Chapter 6

The Oxidation of Ammonia as an Energy Source in Bacteria

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Summary

This chapter deals with the oxidation of ammonia (NH₃ + 1.5 O₂ → HNO₂ + H₂O) as a source of reducing power in the chemolithotrophic bacterium _Nitrosomonas europaea_. Direct knowledge of the enzymes involved together with the sequence of the genome reveal core elements of a redox system unique to oxidation of ammonia to nitrite which feeds into a more traditional bacterial electron transport/terminal oxidase system. The apparently low stoichiometry of protons translocated per ammonia oxidized hints at the basis of the low growth yields of this bacterium. Remarkably, the putative complex of hydroxylamine oxidoreductase (HAO), cytochrome c₅₅₄ (Cyt c₅₅₄) and the membrane cytochrome c₅₅₅₂ (Cyt c₅₅₅₂), which catalyzes the oxidation of a molecule of hydroxylamine and transfer of four electrons to membrane ubiquinone would involve 16 c-hemes per catalytic site or 48 hemes for the hypothetical aggregate containing the trimeric HAO. The dehydrogenation catalyzed at the novel catalytic heme (heme P460) is unique by comparison with other known catalytic hemes which bind substrate to the iron; in all others electrons enter the system and reduce the substrate whereas the reverse is true with HAO. This mode of catalysis may be functionally related to a cross link which is found only in HAO; a covalent bond between a methyne carbon of heme P460 and a ring carbon of a peptide tyrosine. The dramatic crystal structures of HAO and Cyt c₅₅₄ have provided insights into catalysis and electron transfer as well as illustrating evolutionary relationships which are not reflected in homology of amino acid sequence. Considering their relative spatial arrangement, the 4 hemes of Cyt c₅₅₄ can be precisely superimposed with 4 of the hemes of HAO. Evidence suggests that they have a common ancestor and have preserved heme configurations even when sequence homology had been lost. The novel anaerobic oxidation of ammonia (NH₃ + HNO₂ → N₂ + H₂O) by a planctomycete bacterium and the oxidation of ammonia to nitrite in heterotrophic bacteria are described more briefly.

_I. Introduction: Metabolism of Nitrosomonas_

This chapter deals with the biochemistry of the oxidation of ammonia as a source of reducing power for energy transduction and biosynthesis in bacteria. It will focus on the aerobic oxidation of ammonia to nitrite (NH₃ + 1.5 O₂ → HNO₃ + H₂O) in the chemolithotrophic bacterium _Nitrosomonas eu-