Minireview

Mitochondria and L-lactate metabolism

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Abstract Although mitochondria have been the object of intensive study over many decades, some aspects of their metabolism remain to be fully elucidated, including the L-lactate metabolism.

We review here the novel insights arisen from investigations on L-lactate metabolism in mammalian, plant and yeast mitochondria. The presence of L-lactate dehydrogenases inside mitochondria, where L-lactate enters in a carrier-mediated fashion, suggests that mitochondria play an important role in L-lactate metabolism. Functional studies have demonstrated the occurrence of several L-lactate carriers. Moreover, immunological investigations have proven the existence of monocarboxylate translocator isoforms in mitochondria.

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1. Mitochondrial metabolism of L-lactate in mammals

A fundamental change in the overall view of the role of Llactate (L-LAC) in metabolism occurred when it was shown that O_2 limitation is not a requirement for net formation, and that L-LAC is an important intermediary in glucose metabolism, a mobile fuel for aerobic metabolism, perhaps a mediator of redox state among various compartments both within and between cells [1]. Moreover, very recently, L-LAC was proposed to work as a signal in gene expression [2].

Recently, L-LAC metabolism has been the subject of several reviews [1,3–5 and refs. therein] and consequently we will limit the scope of this review to the role of mitochondria in L-LAC metabolism. Indeed, even though mitochondrial L-LAC metabolism was originally reported as early as 1959 [6],

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whether and how mitochondria participate to L-LAC metabolism has mostly been investigated only in the last two decades (Table 1). Contrarily, evidence of the existence of mitochondrial L-LAC carriers, as functionally investigated, was shown only in 2002 [7]. Our present position, based on our own work and that of others reviewed here is that the evidence for mitochondrial metabolism of L-LAC, due to the existence of both L-LAC carrier-mediated transport processes and of the mitochondrial L-lactate dehydrogenase (mL-LDH) is now compelling.

1.1. Spermatozoa

The first evidence in favour of the presence of a putative mL-LDH was from Clausen who found that about 40% of total activity in sperm cells was present in a particulate fraction showing high succinate dehydrogenase activity [8].

The existence of the mL-LDH which can reduce pyridine nucleotide in the mitochondrial matrix was demonstrated in hypotonically treated rabbit epididymal spermatozoa by means of oxygen uptake and fluorimetric studies [9]. It was also shown that the mL-LDH functions actively in these cells. In sperm cells the cytosolic L-lactate dehydrogenase (cL-LDH) and mL-LDH appear to be the same isoenzyme unique to those cells: L-LDH-X. The dual localization of the enzyme enables mammalian spermatozoa to exchange cytosolic and mitochondrial reducing equivalents by means of a L-LAC/ pyruvate (PYR) shuttle, as suggested by Blanco et al. [10] and reconstituted later [11].

1.2. Liver

Since liver possesses the enzymatic machinery for gluconeogenesis (GNG) and since L-LAC is a major substrate for GNG, liver play a major role in L-LAC metabolism. Indeed, metabolism of L-LAC has traditionally been considered solely as a function of the cL-LDH in spite of the fact that the L-LAC oxidation by mitochondria and the existence of an mL-LDH in the inner compartments of isolated rat liver mitochondria (RLM) has been widely reported [12-15]. In a recent detailed investigation de Bari et al. [16] showed that externally added L-LAC can be oxidized in the matrix by an mL-LDH, with reduction of intramitochondrial NAD(P)⁺ and generation of a mitochondrial electrochemical proton gradient. Mitochondrial L-LAC transport was investigated and the rate of L-LAC metabolism in vitro was found to be limited by the rate of L-LAC transport into the mitochondria. Three separate L-LAC translocators, distinct from those which translocate

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Abbreviations: cL-LDH, cytosolic L-lactate dehydrogenase; COX, cytochrome c oxidase; GNG, gluconeogenesis; L-LAC, L-lactate; mL-LDH, mitochondrial L-lactate dehydrogenase; MCT, monocarboxylate transporter; MCT1, monocarboxylate transporter isoform 1; MCT2, monocarboxylate transporter isoform 2; MPC, mitochondrial pyruvate carrier; OAA, oxaloacetate; PYR, pyruvate; RHM, rat heart mitochondria; RLM, rat liver mitochondria

 Table 1

 The history of the L-lactate-mitochondria affair

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