STUDYING MITOCHONDRIA BY USING BACTERIA

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It may be taken as axiomatic that the basic biochemical mechanism by which energy is conserved during respiration is the same in mitochondria and bacteria. In the past, biochemists have concentrated their studies of respiratory bioenergetics on mammalian mitochondria, the favoured sources being either rat liver or, for larger amounts, bovine heart. Recently, bacterial systems have assumed an increasing importance because of the special advantages they offer compared with animal mitochondria. The purpose of the present article is to outline these advantages. First it will be appropriate to indicate briefly the nature of present-day research in bioenergetics, which is strongly influenced by the chemiosmotic hypothesis of oxidative phosphorylation (Mitchell, 1966). According to this theory, the energy released by the oxidation-reduction reactions of the respiratory chain is conserved as an electrochemical gradient of protons across the coupling membrane, which is used by a proton-translocating ATPase in the synthesis of ATP. Since its initial formulation, the chemiosmotic theory has received much experimental support.

The advantages offered by bacteria in general over animal mitochondria are that (a) a uniform population of cells can be grown at small cost and in large quantities under precisely defined conditions by the use of a chemostat (Tempest, 1970) and (b) mutants with specific deletions in the bioenergetic apparatus can be obtained (Cox and Gibson, 1974; Haddock, 1977).

Additionally, particular types of bacteria offer particular advantages. Chromatophores of photosynthetic bacteria can be energised by short flashes of light applied in succession such that single turnovers of the electron-transport chain and associated rapid changes in pH can be studied (Crofts, 1974). The halophile *Halobacterium halobium* provides us with a light-driven proton pump (called bacteriorhodopsin) which can power ATP synthesis in the absence of electron-transport (Oesterhelt *et al*, 1977). Thermophilic bacteria provide a source of membrane-bound enzymes which are much more stable, when isolated, than the corresponding isolated mitochondrial enzymes (Kagawa *et al*, 1976). Bacteria which can live under unusually acidic or alkaline conditions (Brock, 1969) can be used to determine the importance of the transmembrane proton gradient for energy conservation (Haddock, 1977).

Most bacteria have respiratory chains which differ from the mitochondrial respiratory chain. However, there are at least two bacteria which, when grown aerobically, have a respiratory chain which is quite mitochondrial. These bacteria are *Paracoccus denitrificans* and *Rhodopseudomonas spheroides* (John and Whatley, 1975). Membrane vesicles isolated from *P. denitrificans* are of special interest since they show the tight coupling between respiration and ATP synthesis observed in carefully isolated mitochondria. The remarkable similarities between *P. denitrificans* and mammalian mitochondria have been explained on the basis of an evolutionary origin for mitochondria from a prokaryotic ancestor resembling *P. denitrificans* (John and Whatley, 1975).

Of course not all the features of mitochondria can be found in bacteria. Thus the mitochondrial adenine nucleotide translocator is absent from free-living bacteria; the mitochondrial thermogenesis of the brown adipose tissue of hibernating animals (Nicholls, 1976) has no obvious equivalent among bacteria. We may also note that the operation of mitochondrial and bacterial permeases appears to differ in many respects.

In conclusion, we feel that, although particular problems can be solved only by studying animal mitochondria, bacteria have many advantages over mitochondria for the study of basic mechanisms of bioenergetics (see Garland and Haddock, 1977).

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