Energy system of the cell

Cells exhibit a variety of functions (growth, movement, synthetic activity...) that require energy. Metabolism, i.e. the set of all enzyme reactions during which substances and energy are converted, is one of the basic manifestations of life. The ultimate source of energy for all eukaryotic cells is the Sun. Depending on whether they obtain it directly or indirectly, we can divide them into:

- Phototrophic - obtain energy from light through photosynthesis.
- Chemotrophic - obtain energy for the synthesis of organic compounds by breaking down substances they receive from the environment.

We can further divide cells according to the source from which they obtain carbon

- **Autotrophy** - These organisms obtain carbon from inorganic substances (usually carbon dioxide) and synthesize carbon chains from it. see photosynthesis
- **Heterotrophy** - organic substances are the source of carbon for the formation of one's own carbon chains.
- **Mixotropy** - a combination of autotrophy and heterotrophy.

Metabolism

Metabolism is a set of all enzyme reactions (so-called metabolic pathways) during which substances and energy are transformed in cells and living organisms. According to the direction of the ongoing change that occurs with a complex organic molecule, we divide metabolism into anabolism (building process, biosynthesis) and catabolism (decomposition of more complex substances).

a) **Catabolism** – decomposition, dissimilation processes

- is a set of decomposition events during which simpler substances (catabolites) are formed from more complex substances.

- during catabolism, macromolecules are split into smaller molecules with the simultaneous release of a corresponding amount of energy
- provides building material and energy for biosynthetic reactions
- belongs to exergonic reactions
- from the chemical point of view, it is mostly oxidation
- catabolism is regulated by the level of ATP and NADH+H+ in the cell

b) **Anabolism** – synthetic, assimilation events

- during anabolism, more complex macromolecules are formed from simpler ones
- have an endergonic character – energy is consumed (the energy source for these reactions is mainly ATP)
- most reactions of anabolism take place in the cytoplasm
- from the chemical point of view, these are mainly reductions

Bioenergetics

File:Entropy-01.png
Entropy

Cells are chemical systems that must obey all chemical and physical laws. Applies to:

First law of thermodynamics (law of conservation of energy)

The second law of thermodynamics (systems spontaneously change towards higher entropy)

Living cells create order in their struggle to survive and in their reproduction and formation of complex organisms, and thus might seem to defy the second law of thermodynamics. How is it possible? The answer is simple: **the cell is not an isolated system**.

In the course of chemical reactions leading to higher order, part of the energy used by the cell turns into heat. This heat dissipates into the cell's surroundings and increases its disorder, so that the total entropy of the cell and surroundings increases just as the laws of physics require.

Gibbs energy (G)

$G = H - TS$ T is thermodynamic temperature, S is entropy, H is enthalpy

- Molecules in a living cell are equipped with energy due to their vibrations, rotations and due to the energy stored in their chemical bonds.
- Free energy (G) represents the energy of a molecule that could be used to do useful work at constant temperature. G is measured in kJ/mol.

ΔG - indicates the change in free energy during the reaction

Exergonic processes: ΔG < 0

- energy is generated
- they take place spontaneously
- catabolism

Endergonic events: ΔG > 0

- the need for energy supply
- they do not occur spontaneously - only as coupled reactions
- anabolism

Coupled reactions

- combination of endergonic and exergonic reactions.
- reactions can be coupled if they share at least one common intermediate.
- the resulting change in free energy is equal to the sum of the individual values of ΔG
- a reaction that has a positive free energy change is driven by a reaction with an absolutely larger negative free energy value.

Methods of obtaining energy from nutrients

The specific energy pathways used by a cell depend on whether the cell is prokaryotic or eukaryotic. **Eukaryotic animal cells** (which this article is primarily concerned with for the needs of medical students) use **three main processes** transformation of energy into more quickly usable forms (discussed below). In general, however, it can be said that they release the energy stored in food molecules through a series of oxidative reactions. Oxidation is a type of chemical reaction in which electrons are transported from one molecule to another, changing the composition of both molecules. The food molecule acts as a donor here. During each oxidation reaction involved in the decomposition of food, the product has a lower energy than the reactant entering it. At the same time, the acceptor molecules store some of this energy for the next use. Originally large macromolecules leave the metabolic pathway as a waste product in the form of carbon dioxide. Adenosine 5'-triphosphate, or ATP, is the most abundant cellular energy carrier.

Complex organic molecules such as sugars, fats and proteins are rich sources of energy for cells, which is stored here in the form of chemical bonds. The amount of energy contained in a substance can be measured with a simple device - a calorimeter. The following values were set for individual substances consumed by humans:

Food ingredient	Energy in kJ/g	Energy in kcal/g
Fats	37	9
Etanol (potable alcohol)	29	7
Carbohydrates	17	4
Proteins	17	4
Organic acids	13	3
Polyols (polyhydric alcohols, sweeteners)	10	2,4
Fiber	8	2

Energy storage

In case of excess energy eukaryotic cells create large molecules and complexes of molecules for the purpose of storing it. The resulting polysaccharides and lipids are then held in reservoirs inside the cell, some of which are visible even with a light microscope.

In addition, animal cells are able to synthesize branched polymers of glucose known as glycogen, the granules of which are visible with an electron microscope. These stocks are among those that can be mobilized relatively quickly (within a few seconds). The concept of carbo-loading is known among athletes , when they try to maximize their glycogen reserves before a big competition, sometimes consuming 12 grams of carbohydrates per kilogram of body weight within 24 hours[1]. Under normal conditions, a person keeps a store of glycogen with energy that is enough for about one day. Plant cells produce a similar molecule, starch, which is also stored in granules.

Another method used by both plants and animals is the synthesis of fatty acids. One gram of fat contains about six times as much energy as the same volume of glycogen [2], but it is more slowly utilizable. All storage systems (from rapidly usable ATP to medium-fast glycogen to slow fat) play important roles and complement each other. Fats are stored in droplets of specialized cells - adipocytes; providing a person with a supply of energy for several weeks.

Mitochondria

Mitochondria are spherical or filamentous organelles.

- 0.5 µm wide and up to 10 µm long,

- they gather in places with high metabolic activity (apical ends of ciliated cells, middle segments of spermatozoa),
- they transform the chemical energy of metabolites contained in the cytoplasm into a type of energy easily accessible to cells,
- this **energy** is partly **stored** in the macroergic phosphate bonds of certain compounds (e.g. ATP) and they readily release energy when the cell needs it,
- are found in the cytoplasm in high numbers,
- made up of proteins and lipids together with DNA and RNA,
- **consist** of:

1. ***outer mitochondrial membrane***
2. ***inner mitochondrial membranes*** extending towards the interior in projections = **cristae**,

- membranes enclose two spaces - between the outer and inner membrane = *intramembranous space*, related to *intracrystalline spaces* (the space bounded by the inner mitochondrial membrane is the *intercrystalline space* – contains granular matter = *mitochondrial matrix*, which is rich in proteins with a small amount of DNA and RNA),
- **cristae** are usually ridge-like flat septa,
  - cells secreting hormones have *tubular cristae* – this increases the inner surface of the mitochondria – enzymes and other compounds involved in oxidative phosophorylation (the system that changes ADP to ATP),
- the number of mitochondria and their cristae directly depends on the metabolic activity of the cell (for example, in cardiomyocytes they make up 40% of the cell volume),
- **the basolateral labyrinth** serves to transport ions,
- necessary in tissues dependent on the aerobic way of obtaining energy (nervous tissue, retina),
- *are not in erythrocytes*,
- enzymes of the citric acid cycle, are also located in the matrix beta oxidation of fatty acids also takes place here,
- **endosymbiotic theory** – circular double helix DNA, RNA of three types ribosomes,
- **function** (abbreviated): mitochondria transform the chemical energy of metabolites into a form of energy easily usable by the cell for osmotic, mechanical, electrical and chemical work → i.e. in the form of ATP but also heat generation,
  - on the *inner mitochondrial membrane:* oxidative phosphorylation,
  - in the *matrix:* beta-oxidation and the Krebs cycle.

Links

Related articles

- Mitochondria
- mtDNA
- Mitochondrial inheritance
- Bioenergetics of the cell

Reference

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2. http://www.nature.com/scitable/topicpage/cell-energy-and-cell-functions-14024533

References

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