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MORPHOLOGICAL CHARACTERISTICS OF THE HEART OF ARGALI LIVING PERMANENTLY AT HIGH ALTITUDES

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Studies of the functional [2, 3, 8] and structural [1, 4-7, 10] bases of long-term adaptation to high-altitude and other extremal conditions have recently been published. Typical representatives of permanent mountain-dwellers are the argali, which live in herds on exposed spaces of mountain plateaus at altitudes of 3800-5000 m above sea level. The specific features of their ecologic environment make special demands on the argali. They have a strong constitution, they have great powers of endurance, and if necessary they can cover great distances over rocky mountains at high speed. No appreciable functional disturbances of the cardiovascular and respiratory systems arise in the argali. Yet no investigations have yet been undertaken to study the particular features of the ultrastructure of the cardiomyocytes in the argali. It was accordingly decided to study the myocardium of these animals by the use of light-optical and electron-microscopic methods of investigation.

EXPERIMENTAL METHOD

Pieces of myocardium from the left and right ventricles of argali were taken 20-30 min after slaughter of the animals. The length of the hearts varied from 11 to 12 cm, the transverse diameter from 9 to 12 cm, and the anteroposterior diameter 6-8 cm. The thickness of the wall of the left ventricle was 1.8-2.2 cm, of the right ventricle 0.5-1 cm, and of the ventricular septum 1.4-1.8 cm, which corresponds to moderate and uniform hypertrophy of the myocardium.

Pieces of myocardium for light microscopy were fixed in 10% neutral formalin solution and embedded in paraffin wax. Sections were stained with hematoxylin and eosin. Material for electron microscopy was fixed in 1% osmium tetroxide solution in veronal-acetate buffer, pH 7.4, for 2 h. The fragments were dehydrated in alcohols of increasing concentration. After appropriate rinsing and processing they were embedded in a mixture of Epon-812 and Araldite. Ultrathin sections were stained with lead citrate by Reynolds' method and examined in the JEM-100B electron microscope. Semithin sections 1 μ thick also were cut from the blocks embedded for electron-microscopy and these were stained with toluidine blue.

EXPERIMENTAL RESULTS

Macroscopically, the heart had the concical shape usual for mammals. The almost complete absence of adipose tissue beneath the epicardium was noted. A very small quantity of adipose tissue was confined to the coronary sulcus. The course of the branches corresponded to the left coronary type of blood supply to the heart. The main branches were straight in their course. On section their intima was smooth. The tissue of

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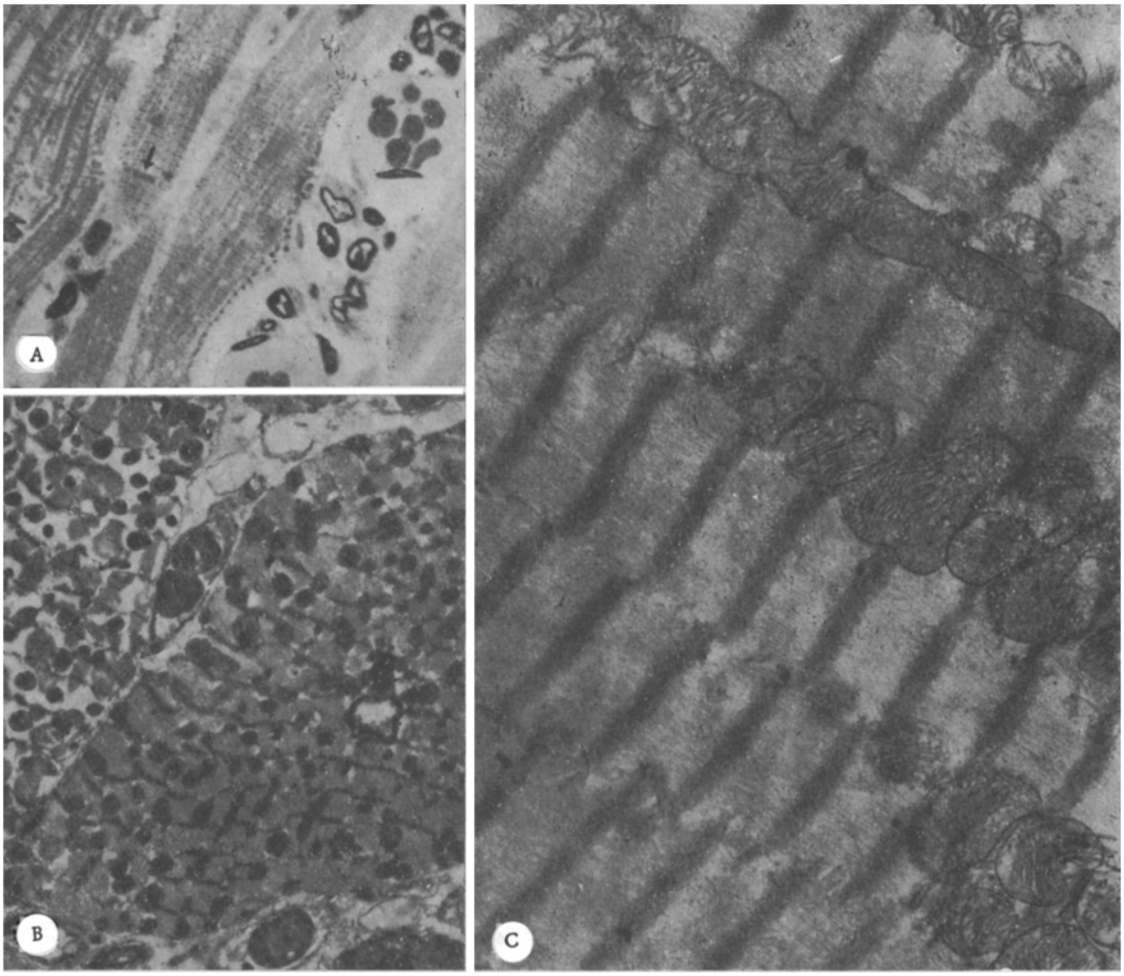

Fig. 1. Photomicrographs of the argali myocardium. A) Semithin longitudinal section through myocardium of left ventricle. Cross-striation of myofibrils formed by thickened Z-lines is clearly defined. Intercalated disks, shown as optically dense lines, run perpendicularly to long axis of myofibrils (arrow). 900×; B) myocardium of left ventricle. In the intercellular space around a single myocyte five or six capillaries can be seen. 2700×; C) myocardium of right ventricle. Z-lines of myofibrils grossly thickened (up to 0.32 μ). Single mitochondria extend over a length of seven sarcomeres or more. 12,500×.

the heart muscle was pale brown in color. In transverse histological sections the cardiomyocytes were polygonal in shape, with a central nucleus and small dark rims at the poles and near the membrane. The stroma was thin everywhere and delicate. Beneath the intima of the coronary arteries longitudinally oriented smooth-muscle cells could be seen as well as circular muscle cells in transverse sections. Here and there they were arranged as single bundles, or they joined together to become sickle-shaped, when they occupied a segment of the arteries. Between the muscle layers and muscle bundles there was a thin reticulum consisting of delicate fibers. Each cardiomyocyte made contact with three or four capillaries or more, evidence of the good blood supply to the organ. Collagen and elastic fibers could be identified in the stroma, with solitary lymphocytes, fibroblasts, and mast cells among them. In longitudinal ordinary and semithin sections the myofibrils were parallel to one another and formed small bundles. The cross-striation of the myofibrils, formed by the thickened Z-lines, was well defined. The intercalated disks were seen as dark zigzag lines running perpendicularly to the length of the myofibrils (Fig. 1, arrow).

On electron-microscopic investigation, five or six capillaries were observed around one myocyte (Fig. 1B). The Z-lines of the myofibrils are greatly thickened, on average to 0.32 μ (for comparison, the thickness of the Z-lines in the dog's myocardium is about 0.12 μ [9]). The mitochondria were of various shapes and sizes. Some of them in both ventricles stretched over a distance of seven sarcomeres or more (Fig. 1C).

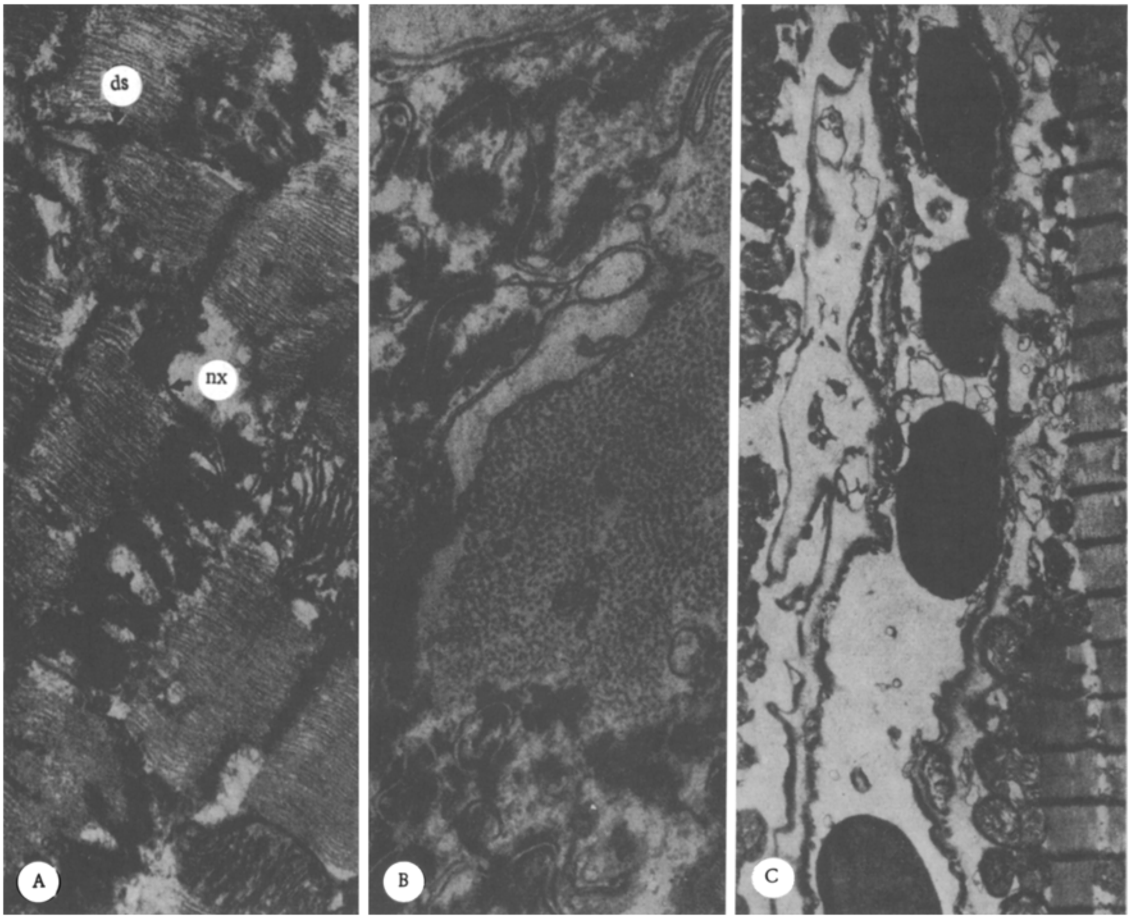

Fig. 2. Intercalated disks and capillary of argali myocardium. A) Myocardium of left ventricle. Intercalated disks arise from membrane of T-system. Nexuses (nx) and desmosomes (ds) well marked. 27,000×; B) Myocardium of right ventricle. Multiple intercalated disks arise from sarcolemmal membrane. 20,000×; C) Myocardium of right ventricle. Capillary wall seen on longitudinal section is very thin. Cytoplasm has irregular electron density. 6,000×.

Their cristae were densely packed, mainly parallel in their arrangment, and perpendicular to the long axis of the mitochrondria. During the analysis, no appreciable hypertrophy of the right ventricle and no hypertropy or hyperplasia of individual organelles could be observed in the experimental animals as a result of adaptation to hypoxia and physical exertion under high mountain conditions. Meanwhile, the number of capillaries around the cardiomyocytes was increased. This rule evidently determines the improvement in the blood supply of the organ and in oxygen transport to it, thus preventing the development of hypoxia under conditions of continuous exertion at high altitudes in the mountains. In longitudinal sections intercalated disks were found in the region of the Z-lines in the form of zigzag electron-dense lines with clearly defined structural components (Fig. 2A). In transverse sections, multiple intercalated disks could be seen arising from the sarcolemmal membrane or T-system (Fig. 2B). The nexuses were seen as darker lines about 200 A thick, formed by fusion of two plasma membranes of the sarcolemma; the space between the membranes could not be detected visually. The multiple intercalated disks evidently increase the cohesive force of the cardiomyocytes and the extent of zones of low electrical resistance, thus facilitating the transmission of excitation from cell to cell. The nucleus of the cardiomyocytes was rectangular in shape, with chromatin of high electron density unevenly distributed in the karyoplasm. The chromatin was distributed mainly at the periphery, beneath the nuclear membrane. Absence of lipid and glycogen granules in the cytoplasm of the cardiomyocytes was noted.

The T-systems of the sarcoplasmic reticulum penetrated deep into the cell as a continuation of the sarcolemma in longitudinal sections. In transverse sections the blood capillaries were lines with one or two, less frequently three, thin endothelial cells of varied electron density. In longitudinal sections the endothelial cells of the blood capillaries also were thin and had uneven electron density (Fig. 2C). Many microvilli facing the lumen of the capillary, and micropinocytotic vesicles of varied diameter, could be seen in them. This state of the endothelial cells of the capillaries evidently improves the blood supply to the organ and intensifies the transport of materials and oxygen through the vessel wall.

These investigations into the structure of the argali heart thus showed the presence of an increased number of capillaries around the cardiomyocytes, absence of marked hypertrophy of the myocardial cells and their organelles, and thickening of the Z-lines of the myofibrils; these are the distinguishing features of the structure of the myocardium in argali, animals with great adaptive reserves which can stand high-altitude hypoxia.

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STUDY OF THE ARGYROPHILIC STRUCTURES OF THYMUS CONNECTIVE TISSUE AFTER EXPOSURE TO X-RAYS

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KEY WORDS: thymus; reticular tissue; argyrophilic structures; irradiation.

A study of the internal medium of the thymus, in the microenvironment of which the thymocytes differentiate, is of considerable interest. In embryogenesis the thymus is laid down as an epithelial organ, but later, in the course of organogenesis, mesenchymal cells penetrate into the parenchyma to form the stroma of the thymus: interlobular septa, vessels, and capsule [1, 5, 11]. These structures are formed of reticular and loose and dense connective tissue. The epithelial cells of the thymus, bordering on connective-tissue structures, are disposed on the basement membrane [9, 10]. As a result of light-optical and electron microscopic studies, besides cells of the epithelial reticulum, cells of connective-tissue nature forming reticular tissue have been described in the internal medium of the lobule. As well as reticular cells, it contains macrophages and lymphoblasts. The macrophages of the thymus have been shown to have the power of phagocytosis [1, 2, 6].

Studies of the connective-tissue framework of the thymus have shown that there are extremely few argyrophilic fibers in both its cortex and its medulla. They mainly form the basis for the walls of blood vessels, they virtually do not extend into the medullary zone, and they do not reach the Hassall's corpuslces [1, 5].

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