

Chapter 9

The Metabolic Physiology of Soil Microorganisms

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I THE BASICS OF REDOX REACTIONS AND BIOENERGETICS

The content of the chapter assumes an understanding of the basics of chemical thermodynamics, including the concepts of redox reactions, chemical equilibrium, Gibbs free energy, activation energy, and metabolic pathways. The basics of energy calculations in microbial energetics are available in a large number of sources, including Appendix 1 of *Brock Biology of Microorganisms* by Madigan et al., which is now in its 13th Edition.

II ONLINE VIDEOS

There are a large number of online resources that can be used as a refresher for the fundamental biology and chemistry that govern the metabolic physiology of soil microorganisms. Here are two series of YouTube videos that provide excellent overviews of these principles:

Crash Course is an educational YouTube channel started by Hank Green and John Green, also known as the VlogBrothers. Chemistry episode #10 covers redox reactions (<http://youtu.be/IQ6FBA1HM3s>), and episodes 17 through 20 cover various aspects of chemical thermodynamics, including energy and chemistry (#17, <http://youtu.be/GqtUWyDR1fg>), enthalpy (#18, <http://youtu.be/SV7U4yAXL5I>),

and entropy (#20, <http://youtu.be/ZsY4WcQOrfk>). Biology episode #7 (http://youtu.be/00jbG_cfGuQ) covers ATP and respiration.

The Bozeman Science channel on YouTube is maintained by Paul Andersen, a science teacher in Bozeman, MT. He is the 2011 Montana Teacher of the Year. Topics covered include activation energy (<http://youtu.be/YacsIU97Ofc>), ATP (<http://youtu.be/5GMLMIVUvo>), cellular (<http://youtu.be/Gh2P5CmCC0M>) and anaerobic (<http://youtu.be/cDC29iBxb3w>) respiration, bioenergetics (<http://youtu.be/nDCxIpiI7-Y>), Gibbs free energy (<http://youtu.be/DPjMPeU5OeM>), redox reactions (<http://youtu.be/RX6rh-eeflM>), and “life requires free energy” (<http://youtu.be/JBmykor-2kU>).

III GLOSSARY

Activation energy	Energy input required for a reaction to proceed spontaneously; enzymes lower activation energy.
Anabolism	The metabolic processes involved in the synthesis of organic molecules from simpler compounds, generally requiring energy.
Anoxygenic cycle	The suite of non-O ₂ producing electron flow paths resulting from microbial metabolism. Contains a single circuit connecting C reduction by photolithotrophs to C oxidation by anaerobic chemoorganotrophs.
Autotroph	An organism able to use CO ₂ as a sole source of carbon.
Catabolism	The metabolic processes involved in the breakdown of organic or inorganic molecules, usually releasing energy.
Catalyst	A substance that promotes a biochemical reaction without itself being altered in the process.
Chemolithotroph	An organism obtaining its energy from the oxidation of inorganic compounds.
Chemoorganotroph	An organism obtaining its energy from the oxidation of organic compounds.
Coenzyme	A low-molecular-weight molecule that participates in an enzymatic reaction by accepting or donating electrons or functional groups. Examples include NAD ⁺ , FAD ⁺ .
Endergonic	An energy-consuming reaction.
Enzyme	A catalyst composed of protein that promotes specific reactions or groups of reactions.
Exergonic	An energy-generating reaction.
Gibb's free energy	A thermodynamic quantity representing the work obtainable from a thermodynamic system at constant pressure and temperature.
Heterotroph	An organism that requires a reduced carbon source.
Oxidation-reduction (redox) reaction	A pair of reactions in which one compound becomes oxidized and releases electrons, while another compound becomes reduced and uptakes electrons.
Oxidation state	A measure of the degree of oxidation of an element in a compound (i.e., the number of electrons lost or gained by the element).

Oxidative phosphorylation	The production of ATP by use of a proton motive force formed by electron transport.
Oxygenic cycle	The suite of O ₂ producing electron flow paths resulting from microbial metabolism. Contains two circuits: (1) a photo-chemo circuit connecting C reduction by photoaquatrophs and C oxidation by chemoorganotrophs, and (2) a chemo-chemo circuit connecting C reduction by aerobic chemolithotrophs and C oxidation by anaerobic chemoorganotrophs.
Photoaquatroph	An organism that uses the sun as its energy source and water as its electron source.
Photolithotroph	An organism that uses the sun as its energy source and inorganic compounds as its electron source.
Prosthetic group	A non-protein portion of an enzyme required for its function
Redox	See oxidation-reduction reaction.
Reduction potential (E'_o)	The inherent tendency, measured in volts, of the oxidized compound in a redox pair to become reduced.
Substrate-level phosphorylation	Synthesis of ATP by direct transfer of a phosphoryl group from a reactive organic intermediate substance to adenosine diphosphate (ADP) or guanosine diphosphate (GDP).

