Adenosine triphosphate

Adenosine triphosphate (ATP, systematic name ((2R,3S,4R,5R)-5-(6-amino-9H-purin-9-yl)-3,4-dihydroxytetrahydrofuran-2-yl)methyl hydrogen triphosphate) is called: **macroergic compound**, from which a large amount of energy can be released. It is needed in the body for various energy-intensive processes (active transport, muscle contraction etc.). We can thus conclude that the ATP molecule serves as a universal source of energy in the body**.**

ATP hydrolysis produces adenosine diphosphate (**ADP**), which can still be split for energy. This is a **significantly exergonic event**. Cleavage of ADP produces adenosine monophosphate, a molecule that cannot be cleaved anymore (**AMP**). Most ATP is generated during respiratory chain, smaller amounts during other reactions (so called at the substrate level).

ATP was first isolated by K. Lohmann from muscle extract in 1929.[1] It was first artificially prepared in 1948 by Alexander Todd.

Structure

ATP is nucleotide, which belongs to the group of adenosine phosphates. It is made up of adenine, ribose and triphosphoric acid. It belongs to the group of so-called. **5' ribonucleotides**, which means that the phosphate groups are attached to the 5' carbon. It is between adenine and ribose **N-glycosidic** bond, the phosphate groups are linked **anhydrides** bonds, and attached to ribose by a bond **phosphodiester**.

Process of obtaining energy

The ATP molecule provides **storage and transfer** chemical free energy v cell. Its cleavage (by transferases, hydrolases and ligases) produces ADP or AMP. If it is cleaved by adenylate cyclase, it produces cAMP, which is important for cell signaling. ATP is also an inhibitor of catabolic pathways, esp citrate cycle and glycolysis.[2]

Energy is released **from the anhydride bonds of phosphates**. First, there is **substrate phosphorylation**, thereby releasing ADP. The phosphorylated product is rich in energy. In the next phase, it reacts with another reactant, at the present time **release of phosphate anion**. Binding of inorganic monophosphate $H_2PO_4^-$ (P_i) a difosfátu $H_2P_2O_7^{2-}$ (PP_i) will enable the activation of substrates that are able to phosphorylate other compounds.[3]

The adenosine part of ATP has a recognition function. Used to **binding to enzyme molecules**, which use ATP as a cofactor.[1]

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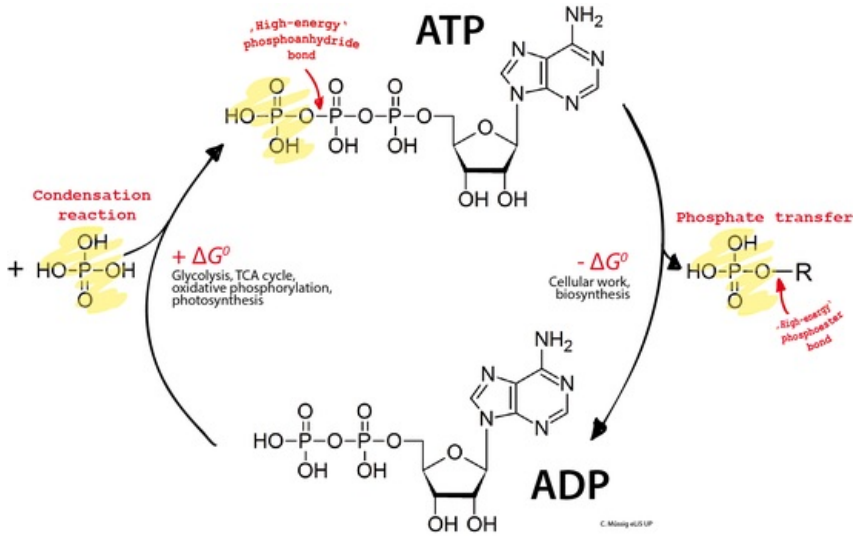

ATP hydrolysis cycle

Use

ATP is usually found intracellularly. Its concentration varies according to the energy demand of the tissue. It usually ranges around values **1–10 mmol/l**. It can also be found in small amounts in tissue fluid and blood.

It serves as a source of phosphate groups for **phosphorylation**, in the initial stages of glycolysis and as a nuclear base for **nucleic acid synthesis**. At the same time, it is necessary for many energy-demanding physiological processes, such as. active transport, synaptic transmission or muscle contraction.[3]

Importance of ATP and other adenosine phosphates (ADP, AMP) is essential for the energy balance of cells. Current intracellular concentrations of these molecules can be calculated by the so-called. **energy charge(EN)**, which expresses the energy state of the entire cell. Values range from 0 to 1.[4]

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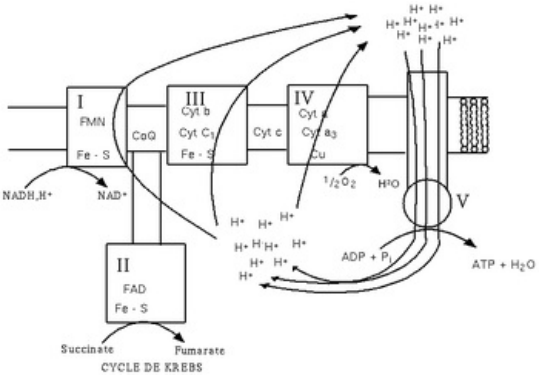
Synthesis of ATP

MA molecule of ATP is created from a molecule **ADP** and **P_i**. Among the processes during which it can arise we include:

- **oxidative phosphorylation and photophosphorylation** (ADP + P_i → ATP + H_2O);
- **substrate phosphorylation** in metabolism carbohydrates (substrát-OPO_3^{2-} + ADP → substrate + ATP);* and **adenylate kinase reaction** (AMP is converted to ADP by the action of adenylate kinase, forming two molecules of ADP, which are converted into ATP).[3]

Oxidative phosphorylation

This term is used for ATP synthesis at the inner membranemitochondria during the respiratory chain. There is a transfer of electrons from the Krebs cycle(NADH, $FADH_2$) on oxygen. Electrons are transferred through a coupled system of oxidation and reduction on oxidoreductase complexes. These complexes also serve as **proton pumps**. [5]



Oxidative phosphorylation

Transmission H^+ from the mitochondrial matrix through the inner mitochondrial membrane, causing a drop in pH on the side of increased proton concentration.[6]

By this mechanism it arises **electrochemical proton potential.** ***Přenosem of electrons obtained from*** *NADH'* it is thus transferred to the outer side of the inner mitochondrial membrane **10 protons** (of $FADH_2$ 6 protons). ATP-synthase consumes during the synthesis of new molecules **4 protons**.

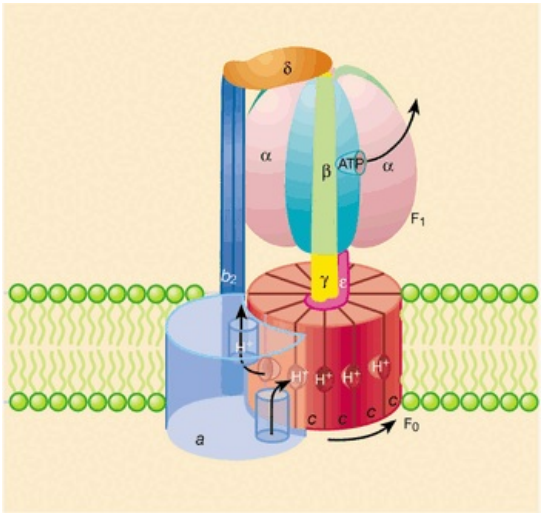
It follows that:

- **1 NADH = 2,5 ATP** (10:4)
- **1 $FADH_2$ = 1,5 ATP** (6:4).

🔎 *For more information see Respiratory chain.*

ATP-synthase

Peter Mitchell, who in 1961 proposed that the energy of the proton gradient across the inner mitochondrial membrane is used to phosphorylate ADP, was responsible for explaining the principle of ATP-synthase (complex V) function. It took another 17 years for this view to be appreciated and accepted, and so John Mitchell was awarded the Nobel Prize 17 years later for this discovery. Today, his hypothesis has already been confirmed and there is an explanation of how ATP synthase converts the electrochemical potential into the energy-rich anhydride bond in ATP. Boyer and Walker won the Nobel Prize in 1997 for elucidating the function of ATP synthase . [5]



Structure of ATP-synthase

ATP-synthase is composed of 2 parts::

- **F0 (proton channel)** – taken into the mitochondrial membrane, composed of several subunits.
  - Subunit a, which contains 2 hemichannels, sits laterally on the hydrophobic cylindrical complex of subunits c. This subunit is bound by other subunits that prevent it from moving, so it behaves like a **stator**.
  - Cylindrical c-subunit complex that rotates about its longitudinal axis in the lipid bilayer, behaving like a**rotor**. In the middle of each subunit c is an aspartate molecule, to which the channels of the subunit a bind. [5]

- **F1(catalytic center of ATP-synthase) .**
  - The three subunits α and β form the core of the F1 part. **The β subunits** have catalytic activity, and during the rotation of the hydrophobic cylinder, they cyclically change their conformation, thereby enabling the synthesis of ATP.
  - The δ subunit connects F1 to the stator.
  - The γ subunit serves as an extension of the rotor of the F0 part, allowing the β subunit to change conformation and thereby **convert mechanical energy into macroergic compound energy .**.
    - Conformation L (*loose*, relaxed), ADP and inorganic phosphate are bound to the β subunit.
    - Conformation T (*tight*, těsná), β subunit binds ADP + P so strongly that ATP synthesis is accelerated.
    - Conformation O (*open*, otevřená), the β subunit releases the newly formed ATP.

On the F0 part, all the aspartates of the c units are hydrophobic and are located in the membrane, which will prevent the dissociation of their carboxyl groups (-COOH). Aspartates, which contact both channels of the subunit and behave hydrophilic, are therefore dissociated ($-COO^-$).

Thanks to the proton gradient, H^+ passes from the intermembrane space through the **outer channel of subunit a**. It binds to aspartate, changing its hydrophilic character to undissociated (hydrophobic, -COOH), and the entire cylinder is thus rotated**by one c subunit** in a clockwise direction. This results in the rotation of the second dissociated aspartate, which moves into the place of the first. Meanwhile, one undissociated aspartate from the other side turns to the a subunit. H^+ from the carboxyl of this aspartate dissociates and passes through the second channel into the mitochondrial matrix (with a lower concentration of protons). This causes one proton to pass through**the outer channel of the α subunit**, which binds to another aspartate and rotates together with the rotor through 360°. After one rotation of the rotor, it passes through**the inner channel of subunit a**, and enters the mitochondrial matrix. This mechanism causes the rotor to rotate continuously, until the **concentration of protons on both sides of the membrane is balanced**. [5]

ATP is released into the mitochondrial matrix and then transported to the cytoplasm. This is achieved by a transporter (ADP-ATP-translocase) inside the mitochondrial membrane. Together with ADP, P_i and H^+ are symported into the mitochondrial matrix. For **one molecule of ATP** in the cytosol, the proton gradient must provide a total of **four protons** (3 protons for ATP synthesis and 1 proton for P_i^- a H^+).

From one molecule of NADH, which provides 10 protons **2,5 ATP** (10 : 4), and six protons formed by oxidation are created. The $FADH_2$ molecule provides energy for the synthesis of **1,5 ATP** (6 : 4).[5]

Stores in the organism

The ATP molecule is not able to create reserves by itself, due to its high instability. A quick source of energy for the organism is the more stable molecule creatine phosphate, which can be easily split into ATP molecules when needed. Creatine phosphate is formed when there is an excessive amount of energy, and it is stored in the muscles. If its immediate value is not sufficient for energy-demanding processes, the organism obtains quickly available energy from muscle or liver glycogenu.[3]

Links

related articles

- Active transport
- Ion pumps
- Sodium-potassium pump
- Mitochondria
- Gradient
- Potential

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