COMMENT ON EGAMI'S CONCEPT OF THE EVOLUTION OF NITRATE RESPIRATION

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Abstract. Recent results suggest that the presence of common nitrogen salts (sodium nitrite and nitrate) in the irradiation medium can markedly protect filamentous blue green algae from potentially lethal ultraviolet light irradiation. Our results as well as general biological arguments as presented by Egami (above) support and extend Egami's original view that anaerobic respiratory pathways using nitrite and nitrate as terminal electron acceptors evolved prior to oxygen requiring aerobic respiratory pathways.

Thermodynamic disequilibria, even on a planetary scale, are characteristic of living systems. There is evidence that biogenic atmospheric disequilibria have persisted for >3000 million years, since the early precambrian (Lovelock and Margulis, 1974; Margulis and Lovelock, 1975). Certainly Egami's suggestion that local nitrate would have been available to satisfy the nitrogen requirement of certain microorganisms under anaerobic conditions is completely reasonable. This idea is strongly supported by the recent discovery by Shilo and his coworkers of an *Oscillatoria* with facultative oxygen-eliminating photosynthetic metabolism (Cohen *et al.*, 1975). Such 'cyanobacteria' are logically considered relict populations of the first oxygen producing photosynthetic microorganisms. In the predominantly aerobic and highly competitive extant microbial communities these facultative oxygen producers are apparently limited to extreme ecological conditions such as the warm salt pools of Israel. If found as fossil microbiota in ancient cherts, on morphological grounds alone, these organisms would be assigned without hesitation to the blue green algae; prior to the publication of Shilo's paper the assumption that such a fossil oscillatorian had eliminated oxygen would have been universally accepted. In recognition of this fascinating discovery, it seems reasonable to suggest that under predominantly anoxyic conditions as soon as local cyanobacterial production of oxygen evolved there was a source of oxidizing power to produce nitrates and nitrites in the waters and soils. This accumulation of soil and aquatic nitrites and nitrates logically preceded the net accumulation of atmospheric oxygen. We concur completely with the concept that, on biological grounds alone, consideration of comparative metabolic pathways suggests that nitrate reduction preceded aerobic respiration (please see Egami's comment above for his references).

We have recently discovered that nitrate and/or nitrite in the medium of algal mat blue green algae (e.g., *Lyngbya* sp.) are protective against potentially lethal ultraviolet light irradiation. Extensions of these studies are in progress (Rambler *et al.*, 1976; Margulis *et al.*, 1976). Our observations suggest to us that prior to the development of the oxygenic atmosphere and consequent stratospheric ozone absorption of UV, the uptake of nitrate and/or nitrite was part of a family of responses to the threatening ultraviolet light levels. The use of nitrates and nitrites as protective mechanisms under anaerobic conditions may have preadapted any number of anaerobic microorganisms for eventual evolution of nitrite and nitrate reduction pathways. The

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ferredoxin nature of the enzyme systems involved further support the concept of the ancient origin of assimilation of these substances (Payne, 1974). Of course, as Egami and his coworkers have noted, evolution of nitrate reduction preadapted prokaryotes generally to the evolution of the subsequent oxygen respiratory mechanisms.

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