Nutrition and Learning in Early Childhood: The Cognitive Implications.

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Overview

- Cognitive development is influenced by many factors, including nutrition.
- Nutrients provide building blocks that play a critical role in cell proliferation, DNA synthesis, neurotransmitter and hormone metabolism, and are important constituents of enzyme systems in the brain.
- Brain development is faster in the early years of life compared to the rest of the body, which may make it more vulnerable to dietary deficiencies.

Outline

- Brain development in children
- Cognition and brain development
- Impact of nutrition on learning

How does the Brain Develops?

Brain development

- The brain is an amazing organ. It uses more calories and the most protein on a daily basis than other organs of the body.

- The study of the brain using advanced neuroimaging; PET and MRI, has given rise to greater understanding of the functional and structural development of the brain

- Brain development is faster in the early years of life compared to the rest of the body which makes it most vulnerable to dietary deficiencies.

The foetal nervous system is the first system to develop during intrauterine life and the last to be completed after birth.

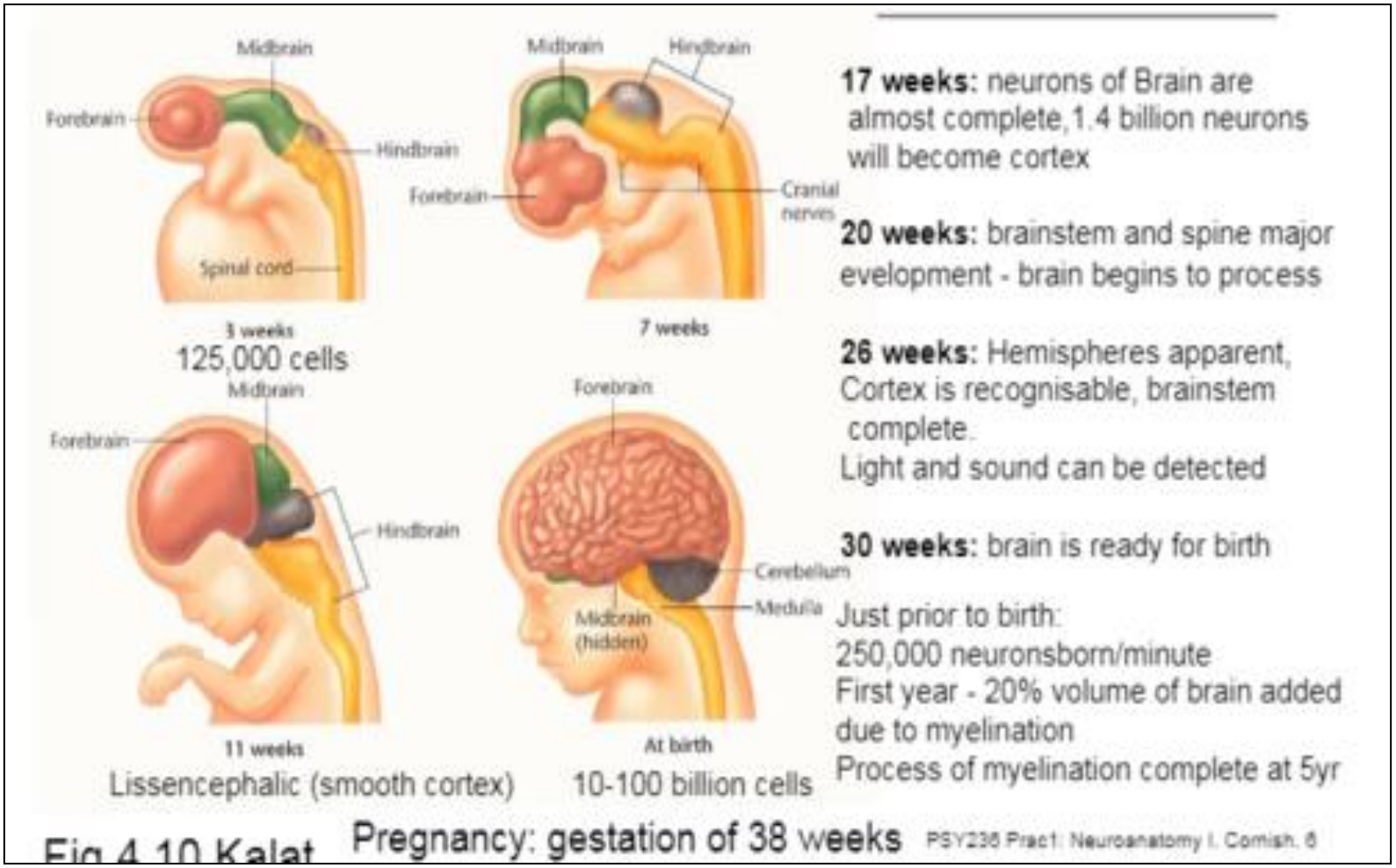
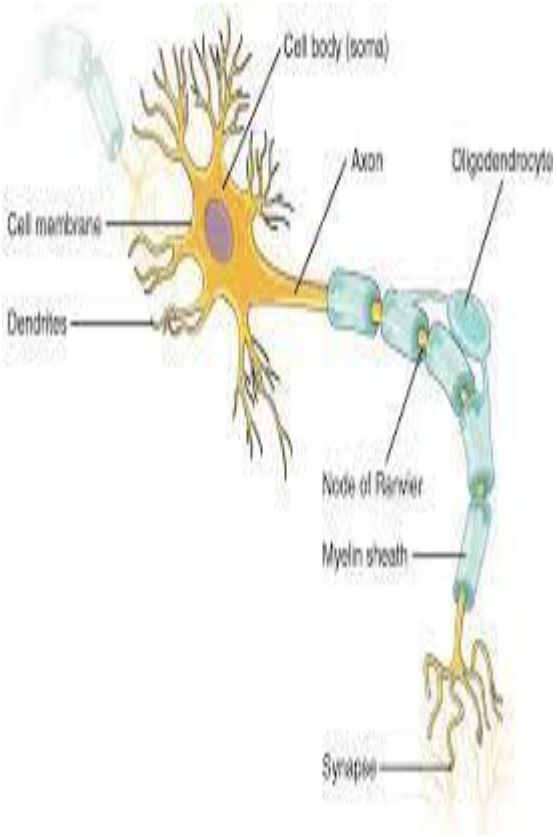


Fig 4.10 Kalat

The brain is made up of different cells



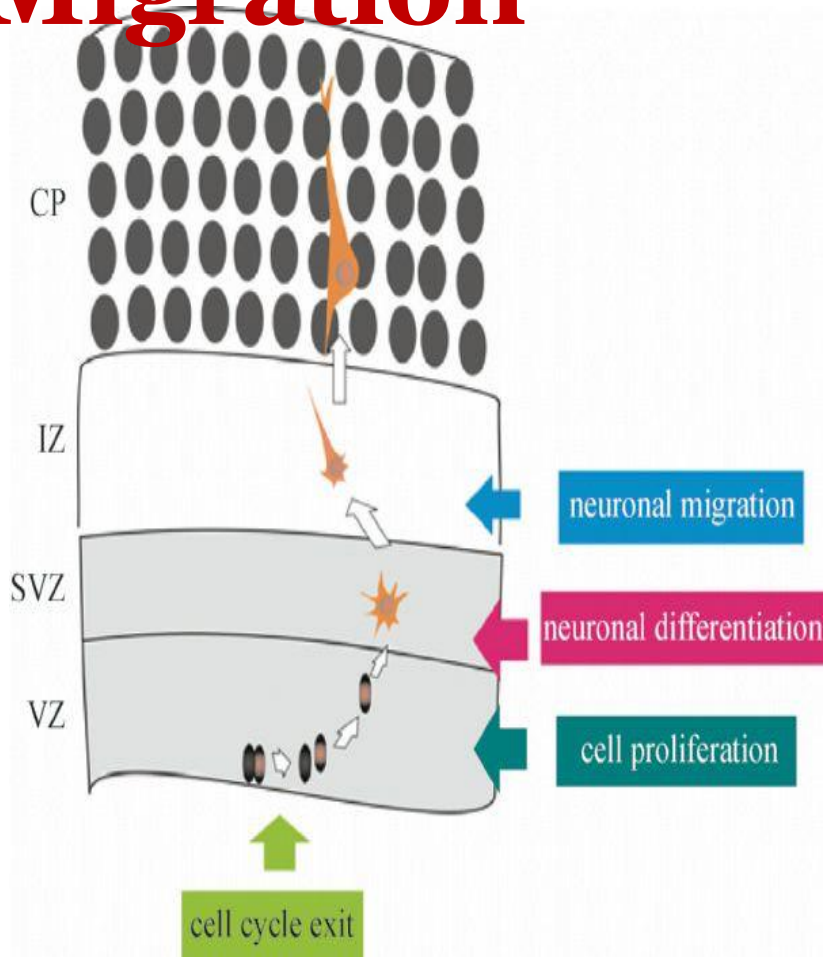
1. Neurons: 80-100billion are involved in the transmission and processing information
2. Non-Neuronal cells- 100 billion
    1. Astrocytes support the BBB, brain enery abd repair damage
    2. Oligodendrocytes deposit myelin
    3. Endothelial cell/pericytes line blood vessels
    4. Microglia are the primary immune defence in the brain.

Developmental processes in brain growth

- Early brain development involves 6 main processes
  - Neurogenesis and neuronal migration
  - Neuronal elaboration and differentiation
  - Synaptogenesis
  - Glia cell formation and myelination
  - Increasing connection between brain regions
  - Pruning excessive synapsis and loss of plasticity

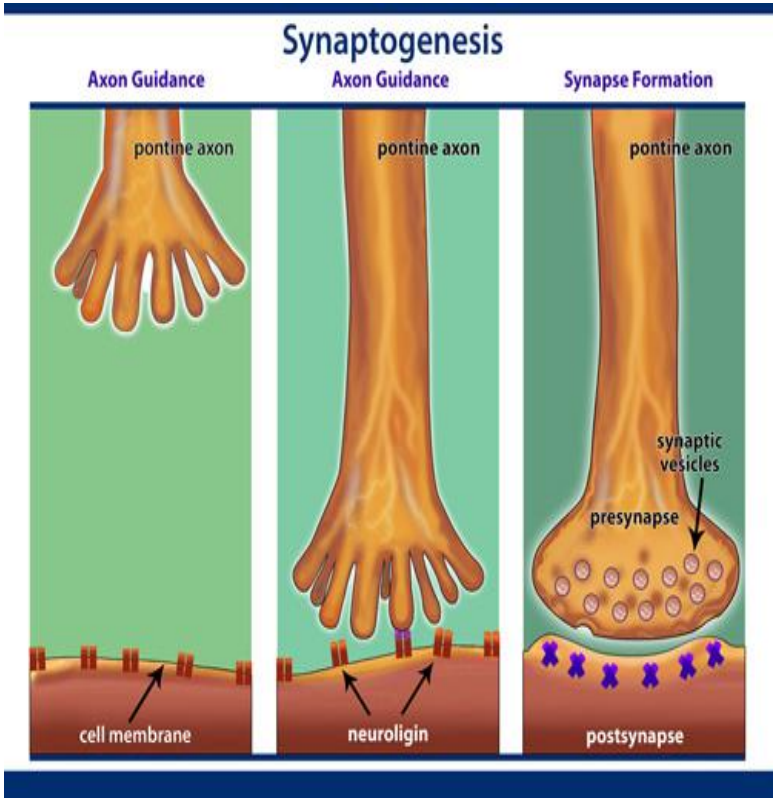
Neuronal proliferation, differentiation & Migration

In the developing brain, neurones must migrate from the areas where they are "born" to the areas where they will settle into their proper neural circuits

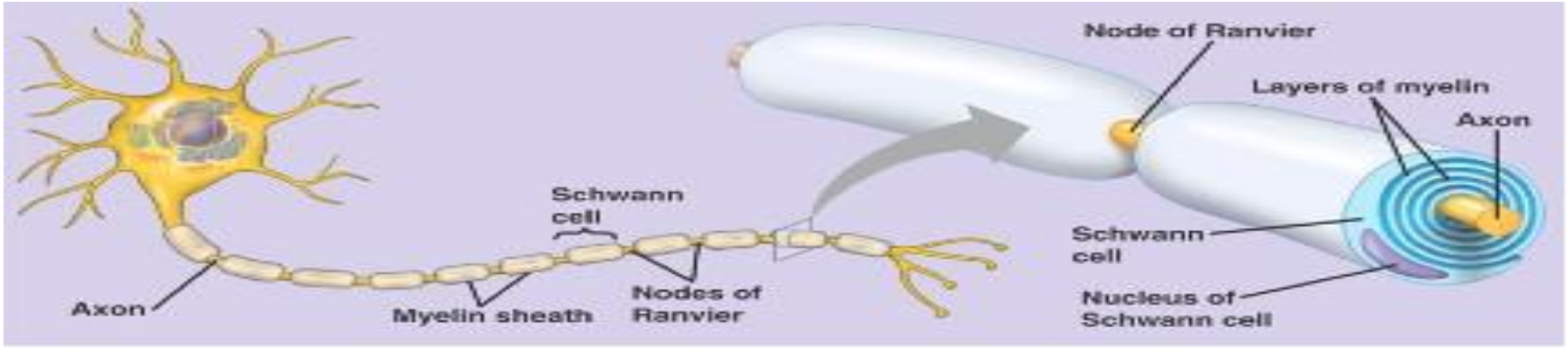


Synaptogenesis

- Communication between neurons and between neuron and muscles occur through synapses.
- Synaptogenesis begins early in fetal life. Occurs in stages but maximum activity is from 3rd trimester thru to 15 to 24 months of life.
  - Concurrent with dendritic & axonal growth and myelination.
- Early synaptogenesis is intrinsically regulated
  - Later stages are influenced by the environment (learning & memory)



Myelin & Myelination



- Axons of neurons are covered by sheaths of fatty material called Myelin.
- Myelin – lipoproteins (about 80% lipid & 20% protein)
  - Galacto-cerebroside (glycolipid), glycoprotein
  - Secreted by oligodendrocytes in the CNS & Schwann cells in the peripheral nervous system

After birth the brain continues to grow in size and complexity

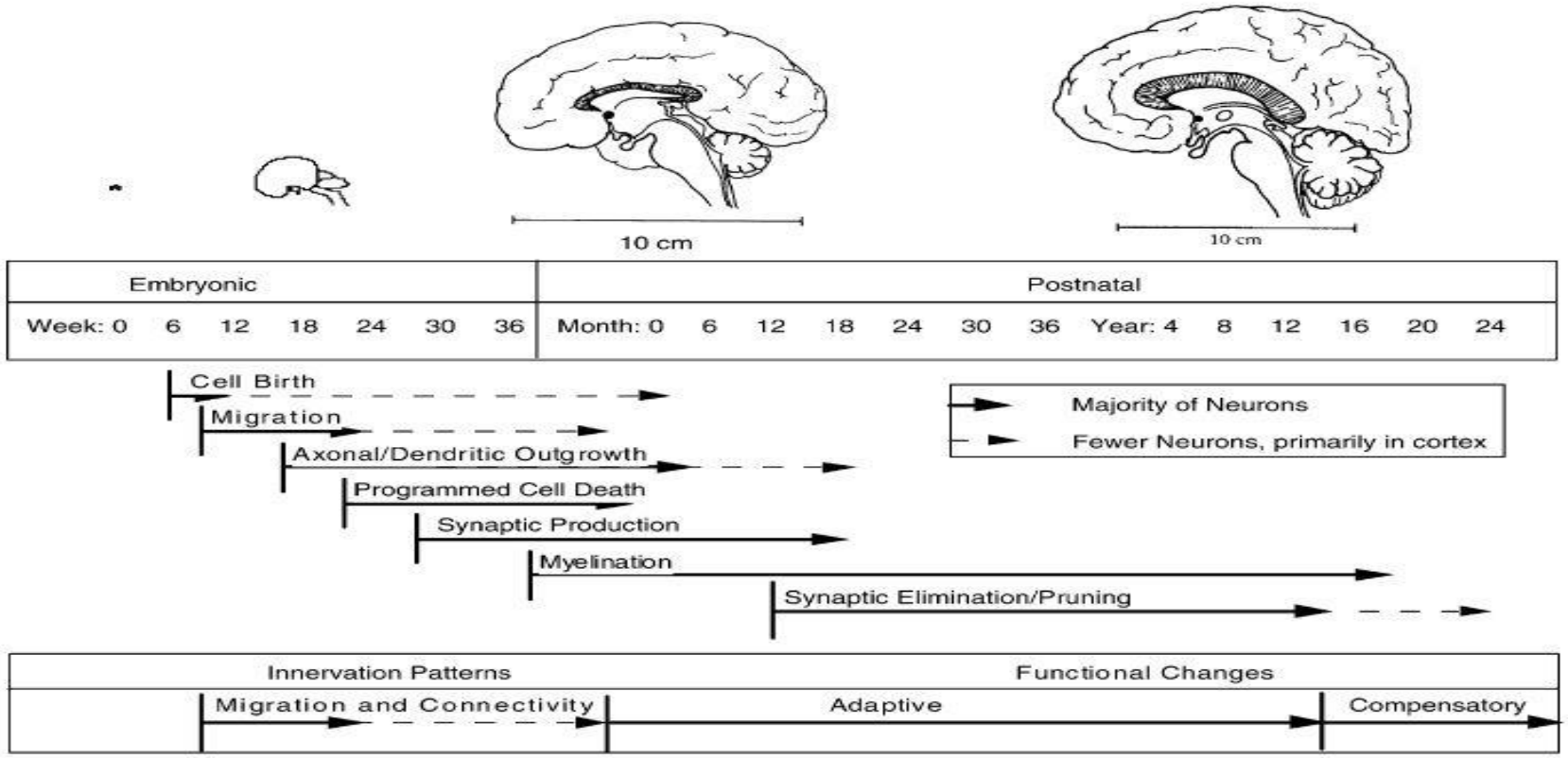


Fig. 1. The stages of brain development (top) and different windows of vulnerability (bottom). Developmental processes occur in phases, setting the stage for potential periods of vulnerability. Insults early in life (bottom) will be assimilated into innervation patterns, whereas a later pre-pubertal insult will cause functional changes that are more adaptive.

Concept of critical/sensitive periods and plasticity in brain development

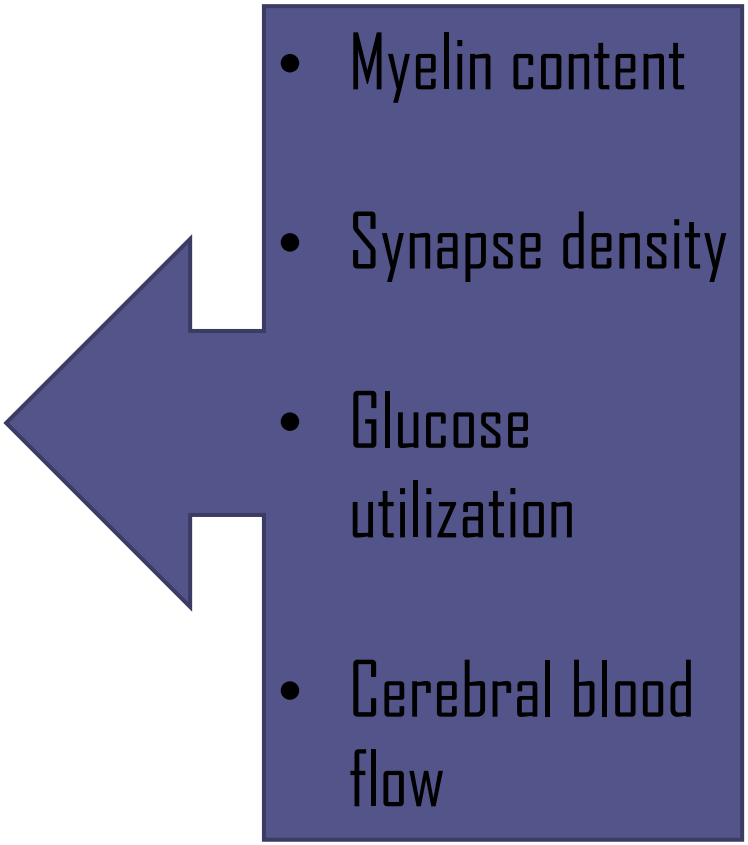
- A **critical period** is a maturational stage in the lifespan of an organism during which the nervous system is especially sensitive to certain environmental stimuli.
  - If the organism does not receive the appropriate stimulus during this "critical period" to learn a given skill or trait, it may be difficult, ultimately less successful, or even impossible, to develop certain associated functions later in life.

- A **sensitive period** is a limited time during development during which the experience on brain function is particularly strong

- **Neuroplasticity** is the ability of neural networks in the brain to change through growth and reorganization. These changes range from individual neuron pathways making new connections, to systematic adjustments like cortical remapping

The brain growth is observed in

- Size
  - 80% of adult size by 2 years
- Connectivity
  - Increase in myelin
  - Decrease in synapses
- Brain activation patterns
- Metabolism
  - Total brain glucose uptake peaks around 4 years
- Brain blood flow
  - Rise sharply from birth to early childhood
  - Supports nutrient delivery



Key factors in brain development

Genes

NUTRITION

Environment

Through out the human life time the brain continues to undergo changes.

Learning and Brain development

What is learning?

- Learning is observable change in behaviour or knowledge attributed to the environment.
- It is about acquiring knowledge and skills
  - This acquisition comes thought the creating and strengthening of frequently used synapses
- Learning is closely related to the cognitive development.

Learning is influenced by brain maturity and development

- Genetics
- Temperament
- Environment
- Age
- Level of development and brain maturity, including vision and visual processing

Brain Development and Nutrition

Infancy and early childhood is a critical window for normal development

- Good nutrition during pregnancy and early childhood plays a foundational role in enabling a child to grow, learn and thrive.
- The association between brain development and nutrition has been gaining attention due to emerging evidence on the detrimental effect of nutritional deficiencies on cognitive functioning in infants.
- 60% of the calories that a baby takes in goes to the brain to help build that brain and to help it function.

Nutrition

Biology and genetics

Environment and lifestyle

Adequate energy availability

Brain function

Structural building blocks

Developmental course of the human brain

- Different brain processes require different nutrients.
- Deficiencies of these nutrients at the peak growth have the most detrimental effects.
- Brain nutrition begins in utero and at birth breastmilk is the ultimate super food.
- The effects of poor nutrition on a child's brain development can be profound and long-lasting

Relevant nutrients for early brain development

Brain structure	Brain function	Brain energy
Iodine	Protein	Glucose
Zinc	Iron	Protein
Copper	Zinc	Iron
Folate	Copper	
Vitamin A	Choline	
LC-PUFA(DHA ,ARA)	Phosphatidylcholine	
Phospolipids	Phosphatidylserine	
Sphingomyelin	Sphingomyelin	
B12		

Key Nutrients that Support Brain Development

Nutrient	Associated Processes	Structural Impact	Functional Benefits
Protein[1]	• Cell proliferation, differentiation • Synaptogenesis • Growth factors	• Global • Cortex • Hippocampus	• Supports developmental processes and growth
DHA, AA, & Other LC-PUFAs[1,2]	• Synaptogenesis • Myelin	• Global • Visual cortex, retina • Cortex	• Supports visual and cognitive development
Folate[2]	• Neural tube closure • DNA methylation	• Global	• Supports neurological development
Iron[1]	• Myelin • Monoamine synthesis • Neuronal and glial energy metabolism	• White matter • Striatal-frontal • Hippocampal-frontal	• Supports mental, cognitive and motor development

PDI = Psychomotor Developmental Index; MDI = Mental Developmental Index

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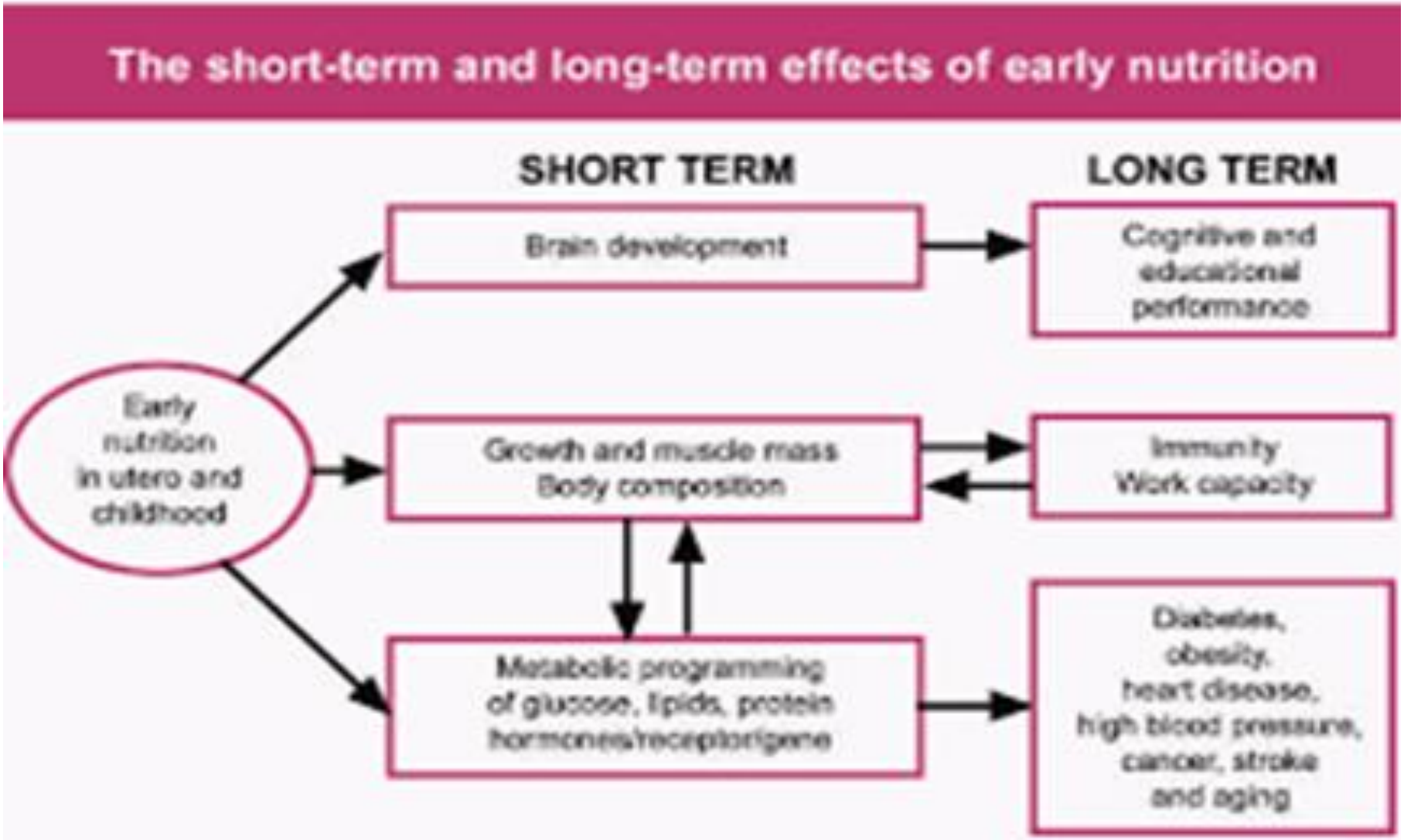
4. Morreale de Escobar G, et al. *Eur J Endocrinol.* 2004;151:U25-37.

Key Nutrients that Support Brain Development

Nutrient	Associated Processes	Impacted Area	Functional Benefits
Zinc[1]	• DNA synthesis • Neurotransmitter release	• Autonomic nervous system • Hippocampus • Cerebellum	• Supports memory and motor development
Choline[1]	• Acetylcholine synthesis • DNA methylation • Myelin synthesis	• Global • Hippocampus • White matter	• Supports memory development
Iodine[3,4]	• Cell proliferation	• Global	• Supports cognitive and neurological development
Lutein[2-4]	• Antioxidant, filters blue UV light	• Retina and macula • Frontal, auditory, occipital cortex and hippocampus	• Supports visual development and may support brain development*

*Lutein is found in areas of the brain associated with learning, more data are needed to determine functional benefit
DHA = Docosahexaenoic Acid; AA = Arachidonic Acid; LCPUFAs = Long-chain Polyunsaturated Fatty Acids
1. Georgieff MK. *Am J Clin Nutr.* 2007;85:614S-20S; 2. Lien EL, Hammond BR. *Prog Retin Eye Res.* 2011;30:188-203; 3. Alves-Rodrigues A, Shao A. *Toxicol Lett. 2*004;150:57-83; 4. Kijlstra A, et al. *Prog Retin Eye Res.* 2012;31:303-15.


The short-term and long-term effects of early nutrition
SHORT TERM
LONG TERM
Early nutrition in utero and childhood
Brain development
Cognitive and educational performance
Growth and muscle mass
Body composition
Immunity
Work capacity
Metabolic programming of glucose, lipids, protein hormones/receptorgene
Diabetes, obesity, heart disease, high blood pressure, cancer, stroke and aging

Nutrition and Cognition

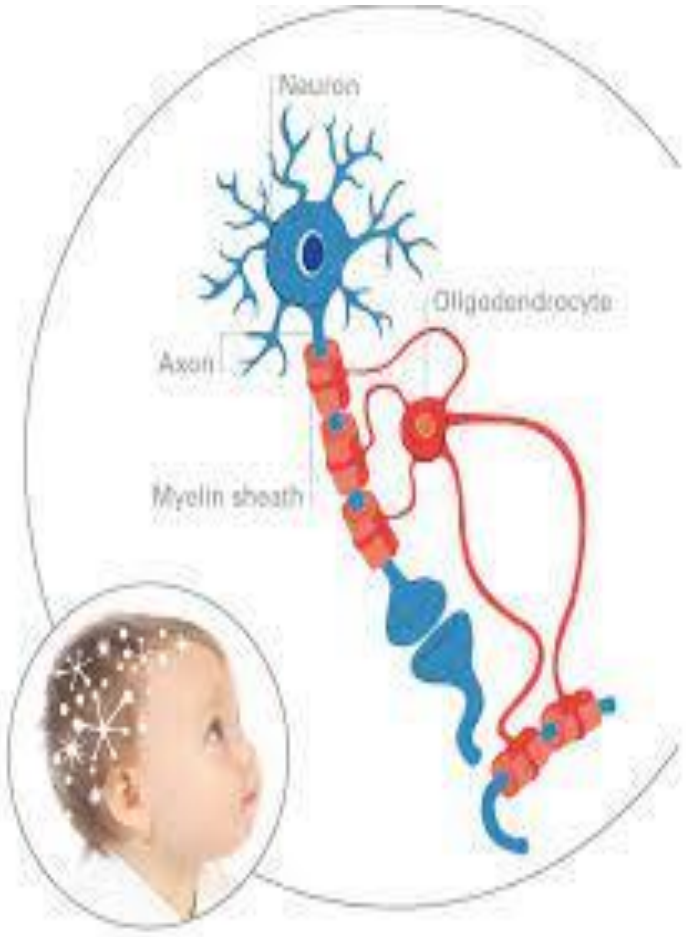
The facilitation of the impact of nutrition on learning is by the impact the various nutrients have on brain structure and function during development.

The first 1000 days

- The first 3 years of life represent a rapid and dynamic period of brain maturation
- An important neurodevelopmental process during this postnatal period is the maturation of the myelinated white matter, which facilitates rapid communication across neural systems and networks
- Early life nutrition is an important and modifiable factor that can shape myelination and subsequently cognitive outcomes

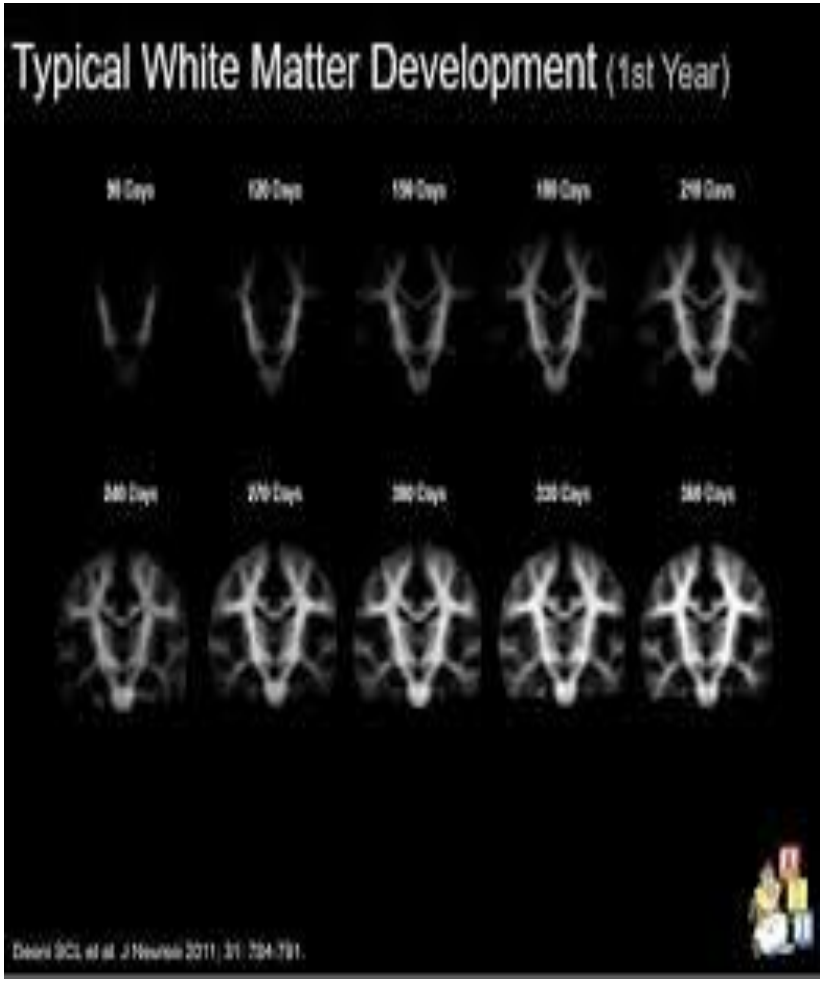
Myelination

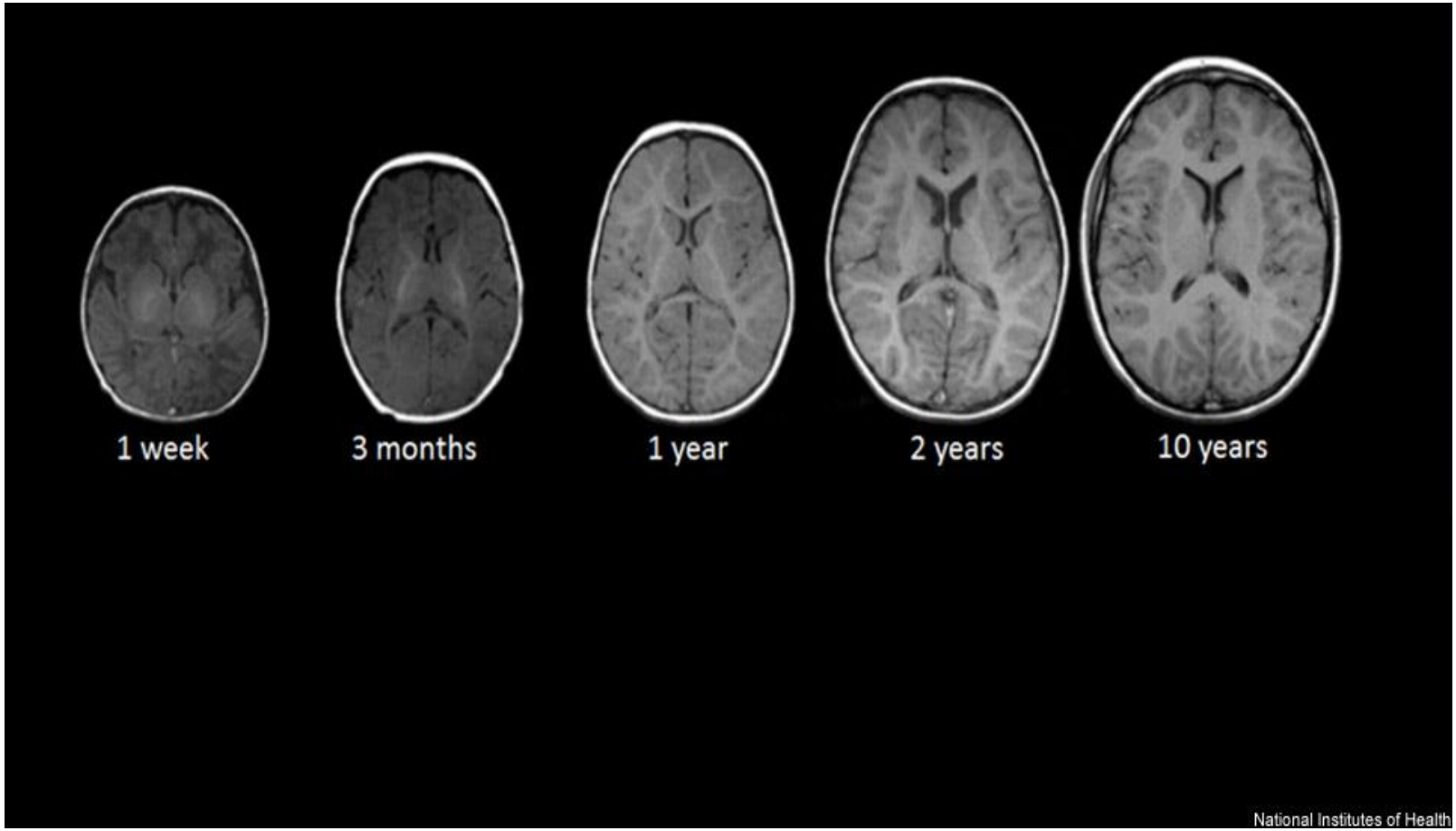
- Myelination is the hallmark of neurodevelopment
- Myelination begins in-utero and continues into the 3rd decade of life.
  - Wrapping of nerve fibers with lipid rich sheets.
    - Ensures Fast, effective and synchronized communication between cells and networks
    - Myelin protects the nerve axons
    - Prevents the activation of neighbouring nerve fibers.
- Myelination matures alongside cognitive and behavioural development.



Myelination and cognition

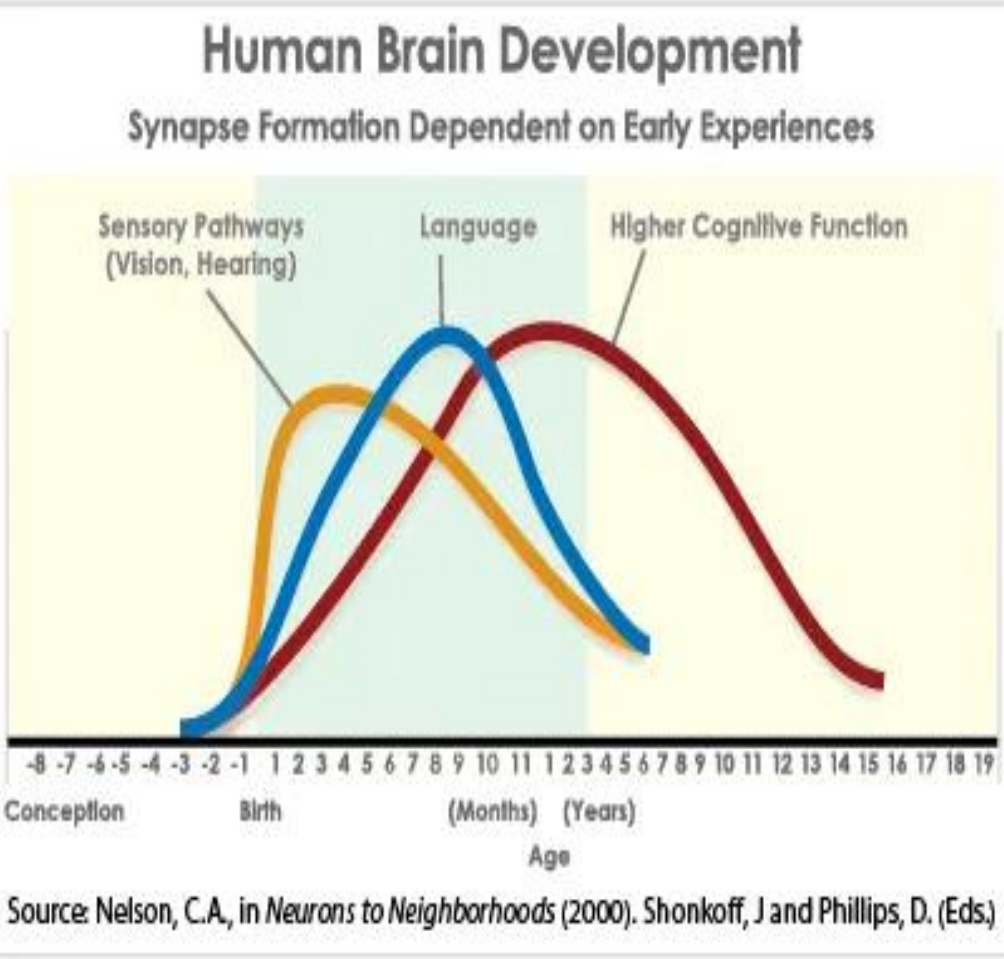
- Clinical studies have demonstrated the link between myelination and cognition including
  - General cognitive ability
  - Language and reading
  - Working memory
  - Processing speed
  - Sensory reactivity
- These are all processes required for learning.




1 week
3 months
1 year
2 years
10 years
National Institutes of Health

There is a strong overlap in the emergence of specific cognitive functions and the myelination of the brain regions and networks

- The trajectories of myelination are associated with cognitive abilities and outcomes.
- The assembly and maintenance of the myelin sheet requires a meticulous delivery of nutrients.
- Deficiencies in these nutrients throughout infancy can significantly alter myelin content, composition, and morphology, potentially disrupting normal brain function and impairing cognitive outcomes.



Nutrition is the biggest modifiable early life influencers of myelination.

- Long-chain polyunsaturated fatty acids (LC-PUFAs), choline, iron, zinc, cholesterol, phospholipids, and sphingomyelin play essential roles in myelin elaboration as key components of the myelin sheath and/or energy sources.

- **Composition of human breastmilk provides many of the nutritional building blocks that support healthy physical and immune system development and brain maturation.**

- Early nutrition influences developmental myelination and cognition in infants and young children
- Sean Deoni,[a,*] Douglas Dean, III,[b] Sarah Joelson,[a] Jonathan O'Regan,[c] and Nora Schneider[d]
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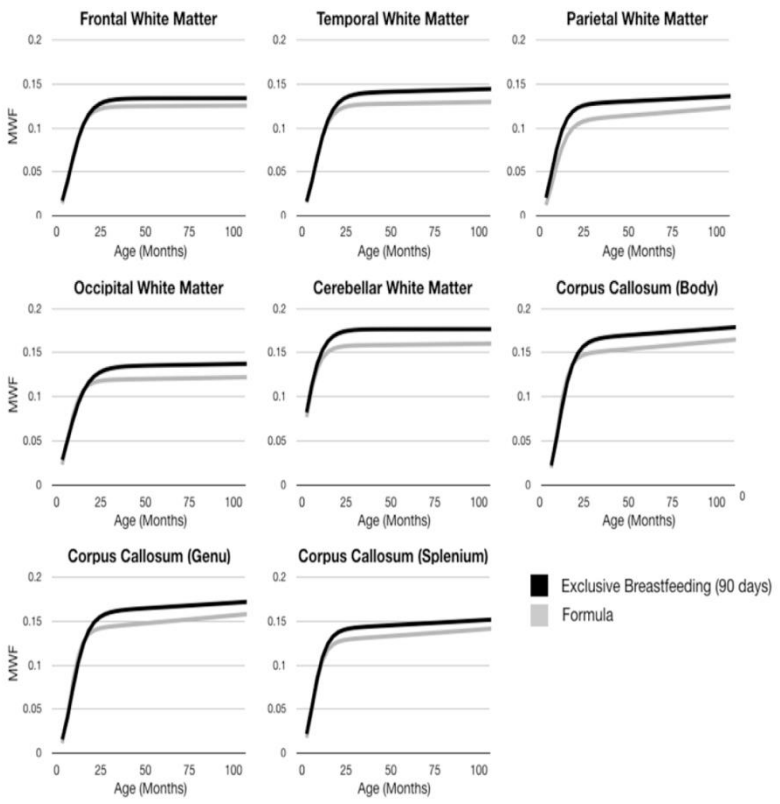

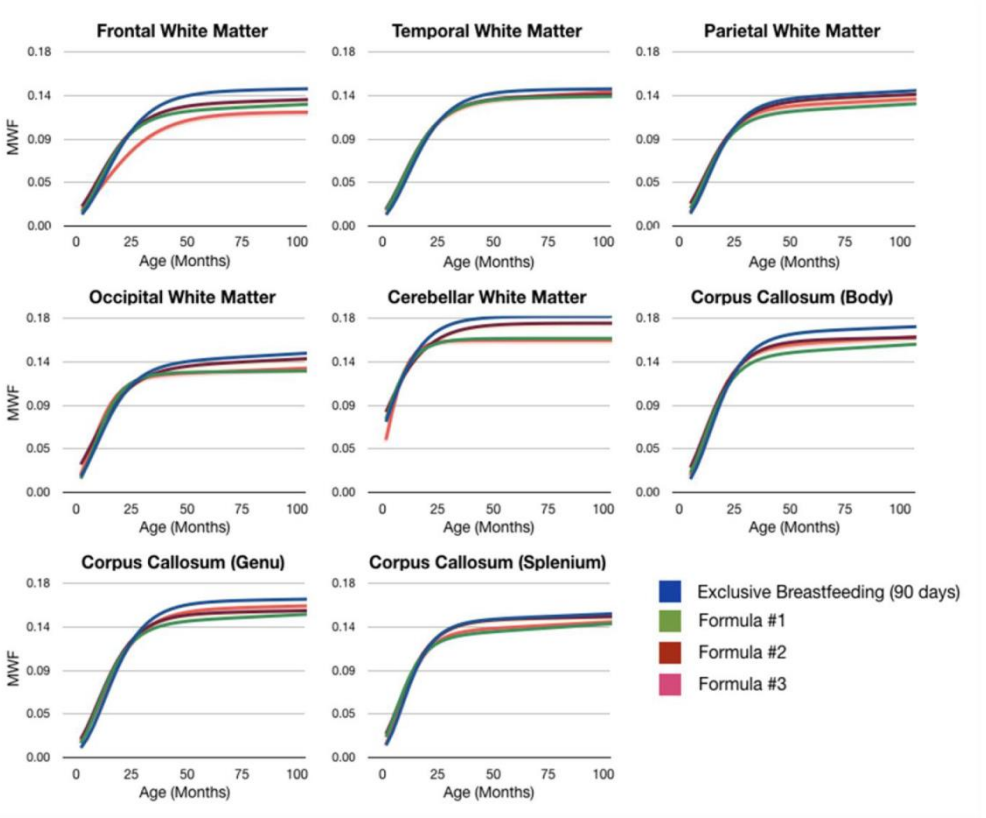

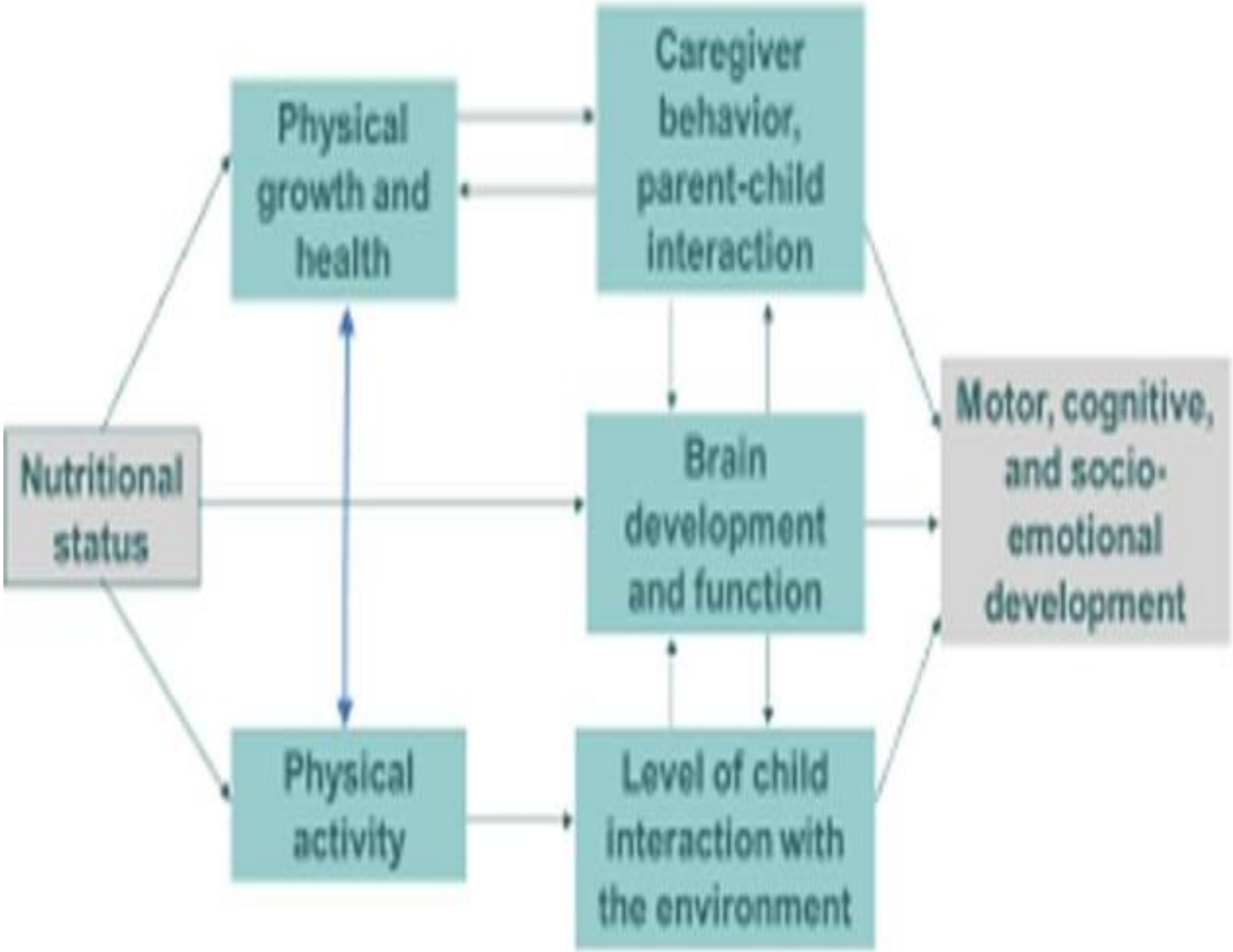
Caregiver behavior, parent-child interaction
Physical growth and health
Nutritional status
Brain development and function
Motor, cognitive, and socio-emotional development
Physical activity
Level of child interaction with the environment

CONCLUSION

- Brain development starts early; during gestation.
- Most of its development is completed in the early years of life.
- Absence of these nutrient elements at critical moments of brain development result in impaired function and sometimes disease states.
- Therefore good maternal health, breast feeding and feeding of diets rich in these nutrients have a positive effect on cognitive development.

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Thank You for Your Attention