J. Anat. (1983), **137**, 3, pp. 483–488
With 10 *figures*
Printed in Great Britain

Fine structure of astrocytic mitochondria in the hypothalamus of the hamster

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(*Accepted* 27 *January* 1983)

INTRODUCTION

In general, the mitochondria of astrocytes are elongated and their fine structure conforms with the common pattern found in most types of cell. In addition to such standard forms of mitochondria, astrocytic mitochondria containing triangular prismatic cristae (as seen in transverse section) are illustrated by Mugnaini & Walberg (1964) in cat brain. Blinzinger, Rewcastle & Hager (1965) describe such mitochondria in perivascular, marginal and intracortical astrocytes of the hamster brain. Similar mitochondria in astrocytes are also located in the cerebellum and the spinal cord of both cats and hamsters (Morales & Duncan, 1971). Mitochondria with prismatic cristae are also described in astrocytes of the spinal cord of the dog, cat and monkey (Duncan & Morales, 1973).

Other unusual forms of astrocytic mitochondria have been demonstrated (Farquhar & Hartmann, 1957; Schultz *et al.* 1957; Gray, 1959; Nelson *et al.* 1961; Morales & Duncan, 1971; Duncan & Morales, 1973). In astrocytes of amphibian brain, Szebro (1965) describes mitochondrial structures that he terms gliosomes. Gliosomes are also described by Donelli, D'Uva & Paoletti (1975) in ependymal cells of the lizard.

In this paper we report observations on prismatic and other unusual forms of mitochondrial cristae in the hypothalamic astrocytes of the golden hamster. To our knowledge, this is the first observation of such atypical mitochondria in astrocytes of mammalian hypothalamic nuclei.

MATERIALS AND METHODS

Twelve golden hamsters, of both sexes, weighing between 80 and 100 g, were used. Under pentobarbital anaesthesia (20 mg/kg body weight), the hamsters were perfused through the heart with 2·5 % glutaraldehyde (Millonig buffer, pH 7·3). After isolating the hypothalamus and dicing it into blocks approximately 1 mm^3, the tissue was immersed in cold fixative for 3–4 hours. Blocks were post-fixed in 1 % osmium tetroxide, dehydrated in acetone and embedded in Araldite. Thin sections were stained with lead citrate and examined in a Zeiss 109 electron microscope.

RESULTS

Mitochondria containing prismatic cristae, which had triangular profiles in cross section, were found in astrocytes located in the hypothalamus. They were more abundant in the suprachiasmatic and paraventricular nuclei. These mitochondria were typically found within perivascular astrocytic processes (Figs. 1, 2).

In transverse section, the double membranes of mitochondria were conspicuous and the intramitochondrial matrix was amorphous or finely granular. Within the matrix there were prismatic cristae which had profiles approximating to equilateral triangles (Fig. 2). The profiles often appeared to form a hexagonal array, with a centre to centre spacing of about 48 nm thick (Figs. 3, 4). Mitochondria containing prismatic cristae often had a peripheral zone where the cristae were like sheets, and dense granules close to these cristae were observed (Figs. 2, 5). The triangular profiles did not show any regular pattern in the orientation of their sides. The inner part of the triangular cristae was less dense than the matrix and was similar to that of the space between the outer and inner limiting membranes. Sometimes, groups of mitochondria with prismatic cristae were observed in certain perivascular areas of the suprachiasmatic nucleus (Fig. 6), related by means of intertwining membranes of endoplasmic reticulum.

Organelles, probably mitochondria, were also observed, which were lined by two parallel limiting membranes separated by a continuous space about 7–12 nm in width. They contained a matrix in which lay numerous dark parallel lines separated by lines of lesser density (Fig. 7). These linear structures were oriented parallel to the longitudinal axis of the organelle and they could be interpreted as profiles of internal membranes.

Mitochondria with an abundance of matrix and very few cristae were present within astrocytic processes in the suprachiasmatic and paraventricular nuclei (Fig. 8). Less frequently, an unusual type of mitochondrion was observed in the hypothalamic astrocyte in which the cristae lay in what may have been a helical arrangement along the long axis of the mitochondrion. In this case, the angular cristae were arranged as a series of groups of parallel sheets. Adjacent groups were orientated in different directions and, when seen in transverse section, the cristae presented as profiles of equilateral triangles. This appearance suggested that some process of swelling was associated with the presence of longitudinal and transverse sections of cristae (Fig. 9).

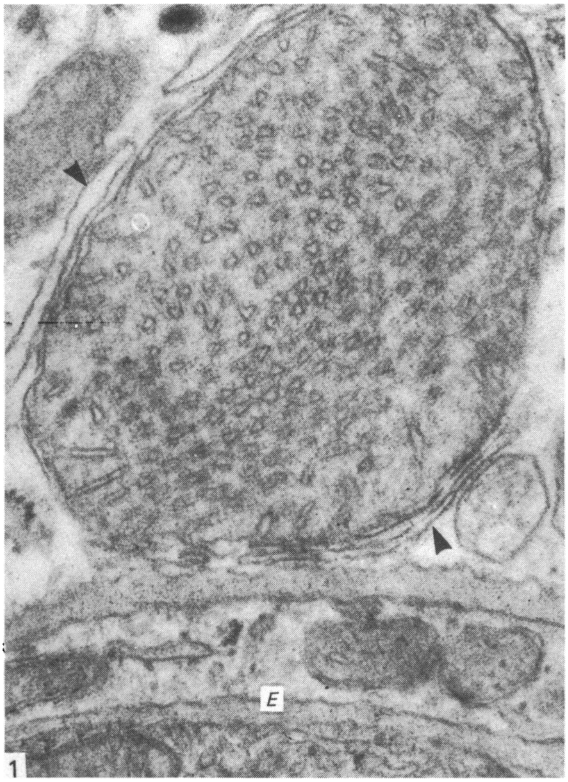
The unusual astrocytic mitochondria were present in the majority of astrocytes of the hamster hypothalamus but they were more abundant in the region located between the ependymal cells and the upper limit of myelinated fibres of the optic chiasma (suprachiasmatic nucleus). In this region capillaries were numerous and consequently the pericapillary astrocytic processes also. Subpial astrocytic processes of the mamillary region contained large mitochondria with their cristae arrayed parallel to the longitudinal axis (Fig. 10). Astrocytes belonging to the paraventricular nucleus (parvicellular component) also showed the various types of atypical mitochondria already described.

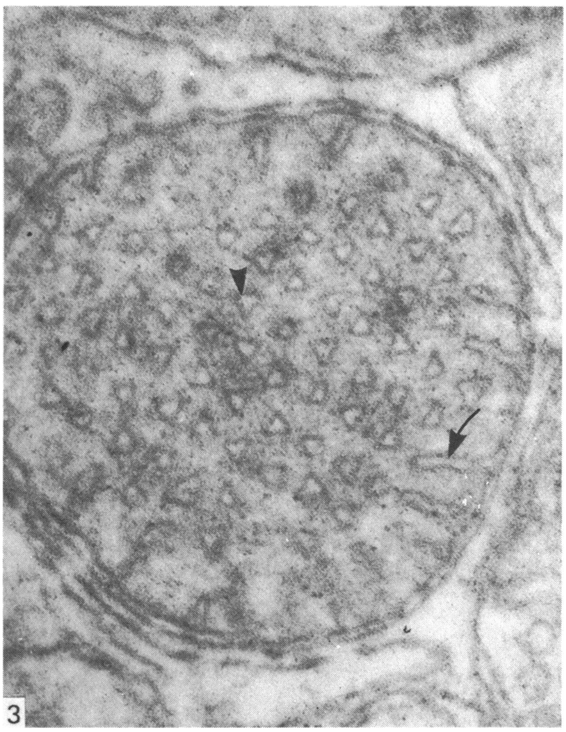
Fig. 1. Perivascular mitochondria in the suprachiasmatic nucleus. *E*, endothelium; arrowhead, endoplasmic reticulum. ×67500.

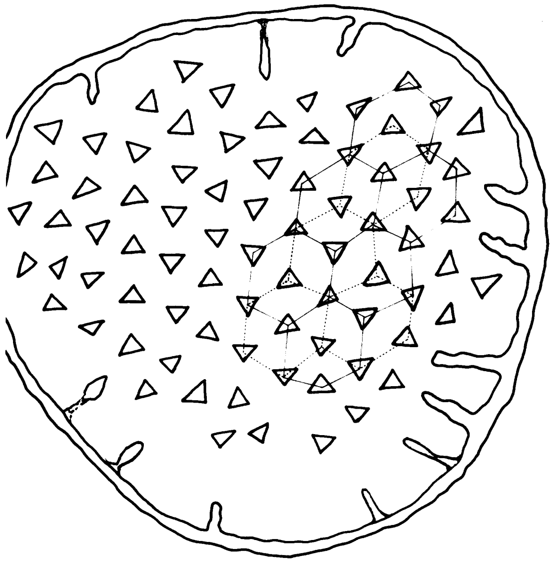
Fig. 2. Perivascular mitochondria in the paraventricular nucleus. *g*, gliofibrils; *bm*, basement membrane; arrowheads, hemidesmosomes. ×60750.

Fig. 3. Mitochondria with prismatic (arrowhead) and laminar (arrow) cristae and granular matrix in the suprachiasmatic nucleus. ×131250.

Fig. 4. Diagram of the mitochondrion of Fig. 3, showing triangular cristae in a hexagonal arrangement.







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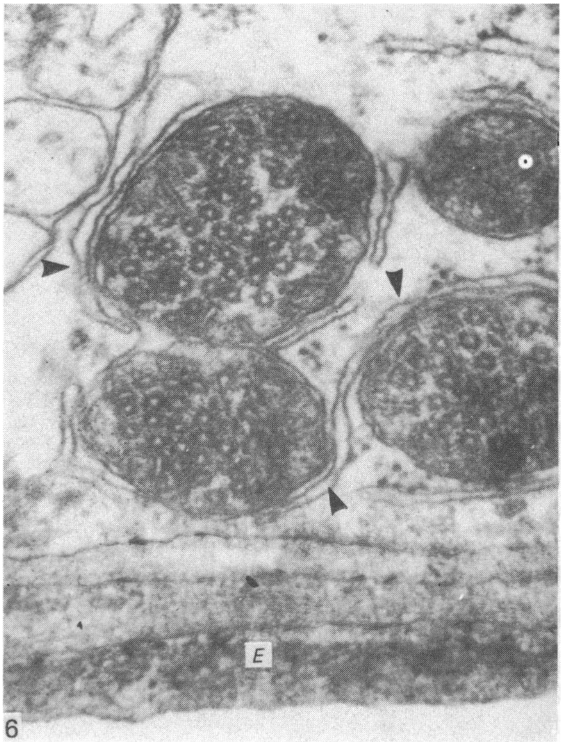

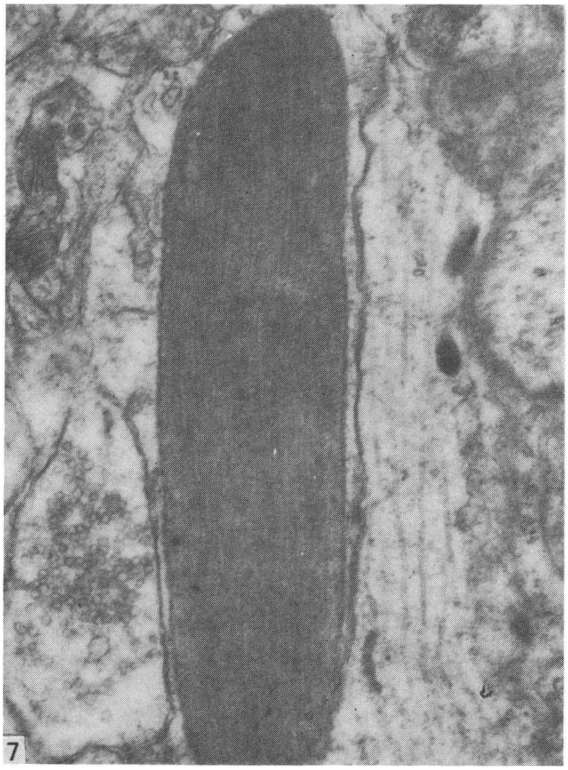

Fig. 5. Mitochondria in the paraventricular nucleus showing similar characteristics to those in Fig. 3. Arrowhead, dense granule. × 194000.

Fig. 6. Group of perivascular mitochondria in the suprachiasmatic nucleus. *E*, endothelial cell; arrowheads, endoplasmic reticulum. × 64400.

Fig. 7. Mitochondria containing parallel structures in the suprachiasmatic nucleus. × 33800.

Fig. 8. Mitochondria, with few cristae (arrowheads) and finely granular matrix, in the paraventricular nucleus. × 56500.

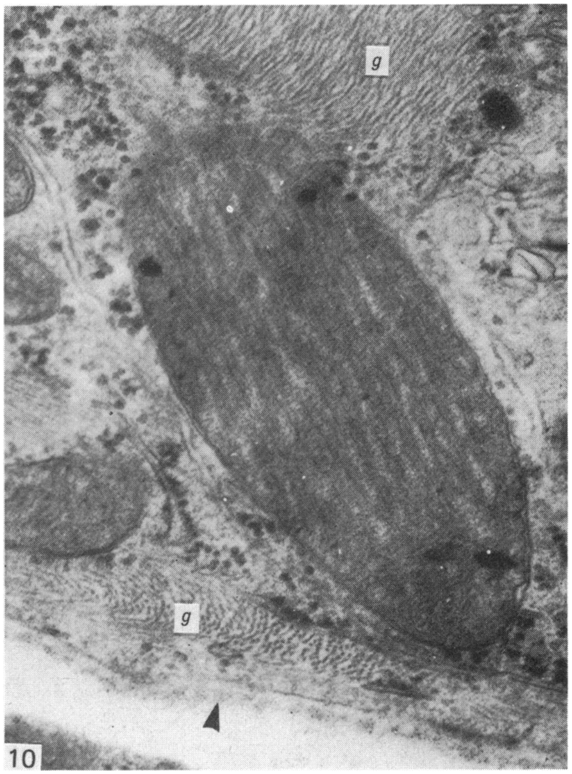

Fig. 9. Mitochondria with angular cristae orientated in several directions in the paraventricular nucleus. *N*, neuron. ×45700.

Fig. 10. Subpial mitochondria with parallel cristae in the mamillary nucleus. *g*, gliofibrils; arrowhead, basement membrane. ×51750.

DISCUSSION

The present findings show that the prismatic cristae and other unusual forms which are described in the mitochondria of the spinal cord and cerebellum of the hamster (Morales & Duncan, 1971; Duncan & Morales, 1973) are also present in the astrocytes of the hypothalamus. Mitochondria with prismatic cristae were first observed in the cricothyroid muscle of the bat by Revel, Fawcett & Philpott (1963), and subsequently were described and illustrated by Blinzinger, Rewcastle & Hager (1965) in hamster brain. According to Duncan & Morales (1973), mitochondria with and without prismatic cristae are normal features of astrocytes in the spinal cord of the dog, cat and monkey and may be present in all mammals. The present results support this point of view.

Other atypical mitochondria with parallel membranes arranged in sheets may represent an earlier form of the prismatic cristae. In astrocytes of the brains of amphibia, Szebro (1965) describes large mitochondria, termed Type 2 gliosomes, containing parallel and longitudinally oriented lamellae. Gliosomes with lamellar matrix are also described by Donelli, D'Uva & Paoletti (1975) in the hypothalamic region of the lizard. According to these authors, the matrix of the gliosomes is in a more or less advanced state of crystallisation and this may be the case with the atypical mitochondria, resembling gliosomes, in the present investigation. Certainly, matrix organisation may play a role in all the unusual mitochondrial forms.

In the large and elongated mitochondria, the spiral arrangement of the cristae as seen in longitudinal sections is regarded as indicative of a twisting of the entire organelle on its axis (Morales & Duncan, 1971).

The possible functional significance of prismatic cristae in mitochondria is still unknown, but conceivably their peculiar morphology indicates differences in metabolism. It is possible that these forms occur in all animals and are associated with some function common to them all (Morales & Duncan, 1971). On the other hand, their appearance may reflect the effects of local mechanical forces within astrocytes, without a concomitant significant alteration of their biochemical properties (Duncan & Morales, 1973).

The possibility exists that the ultrastructural appearance of the unusual mitochondria is the result of fixation artefact. However, since this unusual pattern is found in many species and in many different tissues after using different methods of fixation and embedding (Blinzinger *et al.* 1965), it is reasonable to conclude that the structures described in these organelles reflect their actual state in the living tissue.

SUMMARY

Astrocytic mitochondria in the hypothalamic region of the adult hamster brain have been studied by electron microscopy. Mitochondria showing triangular prismatic cristae, as seen in transverse section, and other unusual forms of mitochondrial cristae, are described and illustrated. Such mitochondria occur primarily in the suprachiasmatic and paraventricular nuclei, especially in perivascular astrocytic processes. The possibility that these atypical mitochondria might develop a specific function is discussed.

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