# ANAEROBIC RESPIRATION AND PHOTOAUTOTROPHY IN THE EVOLUTION OF PROKARYOTES

*(Reply to E. Broda)*

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**Abstract.** Anaerobic respiration preceded photosynthesis. Chemoautotrophy, photoautotrophy, and oxygen respiration were induced directly or indirectly from anaerobic respiration.

We had proposed anaerobic respiration as an intermediary step between fermentation and aerobic respiration and that the cytochrome system and consequently the oxidative phosphorelation were induced at the evolutionary step to the anaerobic respiration (reviews by Takahashi *et al.*, 1963; Egami, 1974). The concept further means that all modern organisms with cytochrome systems are remotely descended from ancestral anaerobic respiers with a primitive cytochrome system.

The concept was repeatedly criticized by E. Broda (1970, 1971a, 1971b, 1975a, 1975b, 1975c, 1977) and I replied to most of his criticisms (1973, 1974, 1976a, 1976b). But I have not replied explicitly to his criticisms concerning the evolutionary relationship between anaerobic respiration and photoautotrophy. That was because photoautotrophy was far beyond the scope of our own research and I did not have any original idea different from the traditional view.

However, quite recently he recriticized our concept with special emphasis on the evolutionary relationship between anaerobic respiration and photosynthesis. Thus I was obliged to reply briefly to his criticisms on this point.

Klein and Cronquist (1967) extensively studied the evolutionary and taxonomic properties of the Thallophytes including prokaryotes and they considered that anaerobic respirations such as sulfate respiration and nitrate respiration preceded photosynthesis. It is essentially consistent with our concept. Thus our concept is not a peculiar idea, but an easily acceptable one consistent with the traditional view. Postgate (1968) postulated an essentially similar view on sulfate respiration.

Combining the traditional view and our concept, the evolution of prokaryotes with special reference to energy metabolism may be briefly summarized as shown in Table I.

As shown in Table I, anaerobic chemoautotrophy such as observed in *Micrococcus denitrificans* etc., anaerobic photoautotrophy such as observed in purple sulfur bacteria etc. and aerobic respiration were derived directly or indirectly from anaerobic respiration. Anaerobic respiration characterized by the cytochrome system and oxidative phosphorylation could evolve to these advanced stages without difficulty. Here I do not insist that the three evolutionary steps were all direct and simple as shown in the Table. It has been

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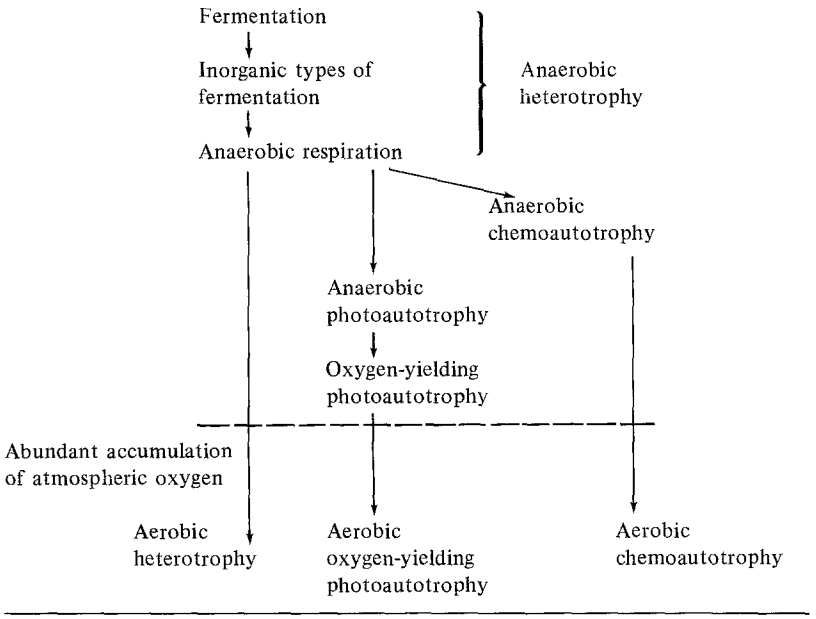
TABLE I

Scheme for the evolution of prokaryotes with special reference to energy-yielding metabolism




generally accepted that chemoautotrophy preceded photoautotrophy (Sapozhnikow, 1959; Klein and Cronquist, 1967; Rabinowitch and Govindjee, 1969). It is not excluded that anaerobic chemoautotrophy was derived directly from anaerobic respiration, and anaerobic photoautotrophy was derived from anaerobic chemoautotrophy as suggested by Klein and Cronquist (1967). It should be added that our concept was supported by Hall (1971, 1973) and it is essentially consistent with the view recently postulated by Horovath (1974).

Contrary to our scheme, Broda's scheme is as follows (1971b) (1) fermentation → (2) photo-organotrophy → (3) photolithotrophy → (4) phytotrophy (plant photosynthesis) → (5) oxidative phosphorylation (essentially, respiration) and it is quite an original one inconsistent with the traditional view. He proposed that the cytochrome system was introduced at the evolutionary step to the photosynthesis and the aerobic respiration was directly derived from photo-synthesis. Nitrate respiration appeared after or simultaneously with oxygen respiration (Broda, 1977). The original idea was essentially based upon the prejudice that before the advent of anaerobic photosynthesis, not only oxidized nitrogen but also oxidized sulfur hardly existed on the Earth and the anaerobic respiration before the advent of photosynthesis could not be taken into consideration. Thus he was obliged to face the difficulty of understanding the origin of bacterial respirations, the difficulty that nobody had encountered before him (Broda, 1971a).

In conclusion we continue to insist, based upon biological considerations, that the anaerobic respiration preceded the oxygen respiration. The conclusion is not inconsistent with recent information from physical and geological sciences (cited in Egami, 1976a, 1976b).

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