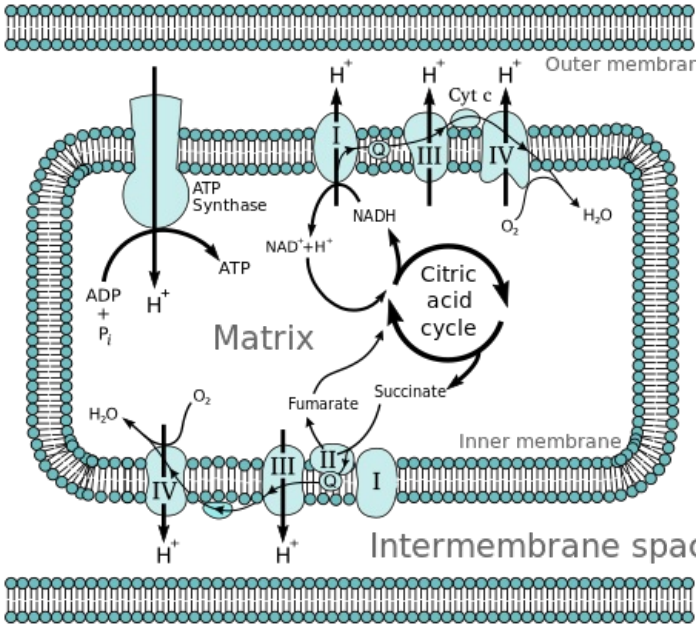
Respiratory chain

The respiratory chain is the terminal sequence of reactions of cellular respiration, which have the task of ensuring the formation of ATP. It uses reduced coenzymes, the transfer of electrons and protons through specific complexes. The product of the chain is energy, heat and water.



Respiratory chain in general

The localization of the chain is on the inner membrane of mitochondria, to ensure the supply of reduced coenzymes from the citrate cycle and β-oxidation. It is manifested by the gradual release of energy, which is stored by **aerobic phosphorylation** in ATP with an efficiency of around 70%.

The intensity of cellular respiration is dependent on the number of cristae in the mitochondria. In energy-stressed cells (e.g. myocardium) there is a high number of mitochondria with a high number of cristae. This enables a higher supply of oxygen, which in the final stage of the chain combines with hydrogen to form water.

The inner membrane of the mitochondrion is highly selective for permeability - this allows the formation of **concentration gradients**, which is essential in maintaining the gradient of hydrogen cations H^+. The electron carriers are not arranged randomly in the chain, but according to the values of the redox potential from the most negative to the most positive. [1]

Components of the respiratory chain [2]

They are generally substances capable of transferring electrons and protons. Among them we include:

Coenzymes:

- Pyridine coenzyme **NADH+H$^+$** – the main electron donor in the respiratory chain
- Flavin coenzyme **FADH$_2$** – secondary electron donor in the respiratory chain
- **Coenzyme Q (ubiquinone)** – freely mobile (hydrophobic) derivative of hydroquinone, its function is to bind electrons and protons and thereby reduce it to **ubiquinol**
- **FeS-protein** – a protein with an electron transporting center
- **Cytochromes** – ferric dyes capable of transferring electrons
- **Cytochrome oxidase** – the last complex of cytochromes, is capable of transferring electrons to oxygen and thereby reacting with hydrogens to create water

In addition to these important components, there are proteins that are referred to as **transmembrane complexes**:

- **complex I** – NADH-ubiquinone reductase (NADH-dehydrogenase – input NADH+H$^+$)
- **complex II** – succinate-ubiquinone reductase (input FADH$_2$)
- **complex III** – ubiquinol-cytochrome c-reductase
- **complex IV** – cytochrome c-oxidase
- (***complex V***) – sometimes referred to as **F$_0$F$_1$-ATP-synthase**

The principle of the respiratory chain

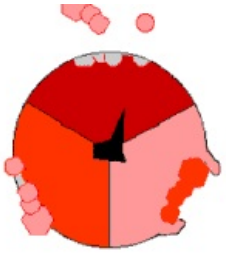
The principle itself is considered by the **chemiosmotic hypothesis**, jas it has not yet been clarified in detail.

Electrons from the flavin and pyridine coenzymes are transferred through the carrier system, thereby providing energy for the formation of **an electrochemical proton gradient.** It is created with the help of **complexes**, that pump hydrogen cations from the mitochondrial matrix into the intermembrane space. **ATP-synthase** forms the only possible pathway under normal conditions where protons can return back to the matrix. Thanks to the high gradient, the energy of the released protons is used to synthesize **ATP** from ADP+P$_i$.

Overview of reactions and yields [3]

1. **complex I** creates the entry of the pyridine coenzyme **NADH+H$^+$** into the system, taking two electrons and two protons from the coenzyme. These electrons are transferred to coenzyme Q. The energy of electron transfer is sufficient to pump 4H$^+$ into the intermembrane space (2 protons from NADH+H$^+$ coenzymes + two normally present protons).
2. **complex II** creates the entry of the flavin coenzyme **$FADH_2$** into the system. However, by transferring its electrons to complex III, proton pumping from complex I is bypassed.
3. **coenzyme Q** donates 2 electrons to **complex III** (cyt c-reductase) – two more protons are pumped into the intermembrane space
4. **complex IV** (cyt c-oxidase) accepts two electrons from complex III and transfers these electrons to **oxygen**. It immediately reacts with free protons to form **water**. At the same time, energy is released to transfer 4H$^+$ to the intermembrane space.

The result of the respiratory chain is: [4]



- reoxidation of reduced equivalents (NADH+H$^+$ and $FADH_2$)
- the creation of water
- transfer of 10H$^+$ to the intermembrane space in the case of using NADH+H$^+$
- 6H$^+$ transfer if $FADH_2$ is used

The final step is aerobic phosphorylation, when the F_0F^{1-}ATPase releases protons into the mitochondrial matrix to generate ATP. For every **4 protons 1 ATP is created**.

- 1xNADH+H$^+$ = 2,5 ATP
- 1x$FADH_2$ = 1,5 ATP

Uncoupling proteins [5]

Uncoupling proteins – proteins in the inner mitochondrial membrane that allow protons to pass from the intermembrane space back into the matrix without generating ATP, only with the generation of **heat**. They are most often found shortly after birth in brown adipose tissue. A representative is, for example, **thermogenin** or the previously used poisonous 2,4-dinitrophenol. Thyroid hormones also have the function of uncouplers.

Links

External links

- Study text for secondary schools (http://www.studiumbiochemie.cz/dr.html#0)

▶Video of ATP-synthase mechanism (https://www.youtube.com/watch?v=PjdPTY1wHdQ) (English)

Related articles

- Mitochondria
- Citrate cycle
- β-oxidation
- Regulation of individual metabolic pathways

Used literature

- LEDVINA, Miroslav. *Biochemie pro studující medicíny. I. díl.* 2. edition. Karolinum, 0000. vol. 269. pp. 85-95. ISBN 978-80-246-1416-8.
- DUŠKA, František. *Biochemie v souvislostech, 1.díl – základy energetického metabolizmu.* 1. edition. Karolinum, 2006. vol. 165. pp. 29-34. ISBN 80-246-1116-3.

Reference

1. DUŠKA, František. *Biochemie v souvislostech, 1.díl – základy energetického metabolizmu.* 1. edition. Karolinum, 2006. vol. 165. pp. 30. ISBN 80-246-1116-3.
2. LEDVINA, Miroslav. *Biochemie pro studující medicíny. I. díl.* 2. edition. Karolinum, 0000. 269 pp. pp. 87-90. ISBN 978-80-246-1416-8.
3. DUŠKA, František. *Biochemie v souvislostech, 1.díl – základy energetického metabolizmu.* 1. edition. Karolinum, 2006. 165 pp. pp. 30-32. ISBN 80-246-1116-3.
4. DUŠKA, František. *Biochemie v souvislostech, 1.díl – základy energetického metabolizmu.* 1. edition. Karolinum, 2006. vol. 165. pp. 32. ISBN 80-246-1116-3.
5. DUŠKA, František. *Biochemie v souvislostech, 1.díl – základy energetického metabolizmu.* 1. edition. Karolinum, 2006. vol. 165. pp. 33. ISBN 80-246-1116-3.