Did you know that the brain cells have extremely high requirements for nutrients, especially vitamin C, and that they consume more energy than most other organs?

Although it is only 2% of our body weight, our brain (about 1300 g) claims almost 25% of our whole energy budget. Just imagine: Every day, one quarter of our food we consumed, is used for the need of this organ. Even when we sleep our brain is very active and still demands continuous supply of energy. While most of it (approx. 95%) is needed for maintaining the basic functions of our body, only 5% is used for the—more or less conscious—processing of environmental stimuli.

The work is done by more than 100 billion nerve cells (neurones). These highly specialized cells are capable to produce and transmit electrical impulses. Interconnected by 100 trillion synapses and surrounded by different supporting glial cells they constitute the nervous system.

But the communication among nerve cells is a combination of electrical impulses and specific chemical messengers (neurotransmitter). Prerequisite for the electric conduction is the separation of charge. Like a tiny capacitor, each neuron must therefore permanently provide a difference in concentration of ions inside (negative) and outside (positive charge) of the cell, so that it can fire when necessary. This persistent readiness consumes a lot of energy.

Contrasting to most other cells, the entrance of glucose in neurons doesn’t require insulin. Even more, the capability of the brain to reduce the insulin production in the pancreas if necessary, underlines the importance of glucose for the nervous system. Nevertheless, a nutrition consisting of complex carbohydrates is much more favourable than a sugar-rich meal which only temporarily raises the glucose level in the blood.
Glucose is almost completely oxidized to CO2 and H2O in the mitochondria. Consequently, the efficiency of our brain strongly depends on an optimal blood circulation for the supply of nutrients and oxygen. In fact, it is not surprising that this high-performance organ is also one of the biggest consumers of oxygen from the arteries. Every day, 1,200 litres of blood flow through the brain, providing it with 75 litre of oxygen.

The high energy expenditure is accompanied by an increased formation of free radicals. This oxidative stress can cause damages to cellular components or structures, which is particularly harmful for neurons, since only certain types of nervous tissue are capable to regenerate. Compounds with antioxidant properties—like vitamin C, the lipid-soluble vitamin E and beta-carotene, the amino acid cysteine, polyphenols, etc.—have, consequently, a prominent role for the brain. But besides the protection from free radicals, there are also some other functions where micronutrients are essential:

- energy supply
- synthesis of neurotransmitters
- blood circulation and stabilization of vessels
- proper stimulus transmission

Several B-vitamins are decisive cofactors for both, the production of ATP—the cellular fuel—in the mitochondria, as well as the protein metabolism. Accordingly, a deficiency of vitamin B1 (thiamine) affects all energy-dependent processes. Diminishing attention, tiredness, lethargy or depressive mood can be typical symptoms. Similar applies to a deficiency of vitamin B3 (niacin) which is important for the energy transfer in the respiratory chain. Much less common is a deficiency of vitamin B5 (pantothenic acid) in the brain, which can also cause symptoms like fatigue, headache, insomnia, numbness in the extremities or muscle pain. The coenzyme A is derived from pantothenate, and the high concentration of CoA in the brain, compared to other tissues, shows its importance. Vitamin B2 (riboflavin) is involved in a number of oxidation-reduction reactions and therefore critical for the energy production. In the nervous tissue vitamin B2 is also needed as cofactor for the synthesis of a class of key enzymes called MAO (monoamine oxidases) which inactivate neurotransmitters.

Vitamin B6 (pyridoxine) plays a role in numerous biochemical processes. One of them is the gluconeogenesis, when our blood-sugar level begins to decrease and our body generates glucose from internal storages. In addition, pyridoxine is required as a coenzyme to produce several important neurotransmitters (e.g. dopamine, serotonin, norepinephrine, GABA). Furthermore, along with vitamin B9 (folic acid) and B12 (cobalamin), it helps to control the concentration of homocysteine in the blood. Homocysteine is associated with the development of cardiovascular diseases.

Folic acid also plays a role in cell division. It is vital for the production of red and white blood cells. As it helps prevent birth defects (spina bifida, the imperfect closure of the embryonic neural tube), folic acid is especially important during pregnancy. However, a lack of folate as well as of cobalamin occurs mainly in older adults. Some of the neurological symptoms, ascribed to a long term deficiency of vitamin B12, seem to be irreversible, as they are related to brain atrophy.
Neurotransmitters serve as messengers in the synaptic gap between nerve cells, or nerve cell and effector cell (e.g. muscle). Contrary to the invariable electrical signal transduction, these chemical substances can have modulating effects. However, whether they are excitatory or inhibitory depends on the property of the particular receptor in the receiving (postsynaptic) cell membrane. Although our body is capable to make most of the neurotransmitters alone, various micronutrients are indispensable for this biosynthesis.

<table>
<thead>
<tr>
<th>neurotransmitter</th>
<th>function (for instance)</th>
<th>substrate and (essential) cofactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>dopamine</td>
<td>mental balance; cogitation and cognitive abilities; motor function; reward circuit; blood circulation</td>
<td>amino acid tyrosine (precursor phenylalanine); vitamin B3, B6, B9 and C; iron, copper, calcium</td>
</tr>
<tr>
<td>norepinephrine (noradrenaline)</td>
<td>advertency, vigilance; learning aptitude; blood pressure</td>
<td>dopamine; vitamin B6, B9, B12 and C; copper, magnesium</td>
</tr>
<tr>
<td>epinephrine (adrenaline)</td>
<td>blood pressure</td>
<td>norepinephrine; methionine; vitamin B6, B9, B12 and C</td>
</tr>
<tr>
<td>serotonin</td>
<td>mental balance; sleep-wake cycle; thermoregulation; appetite; pain perception; cognitive abilities and formation of long-term memory</td>
<td>amino acid tryptophane; vitamin B1, B3, B6, B9, B12, and C; iron, zinc, calcium, magnesium</td>
</tr>
<tr>
<td>acetylcholine</td>
<td>learning aptitude; memory; perception; advertency</td>
<td>choline (component of lecithin) or amino acid serine, methionine (as precursors of choline); vitamin B1</td>
</tr>
<tr>
<td>GABA (gamma-aminobutyric acid)</td>
<td>mostly inhibitory; mental balance; pain perception; sleep-wake cycle; ...</td>
<td>glutamate; vitamin B1 and B6; zinc, magnesium</td>
</tr>
</tbody>
</table>

Other micronutrients trigger or act directly as chemical signals. Intracellular calcium induces the release of neurotransmitters when there is an electrical impulse in the neuron. The short-lived nitric oxide (NO), which derives from the amino acid arginine, not only plays a key role in vascular health, but it also works as a messenger between nerve cells, where it obviously promotes interconnections due to a feedback mechanism and therefore enhances memory formation. Also zinc seems to be associated with the development of memory, learning, advertency and behaviour, as it plays a role in synaptic neurotransmission in cooperation with glutamate, the major excitatory messenger in the brain.

Fatty acids and cholesterol are essential components of the membranes of cells. Lipids are most notably needed to build up the myelin sheath, which surrounds the nerve fibres like an isolator and thus accelerates the transduction of electrical impulses. For the synthesis of myelin, one more time, vitamin B6, B12, methionine, as well as iron and copper are required.
In fact, around two-thirds of the nervous tissue is composed of fats, while again two-thirds of the fatty acids in the brain are polyunsaturated. Especially the omega-3 fatty acids are valuable, as they impart to membranes flexibility and permeability, which is necessary for an optimal signal propagation.\textsuperscript{9} Additionally, omega-3 fatty acids are known to reduce inflammations.\textsuperscript{10}

As mentioned before, an adequate blood circulation is crucial for the brain. Hence, the stability and flexibility of the blood vessel walls is important. Here, lysine, proline, vitamin C, NAc-glucosamine and chondroitin sulphate are key components for the connective tissue. Because vitamin B12 also plays a role in the formation of the red blood cells, a deficiency can impair the oxygen-transport, a disease known as pernicious anaemia. Iron as oxygen-carrying site of the haemoglobin, should, as well, not be forgotten, as another essential mineral to maintain a proper brain function.

Of course, nothing would run without water. Therefore, drinking enough water all day long is equally fundamental for our brain as to ensure that we eat healthy. Everyone knows that copious meals strain the body with digestion, making us drowsy. Smaller and varied meals that are evenly distributed throughout the day are therefore a good way to maintain brain's efficiency. In the first place everyone should refrain from substances that cause damage to the cells. This includes smoking and an overreaching consuming of alcohol.

\textit{Synergy – a principle of life}

Now, that we have seen that tens of micronutrients are so essential for the proper and optimum function of the most important organ—the brain—we should definitely also see how all these micronutrients will bring the optimum effect. The key here is the well scientifically tested \textit{principle of synergy} according to which the maximum possible health benefits of micronutrients is achieved by combining them in groups. Many biological components work together within cells to achieve a desired biological result. So, in other words, synergy is the mutually enhancing interaction between individual micronutrients to obtain a greater health benefit. By studying micronutrient synergy we learned that our bodies do not need extremely high doses of individual vitamins or micronutrients. Optimum health benefits are rather obtained by combining moderate quantities of specific cellular nutrients together to create biological synergies. Synergy also means that the effectiveness of this group of biological components working together is greater than the sum of its individual parts.

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