On Human Metabolism

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At school, you learn the basics of human physiology. For example, you learn that there are organs that perform various vital tasks—the heart pumps blood through the body, the lungs breathe in air, and the brain controls everything. As nice as it is to learn these facts at school, it is unsatisfactory in that the lessons only scratch the surface and leave important questions about the "why" unanswered. In the following article, I would like to explore these aspects of metabolism in a little more depth.

Why Do We Drink?

Humans are multicellular organisms consisting of numerous cells, i.e., spaces enclosed by a membrane, which in turn contain a nucleus and numerous organelles. In the course of evolution, these multicellular organisms have developed from single-celled organisms that originally lived in water. They are therefore accustomed to an aqueous environment; indeed they need it to live. This is the reason why humans also need fluids. It is not for nothing that the average human body consists of around 60% water.

The fluid balance is closely linked to the salt balance (salts are also referred to as electrolytes in this context because they can conduct electricity). Salts occur in liquids in dissolved form. The quotient of the amount of dissolved substance divided by the volume of the liquid is known as the concentration. The osmotic pressure that the salt exerts on the cell membrane depends on this concentration. Osmosis is diffusion through a semi-permeable membrane; in this case, the cell membrane is called semi-permeable because liquid can easily pass through it, but salt less so.

It is unhealthy to drink pure (distilled) water precisely because of this osmotic pressure. If the surrounding fluid contains salt in a lower concentration than the fluid inside the cell, the surrounding fluid is called hypotonic. A spontaneous equalization of pressure occurs; since only water can diffuse through the cell membrane, this means that water flows into the cell. The result is that the cell swells, which can lead to its bursting (lysis). Conversely, if the surrounding fluid contains too much salt (i.e., is hypertonic), water flows out of the cell and the cell shrinks. It is therefore vital that the salt in the extracellular fluid is present in exactly the right concentration. This is regulated by fluid intake (stimulated by the feeling of thirst) and excretion (stimulated by the urge to urinate).

It is not enough to take in a lot of fluid just once in a lifetime and then neither drink nor excrete urine for the rest of your life. This is because the human organism is constantly changing, especially, but not only, during the growth phase. The organism must therefore constantly adapt to new requirements. In addition, food also contains substances with metabolic end products that are water-soluble and are therefore best excreted in the urine.

Why Do We Breathe?

At school, we learn that the air contains oxygen and that this element is essential for life. At some point in biology lessons, a formula is given that explains how this oxygen is used:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O.$$

This formula is as simple as it is meaningless. We take in sugar ($C_6H_{12}O_6$) and burn it with oxygen (O_2) to produce carbon dioxide (CO_2), which is exhaled, as well as water (H_2O), which we take in anyway by drinking. What is the point of this?

The answer is that it is a simplified representation of the metabolic processes in which oxygen and sugar are involved. It may be true that the end products of all these processes are carbon dioxide and water, but the intermediate products are much more important in this case.

Basically, many chemical reactions take place in human body cells that are necessary to keep humans alive—for example, when it comes to translating genes into proteins or converting certain substances into each other to make them transportable. Chemists distinguish between reactions that consume energy (endergonic reactions) and those that release energy (exergonic reactions). Reactions that consume energy must be supplied with energy to make them possible. This is usually done by first triggering an exergonic reaction, which releases the necessary energy. One such exergonic reaction is the splitting off of a phosphate group from the energy-rich compound adenosine triphosphate (ATP): ATP -> ADP + Pi.

ATP is considered the "energy currency of the human organism," because this molecule can be easily transported from cell to cell and also from compartment to compartment within a cell. It can therefore be shipped to exactly where energy is needed.

To obtain ATP, the reverse reaction ADP + Pi is carried out in the mitochondria of the cell, which is of course highly endergonic. Oxygen is required to provide the necessary energy.

You can imagine the entire human metabolism as a network of roads with a traffic circle in the middle: the citric acid cycle. Many roads lead to it, and many roads lead away from it. One leading path is glycolysis, the breakdown of sugar to a compound called pyruvate. This pyruvate is then converted into succinate in the cycle with the help of various enzymes and cosubstrates, and with this we have already entered a leading pathway: the respiratory chain (oxidative phosphorylation). A proton gradient is established across the inner mitochondrial membrane by transferring electrons from one molecule to another, and the influx of protons into the innermost layer of the mitochondria releases the energy required by the enzyme ATP synthetase to catalyze the reaction ADP + Pi -> ATP. Oxygen is needed because it is present in this electron transport chain: as the last step before ATP synthesis, two electrons are transferred to the oxygen. Without oxygen, it would not be possible to synthesize ATP.

Why Do We Eat?

This question is easy to answer: oxygen alone is not enough to produce ATP; another substance is needed to enter the citric acid cycle, such as sugar. Apart from glycolysis, however, many other metabolic pathways lead to the citric acid cycle.

We also need fats to build and maintain the cell membrane, which consists largely of cholesterol. Numerous hormones (messenger substances in the human organism) are also fats.

Proteins are essential for the functioning of the organism. Almost all gene products are ultimately proteins. These can only be formed by the organism if it is supplied with the corresponding amino acids, from which it can then synthesize the proteins.

And let's not forget the vitamins, a chemically heterogeneous group of substances that humans cannot produce on their own and therefore must be supplied through the intake of food.

Conclusion

I hope that I have given a somewhat more thorough introduction to human metabolism than is normally given at school. I invite those who want to learn more about the subject to read textbooks on biochemistry. One book I'd recommend is this:
https://www.amazon.com/Biochemistry-Jeremy-M-Berg/dp/1319114652