

VIVEKANANDA COLLEGE
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NAAC ACCREDITED 'A' GRADE



Topic: **Mitochondria-Structure**

Course Title: **Cell Biology Unit 3: Cytoplasmic organelles II**

Paper: **ZOOA-CC2-4-TH**

Unit: **Introduction to Aquarium Fish Keeping**

Semester: 2

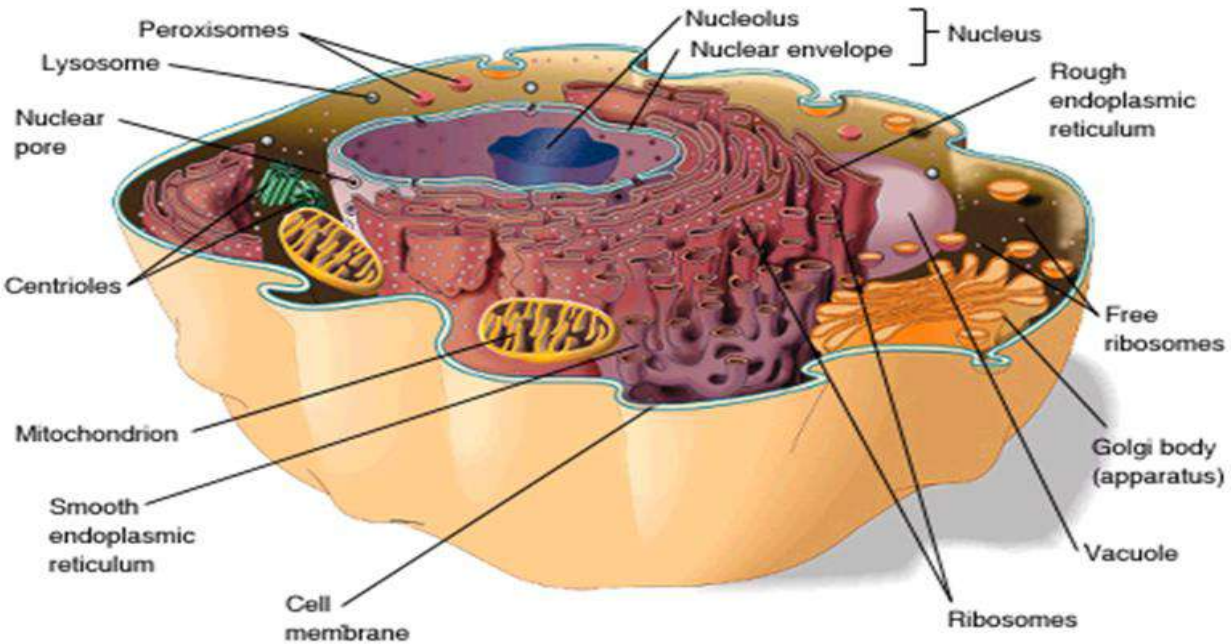
Name of the Teacher: **Dr. Gunjan Dhar**

Name of the Department: **Department of Zoology**

Mitochondria Mitochondrion

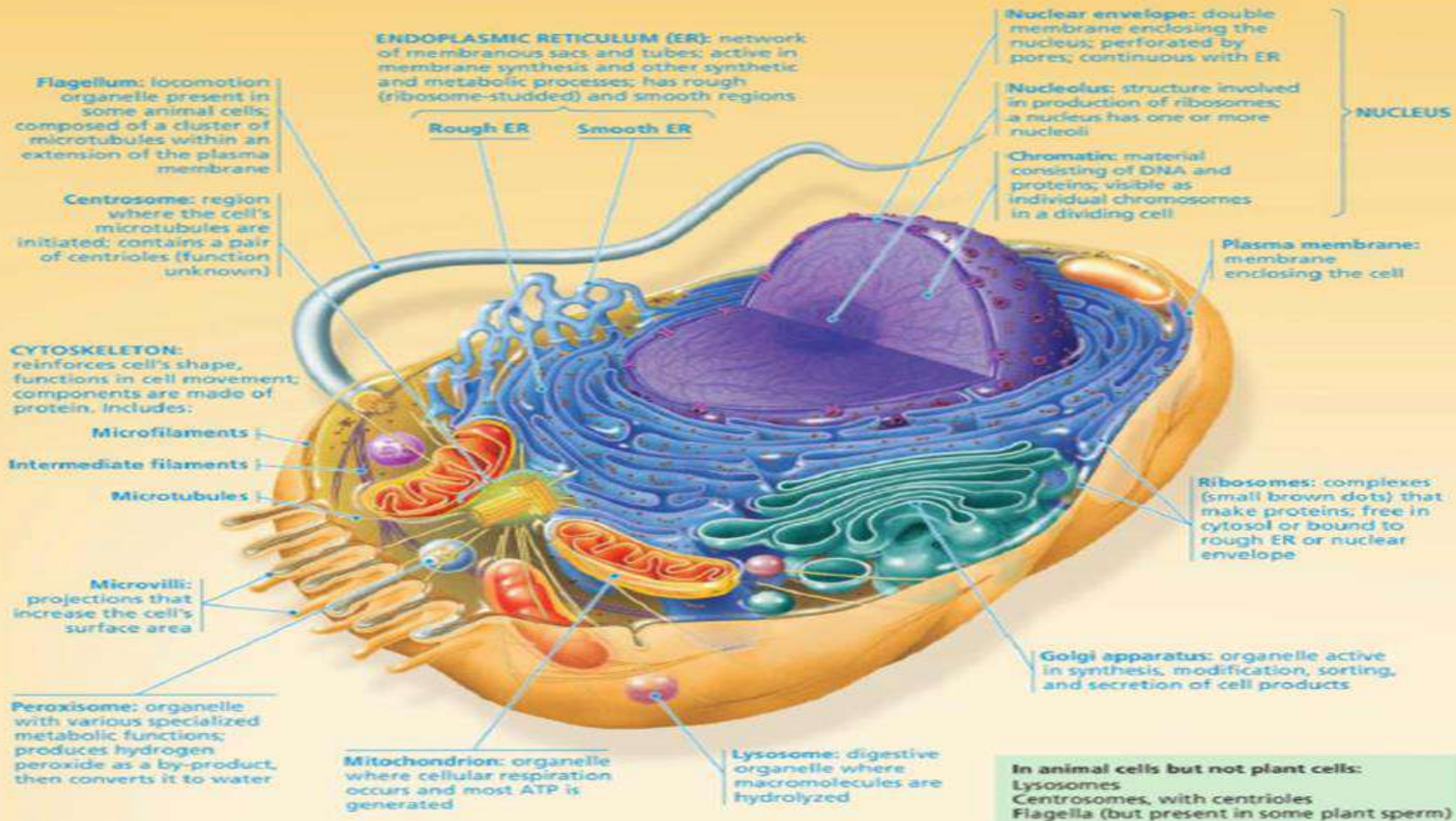
Mitochondria-Structure

Eukaryotic Cell



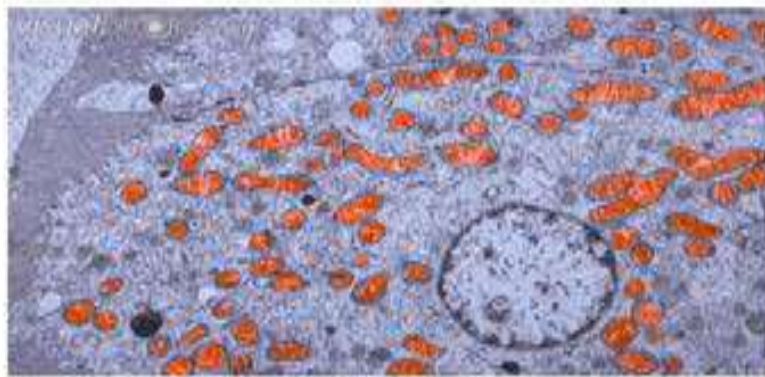
Dr. Gunjan Dhar
2nd Sem UG Hons

Eukaryotic cells contain organelles— membrane-bound structures with specialized functions. This generalized animal cell shows the prominent nucleus, extensive membrane system of the endoplasmic reticulum, mitochondria, other organelles, and numerous ribosomes.



The mitochondrion

- Greek Mitos = „thread”, and chondrion = „granule”
- found in most eukaryotic cells
- „energy factory of the cell”
- 0.5 to 1.0 micrometer (μm)
- Number: 1- several thousand /cell



The mitochondrion (plural mitochondria) (greek: Mitochondria, Mitochondrion)

- ❖ **It is a double membrane bound organelle found in eukaryotic cells.**
- ❖ **mito= thread chondrion = granule like**
- ❖ **Found in cytoplasm of the cell.**
- ❖ **Power house of cell.**
- ❖ **First observed by Kolliker (1894).**
- ❖ **Term mitochondria was coined by Carl Benda (1898).**

They are usually scattered throughout the cytoplasm of most cells, but they often concentrate in specific areas where high energy utilization, in the form of ATP, occurs. Such areas include apical regions of ciliated cells, basal areas of ion-transporting cells, and subsarcolemmal areas of skeletal and cardiac muscle cells.

Their number and size vary with metabolic activity and type of cell. Mature erythrocytes have none; a hepatocyte has up to 2500.

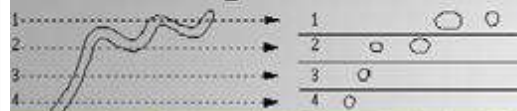
These very dynamic organelles show constant motion, fusion, and division in cells

They are quickly affected by temperature and autolysis and are among the first structures to disappear on death of the cell; for this reason early fixation is necessary for their demonstration.

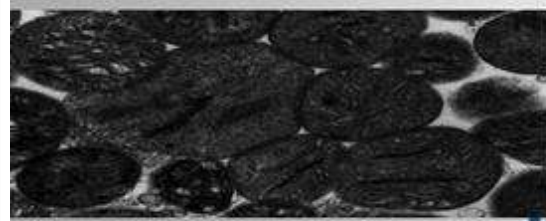
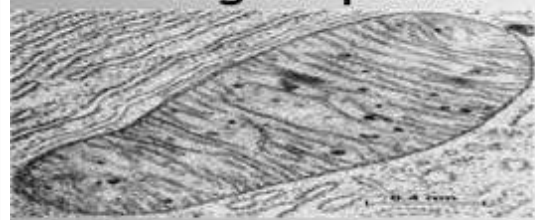
It is now evident that mitochondria increase in number by division throughout interphase, and their divisions are not synchronized with the cell cycle.

SHAPE, DISTRIBUTION & NUMBERS

shape



Higher plants



Animals

❖ Very small organelles ($0.5 \times 1-2 \mu\text{m}$).

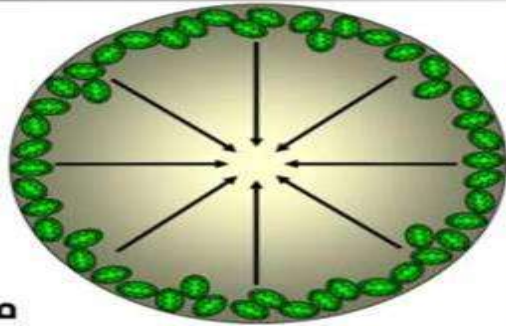
❖ **Rod shape** with hemispheroidal ends, Some are cup or **filamentous** shape.

Vary from **globular** to **threadlike** or **branched**

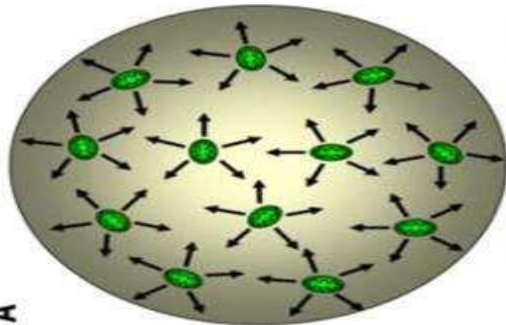
❖ Long filaments, **not spatial** in arrangement.

SHAPE, DISTRIBUTION & NUMBERS

Distribution



B



A

- ❖ Cells with **active processes**, Near wall ingrowths or chloroplast.

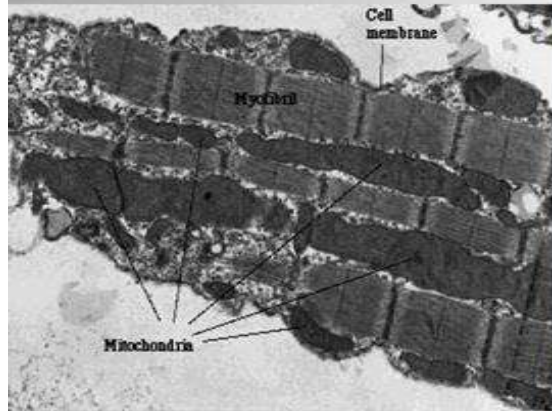
- ❖ **Free** in the cytoplasm.

- ❖ **Packed** in rigid structures, such among the myofibrils of **cardiac muscle tissue**.

SHAPE, DISTRIBUTION & NUMBERS

Numbers

Examples



Surviving

❖ Depends on what the cell needs to do.

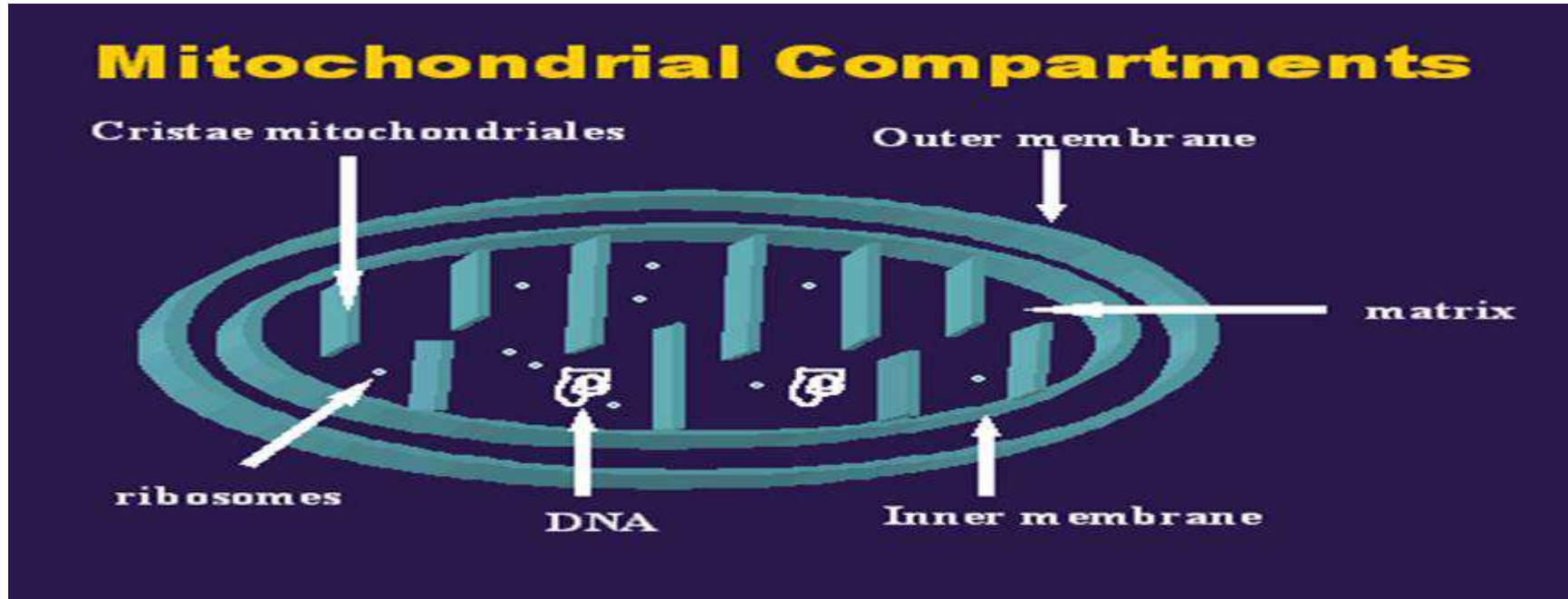
❖ **Flagellated protozoa or sperm**, they are found around the base of the flagellum.

❖ **Cardiac muscle**, they surround the contractile parts.

❖ **Hummingbird flight** muscle is the richest sources of mitochondria.

❖ When energy is **not enough**, more mitochondria are created, they **grow, move, and combine** with other mitochondria.

Diagram of the mitochondria structure



The morphology of mitochondria varies with cell type. In cells with a high oxidative metabolism, mitochondria are commonly large and serpiginous. In steroid hormone-secreting cells, such as those of the adrenal cortex, the cristae are tubular structures rather than flat plates.

Shelflike cristae in protein-secreting cells and tubular cristae in steroid secreting cells

Mitochondria

Mitochondria contain two membranes, separated by space. Inside the space enclosed by inner membrane is the matrix.

These appears moderately dense and one may find strands of DNA, Ribosome, or small granula in the matrix.

The above diagram shows the diagram of the mitochondrial membranes and the enclosed compartment.



Mitochondrial compartments

Inner membrane

- Respiratory chain and ATP synthase
- impermeable to most charged molecules
- highly folded into invaginations called *cristae*.

Outer membrane

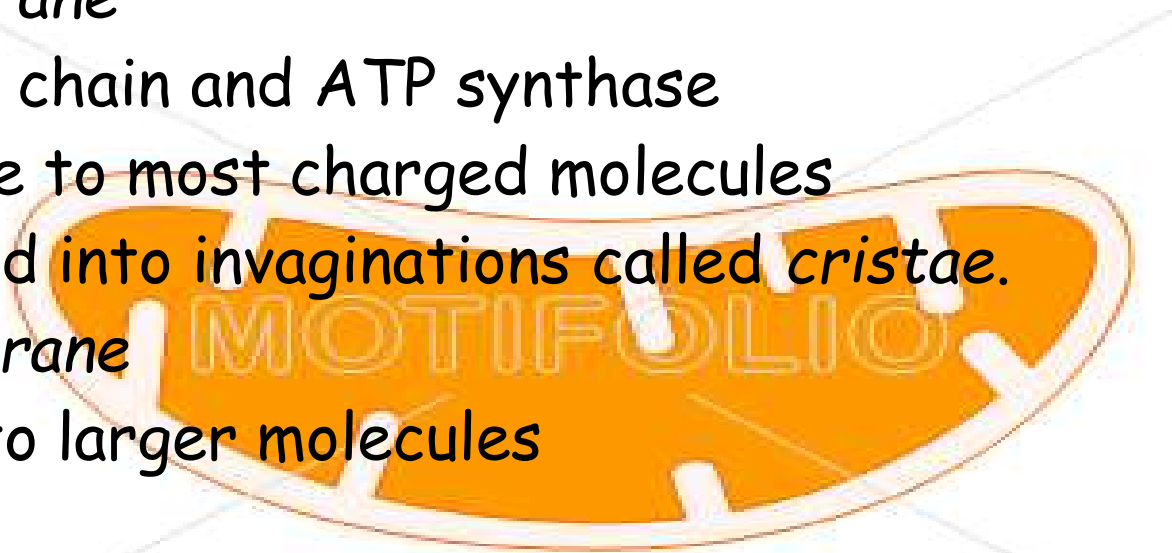
- Permeable to larger molecules

Matrix

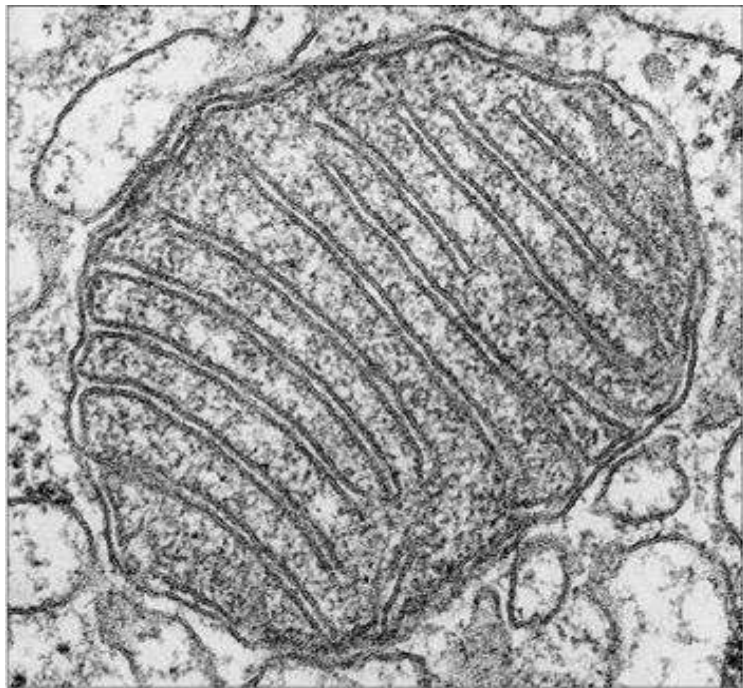
- Enzymes of the citric acid cycle, mtDNA

Intermembrane space

- space between inner and outer membranes



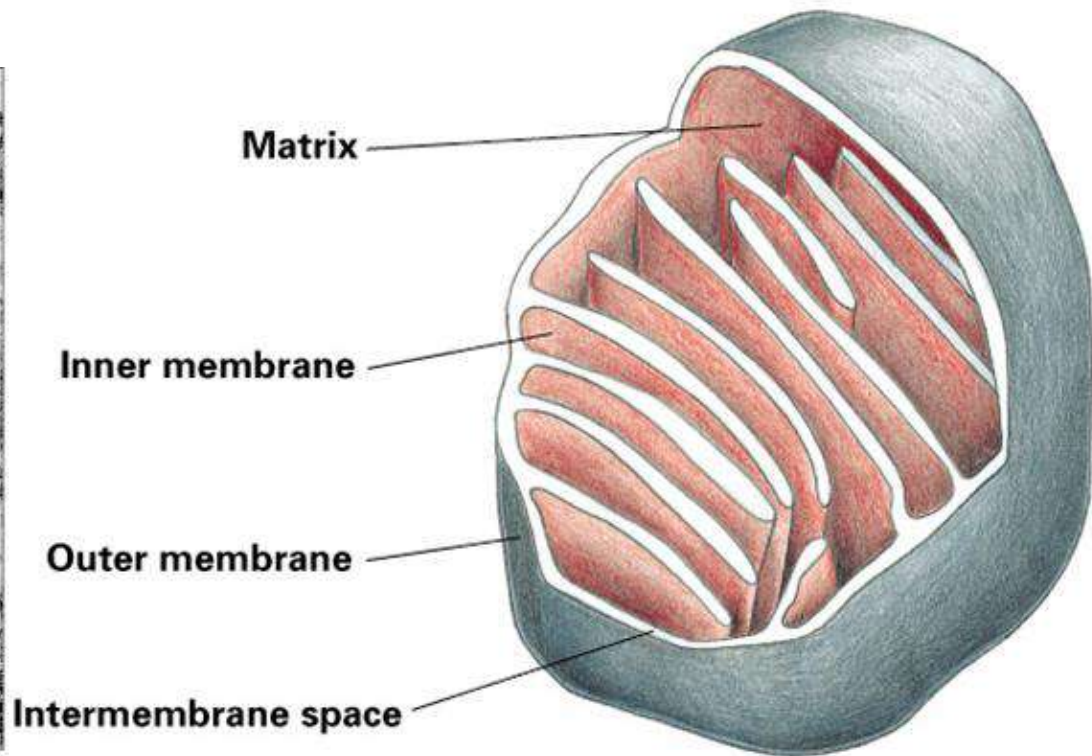
Mitochondrial compartments



100 nm

Figure 14-8 part 1 of 3. Molecular Biology of the Cell, 4th Edition.

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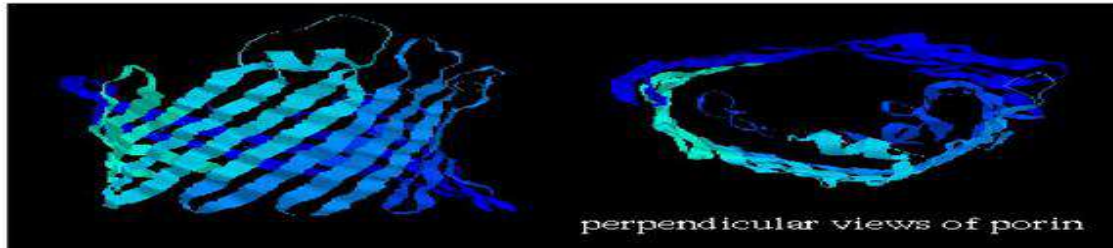


Intermembrane space

Figure 14-8 part 2 of 3. Molecular Biology of the Cell, 4th Edition.

1. Outer membrane

- similar to the eukaryotic plasma membrane (protein:phospholipid = 1:1)
- Contain porin proteins → make the membrane permeable to 10.000 Dalton



The outer mitochondrial membrane also contains transmembrane pores that can assemble and open to release large mitochondrial proteins into the cytosol.

This action is triggered by a variety of cell stimuli and leads to activation of cell death mechanisms (apoptosis). Porins are **voltage- dependent anion channels**

In this way, the mitochondrion acts as an important transducer for certain stimuli that lead to cell death.

The outer membrane possesses receptors for proteins and polypeptides that translocate into the intermembrane space. It also contains several enzymes, including phospholipase A2, monoamine oxidase, and acetyl coenzyme A (CoA) synthase

2. Inner membrane



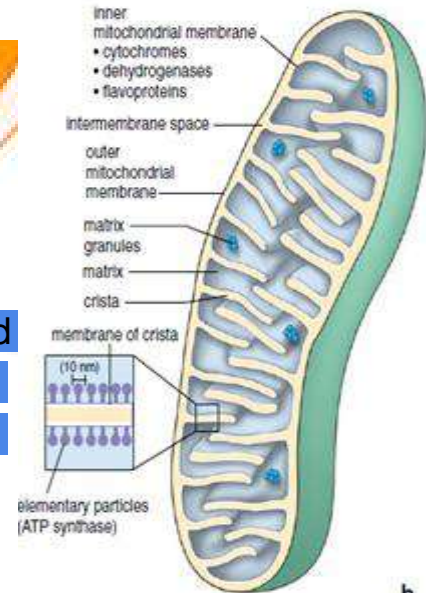
- protein:phospholipid = 80:20
- rich in cardiolipin (phospholipid) → makes the inner membrane impermeable
- molecules require special transport proteins to enter or exit the matrix
- forms cristae

Impermeability is essential to mitochondrial function as it permits the development of electrochemical gradients during the production of high-energy cell metabolites.

The membrane forming the cristae contains proteins that have three major functions:

(1) performing the **oxidation reactions** of the respiratory electron-transport chain, (2) **synthesizing ATP**, and (3) **regulating transport** of metabolites into and out of the matrix.

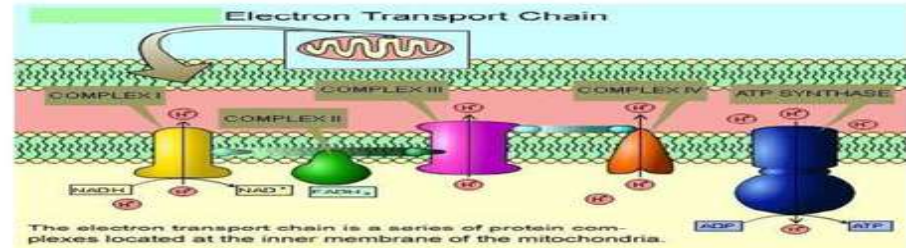
The enzymes of the **respiratory chain** are attached to the inner membrane and project their heads into the matrix (Fig. 2.37, *rectangle*). With the TEM, these enzymes appear as tennis racquet-shaped structures called **elementary particles**. Their heads measure about 10 nm in diameter and contain enzymes that carry out oxidative phosphorylation, which generates ATP



2. Inner membrane

- **Cristae**

- expand the surface area of the inner mitochondrial membrane
- Contain proteins:
 - Specific transport proteins
 - Proteins of the electron transport chain
 - ATP-synthase



Mitochondrial **cristae** vary greatly in size, shape, and number depending on cell type and metabolic activity.

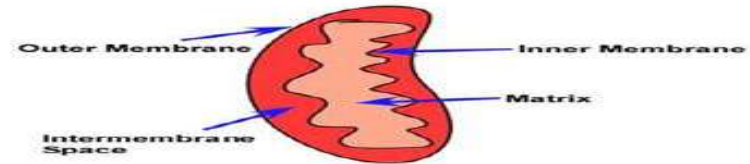
Cristae greatly increase surface area for ATP synthesis and reactions related to *electron transport*, *Krebs citric acid cycle*, and *oxidative phosphorylation*.

Cristae usually, but not always, extend across the interior of a mitochondrion. Most cells have flattened, lamellar cristae, which are usually perpendicular to the longitudinal axis of the mitochondrion.

Tubular and tubulovesicular cristae are most common in **steroid-secreting cells**, where cristae also contain enzymes for *steroidogenesis*.

3. Intermembrane space

- Between the outer membrane and the inner membrane
- the concentrations of molecules in the intermembrane space is the same as in the cytosol

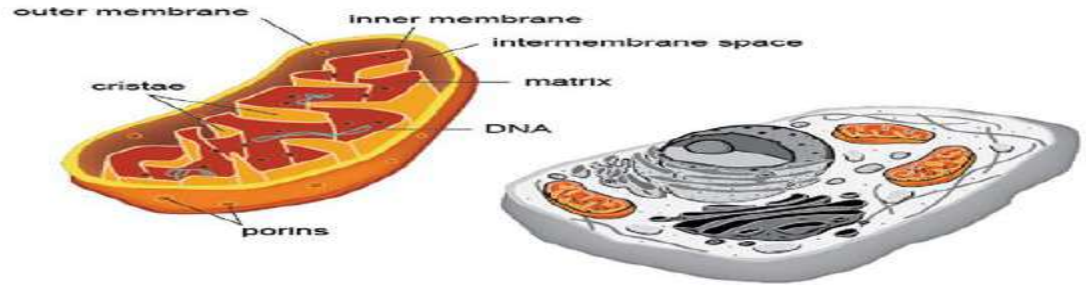


The intermembranous space contains:

- Metabolic substrates which diffuse through the outer membrane
- ATP generated by the mitochondrion
- Ions pumped out of the matrix space during oxidative phosphorylation. The matrix space contains enzymes to oxidize fatty acids and pyruvate as well as for the citric acid (TCA) cycle. It also contains mitochondrial DNA and specific mitochondrial enzymes for mitochondrial DNA transcription.

Enzymes creatine kinase, adenylate kinase, and **cytochrome c**. The latter is an important factor in initiating apoptosis

4. Matrix



- Gel-like
- Contains:
 - hundreds of enzymes
 - special mitochondrial ribosomes, tRNAs and mRNAs
 - several copies of the mitochondrial DNA genome

The **matrix** contains many enzymes needed for oxidation reactions of the Krebs cycle.

Mitochondria have a degree of autonomy in a cell. They have their own closed-loop *DNA*, *RNA*, and *ribosomes* in the matrix

Mitochondria sequester calcium and other divalent cations that are stored as small **matrix granules** (diameter: 30-50 nm). They can respond to a cell's functional demands. They are especially prominent in osteoblasts that form bone matrix and in ion-transporting cells, such as those of the kidney and small intestine.

Enzymes of the **citric acid cycle (Krebs cycle)** and the enzymes involved in **fatty-acid –oxidation**. The major products of the matrix are CO₂ and reduced NADH, which is the source of electrons for the electron-transport chain.

Mitochondria is the Power house of the cell.

How are mitochondria organized to be power house.

The food we eat is oxidized to produce high energy electrons that converted to store energy. This energy is stored in high energy phosphat bond in a molecule called Adenosine Triphosphate (ATP).

ATP is converted from Adenosine Diphosphat by adding the phophat group with high energy bond.

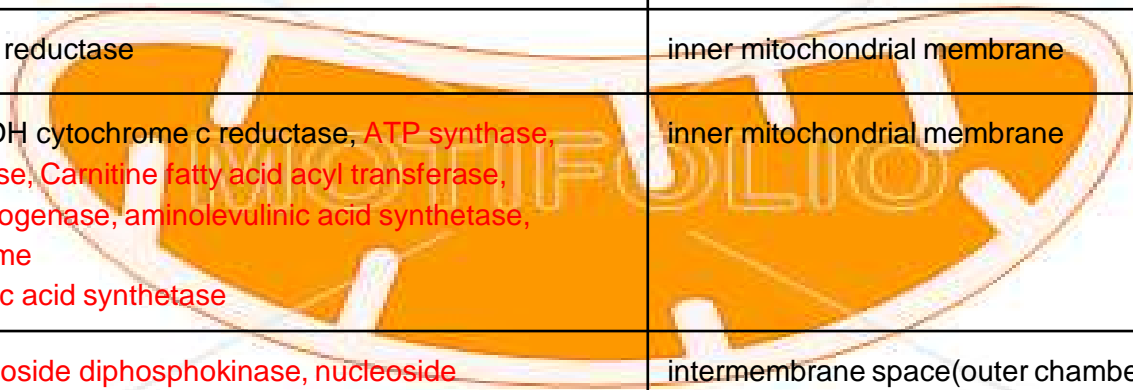
Various reaction in the cells can be either use energy (where by the ATP is converted back to ADP(releasing the high energy bond).

- The mitochondria are responsible for the process of respiration and phosphorylation in the cell, involving the interaction of at least seventy different enzymes and coenzymes
- Glycolysis converts glucose anaerobically to pyruvate in the cytoplasm, releasing some energy. The rest of the energy is captured when pyruvate is imported into mitochondria and oxidized to CO_2 and H_2O . Mitochondrial enzymes yield 15 times more ATP than is produced by glycolysis alone. Some of the energy released in mitochondria is not stored in ATP but is dissipated as heat that maintains body temperature.

D. Functional compartmentalization

1. The **outer membrane** contains the enzymes:
 - a. NADH-cytochrome c oxidoreductase
 - b. Cytochrome b
 - c. Acyl-coenzyme A synthetase
 - d. Monoamine oxidase
 - e. Kynurenine hydroxylase
2. The **inner membrane** contains the enzymes:
 - a. Cytochromes b, c, c₁, a, and a₃ (for electron transport)
 - b. Succinate dehydrogenase (the only TCA cycle enzyme in the inner membrane)
 - c. ATP-synthesizing enzymes
3. **Inside the mitochondrion** is an amorphous matrix, bounded by the inner membrane.
 - a. Within this matrix are found the rest of the TCA cycle enzymes, including:
 - (1) Citrate synthetase
 - (2) Aconitase
 - (3) Isocitrate dehydrogenase
 - (4) Fumarase
 - (5) Malate dehydrogenase
 - (6) Pyruvate dehydrogenase
 - b. This matrix also contains enzymes for the synthesis of proteins and nucleic acids, most likely for endogenous utilization, and enzymes for fatty acid oxidation.

Name of the enzyme	Location in Mitochondria
Rotenone-insensitive NADH cytochrome c reductase	outer mitochondrial membrane
Kynurenine hydroxylase	outer mitochondrial membrane
Monoamine oxidase, Fatty acid CoA ligase, enzymes involved in phospholipid metabolism	outer mitochondrial membrane
Succinate cytochrome c reductase	inner mitochondrial membrane
Rotenone-sensitive NADH cytochrome c reductase, ATP synthase, Succinate dehydrogenase, Carnitine fatty acid acyl transferase, Hydroxybutyrate dehydrogenase, aminolevulinic acid synthetase, enzymes involved in heme Synthesis, aminolevulinic acid synthetase	inner mitochondrial membrane
Adenylate kinase, Nucleoside diphosphokinase, nucleoside monophosphokinase, Sulfite oxidase, yeast cytochrome c peroxidase	intermembrane space(outer chamber)
Enzymes of TCA cycle-NAD ⁺ malate dehydrogenase	mitochondrial matrix(inner chamber)
NAD ⁺ glutamate dehydrogenase	mitochondrial matrix
Enzymes for fatty acid oxidation:Citrate synthase	mitochondrial matrix



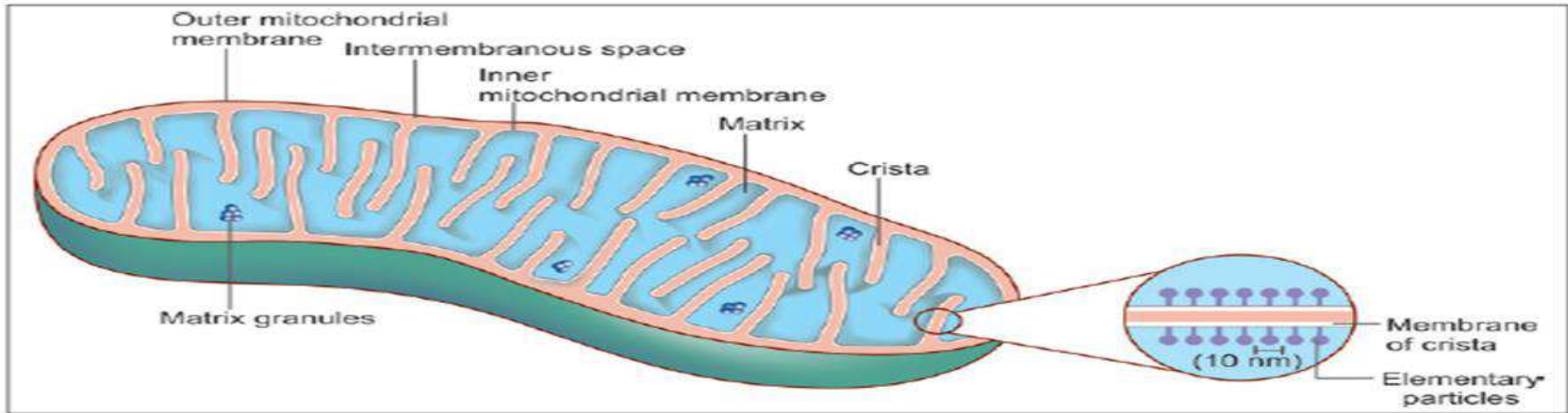


Fig. 2.20: Structure of a mitochondrion (Schematic representation)

Added Information

The enzymes of the TCA cycle are located in the matrix of mitochondria, while enzymes associated with the respiratory chain and ATP production are present on the inner mitochondrial membrane. Enzymes for conversion of ADP to ATP are located in the intermembranous space. Enzymes for lipid synthesis and fatty acid metabolism are located in the outer membrane.

Mitochondrial Abnormalities

Mitochondrial DNA can be abnormal. This interferes with mitochondrial and cell functions, resulting in disorders referred to as **mitochondrial cytopathy syndromes**. The features (which differ in intensity from patient to patient) includes muscle weakness, degenerative lesions in the brain and high levels of lactic acid.

The condition can be diagnosed by EM examination of muscle biopsies. The mitochondria show characteristic para-crystalline inclusions