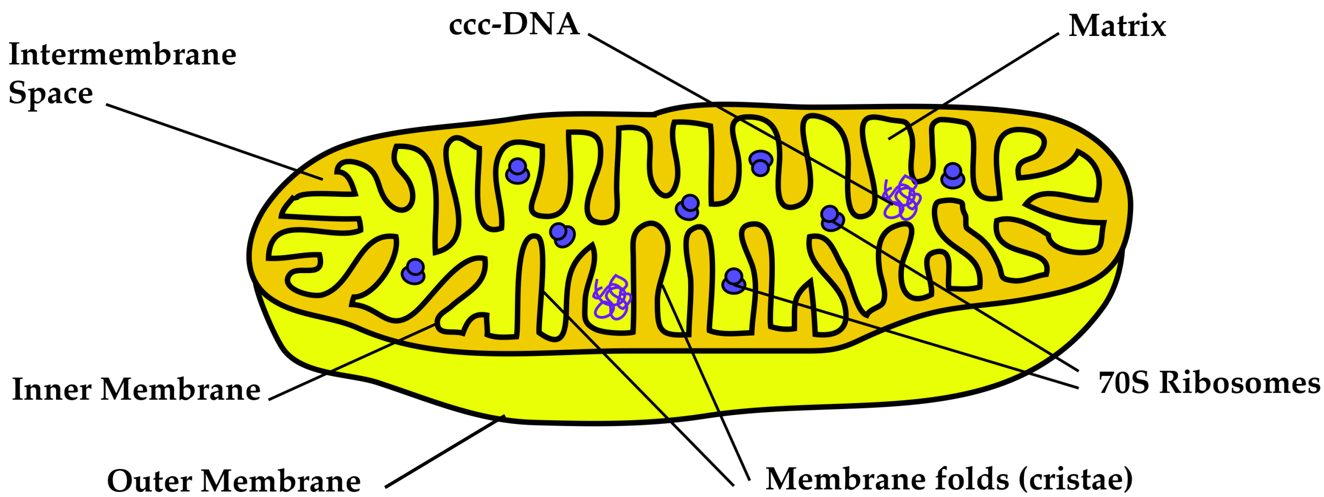
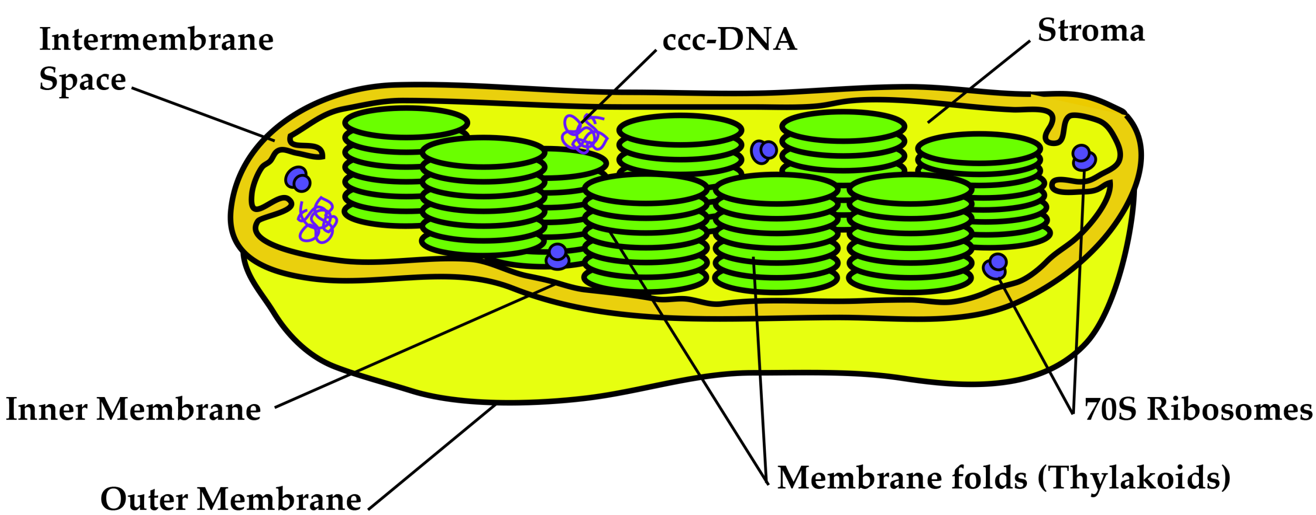
ANATOMICAL, PHYSIOLOGICAL AND BIOCHEMICAL SIMILARITIES OF MITOCHONDRIA AND CHLOROPLASTS

Mitochondria are membranous organelles found in association with almost all types of eukaryotic microorganisms, while **chloroplasts** are found only in association with certain forms, e.g., algae and euglenoids. Although these organelles vary considerable in size, shape and number in different species of organisms, they tend to follow some basic patterns, and have many similarities in their structure, function and biochemistry. Both mitochondria and chloroplasts are surrounded by **outer membranes** typical of eukaryotic cells (50:50 lipid protein ratio plus ring form lipids), and have **inner membranes** typical of prokaryotic cells (40:60 lipid protein ratio and no ring-form lipids). These inner membranes are highly folded (forming **cristae** or **thylakoids**), and contain **ATP-synthase** enzymes. ATP synthesis involves **photophosphorylation** in chloroplasts, and **oxidative phosphorylation** in both mitochondria and chloroplasts. Like bacteria, mitochondria and chloroplasts contain ccc-DNA and 70S ribosomes, they reproduce by means of binary fission, and are sensitive to antimicrobial drugs.



Basic Organizational Pattern of a Typical Mitochondrion



Basic Organizational Pattern of a Typical Chloroplast

EVIDENCE FOR THE ENDOSYMBIOTIC THEORY

Mitochondria evolved from Proteobacteria and Chloroplasts evolved from cyanobacteria; both organelles were initially prokaryotic organisms that were ingested by eukaryotic cells.

Anatomical Features:	Significant Details:
Outer membrane	Encloses organelle, composition typical of eukaryotic plasma membrane with 50:50 lipid to protein ratio plus ring-form lipids.
Intermembrane space	Potential space between membranes (spatially equivalent to the periplasmic space typical of prokaryotic cells).
Inner membrane	Composition typical of prokaryotic plasma membrane with 40:60 lipid to protein ratio and no ring-form lipids. Highly folded (cristae and thylakoids) with greater surface area for enzymes and pigments (ATP-synthase, cytochromes and chlorophylls).
Background material (matrix and stroma)	Protoplasm containing a variety of dissolved molecules, enzymes, 70S ribosomes and ccc-DNA. The mitochondrial matrix and chloroplast stroma are equivalent to prokaryotic cytoplasm.

Physiological Features:	Significant details:
ATP production	Reactions resulting in the formation of ATP from ADP plus phosphate involve ATP-synthase enzymes associated with the cristae and thylakoids (prokaryotic membranes). The processes involved are oxidative and photophosphorylation respectively, with energy provided by a proton flow across the membranes. Substrate level phosphorylation occurs within the matrix and stroma.
Reproduction	Both mitochondria and chloroplasts reproduce by means of binary fission, and cells lacking these organelles cannot make them.
Sensitivity to Antimicrobial drugs	Like many types of bacteria, mitochondria and chloroplasts are sensitive to (damaged by) exposure to antimicrobial drugs.

Biochemical Features:	Significant Details:
Membrane composition	Similar variations in outer and inner membranes as described above. Inner membranes contain more protein and lack ring-form lipids.
Electron carriers	Molecules that can serve as electron donors and recipients are abundant in the inner membranes. Some of these are enzymes, some pigments and some coenzymes (NAD, FAD, CoQ, etc.).
Proton motive force	Electron transfer is linked to the “pumping” of hydrogen protons into the intermembrane space of mitochondria, or into the thylakoid interiors in chloroplasts. The concentration and electrical gradient created (proton motive force) causes protons to flow back across the membranes through ATP-synthase enzymes.
ATP-synthase	ATP-synthase is an integral protein complex associated with prokaryotic cell membranes. It uses the potential energy provided by the proton flow to bind ADP + PO_4 into ATP.
DNA	The DNA found within mitochondria and chloroplasts occurs as covalently closed circular molecules (ccc-DNA). This DNA is typically not associated with histone proteins.
Ribozymes	The r-RNA molecules that catalyze the formation of peptide bonds between amino acids at ribosomes are 23S (ribosomes are 70S).