Electron Transport Chain
Oxidative Phosphorylation

Electron transport chain (ETC): This is the final common pathway in aerobic cells by which electrons derived from various substrates are transferred to oxygen.

1- The ETC is localized in the mitochondria

2- Energy-rich molecules, such as glucose, are metabolized by a series of oxidation reactions ultimately yielding CO_2 and water

3- ATP is generated as a result of the energy produced when electrons from NADH and $FADH_2$ are passed to molecular oxygen by a series of electron carriers, collectively known as the electron transport chain

4- Electron transport and ATP production occur simultaneously and are tightly coupled.

5- NADH and $FADH_2$ are oxidized only if ADP is available for conversion to ATP.

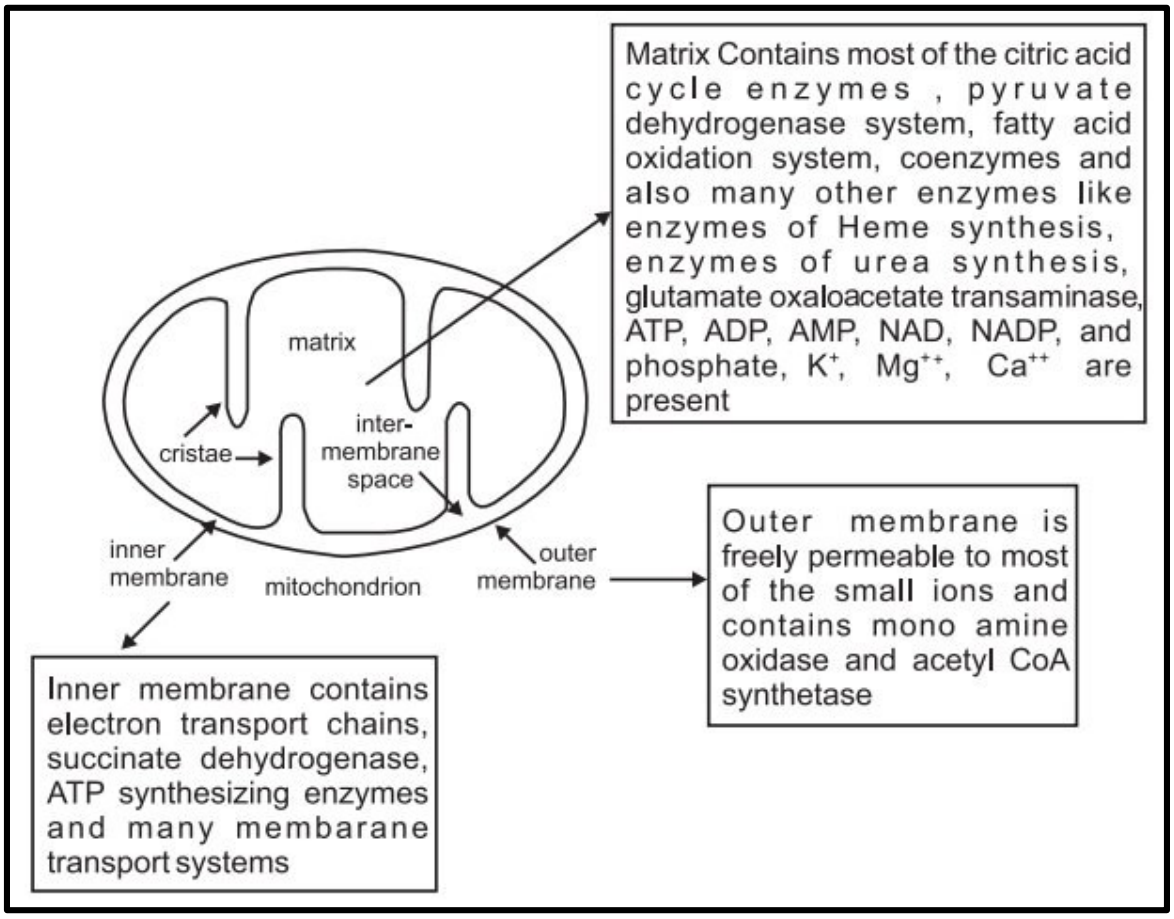
6- The electron transport chain in the mitochondrial membrane has been separated on four complexes

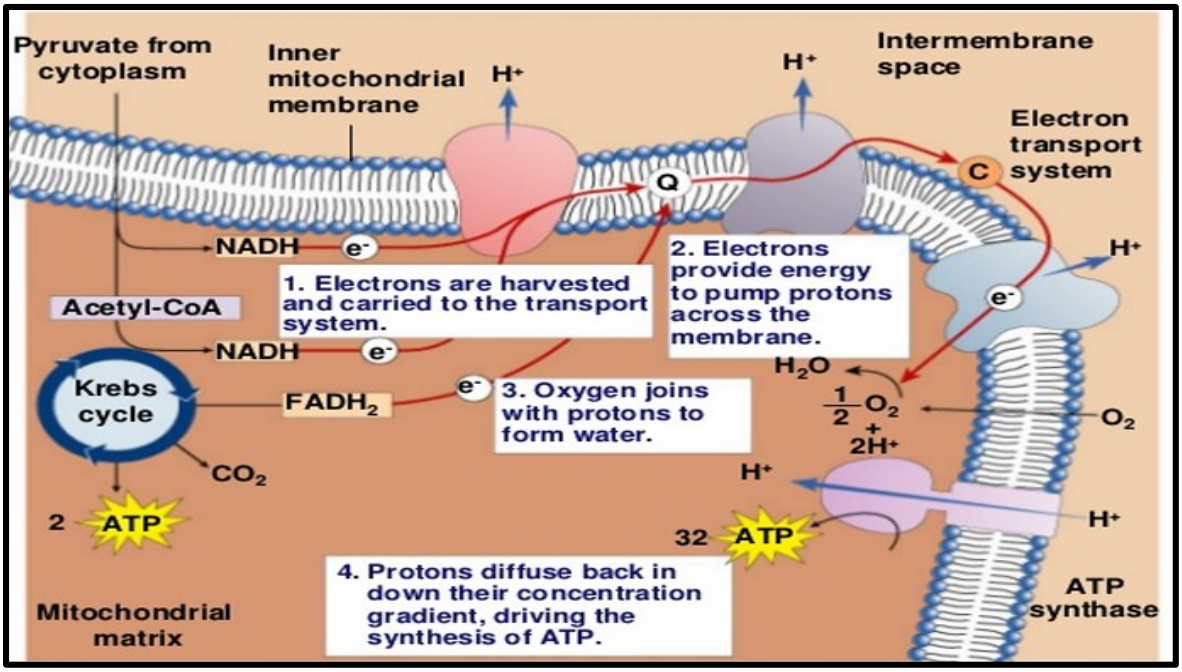
7- The components of the chain include: complex I (FMN : Flavin mononucleotide), Fe-S centers, complex II (coenzyme Q) , and complex III , Complex IV (a series of cytochromes b, c1, c and aa3) and complex V (ATP synthase .

8- The process occurs in each complex :

- **Complex I** (NADH reductase)
- **Complex II** (succinate dehydrogenase)
- **Complex III** (cytochrome reductase)
- **Complex IV** (cytochrome oxidase)

Note: Cyt. C does not form a part of any complexes. It is mobile and acts as a shuttle between complex – III and complex – IV to transfer e- (electron).


Matrix Contains most of the citric acid cycle enzymes , pyruvate dehydrogenase system, fatty acid oxidation system, coenzymes and also many other enzymes like enzymes of Heme synthesis, enzymes of urea synthesis, glutamate oxaloacetate transaminase, ATP, ADP, AMP, NAD, NADP, and phosphate, K+, Mg++, Ca++ are present
matrix
cristae
inter-membrane space
inner membrane
mitochondrion
outer membrane
Outer membrane is freely permeable to most of the small ions and contains mono amine oxidase and acetyl CoA synthetase
Inner membrane contains electron transport chains, succinate dehydrogenase, ATP synthesizing enzymes and many membarane transport systems


Pyruvate from cytoplasm
Inner mitochondrial membrane
H+
H+
Intermembrane space
Electron transport system
Q
C
NADH
e-
1. Electrons are harvested and carried to the transport system.
2. Electrons provide energy to pump protons across the membrane.
H+
Acetyl-CoA
NADH
e-
e-
H2O
Krebs cycle
FADH2
e-
3. Oxygen joins with protons to form water.
½ O2 + 2H+
O2
CO2
H+
2 ATP
32 ATP
H+
4. Protons diffuse back in down their concentration gradient, driving the synthesis of ATP.
Mitochondrial matrix
ATP synthase

The electron transport chain can be divided into 4 key processes which are:

1-The transfer of electrons by NADH and $FADH_2$ to complex I and II, respectively.

$$NADH + H+ + FMN \rightarrow FMN.H2 + NAD+$$

2-The establishment of an electrochemical gradient by proton pumping and movement of electrons through the chain

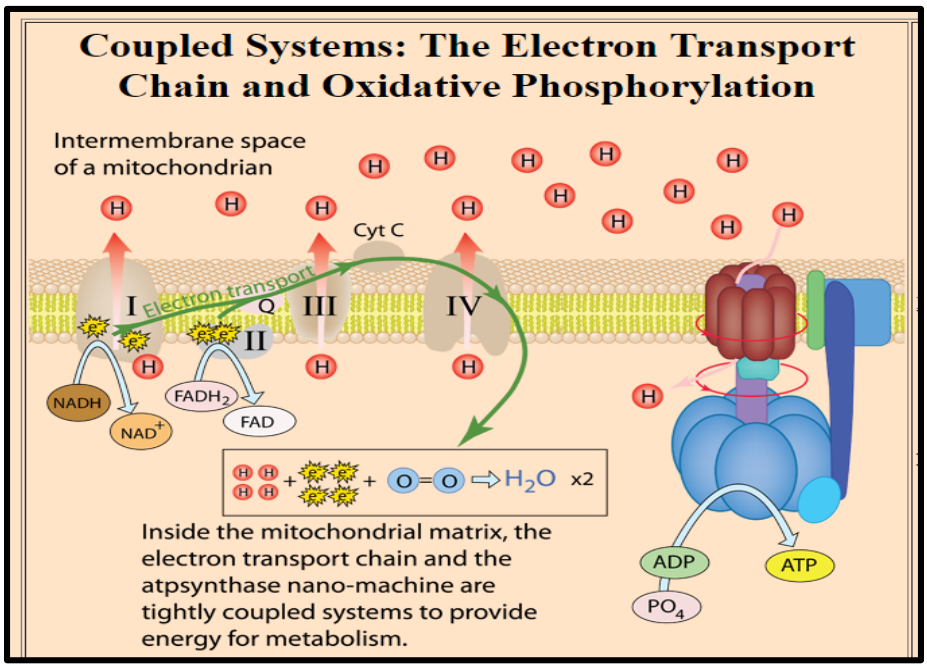
$$Succinate + CoQ \rightarrow Fumarate + CoQ.H2$$

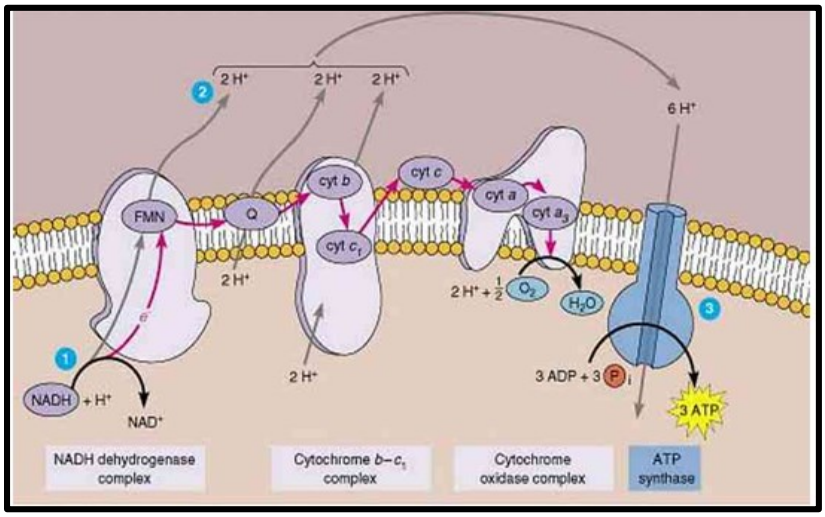
3-Splitting of oxygen molecule to form water

$$Co.Q.H_2 + 2\ Cyt.C\ (Fe^{+3}) \rightarrow Co.Q + 2\ Cyt.C\ (Fe^{+2}) + 2H^+$$

4-Generation of ATP molecules by ATP synthase

$$4Cyt.C\ (Fe^{+2}) + 4H^+ + O_2 \rightarrow 4\ Cyt.C\ (Fe^{+3}) + 2H_2O$$



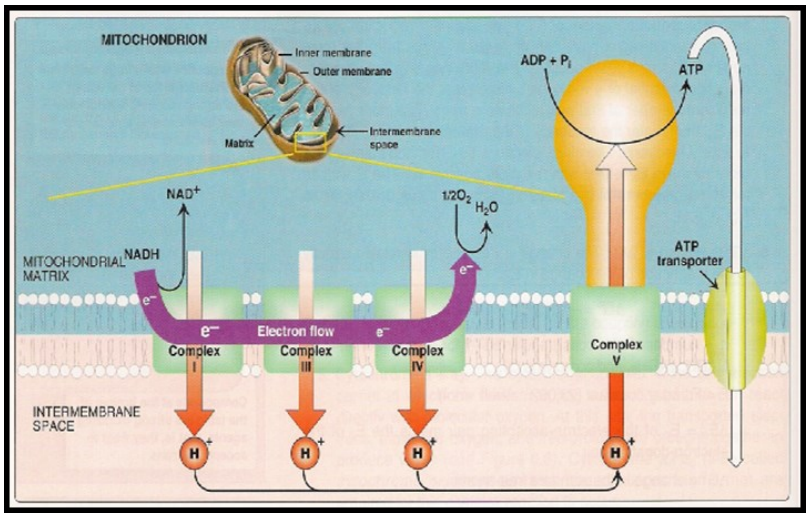


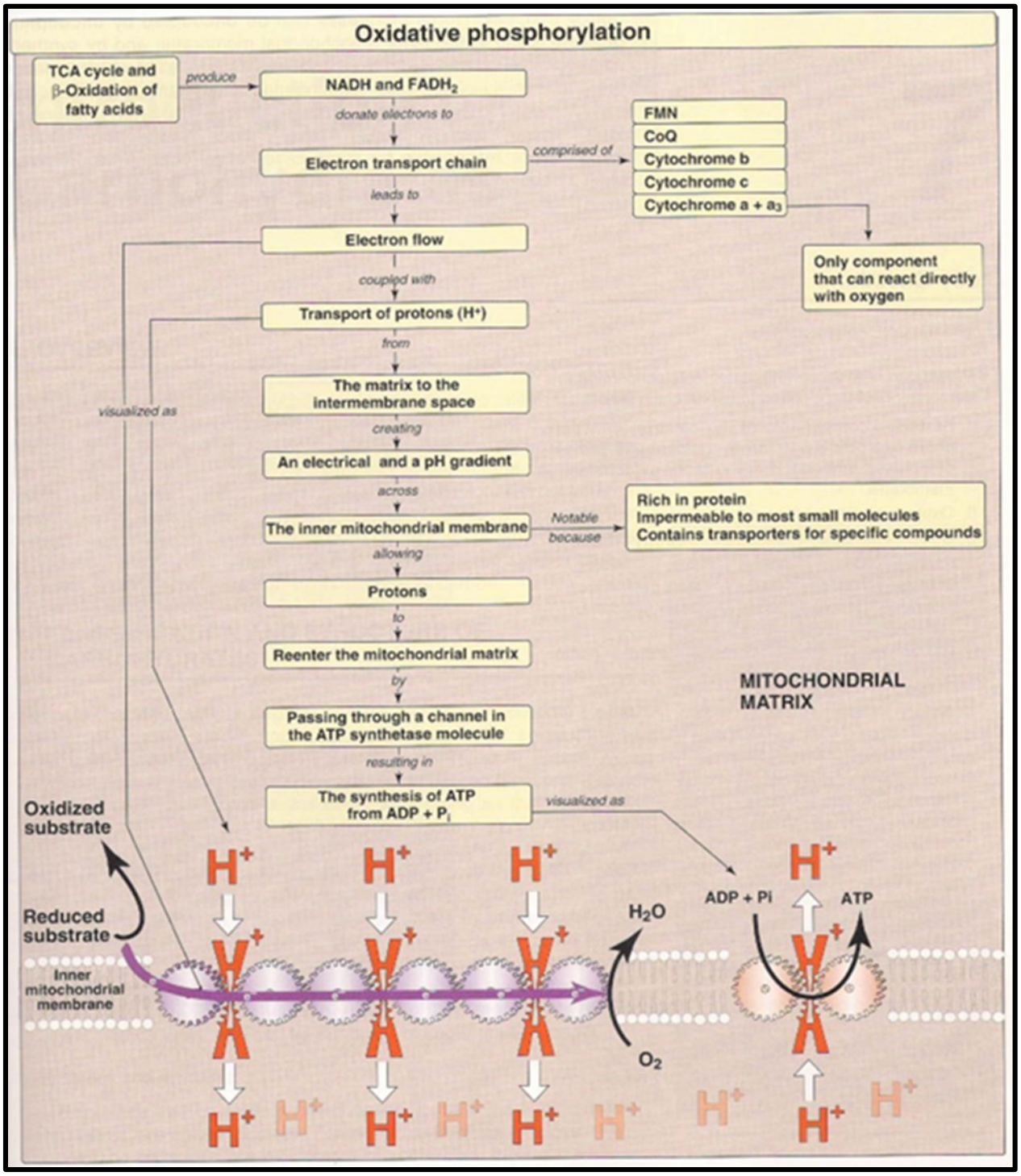
* The energy derived from the transfer of electrons through the electron transport chain is used to pump protons across the inner mitochondrial membrane from the matrix to the cytosolic side. An electrochemical gradient is generated, consisting of a proton gradient and a membrane potential.

* Protons moves back into the matrix through the **ATP synthase complex**, causing ATP to be produced from ADP and inorganic phosphate.

*ATP is transported from the mitochondrial matrix to the cytosol in exchange for ADP **(the ATP-ADP antiport system)**

*Because energy generated by transfer of electrons through the electron transport chain to O_2 is used in the production of ATP, the overall process is known as **oxidative phosphorylation.**




Oxidative phosphorylation
TCA cycle and β-Oxidation of fatty acids
produce
NADH and FADH2
donate electrons to
Electron transport chain
comprised of
FMN
CoQ
Cytochrome b
Cytochrome c
Cytochrome a + a3
leads to
Electron flow
Only component that can react directly with oxygen
coupled with
Transport of protons (H+)
from
The matrix to the intermembrane space
visualized as
creating
An electrical and a pH gradient
across
The inner mitochondrial membrane
Notable because
Rich in protein
Impermeable to most small molecules
Contains transporters for specific compounds
allowing
Protons
to
Reenter the mitochondrial matrix
by
Passing through a channel in the ATP synthetase molecule
MITOCHONDRIAL MATRIX
resulting in
The synthesis of ATP from ADP + Pi
visualized as
Oxidized substrate
Reduced substrate
Inner mitochondrial membrane
H+
H2O
O2
ADP + Pi
ATP

Clinical correlations

- Cyanide poisoning: Cyanide binds to Fe^{+3} in cytochrome aa3. As a result, O^2 can not receive electrons, respiration is inhibited, energy production is halted, and death occurs rapidly. After cyanide poisoning, the electron transport chain can no longer pump electrons into the intermembrane space. The pH of the intermembrane space would increase, and ATP synthesis would stop.

Acute myocardial infarction: Coronary arteries frequently become narrow because of atherosclerotic plaques. If coronary occlusions occur, regions of heart muscle may be deprived of blood flow and, therefore, of oxygen for prolonged periods of time. Lack of oxygen causes inhibition of the processes of electron transport and oxidative phosphorylation, which results in a decreased production of ATP. Heart muscle, suffering from a lack of energy required for contraction and maintenance of membrane integrity, becomes damaged. Enzymes from the damaged cells (including the MB fraction of creatine kinase) leak into the blood. If the damage is relatively mild, the person may recover. If heart function is severely compromised, death may result.