

Highlights of Electron Transport

1. For every oxidation, there is an equal and Loss of electrons by one molecule means gain of them by another one. Oxidation is a process that involves the loss of electrons. Reduction is a process that involves the gain of electrons.
2. Electrons are carried to the electron transport system in the mitochondria by NADH and FADH_2 .
3. Mitochondria are the site of electron transport and oxidative phosphorylation.
4. Electrons from NADH enter the electron transport system through complex I.
5. Electrons from FADH_2 enter the electron transport system through complex II.
6. Coenzyme Q (CoQ) accepts a pair of electrons from either complex I or complex II and passes electrons singly to cytochrome c through complex III. Thus, coenzyme Q acts as a "traffic cop" for electrons.
7. The sequence of electrons passing from coenzyme Q is as follows: Coenzyme Q \rightarrow Complex III \rightarrow Cytochrome c \rightarrow Complex IV \rightarrow oxygen (to form water)
8. Oxygen is thus the terminal electron acceptor and is a limiting compound during periods of heavy exercise.
9. If oxygen is not available, electrons will NOT pass through the electron transport system and NADH and FADH_2 will not be reoxidized. For these reasons, the citric acid cycle will not run either. This is part of metabolic control.
10. Several compounds inhibit electron transport - rotenone (an insecticide) and amytal block all action of Complex I. Antimycin A blocks all action of Complex III. Cyanide, azide, and carbon monoxide block all action of complex IV.
11. Movement of electrons through Complex III is known as the Q cycle. This cycle begins with the binding of two molecules of CoQ (QH_2 and Q) to Complex III. QH_2 has two electrons and two protons. Q has neither.
12. After QH_2 and Q bind, QH_2 sends one electron to Q, creating Q^- and one electron to cytochrome C. The two protons QH_2 was carrying are expelled into the intermembrane space. This converts QH_2 to Q. Both cytochrome C and Q leave the complex, but Q^- remains behind.
13. Next, another QH_2 and another cytochrome C binds to Complex III. QH_2 sends one electron to Q^- , creating Q^{2-} and one electron to cytochrome C. It also expels its two protons to the intermembrane space and becomes Q. Then Q^{2-} extracts two protons from the matrix and becomes QH_2 . Last, cytochrome C, QH_2 , and Q all leave the complex. (As you can see, words describing the process are complicated. The figure shows it much more clearly).
14. Electron transfer through complex IV occurs one electron at a time (since one electron arrives at a time from cytochrome c). Interruption of electron flow can result in production of reactive oxygen species. Cellular enzymes, such as superoxide dismutase and catalase (see below) help to deactivate superoxides.

15. In electron flow through complex IV, the first electron is transferred to copper and the second one is transferred to iron. Oxygen then binds to the iron first, followed by formation of a peroxide bridge between the iron and copper atoms. Addition of a third electron (to the oxygen on the copper) and binding of a proton from the matrix causes the O-O bond to be cleaved. A fourth electron then reduces the oxygen on the iron and a proton binds from the matrix as well. Last, two protons from the matrix bind to the hydroxyls on the iron and copper, forming two water molecules, which are released and the cycle is complete.

16. During electron movement through Complex IV, four protons are taken from the matrix and combined with oxygen to form two water molecules. In addition, four other protons are taken from the matrix by the complex and pumped outside the mitochondrial matrix. As a consequence, the proton numbers in the matrix decrease by 8 during the process. The proton numbers outside the mitochondrion INCREASE by four in the process, so the net difference is 12 protons just for movement through complex IV.

Oxidative Phosphorylation

1. ATP is created in oxidative phosphorylation by the movement of **protons** back into the mitochondrial matrix through complex V (also called the ATP synthase).

2. Two essential functions of electron transport - 1. Pump protons out of mitochondrial matrix and 2. Reoxidize NADH and FADH₂ to NAD and FAD, respectively. In healthy, normal cells, oxidative phosphorylation is tightly coupled to electron transport. Stopping electron transport will ultimately stop oxidative phosphorylation in tightly coupled mitochondria.

3. The chemiosmotic hypothesis, originally proposed by Peter Mitchell, explains how mitochondria make ATP in oxidative phosphorylation. Important aspects of it include:

- a. Intact inner mitochondrial membrane
- b. Electron transport creates a proton gradient
- c. ATP is made by movement of protons back into the mitochondria

4. Coupling of electron transport and oxidative phosphorylation at a practical level means that the mitochondrial inner membrane remains impermeable to protons, except for those that enter via the ATP synthase and result in ATP production.

5. The ATP synthase consists of a turbine-like structure containing 3 sites called Loose (L), Tight (T), and Open (O). Functions of these forms include

L - Holds ADP and Pi in preparation for ATP formation

O - Releases ATP formed in T and binds ADP + Pi

T - Causes ADP and Pi to join and form ATP

6. Movement of protons through the ATP synthase causes rotation/conformational changes in the complex that result in formation of ATP from ADP and Pi. Conversions in the process occur as

follows:

O goes to L

L goes to T

T goes to O