

Brain Nutrients: Where & How They Work Together to Support Cognitive Development and Learning

Nutrients can be structural brain components, support specific brain functions, and provide energy or metabolites for brain structures and functions, and thus, enable or support cognitive development.

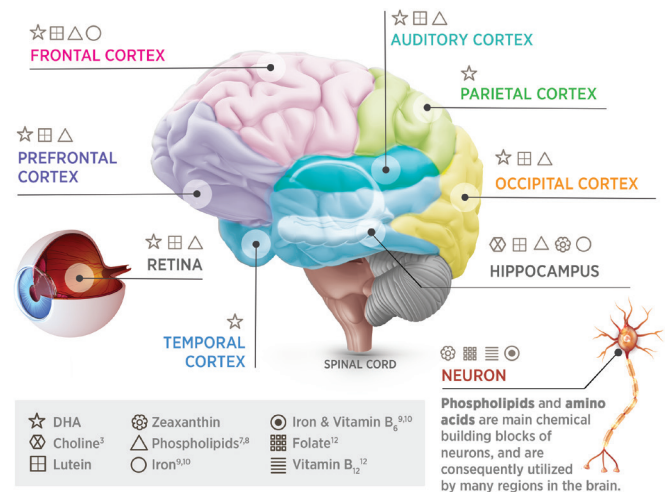
The impact of nutrition on neurodevelopment during infancy and early childhood is continually evolving. The support roles of nutrients, individually or in combination, may be limited to specific brain regions and brain functions or be more widespread.¹ During growth and development, the brain can also be particularly vulnerable to adverse effects of insufficient or excessive intake of nutrients.²

Nutrients and growth factors (such as protein and hormones) provide energy and building blocks to the brain, thus support and regulate brain development. While some nutrients seem to support specific functions of the brain, e.g. the availability of choline has been shown to impact the hippocampus, the brain's memory center³, other nutrients are needed as structural components of the brain, e.g. amino acids make up the structural membrane of the nerve cell (neuron); phospholipids make up about 45% and 70% of the brain's lipid white and grey matter, respectively.⁴ Nutrients can also be cofactors in complex neurologic processes including synapse formation and myelination.⁵ (Figure 1)

The following are examples of nutrients that may have either structural or functional roles in the areas of the brain^a, as well as nutrients with interactive roles where they may work in concert with other nutrients.

- **Docosahexaenoic acid (DHA)** is a major structural lipid deposited in neuronal membranes of the central nervous system including the brain and eye, and present in high concentrations in the membrane-rich nervous tissue of the brain grey matter.^{6,7} DHA is important for synaptogenesis, membrane function, and potentially myelination¹. DHA uptake into the brain may be facilitated by choline.⁸
- **Choline metabolites** are found in a number of brain areas including the frontal, midline and central areas, particularly the hippocampus, the brain's memory center.^{3,a} Choline is an essential constituent of membrane phospholipids in the developing brain and liver.³ Choline has been shown to protect the integrity of the hippocampus⁹ and may have roles in visuospatial memory functions.¹⁰
- **Lutein and zeaxanthin** are major carotenoids in the occipital cortex, auditory cortex, hippocampus, frontal cortex and prefrontal cortex in infant brain tissues.¹¹ In young rats, lutein enhances neuron outgrowth in the hippocampus.¹² Lutein also accumulates in the macula of the eye where it has antioxidant and protective effects.¹³

Figure 1: Key nutrients in the brain that support cognitive development.^b



BRAIN AREAS AND FUNCTIONS

Frontal Cortex: Selects and integrates relevant information to complete tasks; contains motor cortex responsible for voluntary body movements^{20,21} **Parietal Cortex:** Processes sensory information, like pressure, touch and pain^{20,21} **Temporal Cortex:** Responsible for interpreting sounds and language, as well as recognition and behavior.^{20,23} **Occipital Cortex:** Associated with interpreting visual stimuli.²² **Prefrontal Cortex:** Associated with higher cognitive functions, like decision-making, and personality²⁴ **Auditory Cortex:** Processes auditory information, like pitch, rhythm, and loudness.²⁴ **Hippocampus:** Processes new information and coordinates memory functions.²⁴

- **DHA & choline and lutein & choline** are suggested to interact in the frontal, central, and midline areas of the brain^a and associated with better recognition memory of breast-fed infants at 6 months of age in an observational study.¹⁴

^a The frontal area encompasses the prefrontal and frontal cortices. The midline area separates the left and right brain hemispheres. The central area include the thalamus, hypothalamus, pituitary gland, and hippocampus.

^b Illustration is not intended to represent a comprehensive description of all nutrients in brain.

IMPORTANT NOTICE: The World Health Organization (WHO*) has recommended that pregnant women and new mothers be informed on the benefits and superiority of breast-feeding – in particular the fact that it provides the best nutrition and protection from illness for babies.

Mothers should be given guidance on the preparation for, and maintenance of, lactation, with special emphasis on the importance of a well-balanced diet both during pregnancy and after delivery. Unnecessary introduction of partial formula-feeding or other foods and drinks should be discouraged since it will have a negative effect on breastfeeding. Similarly, mothers should be warned of the difficulty of reversing a decision not to breast-feed.

Before advising a mother to use an infant formula, she should be advised of the social and financial implications of her decision: for example, if a baby is exclusively formula-fed, more than 400g per week will be needed, so the family circumstances and costs should be kept in mind. Mothers should be reminded that breast-milk is not only the best, but also the most economical food for babies.

If a decision to use an infant formula is taken, it is important to give instructions on correct preparation methods, emphasizing that unboiled water, unsterilized bottles or incorrect dilution can all lead to illness.

*See: *International Code of Marketing of Breast Milk Substitutes, adopted by the World Health Assembly in Resolution WHA 34.22, May 1981. For healthcare professionals use only. Not intended for public distribution*

- **Phospholipids** including sphingomyelin are contained in the myelin sheath, and make up the bulk of the brain's lipid content.^{4,15}
- **Iron** has an active metabolic involvement in the hippocampus and frontal cortex.¹ Additionally, deficits affect recognition memory, procedural memory, motor function, and spatial navigation that indicate iron's structural and functional roles in the hippocampus and striatum.^{1,2}
- **Iron and vitamin B₆ (pyridoxine)** are both cofactors in the synthesis of neurotransmitters, and have roles related to myelin, and sphingoid bases, respectively.^{1,2,16}
- **Folate and vitamin B₁₂ (cyanocobalamin)** are crucial during early development of the neural tube, and continue to be key nutrients in

the brain and spinal cord. Deficiencies result in impaired DNA synthesis and vitamin B₁₂ deficiency negatively affects myelination¹⁷, hence, the importance of other nutrients in myelination.

The roles of nutrients in the brain during an infant and young child's critical period of cognitive development is no doubt complex and additional research is needed to understand more. But, what is known, is that nutrition is instrumental in helping infants and children develop their cognitive and learning abilities. Other factors that play a role in favorably influencing a child's cognitive development are providing a socially stimulating environment in conjunction with a good nutritional status.^{18,19}

KEY TAKEAWAYS

- Nutrients can be structural brain components, support specific brain functions, and provide energy or metabolites for brain structures and functions; thus nutrients can enable or support cognitive development.
- Nutrients can be interactive and work in concert with other nutrients in the brain
- Effects of nutrients in the brain can occur together in the same brain region or be more widespread
- The impact of nutrition during the brain's critical period of development can be instrumental in helping infants and children develop their cognitive and learning abilities. Additional factors can favorably influence cognitive development such as providing a socially stimulating environment in conjunction with good nutrition.

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