Calorimetry of Microbial Utilization of Electrical and Photon Energy

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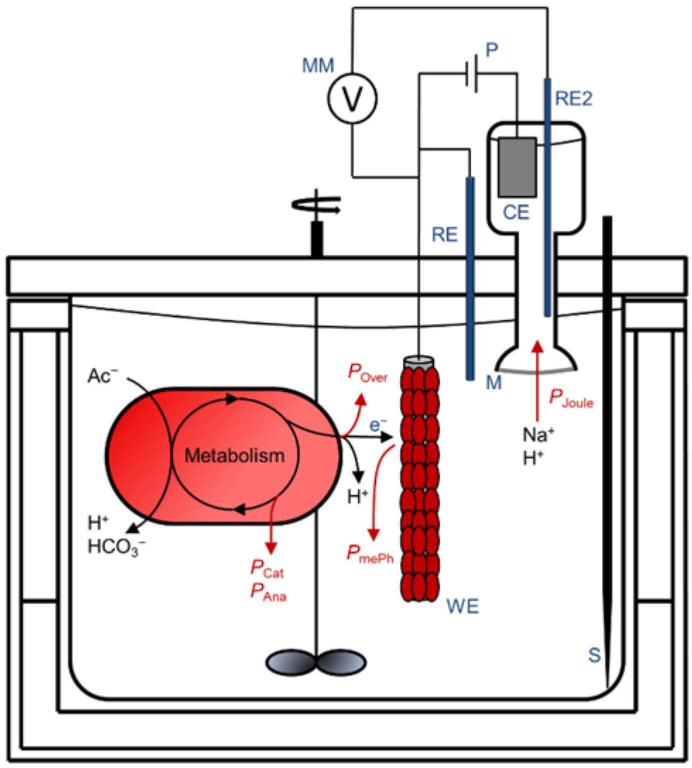
The most microbial organisms grow chemoorganoheterotrophically, which means they use the energy that is chemically linked to nutrients for biosynthesis, maintenance of the structures, replication and growth. The maximum possible growth efficiencies[1] as well as the growth rates[2] are determined by thermodynamic rules and can be calorimetrically monitored in real time. This is of great practical importance if, for example, microorganisms are to be used as producers in the chemical industry or for contaminant degradation in ecosystems. Interestingly, despite the successes of bio-thermodynamics and calorimetry in the area of microbial utilization of chemical sources of energy, non-chemical energy sources for microbial growth (e.g. light and electricity) were so far rarely considered. Here, the energy of photons and electrons allows the microbial reduction of CO_2 and make bio-reactions feasible which are thermodynamically not allowed. Potential reasons for this surprising lack of knowledge are challenges to develop the required tailor-made calorimeters and to quantify very low energy conversion efficiencies in case of photosynthesis.
For these reasons, new photocalorimeters and bioelectrocalorimeters were developed and tested. In the case of light energy, it is now possible to determine the efficiency of energy conservation as a function of environmental conditions in real time with an accuracy and throughput which is not accessible by other methods. The measuring principle is demonstrated at the example of microalgae of industrial importance (i.e. *Chlamydomonas reinhardtii*). In the case of electrical energy, we succeeded with our tailor-made calorimeter in quantifying previously unknown energetic burden for growth on electrodes (i.e. microbial electrochemical Peltier heat).[3] Scheme 1 shows exemplarily the principle of a bioelectrocalorimeter. Numerous applications of the new two calorimetric techniques are conceivable.



Scheme 1: Illustration of the bioelectrocalorimeter and a simplified flow of metabolites, electrons, ions and heat during *Geobacter* biofilm growth on acetate (Ac^-). Details are given in [3].

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(3) Korth, B.; Maskow, T.; Picioreanu, C.; Harnisch, F. *Energy Environ. Sci.* **2016**, *9*, 2539-2544.