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Nutritional Neurosciences

The Mental Health - Nutrition/Dietary Ingredient Connection

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Nutritional Neurosciences:
The mental health - nutrition/dietary ingredient connection

Douglas Kalman PhD, RD

Dr. Kiran C. Patel College of Osteopathic Medicine at Nova Southeastern University

Related History

- Published and presented nationally and internationally on “cognitive nutrition”.
- Olympic & Collegiate Sports Nutritionist - 1998 Nagano, 2002 Salt Lake City, 2006 Torino, 2008 Beijing, 2012 London, 2016 Rio de Janeiro, 2020 Tokyo; Florida International University Athletics Department (8 years)
- Sports Nutritionist, Professional athletes/teams: UFC, Bellator, Boxing, Track & Field, Tennis, Swimming.
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- Web: www.nova.edu

Highlights of Nutritional Neurosciences

- The body is a complex organism.
- The nutritional neurosciences are the scientific discipline centered on the impact of dietary components, such as hydration, vitamins, minerals, essential nutrients, phytonutrients and other dietary compounds have on neurochemistry and neurobiology, and memory, executive function, behavior and cognition.
- This includes feelings of well-being, mood-states and lifecycle health.

The Neurosciences Integrates Nutrition

- Understanding brain energetics is also important as this too impacts the nutritional neurosciences.
- Relatively speaking, the brain consumes an immense amount of energy in comparison to the rest of the body.
- The human brain is approximately 2% of the human body mass but yet uses 20–25% of the energy expenditure.
- Feeding the brain for optimal support now and later is central for lifetime health.

Nutritional Neurosciences

- Nutrition has an impact on the brain throughout the lifecycle, which can impact on the development of neurodevelopmental conditions and also neurodegenerative diseases in later life.
- How we eat impacts cognitive health and disease risks over a lifetime.
- A high saturated fat diet is associated with increased Alzheimer's disease risk, while being iron-deficient is correlated with depression (nutrient status-mental health connection), not to mention that sub-optimal intake of essential fats is also known to impact mood states.

Connecting the Neurosciences & Nutrition

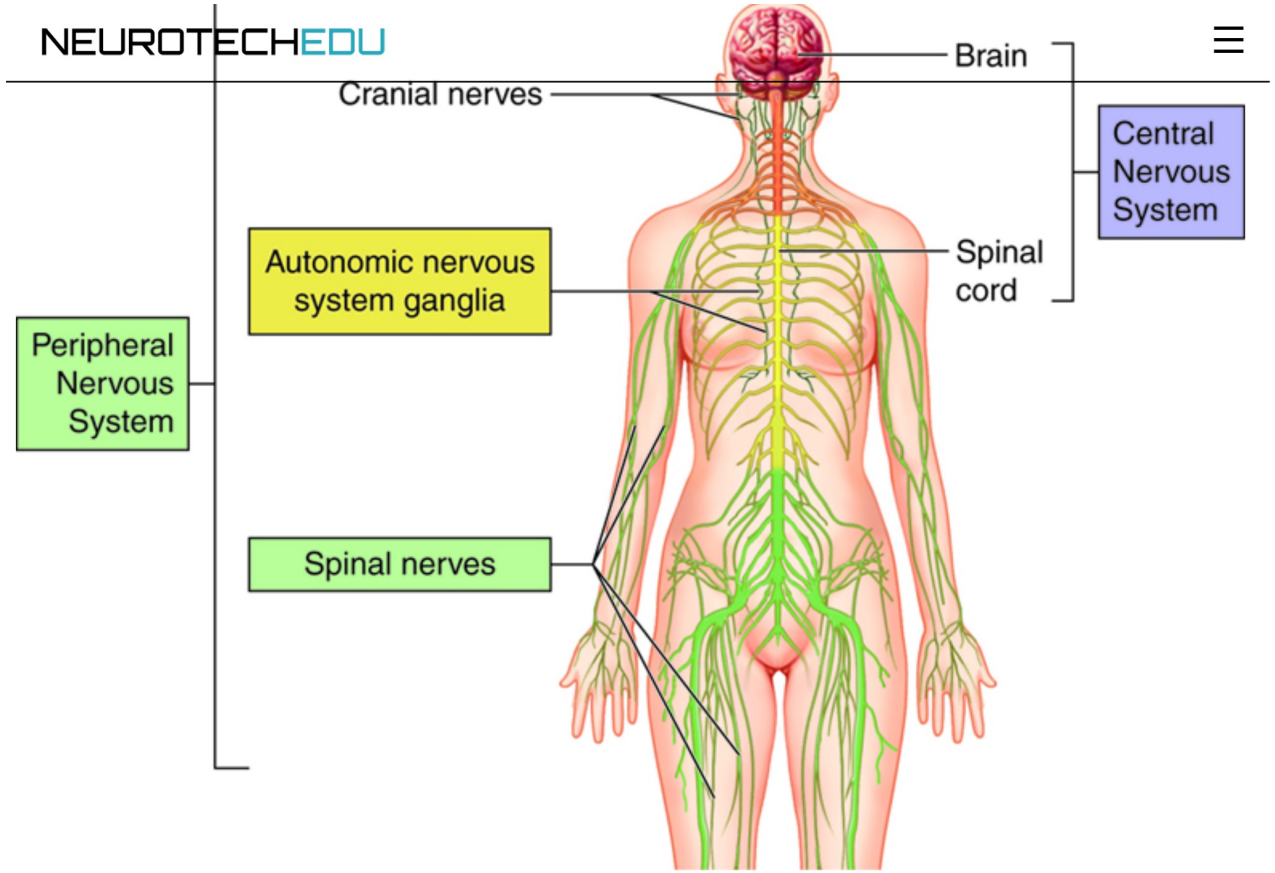
- Neuroscience is a study devoted to understanding the nervous system and its core component, the brain.
- Neuroscience also focuses on the brain and its impact on behavior and cognitive functions, or how people think.
- Neuroscience also examines how disease states and conditions impact the nervous system.
- Neuroscience is an interdisciplinary science that works closely with other disciplines, such as mathematics, linguistics, engineering, computer science, chemistry, philosophy, psychology, and medicine.
- Why not nutrition too?

Some Branches of Neurosciences

+ Affective
+ Behavioral
+ Clinical
+ Cognitive
+ Developmental
+ Molecular/cellular
+ Neuroimaging
+ Neuroinformatics
+ Neurolinguistics
+ Neurophysiology

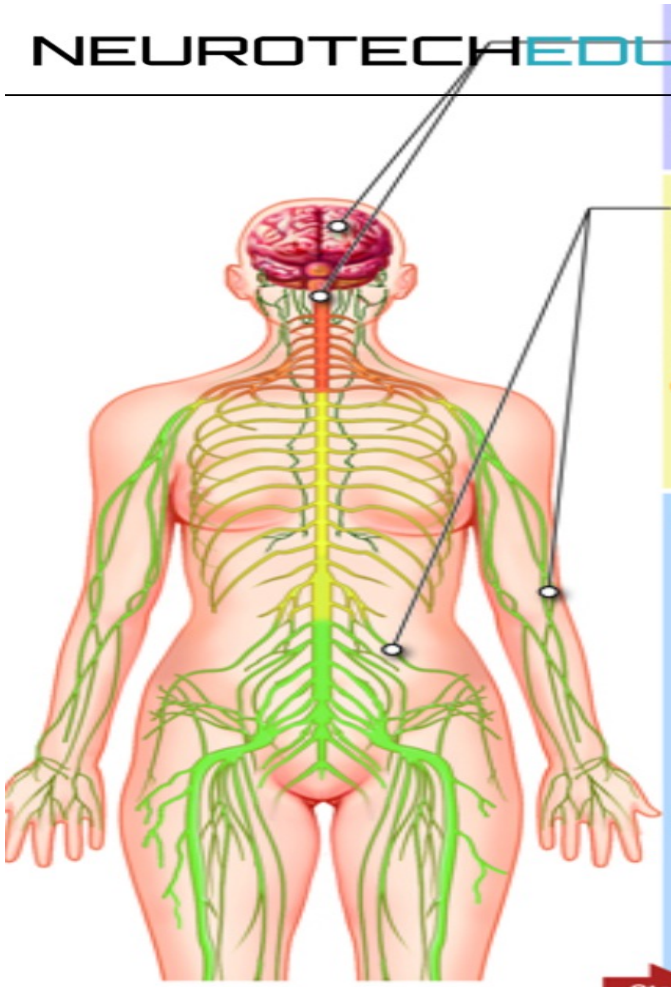
About the Nervous System

- Nervous system – two classes
  - Central nervous system
  - Peripheral nervous system
    - Sensory/Afferent
    - Motor/Efferent
    - Somatic
    - Autonomic
    - Sympathetic
    - Parasympathetic



Flow of the Nervous System

NEUROTECHEDU



Central Nervous System
The **central nervous system (CNS)** includes the brain and the spinal cord, which are enclosed in the skull and vertebral column, respectively. The CNS is connected to all other parts of the body by the PNS nerves.

Peripheral Nervous System
The **peripheral nervous system (PNS)** consists of all neural tissue outside of the brain and spinal cord. The PNS includes the cranial nerves and spinal nerves, sensory receptors and ganglia (cell bodies of neurons that lie outside the CNS). The PNS brings sensory information to the CNS, or carries motor output from the CNS to initiate a reaction.

Start

1. **Receptors** can be neurons, cells or specialized structures. They monitor and detect changes to the body's internal or external environment.

The **somatic sensory receptors** are widely distributed throughout body tissues. They are located in, and sense information from, the structures of the skin, muscles, and joints (including the related structures of tendons and ligaments). These somatic senses include gustation, olfaction, hearing, equilibrium and vision.

The **receptors of special senses** are found in specialized organs localized in the head. These special senses include smell, taste, sight, hearing and equilibrium.

The **visceral or autonomic sensory receptors** conduct signals predominantly from organs contained in the thoracic and abdominopelvic cavities (ex. heart, lungs, intestines, bladder, etc.). Visceral receptors detect changes in the chemical environment of body fluids and state of internal organs, such as pressure and stretch.

2. The **sensory division** of the PNS contains nerves carrying sensory information into the CNS. The sensory neurons in the sensory or mixed nerves are also called afferents.

3. The **central integration** of sensory information, sometimes with higher cognitive functions to become a conscious perception, may then lead to either a conscious or subconscious motor response.

4. The **motor division** of the PNS contains nerves carrying information out of the CNS to target organs. The motor neurons in the motor or mixed nerves are also called efferents.

includes

The **somatic motor division** controls the voluntary actions of the skeletal muscles in the body. The responses in these targets are usually voluntary.

The **visceral motor division**, more commonly called the autonomic nervous system, controls the actions of cardiac muscle, smooth muscle, and glands. The responses in these targets are usually involuntary. Body processes controlled by the autonomic nervous system include the contractions of the stomach and other digestive organs, the heart rate, and contractions of blood vessels to control blood pressure and flow though the body.

Skeletal muscle

The **sympathetic division** mobilizes body systems during activity ("flight or fight"). It controls functions that speed up the heart and increase energy usage during emergencies or times of stress.

The **parasympathetic division** promotes "housekeeping" functions ("rest and digest"). It controls functions that have the opposite effect to reduce heart rate and decrease overall energy usage when the body is returning to normal after an emergency or during normal functioning.

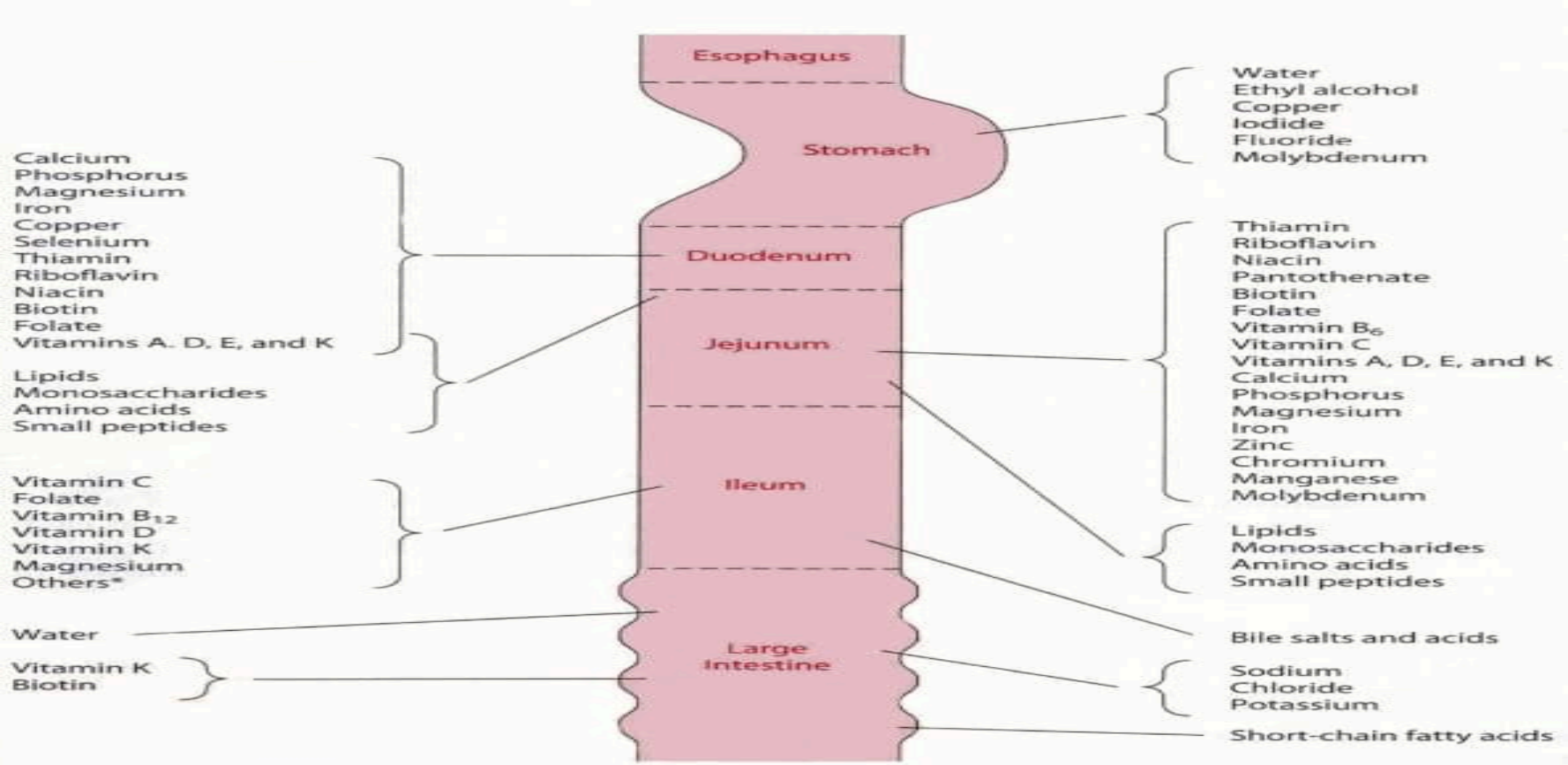
The **enteric division** contains neurons located in the walls of the digestive tract. Some scientists view the enteric nervous system as a completely independent part of the nervous system akin to the CNS and PNS since it can function independently to generate gland secretion and some aspects of motility and is anatomically discrete. Other scientists classify the enteric nervous system as a subdivision of the motor arm of the PNS because it innervates the same type of effectors (muscles and glands), the scheme we will use here.

5. **Effectors** are muscles or glands that respond to motor nerve impulses.

Integrating Nutrition

+ Is it as simple as……. an apple a day?

Nutrient absorption made easy



*Many additional nutrients may be absorbed from the ileum depending on transit time.

Courtesy: *Advanced Nutrition and Human Metabolism, fifth edition.*

The Basics

- Macronutrients
  - Carbohydrates
  - Proteins
  - Fats
- Macronutrients are the nutrients the body requires in relatively large amounts
- These provide energy, maintain structure, and provide functional integrity to the body and its systems

Carbohydrates

- Monosaccharides
  - One sugar molecule
- Disaccharides
  - Two sugar molecules bonded together
- Polysaccharides
  - Chains of sugar molecules, usually glucose
- Serves as an energy source or reserve (circulating & glycogen)
  - Fuel for the CNS & for RBC's

Does CHO Type Matter for Cognition?

Long-term Effects of a Very Low-Carbohydrate Diet and a Low-Fat Diet on Mood and Cognitive Function

Grant D. Brinkworth, PhD; Jonathan D. Buckley, PhD; Manny Noakes, PhD; Peter M. Clifton, PhD; Carlene J. Wilson, PhD

Background: Very low-carbohydrate (LC) diets are often used to promote weight loss, but the long-term effects on psychological function remain unknown.

Methods: A total of 106 overweight and obese participants (mean [SE] age, 50.0 [0.8] years; mean [SE] body mass index [calculated as weight in kilograms divided by height in meters squared], 33.7 [0.4]) were randomly assigned either to an energy-restricted (approximately 1433-1672 kcal [to convert to kilojoules, multiply by 4.186]), planned isocaloric, very low-carbohydrate, high-fat (LC) diet or to a high-carbohydrate, low-fat (LF) diet for 1 year. Changes in body weight, psychological mood and well-being (Profile of Mood States, Beck Depression Inventory, and Spielberger State Anxiety Inventory scores), and cognitive functioning (working memory and speed of processing) were assessed.

Results: By 1 year, the overall mean (SE) weight loss was 13.7 (1.8) kg, with no significant difference between groups (P=.26). Over the course of the study, there were significant time × diet interactions for Spielberger State Anxiety Inventory, Beck Depression Inventory, and Profile of Mood States scores for total mood disturbance, anger-hostility, confusion-bewilderment, and depression-dejection ($P<.05$) as a result of greater improvements in these psychological mood states for the LF diet compared with the LC diet. Working memory improved by 1 year ($P<.001$ for time), but speed of processing remained largely unchanged, with no effect of diet composition on either cognitive domain.

Conclusions: Over 1 year, there was a favorable effect of an energy-restricted LF diet compared with an isocaloric LC diet on mood state and affect in overweight and obese individuals. Both diets had similar effects on working memory and speed of processing.

Trial Registration: anzctr.org.au Identifier: 12606000203550

Arch Intern Med. 2009;169(20):1873-1880

Simple/Refined CHO's & Neurocognitive Deficits

CURRENT OPINION

Carbohydrates and cognitive function

Misty A.W. Hawkins, Natalie G. Keirns, and Zachary Helms

Purpose of review
Recent evidence documents the negative impact of obesity, diabetes mellitus, and other metabolic dysregulation on neurocognitive function. This review highlights a key dietary factor in these relationships: refined carbohydrates.

Recent findings
Chronic consumption of refined carbohydrates has been linked to relative neurocognitive deficits across the lifespan. Hippocampal function is especially impacted, but prefrontal and mesolimbic reward pathways may also be altered. Early life exposure to refined carbohydrates, (i.e., prenatal, juvenile, and adolescence periods) may be particularly toxic to cognitive functioning. The impact of acute carbohydrate administration is mixed, with some findings showing benefits while others are neutral or negative. Potential mechanisms of the carbohydrate-cognition relationship include dysregulation in metabolic, inflammatory, and vascular factors, whereas moderators include age, genetic factors, physiological (e.g., glucoregulatory) function and the timing and type of carbohydrate exposure. Critically, the negative neurocognitive impacts of diets high in refined carbohydrates have been shown to be independent of total body weight.

Summary
Neurocognitive deficits induced by a diet high in refined carbohydrates may manifest before overt obesity or metabolic disease onset, suggesting that researchers and providers may need to target subclinical metabolic, inflammatory, and vascular dysregulation factors in efforts to preserve cognitive function across the lifespan.

Keywords
carbohydrate, cognition, cognitive function

Curr Opin Clin Nutr Metab Care 2018, 21:302 – 307

Protein

- Protein – we breakdown intact protein from foods into amino acids for use in the body.
- The body requires 20 different amino acids.
- The potential for combining the 20 amino acids creates an almost infinite number of possible proteins.
- There are essential (~9) and non-essential amino acids (~11).
- Protein and amino acids play large role in health maintenance and in the nutritional neurosciences.

Protein Amino Acid Neurotransmitter Connection

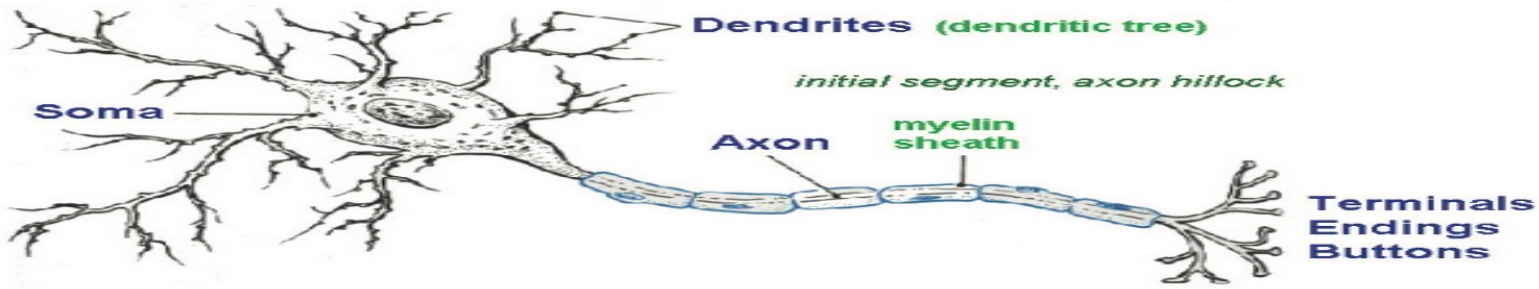


Figure 1.
Structure of neuron.

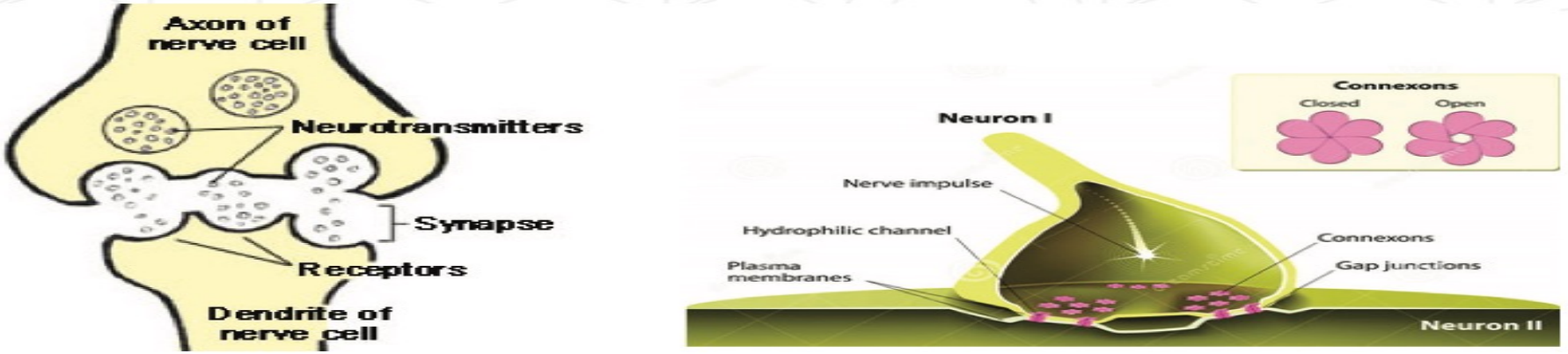


Figure 2.
Structure of chemical and electrical synapse.

Three Major Categories of Neurotransmitters

- Amino acids: The neurotransmitters of this group are involved in fast synaptic transmission and are inhibitory/excitatory in action (primarily glutamic acid, GABA, aspartic acid, and glycine). Amino acids are among the most abundant of all neurotransmitters present within the central nervous system (CNS).
- Amines: Amines are the modified amino acids such as biogenic amines, e.g., catecholamines. The neurotransmitters of this group involve in slow synaptic transmission and are inhibitory and excitatory in action (noradrenaline, adrenaline, dopamine, serotonin, and histamine).
- Others: The one which do not fit in any of these categories (acetylcholine and nitric oxide).

DOI: http://dx.doi.org/10.5772/intechopen.82121

Protein and AA Importance

- The aromatic amino acids (tryptophan, tyrosine, phenylalanine) are the biosynthetic precursors for the neurotransmitters serotonin, dopamine, and norepinephrine.
- Other amino acids active in the CNS and brain include – glutamic acid, aspartic acid, , glutamine, cysteine, methionine, proline, asparagine, GABA, lysine, arginine, glycine, serine, alanine, threonine, beta-alanine.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7503967/

Some Structure Function Roles of AA

Table 1
Metabolic roles of essential amino acids in optimal human health

Essential amino acid	Metabolic roles in addition to protein synthesis
Histidine	Histamine and carnosine synthesis [5]
Isoleucine	Anaphoretic role in citric acid cycle [6]
Leucine	Activation of the mTORC1 pathway; alanine and glutamine synthesis [7,8]
Lysine	Carnitine synthesis (fatty acid oxidation) [4]
Methionine	One-carbon metabolism for RNA and DNA; precursor for cysteine, glutathione, and taurine [9,10]
Phenylalanine	Dopamine synthesis (neurotransmitter) [11]
Threonine	Mucin production within gastrointestinal tract [12]
Tryptophan	Serotonin and nicotinic acid synthesis [4]
Valine	Anaphoretic role in citric acid cycle [6]

Abbreviation: mTORC1, mammalian target of rapamycin complex 1.

The Journal of Nutrition 153 (2023) 2137–2146

Protein Portion and Sleep Quality While Dieting

Randomized Controlled Trial Am J Clin Nutr. 2016 Mar;103(3):766–74.
doi: 10.3945/ajcn.115.124669. Epub 2016 Feb 10.

Higher–protein diets improve indexes of sleep in energy–restricted overweight and obese adults: results from 2 randomized controlled trials

Jing Zhou [1], Jung Eun Kim [1], Cheryl Lh Armstrong [1], Ningning Chen [2], Wayne W Campbell [3]
Affiliations
PMID: 26864362 PMCID: PMC4763499 DOI: 10.3945/ajcn.115.124669

Abstract

Background: Limited and inconsistent research findings exist about the effect of dietary protein intake on indexes of sleep.

Objective: We assessed the effect of protein intake during dietary energy restriction on indexes of sleep in overweight and obese adults in 2 randomized, controlled feeding studies.

Design: For study 1, 14 participants [3 men and 11 women; mean ± SE age: 56 ± 3 y; body mass index (BMI; in kg/m(2)): 30.9 ± 0.6] consumed energy-restricted diets (a 750-kcal/d deficit) with either beef and pork (BP; n = 5) or soy and legume (SL; n = 9) as the main protein sources for 3 consecutive 4-wk periods with 10% (control), 20%, or 30% of total energy from protein (random order). At baseline and the end of each period, the global sleep score (GSS) was assessed with the use of the Pittsburgh Sleep Quality Index (PSQI) questionnaire. For study 2, 44 participants (12 men and 32 women; age: 52 ± 1 y; BMI: 31.4 ± 0.5) consumed a 3-wk baseline energy-balance diet with 0.8 g protein · kg baseline body mass(−1) · d(−1). Then, study 2 subjects consumed either a normal-protein [NP (control); n = 23] or a high-protein (HP; n = 21) (0.8 compared with 1.5 g · kg(−1) · d(−1), respectively) energy-restricted diet (a 750-kcal/d deficit) for 16 wk. The PSQI was administered during baseline week 3 and intervention weeks 4, 8, 12, and 16. GSSs ranged from 0 to 21 arbitrary units (au), with a higher value representing a worse GSS during the preceding month.

Results: In study 1, we showed that a higher protein quantity improved GSSs independent of the protein source. The GSS was higher ($P < 0.05$) when 10% (6.0 ± 0.4 au) compared with 20% (5.0 ± 0.4 au) protein was consumed, with 30% protein (5.4 ± 0.6 au) intermediate. In study 2, at baseline, the GSS was not different between NP (5.2 ± 0.5 au) and HP (5.4 ± 0.5 au) groups. Over time, the GSS was unchanged for the NP group and improved for the HP group (P-group-by-time interaction < 0.05). After intervention (week 16), GSSs for NP and HP groups were 5.9 ± 0.5 and 4.0 ± 0.6 au, respectively ($P < 0.01$).

Conclusion: The consumption of a greater proportion of energy from protein while dieting may improve sleep in overweight and obese adults. This trial was registered at clinicaltrials.gov as NCT01005563 (study 1) and NCT01692860 (study 2).

Lipids (fats)

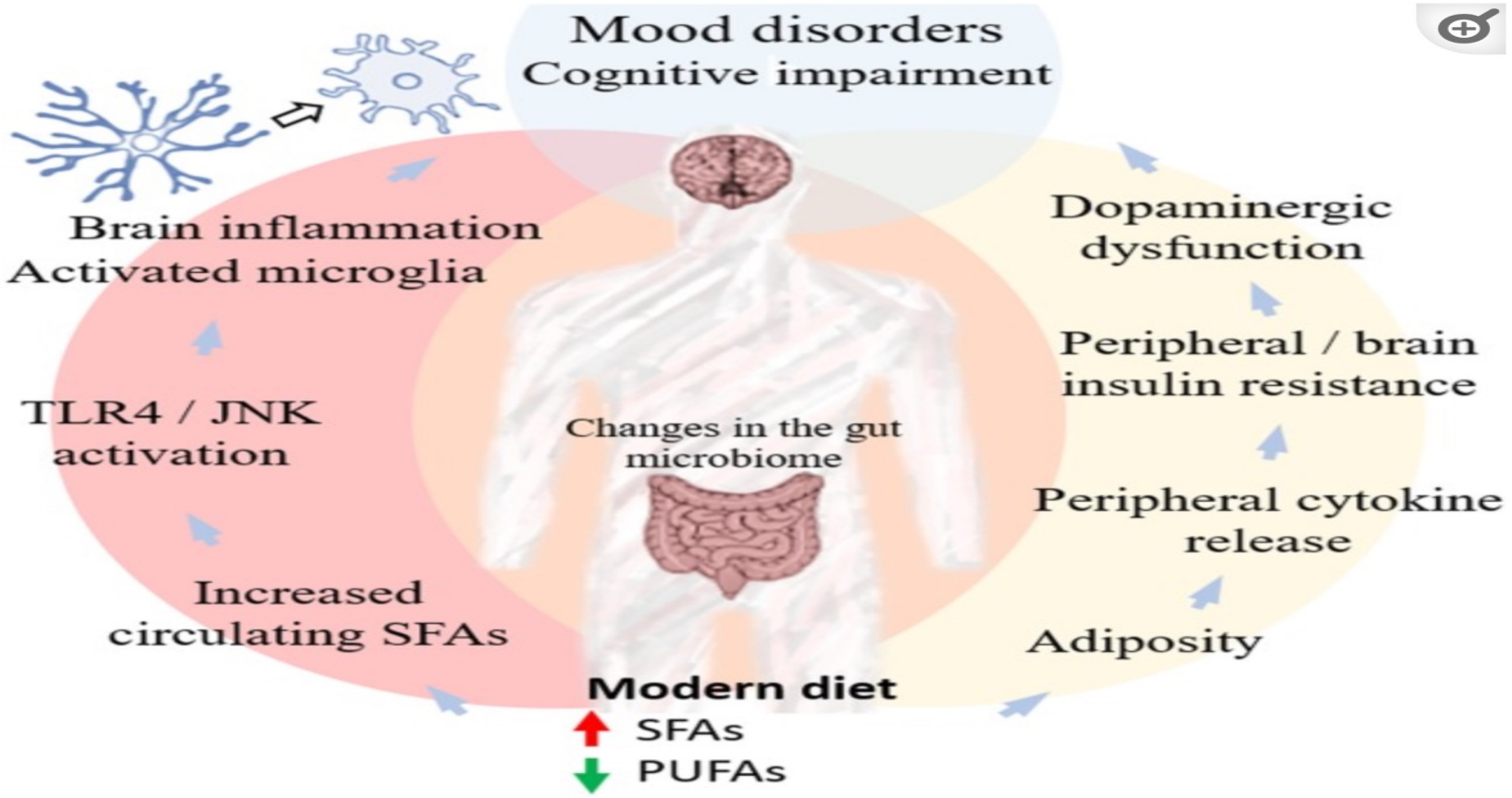
- Dietary lipids (fat) predominately comes in triglyceride form.
- The human storage form of fat is triglyceride.
- Lipids include simple (TG), compound (phospholipid), or derived (cholesterol)
- Dietary Fat Types:
  - Saturated
  - Monounsaturated
  - Polyunsaturated
  - Essential fatty acids (linoleic, alpha linolenic acid)

Lipids and Metabolism

Lipid class	Subtypes
Fatty acyls	Free fatty acids and conjugates; eicosanoids; docosanoids; fatty alcohols, aldehydes and esters
Glycerolipids	Mono-, di-, and triacylglycerols
Glycerophospholipids	Phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine, phosphatidylinositol
Sphingolipids	Ceramide, sphingobases, sphingomyelin, glycosphingolipids (gangliosides)
Sterol lipids	Sterols including cholesterol, steroids, bile acids
Prenol lipids	Isoprenoids, polyprenols, quinones, hopanoids
Saccharolipids	acylaminosugars, acylaminosugar glycans
Polyketides	Macrolide and Aromatic polyketides

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2174836/

Diet, Lipid Type and Mental Health



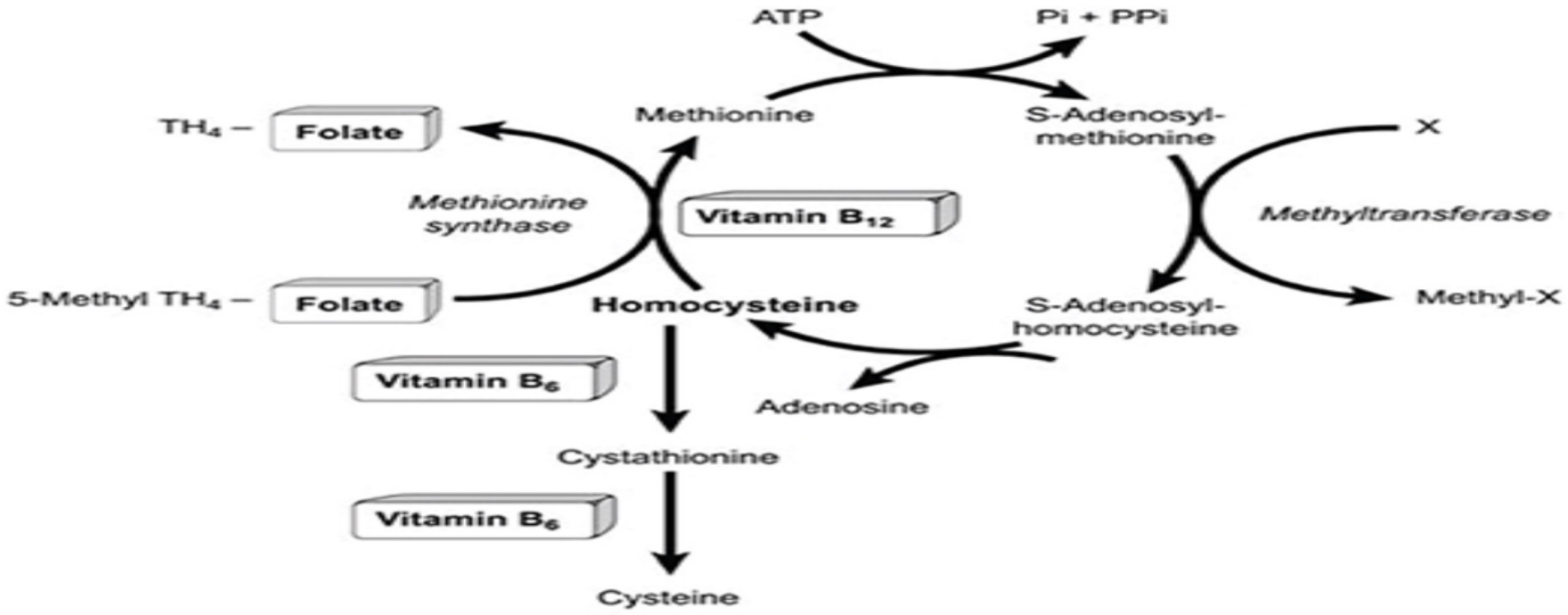
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6448040/

Integrated Nutrition – Brain/CNS Metabolism

- The brain uses 20-25% of REE.
- Energy metabolism of neurons and glial cells includes need for biotin.
- Glucose metabolism requires thiamin, riboflavin, niacin, pantothenic acid & lipoic acid. Magnesium, iron & manganese too.
- Neurotransmitter synthesis also requires thiamin, riboflavin, niacin, B6, folate, B12, vitamin C, zinc and choline.
- Folate & B12 impact integrity of myelin sheath (propagation of nerve impulses), thiamin needed too.

B Vitamins in Homocysteine Metabolism

- ↑ levels of homocysteine is a risk factor for Alzheimer's disease, dementia & CVD.



https://lpi.oregonstate.edu/mic/health-disease/cognitive-function

Often Overlooked

Objective: It remains debated whether anemia is associated with depression, independently of physical health factors. We report a large-scale cross-sectional study examining this association in adults free of chronic disease and medication from the general population.
Method: Hemoglobin levels were measured among 44 173 healthy participants [63% men; mean [standard deviation] age = 38.4 (11.1) years] from the 'Investigations Préventives et Cliniques' (IPC) cohort study. Depression was measured with the Questionnaire of Depression 2nd version, Abridged. Logistic regression analyses were performed to examine the association between anemia and depression, while adjusting for a wide range of sociodemographic characteristics and health-related factors (i.e., sex, age, living status, education level, occupational status, alcohol intake, smoking status, physical activity, and body mass index).
Results: Depressed participants were significantly more likely to have anemia compared to non-depressed participants, even after adjustment for sociodemographic and health-related variables [odds ratio = 1.36; 95% confidence interval = (1.18; 1.57)]. Anemia prevalence increased with depression severity, suggesting a dose–response relationship (*P* for trend <0.001).
Conclusion: In healthy adults from the general population, we found a significant and robust association between depression and anemia. Further studies are needed to assess the longitudinal relationship between both conditions and determine the mechanisms underlying this association.

Acta Psychiatr Scand 2016: 1–11

Iron, Brain Development and Behavioral Health

Over 50 studies demonstrate dietary ID between 6 and 24 months leads to:

- Behavioral abnormalities (Lozoff et al, 2000)
  - Motor and cognitive delays while iron deficient
  - Cognitive delays 19-23 years after iron repletion
    - Arithmetic, writing, school progress, anxiety/depression, social problems and inattention (Lozoff et al, 2000)
  - Characteristic of monoamine and hippocampal dysfunction
- Electrophysiologic abnormalities (delayed ABR latencies)
  - At 6 months while iron deficient (Roncagliolo et al, 1998)
  - At 2-4 years after iron repletion (Algarin et al, 2003)
  - Characteristic of impaired myelination

Source: Iron Deficiency and the Developing Brain
Michael K. Georgieff, M.D. University of Minnesota Masonic Children's Hospital

Hoofbeats, Horses and Zebras

Abstract

Objectives: Thiamine deficiency (TD) presents with various physical and psychiatric symptoms, but no cases with depression-like symptoms have been reported.

Methods: We report a patient with cancer who appeared to attempt suicide as a consequence of depressive mood likely related to TD.

Results: The patient was a 58-year-old woman diagnosed with recurrent endometrial cancer, with lung metastasis and pelvic dissemination. The patient apparently attempted suicide was referred to the psycho-oncology department. At the time of the examination, major depressive disorder was suspected based on her mental symptoms, but when thiamine was administered intravenously in response to her poor dietary intake, her palpitations, dyspnea, anorexia, and insomnia improved, and her suicidal ideation disappeared at her reexamination 1 hour later after thiamine administration.

Significance of results: It is likely that the observed palpitations, dyspnea, anorexia, and insomnia, as well as the severe depression and the attempted suicide, which were thought to be physical symptoms associated with depression, were actually related to TD. Suicidal ideation and attempted suicide are conspicuous as psychiatric symptoms. However, in such cases, rather than simply starting treatment for depression, it is necessary to consider reversible TD as a cause of these symptoms and perform differential diagnosis to confirm the physical illness.

https://pubmed.ncbi.nlm.nih.gov/37496388/

The Nutritional Neurosciences

- Is fascinating!
- Is an emerging area of science.
- Is an emerging area of practice.
- Is an opportunity to think more “whole person”.
- From infancy throughout lifecycle, nutrition matters.
- As science & application grow, so will overall awareness of how nutrition can intimately impact quality of life and more.

Questions?

- Thank you to SupplySide West and Informa Markets for allowing me to be a speaker.
- Do you find this topic interesting?
- I wish to extend special appreciation to Sarah Waschler.
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