An **organelle** is a discrete membrane bound cellular structure **specialized functions**. An organelle is to the cell what an organ is to the body (hence the name *organelle*, the suffix *-elle* being a diminutive).

**Eukaryotes have organelles**
Although the term "organelle" is considered by some cell biologists to be synonymous with "cell compartment", some cell biologists strictly limit the term's definition to mitochondria and chloroplasts.
Mitochondria and chloroplasts

- Structural similarities (double membrane bound compartment and contain their own genetic material)
- Functional similarities (energy conversion, ATP producing)
- Highly specialized membranes (site of electron transfer reactions)
- Similar evolutionary history (bacterial ancestors)
- Semi autonomy (require nuclear encoded proteins for function)
Energy-transducing membranes

- Specialized biological membranes in bacteria/archaea/eukaryotes
- Energy conversion (ATP production)
- Electron transfer reactions by multimeric enzymes/carriers

\[
\text{Electron donor} \longrightarrow \text{Electron acceptor} \quad p\text{-side} \quad n\text{-side}
\]

\[
\begin{align*}
&\text{H}^+ \\
&\text{H}^+ \quad e^- \\
&\text{ATP}
\end{align*}
\]
Energy-transducing membranes

- **Bacteria/Archaea**

- **Chloroplasts**

- **Mitochondria**
Mitochondrion, the site of respiration
Mitochondrial structure

- **outer membrane**
  - similar to the outer membrane of gram-negative bacteria

- **inner membrane**
  - highly folded to form *cristae* (s., *crista*)
  - location of enzymes and electron carriers for electron transport

- **matrix**
  - contains the genetic material
  - location of TCA (Krebs) cycle
  - Amino acid metabolism, metal cofactor synthesis (heme) etc.
Mitochondrial inner membrane

- Mitochondrial inner membrane is involved in energy transduction
- Electron donors: NADH, succinate, electron acceptor: oxygen
- ATP is produced in the matrix
Mitochondrial dysfunction causes disease

healthy

myopathy
Chloroplasts

Figure 14–35. Molecular Biology of the Cell, 4th Edition.
Thylakoids

- flattened, membrane-delimited sacs
- **grana** (s., granum) – stacks of thylakoids
- site of light reactions (trapping of light energy to generate **ATP**, **NADPH**, and oxygen)
Stroma

- **stroma** is site of light independent reactions of photosynthesis (formation of carbohydrates from carbon dioxide fixation)
Thylakoid membrane

- Thylakoid membrane is involved in energy transduction
- Electron donor: water; electron acceptor: NADP
- ATP is produced in the stroma
Stromules Connect Plastids

Stroma-filled tubules
Contain inner and outer membrane

Autofluorescence of chlorophyll  Overlay  Stromal GFP

10 µm
Plastids

Different types of plastid in different cells and developmental stages. Proplastids, meristems; chromoplasts, fruits and flowers; amyloplasts, roots; etioplasts, etiolated seedlings.
Etioplasts

• Arrested in the development from proplastids to chloroplast because of the absence of light.

• Etiolated seedlings.

• Lack chlorophyll but contain large amounts of precursor (protochlorophyllide)

• Prolamellar body: storage form of thylakoid membrane lipids.
Greening Etioplast
Chloroplasts and Mitochondria compared

Figure 14–36. Molecular Biology of the Cell, 4th Edition.
Origin of Mitochondria and Chloroplasts

The diagram illustrates the evolution of mitochondria and chloroplasts from ancestral eucaryotic cells. Initially, an internal membrane surrounds the nucleus. The addition of a bacterium leads to the formation of early eucaryotic cells with mitochondria. Further evolution results in chloroplasts capable of photosynthesis.
Cyanobacteria (here *Anabaena*) are photosynthetic prokaryotes with thylakoids and nucleoids

Supports (but does not prove) the endosymbiotic theory of chloroplast evolution
Organelle proteins are encoded by two genomes. Most organelle proteins encoded by nuclear genome and synthesized on free cytoplasmic ribosomes. Contain “prokaryotic” gene expression apparatus.
Gene transfer hypothesis

Different mitochondria have retained different numbers of genes. Human mitochondrial genome is among the smallest.
The origins of mitochondrial RNAs and proteins.
Chloroplast proteins come from different sources

Genomic and proteomic analyses indicate that 2500–4000 different plastid proteins are imported.
Protein import into plastids/mitochondria

- Translocation into mitochondria or chloroplasts is post-translational.
- Signal sequences at the N-terminus
  - Are necessary and sufficient for import.
  - Are removed after import by protease (signal peptidase).
- Fold into alpha helix with positive charges on one side (red).
Mitochondrial protein import
Into the inner mitochondrial membrane
Import into Chloroplasts functions in a similar way

Cytoplasm: chaperones keep protein unfolded

Toc complex in outer, Tic in inner chloroplast membrane.

Toc complex: two homologous GTP-binding proteins, Toc159 and Toc34, and a channel protein, Toc75.

SPP; Signal peptidase in stroma.

Toc 75, Tic 110 and SSP are essential proteins in Arabidopsis (mutants are early embryo lethal).
Into the chloroplast thylakoid

Figure 12–30 part 1 of 2. Molecular Biology of the Cell, 4th Edition.
Four pathways into the thylakoid

Spontaneous and SRP for membrane-associated proteins, Sec and TAT (pH gradient) typically for lumen. Sec pathway similar to bacterial secretion pathway. TAT named after “twin arginine”, a motif c-terminal of singal peptide required for pathway. Can translocate fully-folded proteins.
Mitochondria and chloroplasts divide by fission
Chloroplast development and differentiation

• Watch: