids are absent, tryptophan can easily enter the brain and be converted into serotonin.[6] Serotonin is a neurotransmitter that reduces pain, decreases appetite and can produce a sense of calmness. When serotonin is sent from one nerve to the next it triggers a response in the receiving neuron to send a message to the brain. The serotonin is consequently reabsorbed by the sending neuron. An imbalance in serotonin may be caused by low serotonin levels or reabsorption into the sending neuron too quickly. Serotonin deficiency is a main reason why many diets fail within two weeks and why dieters become depressed in the initial weeks of dieting. This is around the time serotonin levels begin to fall due to a reduced carbohydrate intake.[7]

Natural anti-depressants are found in the nutrients available to us through our diet. Deficiencies in folic acid, a form of vitamin B, causes serotonin levels to decrease, which may lead to various conditions such as depression and cognitive impairment.[8] Psychiatric patients with depression have much lower folic acid concentrations than the general public, suggesting a link between folic acid and psychological pathology.[9] However, increasing the folic acid intake by as little as 800 micrograms in the form of a cup of cooked spinach or a glass of orange juice will relieve depression symptoms.[10] A retrospective study illustrated this by shorter hospital stays and better mood and social functioning for psychiatric patients who received the folic acid supplement.[11] In addition, folic acid supplementation is effective in preventing cognitive decline and dementia in old age.[12] In the particular study illustrating this, men and women between the ages of 50 and 70 years were studied between 1999 and 2004. The 818 participants were randomly assigned 800 micrograms of folic acid or a placebo for three years. Cognitive performance was measured through changes in memory performance, information processing speed, sensorimotor speed and word fluency. Even caffeine from coffee, tea and other foods can perform as a low-grade antidepressant for mild cases of depression that do not require medical intervention.[13]



Brain Corn. Artwork by Benjamin Lawson.

Choline is an additional B complex vitamin that is concentrated in high cholesterol foods such as eggs and liver. In an effort to reduce our cholesterol intake, many of us lack appropriate amounts of choline in our diet.[14] Choline is a precursor to the neurotransmitter acetylcholine which is linked to memory. Choline circulating in blood can readily cross the blood-brain barrier and is taken up by cholinergic nerve terminals. Inside these cells, choline can be converted into acetylcholine by enzymatic processes. In the hippocampus, an area of the brain associated with s memory, acetylcholine is associated with memory strength. Thus, a lack of choline can cause impairment of memory and concentration.[15]

Omega-3 fatty acids have many health benefits and are considered "essential fatty acids," meaning that they cannot be synthesized by the human body, but are nevertheless vital for normal metabolism. Omega-3 fatty acids are dietary lipids that were originally thought to affect the brain through their effects on cardiovascular health.[16] However, they are now recognized for their direct actions on the brain, as they are components of the cell membrane and are essential for normal brain function.[17] Omega 3-Fatty acids contribute to membrane fluidity at the synapses by maintaining membrane integrity, neuronal excitability and synaptic function. Additionally they maintain membrane ionic permeability and the function of transmembrane receptors that support synaptic transmission and cognitive abilities. Dietary deficiency of omega-3 fatty acids in humans has been associated with increased risk of several mental disorders, including attention-deficit disorder, dyslexia, dementia, depression, bipolar disorder and schizophrenia.[18]

On the other hand, high amounts of saturated and trans fats can have negative impacts on brain function. Digestion of foods high in saturated fats and sucrose has been shown to adversely affect cognitive function.[19] In a UCLA experiment, rodents fed with a diet rich in saturated fats and trans fats performed worse in learning tasks due to an increased neurological burden that correlated with experimental brain injury.[20] Increased caloric intake has similar effects on the brain itself. Excess calories can reduce synaptic plasticity (or the ability of the synaptic connections between neurons to strengthen or weaken) because mechanisms that regulate cell metabolism are integrated with mechanisms that control synaptic function. Thus, controlling our caloric intake can then be used to protect the brain by reducing oxidative damage to cellular proteins, lipids and nucleic acids.[21]

Antioxidants are a class of molecules that prevent the oxidation (loss of electrons) of other molecules that can cause chemical chain reactions that lead to cellular death. One such antioxidant, alpha lipoic acid, can be obtained from meats such as kidney and liver as well as vegetables, e.g. spinach, broccoli and potatoes. Studies have shown that intake of alpha lipoic acid alleviates memory deficits and reduced cognitive decay in a small group of patients with Alzheimer's disease.[22] In fact, elderly patients with poor memory performance can improve cognitive function by increasing vitamin E intake. Vegetable oils, nuts, green leafy vegetables and fortified cereals are excellent sources of vitamin E. Ingestion of this coenzyme has been shown to extend lifespan and improve neurological performance and mitochondrial function in aging mice.[23] Although it is not fully understood how Vitamin E affects cognition neurobiologically, it is likely related to its support of synaptic plasticity through protection of the synapse from oxidation. Curcumin, a traditional curry spice of India, has been shown to reduce memory deficits in mammals with Alzheimer's and brain trauma as well. Curcumin is a strong antioxidant that can protect the brain from oxidative degeneration of lipids and nitric-oxide-based radicals. So it is probable that the low rates of Alzheimer's disease in India might be due to their high consumption of curcumin.[24]

Even if we know what foods are good and bad for us, why do we have tendencies to make unhealthy diet choices? It turns out that there are strong physiological and psychological forces that make us crave certain foods that may not be healthy for us. In terms of physiological influences, our bodies release trace amounts of opiates when we eat our favorite foods, elevating our mood and providing the feeling of satisfaction. Food rewards can strengthen a preference for foods that are associated with these good feelings and it is for this reason that certain foods can have addictive qualities depending on the individual.[25] Additionally, environmental factors and social context can influence conditioned responses to food consumption. Often times, hunger can be induced by a certain time of the day as our meals are regularly consumed at these typical times during the morning, afternoon and evening. Mealtime can thus be the reason for eating instead of hunger itself because social signals that precede mealtime become associated with hunger during those specific situations and elicit a "hunger" response.[26]

Moods, emotions, context, hunger and expectations also have a major impact on the way we perceive food. This is because the decision to eat certain foods directly impacts our survival. Odors and appearances play an important role in taste perception because they affect our expectations. Sugar is not just sweet, and bitter is not just disgusting. Sugar is both sweet and good while bitter is both disgusting and bad. Evolutionarily speaking, we use our sense of taste to perceive what might be good to eat and what is a poison.[27] These senses are associated with the insular cortex of the brain, an area that is responsible for many diverse functions including emotion and homeostasis. In fMRI images, the insular cortex "lights up" when humans feel anything from good and bad emotions to thirst and hunger. We then use these senses of taste to learn the full story of what we are eating. Further, our sense of sweetness and umami indicate to us foods that are dense in energy and protein, while sour tastes give indication of spoiled foods, and bitterness signals the presence of toxins that can lead to death.[28]

Taking a look at our taste buds allows us to understand what our brain is telling our body about what we are eating. The umami receptor for example, allows us to taste and be attracted to eating proteins. The human receptor for umami responds best to the amino acids aspartate and glutamate, which explains the intense sensation we feel when eating MSG (monosodium glutamate). Tastes from sweet foods indicate high energy food sources. A sweet responsive cell's DNA codes specifically for a sweet receptor gene. By this, someone with a sweet tooth may have a gene that codes for a low affinity for sugar, so they may need more sugar to depolarize the neuron to the threshold potential and activate the corresponding brain area for sweet tastes.[29] Consuming low to moderate amounts of salt satisfies a primal craving that dates back to when salt was rare as far as diet is concerned. Addition of salt to food was most likely one of the first additives to improve taste when the first *Homo sapiens* decided to add cooked food to sea salt deposits. Since that time, salt has become important in human civilization as a preservative and a flavor booster.[30] As we now know, sodium plays an important role in neurotransmission.[31] Sour taste cells have acid sensors for the hydrogen ions that characterize acidic foods. They are useful in warning us against eating foods that are spoiled or unripe.[32] The remaining of the five elemental tastes is bitterness. Bitter cells have 30 different bitter receptor genes, which are meant to signal the presence of toxins that plants use to protect themselves from being eaten.[33] Despite these physiological indicators that drive our food eating decisions, psychological forces can overwhelm them. It is interesting how adult humans enjoy drinking bitter black coffee even if it is decaffeinated.

Tastes and nutrition have a significant impact on what we eat and the health of our mind and body. The brain itself is a calorically demanding organ. Evolutionarily, as brain size and brain architecture became increasingly complex, the cost of improved intelligence and cognitive function came at the price of the need for a more substantial, calorie rich diet. According to the "expensive tissue hypothesis", early humans began to eat more energy dense foods to provide energy for our ever increasingly large brains.[34] These changes in diet are the cause for the development of taste, as are the physiological and psychological dependencies we have on specific foods that drive the decisions we make while choosing what to eat. Using this molecular biological view of the way nutrition affects our body and brain, the true importance of proper diet and health becomes clear.

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