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What are Chemolithoautotrophic Bacteria?

They have complicated names like *Acidithiobacillus ferrooxidans, Nitrobacter winogradskyi* or *Methanobacterium thermoautotrophicum*. The properties and abilities of these so-called "chemolithoautotrophic bacteria" are just as complex, but at the same time enormously fascinating. The microbes are able to exist without sunlight as an energy source and without organic compounds such as vitamins, sugars or amino acids, which are vital for the nutrition of most organisms.[1] Unlike green plants, they do not use photosynthesis, in which water and carbon dioxide are converted to glucose and oxygen by means of light and chlorophyll. Their form of energy metabolism is called chemosynthesis. Energy is extracted from the oxidation of inorganic substrates such as sulfur compounds, nitrite, iron and ammonium ions or hydrogen, which is why the bacteria are called "chemolithotrophic". And since most of them obtain the carbon necessary for the process from only one source – carbon dioxide – the term used, as with green plants, is autotrophic growth and thus "chemolithoautotrophic bacteria".[2] The reason for this particular kind of metabolism is, according to experts, the fact that in the early stage of the emergence of life on Earth, roughly 4000 and 3500 million years ago, the atmosphere was probably rich in the gases CO, CO2 and H2; the sea, as well as soil and rocks, contained high concentrations of metal ions and sulfur complexes. So the bacteria could use them to build up their own biomass[3] – a biochemical tour de force! Russian microbiologist Sergey Nikolayevich Winogradsky (1856–1953), one of the most important bacteriologists of the late 19th and early 20th century, was the first to prove by comprehensive studies that not only plants, but also bacteria can grow autotrophically. In experiments with sulfur and nitrifying bacteria (1887–1890), he provided preliminary proof that a living being could use an inorganic substance (e.g. stone) as an energy source, oxidize it and

1 Margulis, Lynn/Schwartz, Karlene V. 1989. Die fünf Reiche der Organismen. Ein Leitfaden. Heidelberg. p. 64.
2 Munk, Katharina. 2009. Grundstudium Biologie. Mikrobiologie. Heidelberg/Berlin. pp. 3–21.
3 Drews, Gerhart. 2015. Bakterien – ihre Entdeckung und Bedeutung für Natur und Mensch. 2. Auflage, Berlin/Heidelberg. p. 112.

build up cell mass with carbon dioxide as a fixer. The amazing thing about chemolithoautotrophic bacteria is their ability to generate living matter from dead matter. Winogradsky's concept of "chemolithoautotrophy"[4] continues to be developed steadily through intensive research. Depending on the particular "food" of the chemolithoautotrophic bacteria, the so-called energy substrates, they can be divided into various groups: nitrite and ammonia oxidizers (nitrifiers), sulfur oxidizers, iron oxidizers and hydrogen oxidizers.[5] They are all involved in geobiological and biochemical processes, which are essential not only for the advancement of science, but also to influence ecological questions or even economic developments. From a historical as well as a current perspective, chemolithoautotrophic bacteria offer many exciting insights, only a few of which will be focused on here. The sulfur and iron oxidizers occupy an outstanding standing among chemolithoautotrophic bacteria. Acidophiles, i.e. acidophilic species such as *Acidithiobacillus ferrooxidans*, also used by Thomas Feuerstein in his project, are mostly found in highly toxic, acidic sewage effluents containing large amounts of iron compounds. That is precisely why mounds of mining rubble, where the ore-rich rocks are exposed to the elements are Cockaigne for the bacteria. They use the inorganic sulfur compounds in the rocks as nourishment and their metabolism releases metals such as copper, gold, nickel, molybdenum, zinc or uranium from the remaining ore. This process is referred to as "biomining", but valuable resources are obtained in a biological way, without environmentally harmful emissions and with little energy used. And not only that: the mounds are cleaned up and detoxified. This is also the reason why researchers from the Federal Institute for Geosciences and Natural Resources (BGR) in Hanover are trying to use chemolithoautotrophic bacteria specifically for this purpose. Bioleaching and biooxidation are, according to Axel Schippers, head of the task force for geomicrobiology, established methods of metal extraction from ore. Whereas with bioleaching, insoluble compounds (metal sulfides) are converted biologically into a soluble sulfate and the metal is extracted from the solution, with biooxidation microbes decompose the mineral, release the metal and form acids. The former is particularly useful in the production of copper, the latter in the release of gold from so-called refractory substances. In the latter, the raw material in the minerals of the rock – primarily pyrite – is bound and must be eluted. Biological metal production was practiced in earlier centuries, but it was not until the scientific investigation of the processes in the 1940s that the chemists realized the important role of sulfur bacteria in leaching. Projects exist today that are attempting to cultivate bacteria in order to use them for organic mining around the world. This is intended to replace traditional, energy-intensive and environmentally-damaging smelting processes, which use coal as a reducing agent to heat ore concentrates, in order to accelerate the elution of the metal but which releases sulfuric acid that pollutes the air and, as acid rain, poisons the soil and drinking water. In 2008, the German Patent Office granted new patents for the biological extraction of phosphate from heavy metal and phosphate-containing solutions. According to the experts, the unique ability of microorganisms can also be applied on a large scale.[6] A notable example from history shows that bacteria were apparently important in the production of gunpowder as early as the Middle Ages. This, of course, was not understood by the people of the 14th century, but they did realize that they needed saltpeter. Their experience showed them that it would thrive best in well-ventilated beds of earth, limestone, and nitrogenous substances such as urine, blood, or meat waste (or better, the salts of nitric acid such as ammonium, sodium, or potassium nitrate). After a while, the white deposits were then leached with

4 Madigan, Michael T./Martinko, John M. 2009. Brock Mikrobiologie. 11. aktualisierte Auflage, München. pp. 625–626.
5 Munk. 2009, pp. 3–21/3–22.
6 Schacht, Rüdiger: Bakterien als Bergleute. In: Welt.de, Wissen, 20.09.2010. https://www.welt.de/welt_print/wissen/article9748604/Bakterien-als-Bergleute.html (10.10.2017).

water and evaporated to a solution which provided the saltpeter. The microbiological process behind this, that is, the decomposition of organic material, resulting in ammonia, which is oxidized to nitrate by means of oxygen by nitrifying bacteria and builds up its cellular substance with carbon dioxide, is a discovery of modern science.[7] Chemolithoautotrophic bacteria live in extreme locations – as do some sulfur oxidizers, whose habitats are the deep sea, in so-called hydrothermal vents, where water with a high hydrogen sulphide concentration and with temperatures of up to 405 degrees Celsius merges from the seabed (black smokers). The first deepsea vents and a fantastic underwater world were found in the vicinity of the Galapagos Islands at a depth of 2600 metres in 1979 and were first described as a fantastic underwater world by a team led by microbiology professor Colleen Cavanaugh from Harvard University in 1981. What makes this biotope so special are its animal inhabitants, gigantic tubular worms (Riftia pachyptila), which can reach a length of more than one meter and live in absolute darkness independent of the process of photosynthesis. They enter into a kind of symbiosis with the microbes. In doing so, chemolithoautotrophic bacteria take on the role of the sun as an energy donor by oxidizing the abundant volcanic hydrogen sulphide to sulfur or sulphate. The carbon dioxide dissolved in the water provides the necessary carbon for the construction of their own cell substance. The bacteria and worms live symbiotically because the microorganisms provide them with nourishment (partly completely, partly by excreted sugar molecules from carbon dioxide). In return, the worms offer "their" bacterial protection through their own bodies (trophosome) and ensure a steady supply of hydrogen sulfide and oxygen through their water-filtering gills.[8] While this group of chemolithoautotrophic bacteria plays an essential role in the ecosystem of the deep sea, certain hydrogen oxidizers, also known as oxyhydrogen gas bacteria, could be valuable in human habitats in the future. They have the ability to oxidize the toxic carbon monoxide that enters the atmosphere as industrial, heating and car exhaust emissions and convert it into carbon dioxide.[9] Expectations are high as to which innovative technologies of the future chemolithoautotrophic bacteria will be involved!

7 Gottschalk, Gerhard. 2009. Welt der Bakterien. Die unsichtbaren Beherrscher unseres Planeten. Weinheim. pp. 114–115.
8 Gottschalk. 2009. pp. 47–48.
9 Munk. 2009. pp. 3–22.