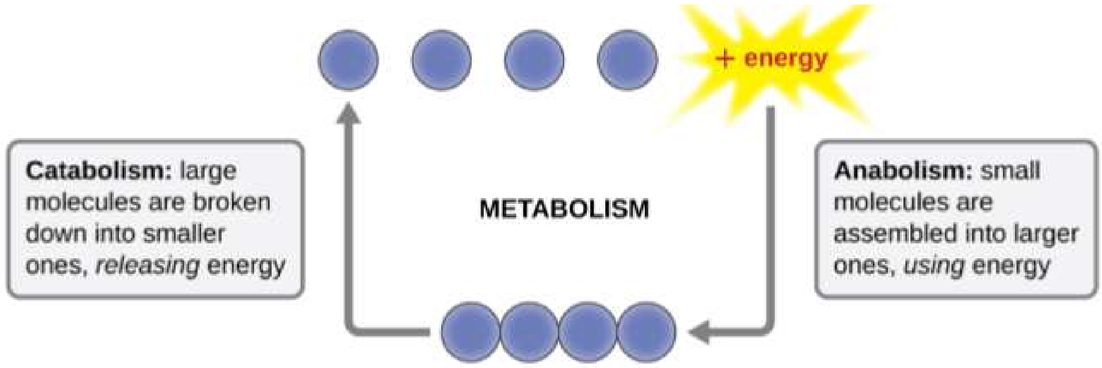
08- Microbial Metabolism part 1 (Instructor: Şeref Tağı)

The term used to describe all of the chemical reactions inside a cell is metabolism. Cellular processes such as the building or breaking down of complex molecules occur through series of stepwise, interconnected chemical reactions called metabolic pathways. Reactions that are spontaneous and release energy are exergonic reactions, whereas endergonic reactions require energy to proceed. The term anabolism refers to those endergonic metabolic pathways involved in biosynthesis, converting simple molecular building blocks into more complex molecules, and fueled by the use of cellular energy. Conversely, the term catabolism refers to exergonic pathways that break down complex molecules into simpler ones. Molecular energy stored in the bonds of complex molecules is released in catabolic pathways and harvested in such a way that it can be used to produce high-energy molecules, which are used to drive anabolic pathways. Thus, in terms of energy and molecules, cells are continually balancing catabolism with anabolism.



Metabolism includes catabolism and anabolism. Anabolic pathways require energy to synthesize larger molecules. Catabolic pathways generate energy by breaking down larger molecules. Both types of pathways are required for maintaining the cell's energy balance (Download for free at https://openstax.org/details/books/microbiology)

Organisms can be identified according to the source of carbon they use for metabolism as well as their energy source. The prefixes auto- ("self") and hetero- ("other") refer to the origins of the carbon sources various organisms can use. Organisms that convert inorganic carbon dioxide (CO2) into organic carbon compounds are **autotrophs**. .Plants and cyanobacteria are well-known examples of autotrophs. Conversely, **heterotrophs** rely on more complex organic carbon compounds as nutrients; these are provided to them initially by autotrophs. Many organisms, ranging from humans to many prokaryotes, including the well-*studied Escherichia* *coli*, are heterotrophic. Organisms can also be identified by the energy source they use. All energy is derived from the transfer of electrons, but the source of electrons differs between various types of organisms. The prefixes photo- ("light") and chemo("chemical") refer to the energy sources that various organisms use. Those that get their energy for electron transfer from light are phototrophs, whereas chemotrophs obtain energy for electron transfer by breaking chemical bonds.

There are two types of **chemotrophs**: organotrophs and lithotrophs. **Organotrophs**, including humans, fungi, and many prokaryotes, are chemotrophs that obtain energy from organic compounds. **Lithotrophs** ("litho" means "rock") are chemotrophs that get energy from inorganic compounds, including hydrogen sulfide (H_2S) and reduced iron. Lithotrophy is unique to the microbial world.

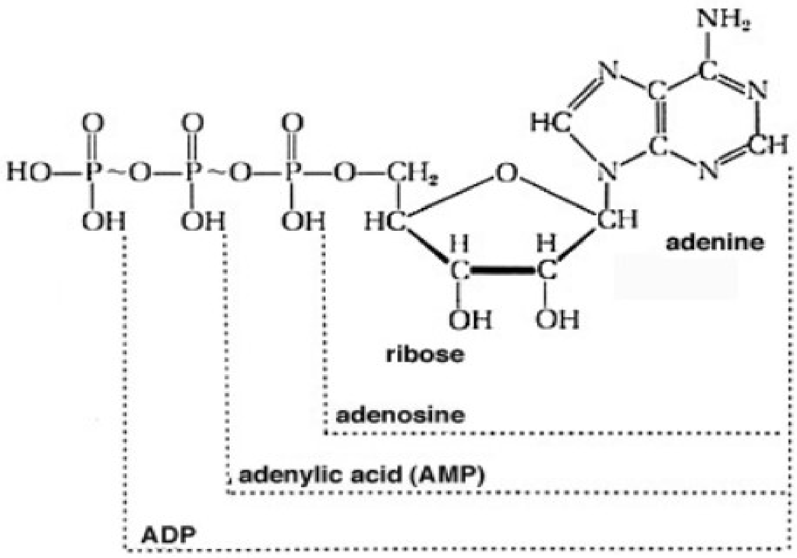
Classifications		Energy Source	Carbon Source	Examples
Chemotrophs	Chemoautotrophs	Chemical	Inorganic	Hydrogen-, sulfur-, iron-, nitrogen-, and carbon monoxide-oxidizing bacteria
	Chemoheterotrophs	Chemical	Organic compounds	All animals, most fungi, protozoa, and bacteria
Phototrophs	Photoautotrophs	Light	Inorganic	All plants, algae, cyanobacteria, and green and purple sulfur bacteria
	Photoheterotrophs	Light	Organic compounds	Green and purple nonsulfur bacteria, heliobacteria

Classifications of Organisms by Energy and Carbon Source (Download for free at https://openstax.org/details/books/microbiology.)

Oxidation and Reduction in Metabolism Thetransfer of electrons between molecules is important because most of the energy stored in atoms and used to fuel cell functions is in the form of high-energyelectrons. The transferofenergy in the form of electrons allows the cell to transfer and use energy incrementally; that is, in small packages rather than a single, destructive burst. Reactions that remove electrons from donor molecules, leaving them oxidized, are oxidation reactions; those that add electrons to acceptor molecules, leaving them reduced, are reduction reactions. Because electrons can move from one molecule to another, oxidation and reduction ocur in tandem. These pairs of reactions are called oxidation-reduction reactions, or redox reactions.

Energy Carriers: NAD+, NADP+, FAD, and ATP The energy released from the breakdown of the chemical bonds within nutrients can be stored either through the reduction of electron carriers or in the bonds of adenosine triphosphate (ATP). In living systems, a small class of compounds functions as mobile electron carriers, molecules that bind to and shuttle high-energy electrons between compounds in pathways. The principal electron carriers we will consider originate from the B vitamin group and are derivatives of nucleotides; they are nicotinamide adenine dinucleotide, nicotine adenine dinucleotide phosphate, and flavin adenine dinucleotide. These compounds can be easily reduced or oxidized. Nicotinamide adenine dinucleotide (NAD+/NADH) is the most common mobile electron carrier used in catabolism. NAD+ is the oxidized form of the molecule; NADH is the reduced form of the molecule. Nicotine adenine dinucleotide phosphate (NADP+), the oxidized form of an NAD+ variant that contains an extra phosphate group, is another important electron carrier; it forms NADPH when reduced. The oxidized form of flavin adenine dinucleotide is FAD, and its reduced form is $FADH_2$. Both NAD+/NADH and FAD/$FADH_2$ are extensively used in energy extraction from sugars during catabolism in chemoheterotrophs, whereas NADP+/NADPH plays an important role in anabolic reactions and photosynthesis. Collectively, FADH2, NADH, and NADPH are often referred to as having reducing power due to their ability to donate electrons to various chemical reactions. A living cell must be able to handle the energy released during catabolism in a way that enables the cell to store energy safely and release it for use only as needed.

Living cells accomplish this by using the compound adenosine triphosphate(ATP). ATP is often called the “energycurrency”of the cell, and, like currency, this versatile compound can be used to fill any energy need of the cell. At the heart of ATP is a molecule of adenosine monophosphate (AMP), which is composed of an adenine molecule bonded to a ribose molecule and a single phosphate group. Ribose isafive-carbon sugar found in RNA, and AMP is one of the nucleotides in RNA. The addition of a second phosphate group to this core molecule results in the formation of adenosine diphosphate (ADP); the addition of a third phosphategroupforms ATP. Adding a phosphate group to a molecule, a process called phosphorylation, requires energy. Phosphate groups a renegatively charged and thus repel one another when they are arranged in series, as they are in ADP and ATP.



The structure of ATP. ATP is derived from the nucleotide adenosine monophosphate (AMP) or adenylic acid, to which two additional phosphate groups are attached through pyrophosphate bonds (~P). These two bonds are energy rich in the sense that their hydrolysis yields a great deal more energy than a corresponding covalent bond(Todar's Online Textbook of Bacteriology, Kenneth Todar)

This repulsion makes the ADP and ATP molecules inherently unstable. Thus, the bonds between phosphate groups (one in ADP and two in ATP) are called high-energy phosphate bonds. When these high energy bonds are broken to release one phosphate (called inorganic phosphate [Pi]) or two connected phosphate groups (called pyrophosphate [PPi]) from ATP through a process called dephosphorylation, energy is released to drive endergonic reactions.

References:

1- Alcamo's Fundamentals of Microbiology, 2011, Ninth Edition (9 ed.) by Jeffrey C. Pommerville, Jones & Bartlett Publishers, Canada
2- "Download for free at https://openstax.org/details/books/microbiology."
3- Todar's Online Textbook of Bacteriology, Kenneth Todar, University of Wisconsin