

Ammonia-Oxidising Archaea – Physiology, Ecology and Evolution

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ABSTRACT

Nitrification is a microbially mediated process that plays a central role in the global cycling of nitrogen and is also of economic importance in agriculture and wastewater treatment. The first step in nitrification is performed by ammonia-oxidising microorganisms, which convert ammonia into nitrite ions. Ammonia-oxidising bacteria (AOB) have been known for more than 100 years. However, metagenomic studies and subsequent cultivation efforts have recently demonstrated that microorganisms of the domain archaea are also capable of performing this process. Astonishingly, members of this group of ammonia-oxidising archaea (AOA), which was overlooked for so long, are present in almost every environment on Earth and typically outnumber the known bacterial ammonia oxidisers by orders of magnitudes in common environments such as the marine plankton, soils, sediments and estuaries. Molecular studies indicate that AOA are amongst the most abundant organisms on this planet, adapted to the most common environments, but are also present in those considered extreme, such as hot springs. The ecological distribution and community dynamics of these archaea are currently the subject of intensive study by many research groups who are attempting to understand the physiological diversity and the ecosystem function of these

organisms. The cultivation of a single marine isolate and two enrichments from hot terrestrial environments has demonstrated a chemolithoautotrophic mode of growth. Both pure culture-based and environmental studies indicate that at least some AOA have a high substrate affinity for ammonia and are able to grow under extremely oligotrophic conditions. Information from the first available genomes of AOA indicate that their metabolism is fundamentally different from that of their bacterial counterparts, involving a highly copper-dependent system for ammonia oxidation and electron transport, as well as a novel carbon fixation pathway that has recently been discovered in hyperthermophilic archaea. A distinct set of informational processing genes of AOA indicates that they are members of a distinct and novel phylum within the archaea, the 'Thaumarchaeota', which may even be a more ancient lineage than the established Cren- and Euryarchaeota lineages, raising questions about the evolutionary origins of archaea and the origins of ammonia-oxidising metabolism.

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