Mitochondria

The term «mitochondria» (thread kernels) goes back to BENDA (1898–1902), who introduced this name for a certain fraction of cell granules inclining to form threads. The function in vesicular breathing was demonstrated first by WARBURG (1913). The statistical significance of their central position in the entire oxydative metabolism was established by the technical possibilities of separating by ultracentrifugation the mitochondria fraction as a large fraction of granules (fig. 36) from the rest of the cellular constituents (SCHNEIDER, 1959; NOVIKOFF, 1961; KLIMA; KRSTIĆ, 1976).

In bacteria, enzymes of the respiratory chain are localised in the peripheral layers of the cytoplasm; higher organisms, however, have special cell organelles for breathing, namely the mitochondria. They are called also «chondriosomes», «chondriochonts» or «plastosomes», «chondriom» in their totality (MEVES, 1907).

Mitochondria are obligatory organelles of all animal cells, with the exception of normocytes. Form and size vary according to the kind of the cells and to their functional activity. The organelles can be made visible, especially by staining with Janus green-B, and can be prepared vitally as greenish-black granules or threads of various sizes. Overdoses of dyestuff produce safranin and a red colour, which causes the degeneration of the mitochondria and immediately the death of the cells. The phase-contrast microscope detects mitochondria during the observation in vivo as moving granules. However, only electron-microscopy (fig. 35–43) has fully disclosed the morphology.

Form and structure

Mitochondria are structures having round, elliptic, filiform, reniform, club-shaped or dumb-bell-shaped cross-sections (fig. 35–43). The diameter of their cross-sections is 0.18 (retina) to 2.0 (myocardium), the length 1.0–5.0 (up to extremely 14.0) mi m; their width varies from 0.2–1.0 mi m (KMENT, KLIMA). In spite of the many different forms, the architectonic structure follows one basic plan: mitochondria have two elementary membranes, an outer one and an inner one, of a total thickness of 100–250 Å. This double-membrane system separates the mitochondria from the rest of the space of cytoplasm. The space between the outer and inner membranes comes to 100–200 Å, and is also referred to as outer phase. The inner membrane forms bulges towards the lumen. These bulges have the function of increasing the surface of the inner membrane; they are also summed up as the inner phase. On the bulges of the inner membrane are ribosome-like particles having a diameter of about 100 Å (fig. 42). According to KRSTIĆ, a liver cell e. g. has about 2500 mitochondria, the surface measures 13 mi m², but the surface of the inner phase some 16 mi m². Depending on the kind of the bulges, several types of mitochondria are distinguished, such as e. g. in transverse bulges:

a) the *Crista type* with Cristae mitochondriales (fig. 38)
b) the *tubulus type* (fig. 39)
c) the *prisma type* (fig. 40)
d) the *sacculus type* (fig. 41).

The elementary particles have a diameter of about 100 Å and are located on a shaft of about 35 Å in diameter. Through this shaft they are connected with the inner mitochondria membrane. There we find structure elements (fig. 42) serving for the enzymatic coupling (b); they contain enzymes of the respiratory

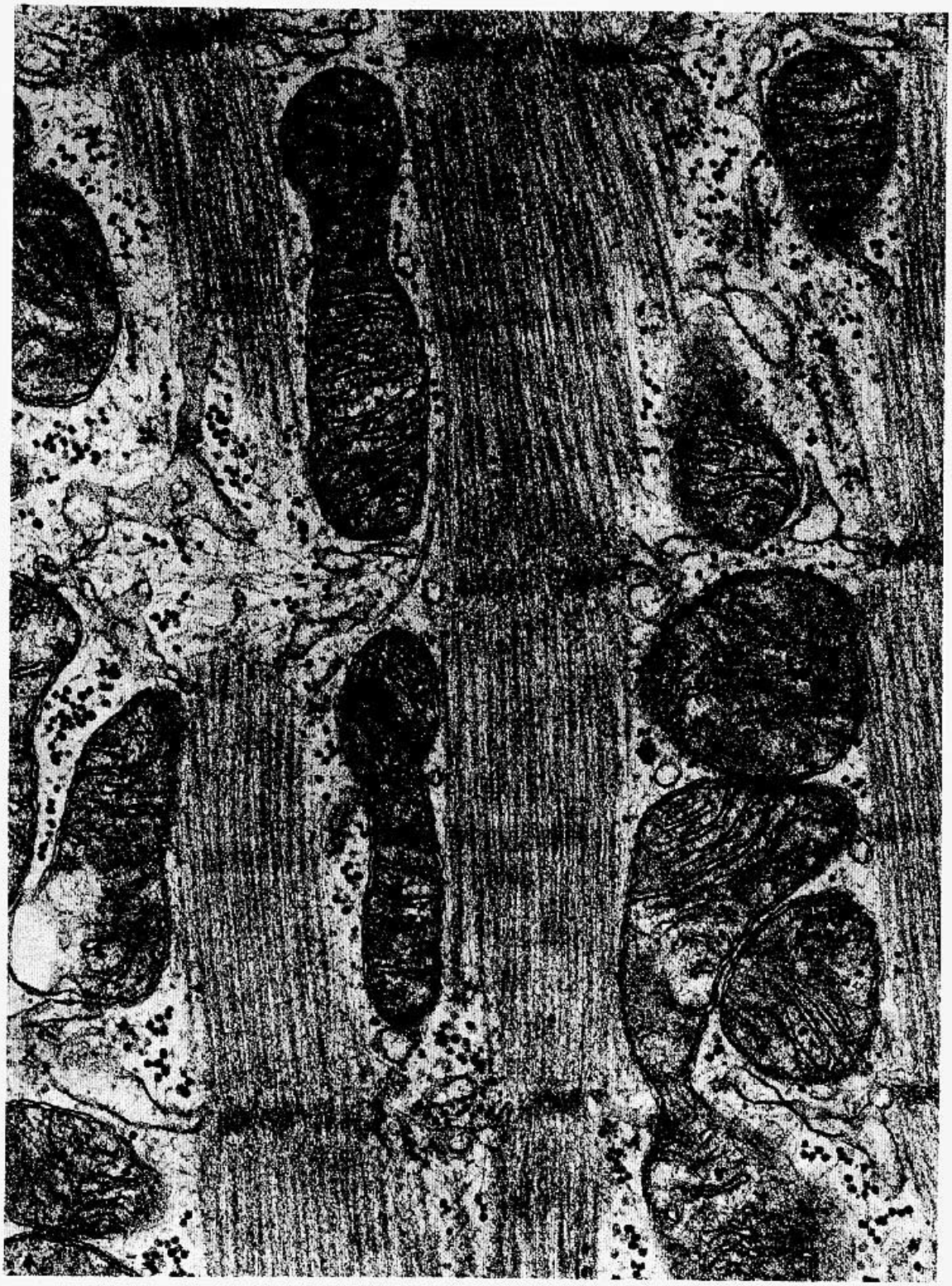


Fig. 35:
Abundance in *mitochondria* in metabolic-active tissues like muscle (H. THEMAN, Münster).

chain (f) and of the cytochrome C (e). In fig. 42, the elementary granules are marked as a, the three-layered inner membranes with b, g and c; b and c mark structural proteins, and g the lipoid layer of the membrane.

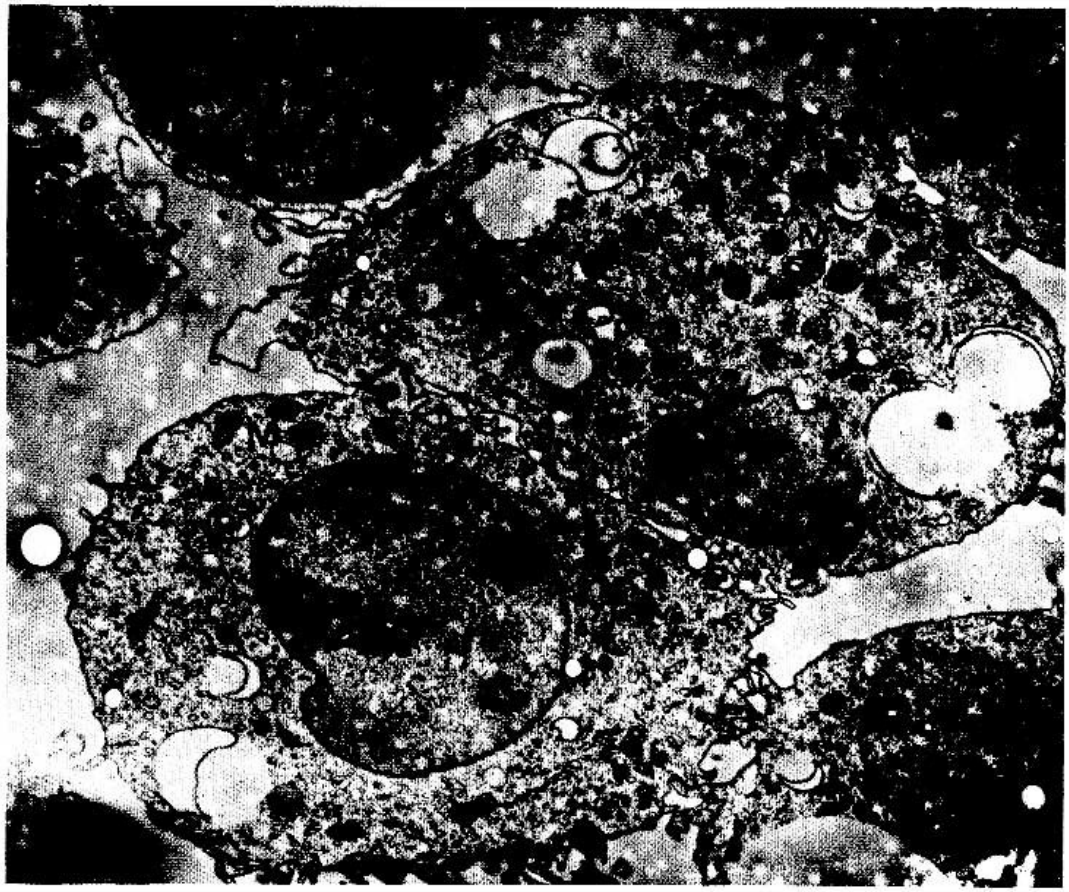


Fig. 36:
«Coarse fraction of granules» = mitochondria in monocytary cells of peritoneal exudate. Guinea-pig. 1:4000.

Outfit of the cell with mitochondria

Number and arrangement of the mitochondria are variable, certain concentrations are found in areas with high metabolic efficiency e.g. in the perinuclear space and in the Golgi-apparatus. The number of the mitochondria, too, depends on the type of the cell and on the metabolism. Embryonic cells contain more mitochondria than cells of adult or aging organisms. Especially liver cells are rich in mitochondria; 1 g of fresh liver is supposed to contain 33×10^{16} mitochondria; glandular cells, renal epithelia, myocardium belong to the organs rich in mitochondria whereas the cells of the thymolymphatic system (thymus, spleen) and the leukocytes are poor in mitochondria.

Related to the *mass of the cell,* a percentage of 15–25% falls to the fraction of mitochondria. Within this fraction of mitochondria, 70% proteins (chiefly en-

zyme protein), 3% RNA and 27% lipoids can be identified; 60% of this lipoid constituent are phosphatides.

The *membranes* consist of two osmiophile layers each about 70–80 Å thick, between them is a somewhat brighter osmiophobic layer 40–50 Å thick; at least one of the membranes is probably semipermeable. The outer membrane is smooth, the inner membrane shows regular particles with macromolecules.

Fig. 37:
Mitochondria (M) with a seemingly empty lumen, in peritoneal macrophages of the guinea-pig, which are about to disintegrate a phagocyted cell (C). Final magnification: 1:20,000.

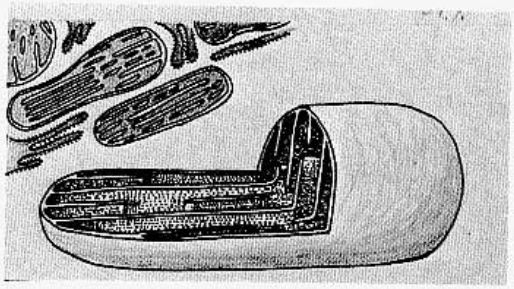
Function

Mitochondria are carriers of the *energy-metabolism* and of *cellular breathing*. They provide the cell with *oxydative energy* and effect the *release of ATP*. Adenosintriphosphate (ATP) is synthetised from *adenosindiphosphate (ADP)* and *phosphate (P)* in the *elementary particles* of the inner membrane. These elementary corpuscles are therefore called sometimes *ATP-osomes*, not *oxysomes* as formerly (KRSTIĆ). As the ATP is split in connection with the enzymes of the breathing chain, the energy for the cellular activity is released. Of the many functions of the mitochondria in close and changing interrelations to the cytoplasm space, statistical significance has been established for the following:

The mitochondria have all enzymes of the Krebs-cycle; tricarbone cycle (fig. 43); respiratory chain coupled with phosphorilation; disintegration of pyruvic-acid; release of CO_2; transfer of hydrogen on coenzymes and their prosthetic groups; hydrogen is carried through the respiratory chain towards O_2 up to the cytochrome system; participation in the glycerophosphate cycle; formation of energy at 3 sites of the metabolic cycles.

Essential elements are, besides the enzymes mentioned, the key-enzymes cytochromoxydase and succino-dehydrogenase (succinic acid-dehydrogenase); the vitamins A and C are required for the function. Aerobians can grow only if the structure and function of the mitochondria are intact.

Still unclear is the question how mitochondria come into existence and multiply, probably they originate from symbionts.



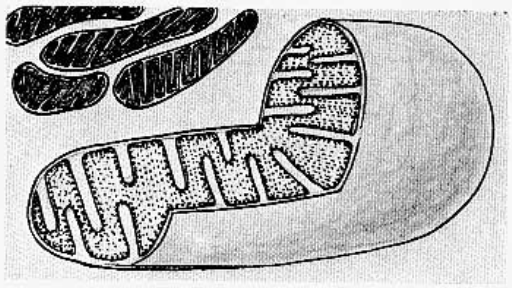


Fig. 38:
Crista-type of the mitochondria

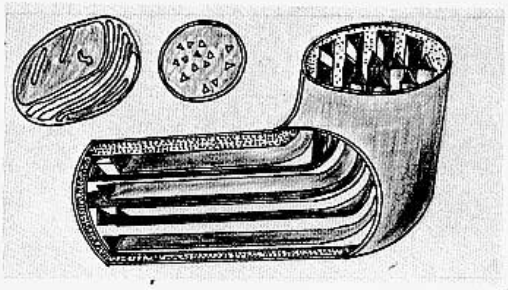


Fig. 40:
Prismatic type of the mitochondria

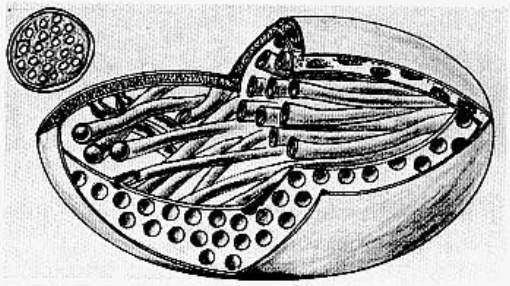


Fig. 39:
Tubulus-type of the mitochondria

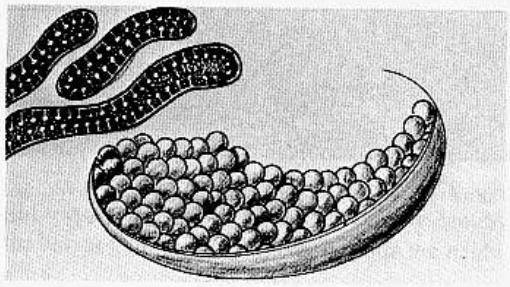


Fig. 41:
Sacculus-type of the mitochondria

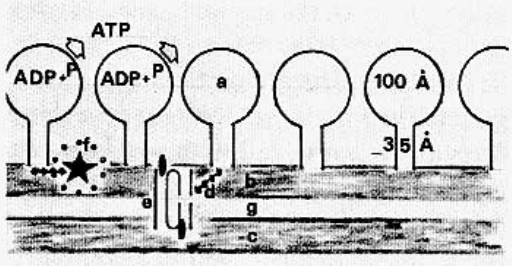


Fig. 42:
Diagram of the inner *surface of mitochondria* (inner phase); see text.

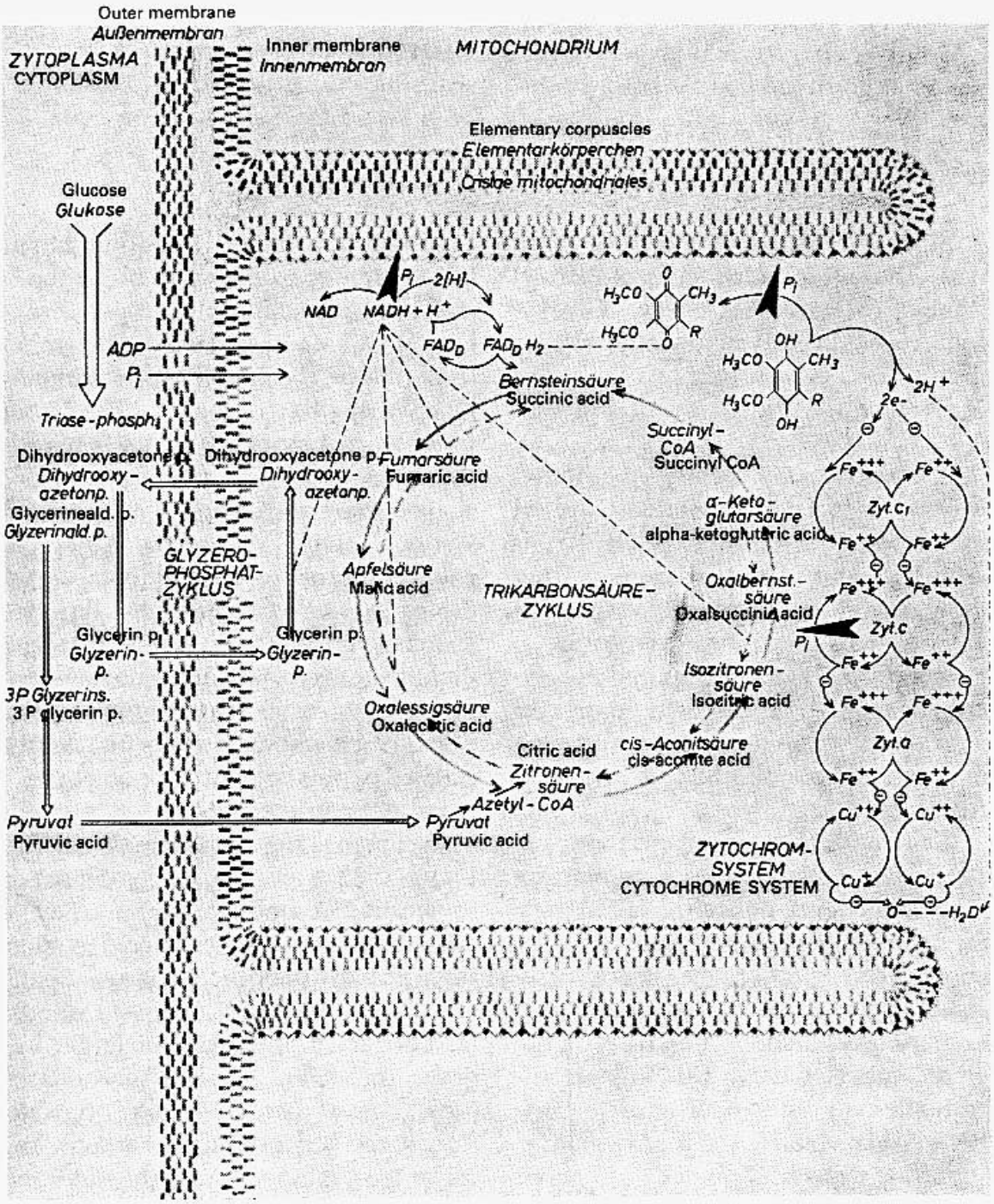


Fig. 43:
Metabolic processes in the mitochondria, especially processes for the production of oxydative energy and interrelation to the cytoplasmatic space. Simplified representation after KLIMA.
In the mitochondria, pyruvic acid is disintegrated via the Krebs-cycle by decarboxylation and dehydration; CO_2 ist released and hydrogen transmitted to coenzymes (NAD and FAD). The hydrogen is guided via the respiratory chain towards the O_2 as far as the cytochrome system. At three sites (wedges), energy (Pi) is formed. The formation of the mitrochondria wall and of the Cristae is represented.