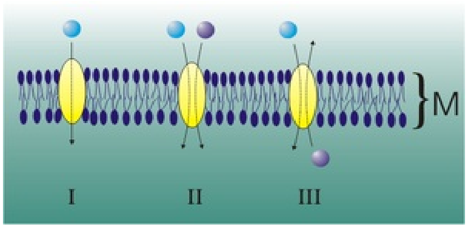
Ion pumps

Ion pumps are **penetrating integral proteins in the cell membrane**:

- contain the enzyme ATPase;
- mediate the active transport of substances.

Active transport

Creates a concentration gradient..[1]



I – uniport, II – symport, III – antiport

There are 2 types of active transport

1. *Primary active transport*:
   - It is used for the transfer of substances against their gradient, consuming energy from ATP, or other high energy phosphate bonds (creatine phosphate CP – in muscle; derivatives of pyrimidine and purine bases – guanosine triphosphate GTP, cytidine triphosphate CTP...).
   - Substances transmitted in this way include sodium, potassium, calcium, hydrogen and other ions.
2. *Secondary active transport*:
   - It combines the movement of several molecules:
     1. **cotransport** – transfers two or more molecules in the same direction = **symport**;
     2. opposite (counter) transport – transmits molecules in the opposite direction = **antiport**.
   - Another possibility is that the gradient generated by the transfer of one molecule will allow the transfer of another molecule against its gradient. (E.g. Na-K-ATPase transport creates a powerful Na gradient that allows secondary active transport of many molecules, e.g. glucose.)

- For more information see related article.

Pump types

Sodium-potassium pump

The NA/K pump (also Na/K-ATPase, Na-K-ATPase, etc.) is the most widely used type of **active carrier**. It is found in the cell membrane of most cells of the human body.

Function

- Draws sodium from the intracellular space to the extracellular space.
- It pumps potassium from the extracellular space to the intracellular space.

The transfer of ions takes place against the concentration gradient. The pump works electrogenically because it transmits 3 Na against 2 K, thus maintaining an uneven distribution of sodium and potassium on both sides of the cell membrane. This fact is essential for the formation and spread of electrical signal in nerve and muscle cells. In addition, the pump regulates the volume of the cell – without its function, the cells would swell and could burst:

- Inside the cell there are macromolecular substances that can not pass through the membrane (e.g. proteins and other organic compounds). Most of these substances have a negative charge and therefore attract positive ions such as Na and K – this would in the absence of a sodium-potassium pump induce the transfer of water to the cell after the osmotic gradient. Na/K-ATPase depletes from cell 3 Na ions and pumps 2 K ions inwards. The membrane is little permeable to Na ions, which tend to remain outside the cell. This mechanism leads to the loss of ions from the cell and to the balancing of osmotic forces, thereby preventing the cell volume from increasing. Any swelling of the cell activates Na/K-ATPases.[2]

Construction

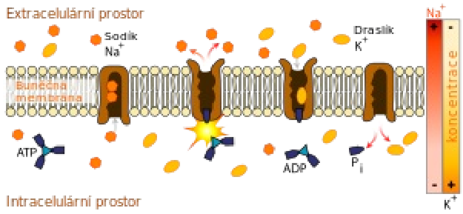
The pump consists of two subunits – alpha and beta. Both subunits are substances of a protein nature that pass through the cell membrane. Alpha subunit transports ions and has ATPase activity, the function of the beta subunit is probably to anchor the pump in the cell membrane. On the intracellular side of the alpha subunit there are binding points for Na and ATP, on the extracellular side there are binding places for K^{+}.

Transport mechanism

After binding 3 Na and 2 K, ATPase is activated – the released energy from the ATP split will cause a change in the structure of the protein and the transfer of sodium ions outside the cell and potassium inside the cell.

For nerve cells, up to 70% of their energy can be consumed by this pump.

Calcium pump



Sodium-potassium pump function scheme

In a normal situation, calcium ions outside the cell are at about 10,000 × concentration, this level inside the cell is provided by calcium pumps in two places:

1. on the cell membrane – transports calcium cations out of the cell;
2. on the membranes of cellular **organelles** (mitochondria and sarcoplasmic reticulum) in muscle tissue – transports Ca^{2+} cations into organelles (these organelles are then an important source of Ca^{2+} cations for muscle activity).

- It works on the same principle as the Na-K pump, has a receptor for Ca^{2+} and the place of active ATPases.

Hydrogen/Proton Pump

An important function is performed in particular by:

- **In the gastric glands**:
  - Here, the pumps are most active throughout the body, thanks to which HCl is excreted in the stomach, so that at the secretion end of the parietal cells in the gastric glands, the H concentration is increased about a million times thanks to these pumps, and then these ions are released into the stomach together with chloride anions – the formation of HCl.
- **In the distal tubules and cortical collection ducts of the kidney**:
  - Excess **hydrogen cations** are transported from the blood to the lumen of the canal (to the urine) – this also maintains acid-base balance of the organism (acidify urine).

Notes

1. In other words, active transport takes place in the direction of the gradient. (The gradient vector is directed to a place with a higher concentration, i.e. how the concentration gradates) A widespread mistake to the contrary stems from a confusion between the concepts of concentration gradient and concentration gradient – both pointing against each other. It is therefore more certain to claim that active transport takes place against the direction of the concentration gradient – this is intuitively understood by most people, as opposed to the concept of gradient, which is a physical term defined on the basis of partial derivatives in space – by the operator nabla ∇.. See gradient. Active transport is directed against passive transport caused by diffusion, which is currently taking place against the direction of the gradient (this is the minus signfick's law).
2. E. HALL, John. *Textbook of Medical Physiology.* 12. edition. Saunders, 2010. 1120 pp. ISBN 978-1-4160-4574-8.

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