Bio-hydrogen: microbes have their own agenda

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Abstract

The international hydrogenase community stages a meeting every 3–4 years, and this time it was held in the University of Reading. Each congress has revealed new aspects of the complex nature of hydrogenases: their structure, molecular mechanisms and biosynthesis are all yielding up their secrets. This following introduction provides background information, and the highlights of the meeting are presented in the papers that follow.

Hydrogenases, enzymes involved in the microbial production and consumption of hydrogen gas, were first described in a series of classic papers in the *Biochemical Journal* by Stephenson and Stickland in the 1930s. The enzymes came to prominence during the fuel crisis of the 1970s, when it became apparent that reserves of fossil fuels were finite, and biological hydrogen production offered a sustainable alternative. Since then, the prospect of climate change has spurred the search for sources of hydrogen that do not involve net production of CO₂. There has been steady progress in our understanding of hydrogen in the biosphere. Hydrogen is produced by photosynthetic cleavage of water, by fermentation of waste materials, and as a by-product of nitrogen fixation. How we could make this bio-hydrogen into a viable fuel source is certainly a challenge for the future. It will not be possible until we understand, in much more detail, how and why organisms produce hydrogen.

It became obvious early on that economic hydrogen production is not just a matter of extracting enzymes or growing monocultures of hydrogen-producing organisms and using them like chemical catalysts. Microbes have their own agenda. Hydrogenases are complex enzymes; their synthesis depends on complex multi-step assembly processes, which are now being elucidated. They use complex machinery to transport the hydrogenases, complete with their elaborate nickel- and iron-containing centres, specifically through cell membranes. Moreover organisms in the environment are accustomed to exchanging metabolites, including hydrogen, to optimize their use of energy sources; production of hydrogen and hydrogenases is tightly regulated. Details are emerging of their mechanisms of control of biosynthesis and environmental hydrogen sensing, by regulatory proteins very similar to hydrogenases.

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Some highlights of the meeting are reviewed in these proceedings. We now recognize that there is diversity of hydrogenases: all contain iron, some also contain nickel. A single organism may express four or more different hydrogenases. Until recently, it had been believed that hydrogenases were all iron–sulphur proteins, but one very unusual hydrogenase from methanogens had been reported to be metal-free. However, as described at this meeting, this has now been
shown to contain an iron centre and carbonyl ligands, which are now recognized as a defining characteristic of hydrogenases.

In terms of using hydrogenases as a source of fuel, to create a system capable of sustained hydrogen production would require an enormous effort in molecular design. An alternative, now being explored by biomimetic chemists, would be to construct inorganic catalysts that imitate the enzymes, but avoid their fragility. There has been a promising start, but it is too early to say if this will overcome the problems of efficiency and inhibitor resistance.

A feature of this meeting was the realization of the relevance of hydrogenases to human biochemistry. The human genome does not encode any hydrogenases, as far as we know, but it does contain genes that resemble the structural genes for iron-containing hydrogenase. As described at this meeting, these narf proteins are essential components involved in the biosynthesis of iron-sulphur proteins. Perhaps the most surprising observation is the involvement of hydrogenases in diseases. Pathogenic bacteria such as Helicobacter and Salmonella have hydrogenase genes, which are necessary for infectivity. They live within the body of the human or mouse, using hydrogen produced in the digestive tract. This biomedical aspect to hydrogenases is clearly one we are going to hear much more about in the future.

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