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Introduction: nitrate reduction and the nitrogen cycle

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Nitrate plays a key role in the biogeochemical nitrogen cycle (fig. 1) which is contributed to by both prokaryotic and eukaryotic organisms. It is a source of nitrogen for assimilation, whereby the key enzymatic reaction is the reduction of nitrate to nitrite at a molybdenum ion of a nitrate reductase. Thereafter, nitrite is further reduced to ammonium, which can be further assimilated into organic nitrogen. The same series of reactions, though often catalysed by distinct enzymes, can also occur as part of a nitrate respiration process in some enteric and sulphate-reducing bacteria, whereby nitrate serves as a terminal electron acceptor during anaerobic metabolism. Nitrate also serves as the substrate for the denitrification process in which nitrate is reduced via nitrite, nitric oxide and nitrous oxide to dinitrogen. This process is largely, though not exclusively, confined to

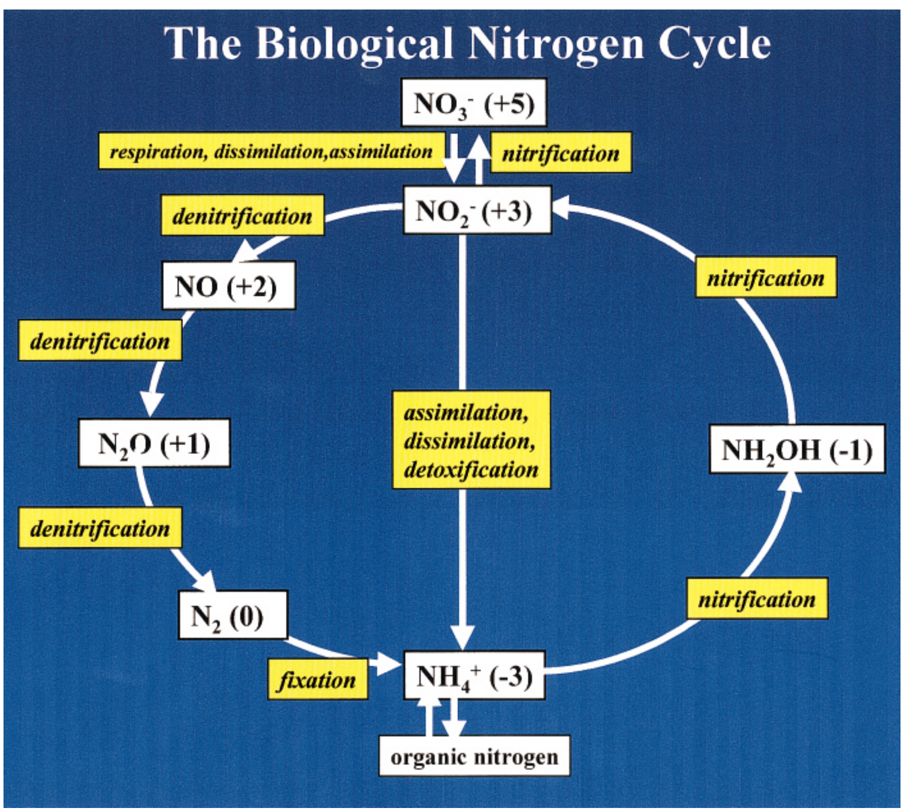

Figure 1. The biological nitrogen cycle.

prokaryotes. Each reaction is catalysed by an enzyme that can be coupled to energy-conserving electron transport pathways. The process as a whole is important in agriculture, where it results in the loss of nitrate fertilizers from fields, and in waste treatment processes where nitrate must be removed from wastewaters before release into the environment. Nitrate is also an end product of ammonia oxidation by the bacterial nitrification process.

Despite being common to both prokaryotes and eukaryotes, nitrate reduction is rarely considered comparatively in the literature or at conferences. This multi-author review seeks to redress this situation by providing an overview of current perspectives of nitrate reduction in prokaryotes and eukaryotes. The review begins with an overview by Richardson and colleagues of the biochemical, genetic and physiological diversity of nitrate reduction in prokaryotes, in which the reader is introduced to a number of different prokaryotic nitrate reductase systems. The phylogenetic distribution of these systems is considered using information emerging from the prokaryotic genome sequencing programmes. The biochemistry and spectroscopy of one of the best-studied prokaryotic nitrate reductase systems, the *Escherichia coli* membrane-bound nitrate reductase, is then considered in detail by Blasco and colleagues. Many of the experimental approaches they outline are illustrative of those being used in a number of laboratories around the world to characterise both prokaryotic and eukaryotic nitrate reductases. Some of the prokaryotic nitrate reductases are located on the inside of the cytoplasmic membrane. This introduces the need to transport nitrate across the plasma membrane in order for it to reach the catalytic site of the nitrate reductase. This process is still poorly understood, and Moir and Wood have presented an overview of the progress being made in this area. In Campbell's article the focus switches to eukaryotic nitrate reduction, with a consideration of the biochemistry of plant nitrate reductases. A particular focus here is the use of kinetic spectroscopies to unravel the catalytic cycle of the enzyme. In plants, nitrate reduction is subject to regulation by light, and the mechanism by which this is achieved, which involves phosphorylation/dephosphorylation of the nitrate reductase, is considered by Mackintosh and Meek. Finally, the problem of nitrate transport across plant cell and organelle membranes is considered by Galván and Fernandez and provides a comparison to the problem of nitrate transport in prokaryotes discussed by Moir and Wood. It is recognised that not all of the topical areas of the nitrate reduction field have been covered, for example nitrate reduction in fungi. It is hoped nevertheless that this multi-author review will provide a taste of current research perspectives in the field of prokaryotic and eukaryotic nitrate reduction that will stimulate further research and collaborative interactions in these two fields.