Microbial ammonia oxidation mediated by metal cofactors

The presence of bioavailable nitrogen in nature plays an essential role in survival and growth of all organisms, as nitrogen is a key element for all life. The global nitrogen cycle describes the biogeochemical processes through which nitrogen is converted between its various redox states. These conversions represent redox reactions that are predominately carried out by microorganisms.

Ammonia/ammonium (NH_3/NH_4^+) is used as an electron donor for both aerobic and anaerobic respiration in prokaryotes. Under aerobic conditions, dioxygen (O_2) is the terminal electron acceptor for ammonia oxidation via two obligate intermediates, hydroxylamine (NH_2OH) and nitric oxide (NO). This process is carried out by both aerobic ammonia oxidizing bacteria (AOB) and archaea (AOA), albeit with distinct enzymes differentiating these classes of ammonia oxidizers. Anaerobic ammonium oxidizing (anammox) bacteria utilize nitrite (NO_2^-) as the terminal electron acceptor and proceed via three consecutive redox reactions. One of the biological novelties of the anammox process is the production of the reactive intermediate hydrazine (N_2H_4), which is subsequently oxidized to dinitrogen (N_2) to yield electrons necessary for energy conservation. Anammox bacteria are not only ubiquitously present in nature—contributing substantially to the global release of fixed nitrogen to the atmosphere—but are also already applied in the wastewater treatment technology, due to its advantages over conventional nitrogen removal strategies.

Understanding the molecular mechanism of ammonium oxidation under both aerobic and anaerobic conditions will not only shed light into our fundamental understanding of the biogeochemical nitrogen cycle, but will both contribute to future biotechnological applications of these processes and to the development of new bioinspired chemical reactions.