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The Electron Transport in the Course of Study Related to the Biological Science at Various Levels

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***Abstract* - Electron transport is a series of redox reaction that resemble a relay race or bucket bridge in that electrons are passed rapidly from one component to the next, to end point of the chain where the electrons reduce molecular oxygen, producing water In the chain form it is so series of protein complexes and other molecules that transfer electrons from electron donor to electron acceptors via redox reactions and couples this electron transfer with the transfer of protons (M+ ions) across a membrane. Many of the enzymes in the electron transport chain are membrane bond.**

Keywords: Electron transport, Proteins, Coenzymes, cytochromes, complexes.

I. INTRODUCTION

All the enzyme - catalyzed steps in the oxidative degradation of carbohydrates, fats and amino acids in aerobic cells converge into electron transport and oxidative phosphorylation, the final stage of cell respiration. This stage consists of flow of electrons from organic substrates to Oxygen with the simultaneous release of energy for the generation of ATP molecules. The average adult human synthesizes ATP at a rate of nearly 10^{21} molecules per second, equivalent to producing his or her own weight in ATP every day. Glycolysis and the citric acid cycle by themselves generate relatively little ATP directly. However, under aerobic conditions, six substrate oxidation steps - one in glycolysis another in the pyruvate dehydrogenase reaction, and four more in the citric acid cycle - collectively reduce 10 moles of NAD^+ to NADH and 2 moles of FAD to $FADH_2$ per mole of glucose. Reoxidation of these reduced electron carriers in cellular respiration generates most of the energy that is then used for ATP synthesis. Respiration constitutes the third stage of the metabolic oxidation of substrates.

In eukaryotic cells, NADH and $FADH_2$ are reoxidized by electron transport proteins bound to the inner mitochondrial membrane. A series of linked oxidation and reduction reactions occurs, with electrons being passed along a series of electron carriers known as electron transport chain, or respiratory chain.

II. COMPONENTS INVOLVED IN ELECTRON TRANSPORT

(i) Nico Tinamide Nucleotide

Two of the oxidations in the tricarboxylic acid circle involve the removal of the equivalent of two hydrogen atoms from the substrates, malate and isocitrate. In two others, those catalyzed by pyruvic dehydrogenase and α-keto-glutarate dehydrogenase, the electrons are transferred first to lipoic acid and then via a flavoprotein to NAD^+

$$SH_2 + NAD^+ \rightleftharpoons S + NADH + H^+$$

(ii) Flavoprotein

The prosthetic groups of flavoproteins are the flavin coenzymes FAD and FMN. These cofactors, in contrast to the nicotinamide nucleotide coenzymes, are much more firmly associated with the protein moiety, and in some instances, are covalently bounded to that protein. The flavin cofactor accepts two electrons and a proton from NADH or two electrons and two protons from an organic substrate such as succinic acid.

$$NADH + H^+ + FMN \longrightarrow NAD^+ + FMNH_2$$

$$Succinate + FAD \longrightarrow Fumarate + FADH_2$$

The flavoproteins of the mitochondrial respiratory chain are complex in that they contain or are closely associated with iron - sulfur proteins, also called non home iron (NHI) proteins. Because the flavin cofactors can accept one electron at a time forming a semiquinone, the flavoproteins represent a point in the respiratory chain where electrons can be transferred one at a time rather than in pairs.

(iii) Iron-Sulfur Proteins

It was first encountered as ferredoxin, a reducing agent involved in nitrogen fixation and photosynthesis in plants, before it was recognised to function in mitochondrial electron transport in animals. Their most characteristic chemical feature is the release of H_2S on acidification (Acid Labile sulfur), a treatment that also remove the iron. The iron atoms are arranged in pairs in an iron-sulfur bridge that, in turn, is

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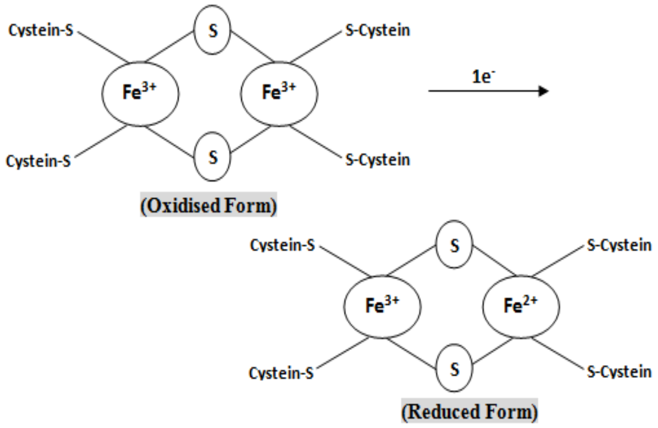
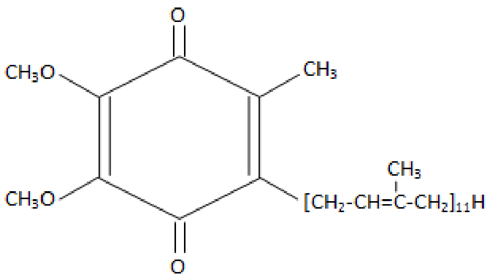
bonded to the sulfur atoms of cysteine residue in the protein. Some iron - sulfur proteins such as spinach ferredoxine contain only two iron atoms (Fe_2S_2) while others contain four (Fe_4S_4).



In the oxidized state, both iron atoms in the model are in the ferric state. When reduced, one iron becomes Fe^{2+} and can be detected by a characteristic EPR (Electron Para Magnetic Resonance) signal. The standard reduction potentials (E_o') range from -0.420 V to as high as 0.300V. Since each Fe^{3+} atom can become reduced, a center with four iron atoms (Fe_4S_4) con store up to four electrons.

(iv) Quinone

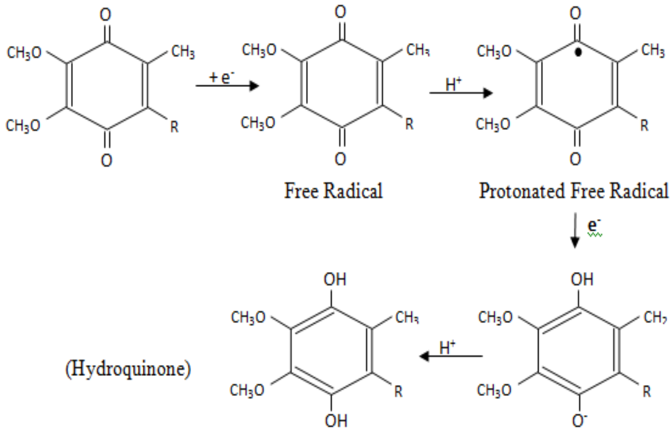
Mitochondria contain a quinone called ubiquinone that has the general structure.



Ubiquinone

The length of the side chain (R) varies with the source of the mitochondria, in animal tissues, the quinone possesses 10 isoprenoid units in its side chain, and ubiquinone is lipid soluble and can be removed from the inner mitochondrial membrane with lipid solvents (e.g. butanol). This is in contrast to all other of the enzymes in the respiratory chain. When the quinone is extracted from the mitochondria, the transport of electrons from substrates to oxygen is prevented; the activity is restored when the quinone is added back.

The complete reduction of one molecule of course, requires two electrons, but coenzyme & also readily undergoes one electron reduction to form free radical intermediate.



Coenzyme Q_{10} occupies a pivotal position in the electron - transport chain where in accepts electrons not only from NADH dehydrogenase but also from the flavin components of succinic dehydrogenase, glycerol phosphate dehydrogenase and fatty acyl dehydrogenase.

(v) Cytochromes

According to Keilin (1926–1927) that in every tissue there usually are three types of cytochrome to which he assigned the letters a, b & c. The amount seemed to be proportional to the respiratory activity of the tissue, heart and other active muscles contain the large amounts of these pigments. The research on the cytochromes was facilitated by the fact that they absorb light of different wavelengths in a characteristic manner.

The three types of the cytochromes (a, b and c. distinguished by the positions of the absorption maxima of the α, β and γ bands. As additional cytochromes were discovered and described they were named c_1 b_1, b_2 and so on. More informative is a classification based on the absorption maximum of the x band, thus c_1 may also be called c_{554} and b_3, b_{557}.

The absorption spectra together with other properties of the cytochromes indicate that these compounds are conjugated proteins having an iron porphyrina as a prosthetic group.

The cytochrome tend to form complexes with HCN, CO and H_2S and such complexes readily defected by their characteristic absorption spectra. These reagents react by virtue of their ability to occupy one or both of the two coordination positions.

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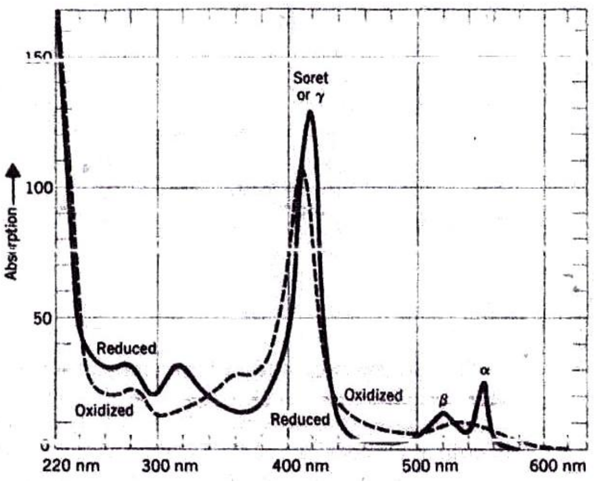
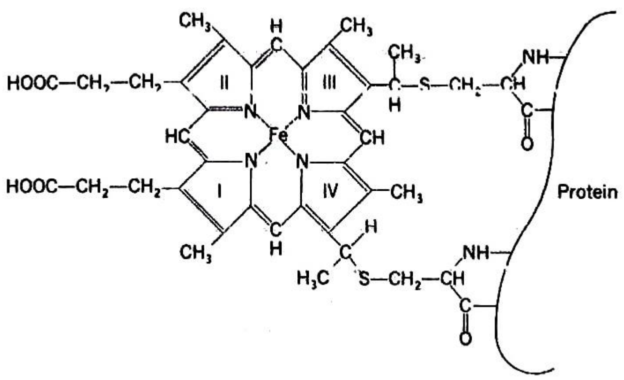
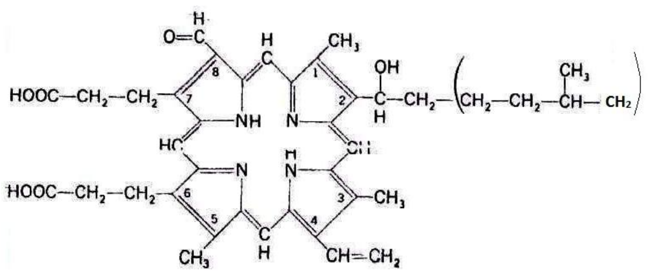


Absorption Spectra of Oxidized and Reduced Cytochrome C. (Source: Reproduced with permission from R. E. Dicker son and R. Timkovich, in The Enzymes, P. D. Boyer, ed., 3rd ed. Vol. 11, p. 399. New York: Academic Press, 1975)



Cytochrome c

It is protoporphyrin IX linked to cystein residue in the protein through thioether linkages with the vinyl groups of rings III and IV. The prosthetic group of cytochrome b is protoporphyrin IX itself. The porphyrin of cytochrome a is porphyrin A, characterized chiefly by a long hydrophobic chain of hydrogenated isoprenoid units. In this regard, porphyrin A resembles the porphyrin of chlorophyll of the Fe (iron) atom that are not occupied by the nitrogen atoms of the pyrrole rings of the porphyrin. In cytochrome c, where those two positions are occupied by other structures, complexes with HCN, CO, and H_2S are not formed at neutral pH.



Porphyrin A

The cytochromes are capable of being alternately reduced and oxidized. The iron of the oxidized cytochromes is ferric iron; it is reduced to ferrous iron by incorporation of one electron into the Valence shell of the iron atom. It is this property that allows the cytochromes to function as carriers in the electron-transport process.

III. THE RESPIRATORY CHAIN

The electron - transport chain in the mitochondrial membrane has been separated into four components or complexes. The chain accomplished the transfer of electrons from NADH or succinic acid to O_2. CoQ_{10} and cytochromes - c are not included in any of the complexes because these two components can be removed with relative ease from the membrane. Cytochrome c is a small, peripheral protein (MW12,000) that is readily extracted by treatment of the membrane with aqueous salt solutions. CoQ_{10} can be extracted with butanol. In either case, the flow of electrons is interrupted at the point in the chain from which these carriers have been removed when they are added back, the activity restored.

1. Complex I: NAD - CoQ Reductase

This complex catalyzes the transfer of electrons between NADH and CoQ.

$$NAD + H^+ + CoQ \longrightarrow NAD^+ + CoQ + H_2$$

The complex, to which is coupled the synthesis of ATP at coupling site contains four iron-sulfur centers and one FMN. The E_0' of the iron-sulfur centre ranges from -0.330 to -0.020V; therefore, the flow of electrons is from NADH to FMN to the iron-sulfur proteins where they flow from the iron-sulfur center with the lowest E_o to that having the highest.

$$NADH \rightarrow FMW \rightarrow (Fe\text{-}S_1) \rightarrow (Fe\text{-}S_2) \rightarrow (Fe\text{-}S_3) \rightarrow (Fe\text{-}S_4) \rightarrow CoQ$$

2. Complex II: Succinate – CoQ Reductase

Catalyzes the reduction of CoQ by electrons removed from succinate.

$$\text{Succinate} + CoQ \longrightarrow \text{Fumarate} + CoQ + H_2$$

This complex, which contains FAD is composed of four polypeptides with molecular weight of 70,000, 27,000 15,000 and 13,000. The two large peptides contain the catalytic site for the oxidation of succinate; the smaller (27,000) subunit of the two contains a Fe_4S_4 center. The two smallest peptides (15,000 and 13,000) contain a Fe_2 S_2 center and a b-type cytochrome.

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3. Complex III: CoQ - Cytochrome c Reductase

The reaction catalyzed by this complex is

$$CoQ + H_2 + 2\ cyt\ e\ (Fe^{3+}) \longrightarrow CoQ + 2\ cyt\ e\ (Fe^{2+}) + 2H^+$$

This complex contains two b-type cytochromes, b_{560} and b_{562}; a c-type cytochrome c_1 - and an iron-sulfur center. It also contains phosphorylation site 2 that produces ATP as electrons flow through the complex. The electrons flow is

$$Co\text{-}Q\ H_2 \rightarrow b_{560} \rightarrow b_{562} \rightarrow Fes \rightarrow cy + cj \rightarrow c$$

The complex is inhibited by the antibiotic antimycin.

4. COMPLEX IV: Cytochrome C Oxidase

Cytochrome Oxidase has long been recognized as the terminal Oxidase of all aerobic cells. It catalyzes the oxidation of reduced cytochrome e big molecular O_2.

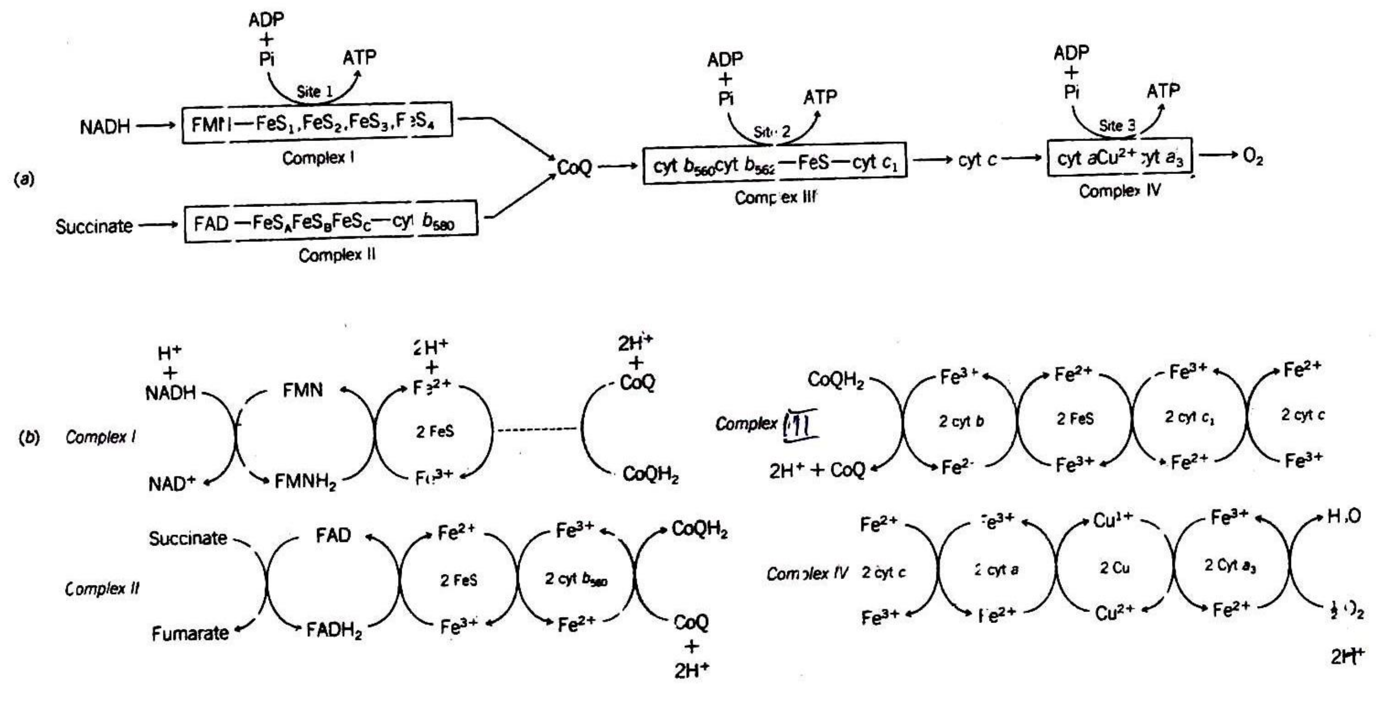
$$4\ Cyt\ e\ (Fe^{2+}) + 4H^+ + O_2 \longrightarrow 4\ Cyt\ e\ (Fe^{3+}) + 2H_2O$$

ATP is also generated as electrons flow through cytochromes oxidase. The complex contains cytochrome a, two Cu^{2+} ions, and cytochrome a_3; the flow of electrons is as follows:

$$Cy + e \rightarrow Cy + a \rightarrow Cu^{2+} \rightarrow Cyt\ a_3 \rightarrow O_2$$

This complex is inhibited by cyanide, anion, carbon monoxide, and sodium azide.

The clarification of the sequence of carries in the electron-transport chain aided the study of the phosphorylation reactions that accompany the transport of electrons from substrate to O_2.



The cytochrome electron-transport chain. (a) Complexes I, II, III, and IV are shown together with the specific carrier components for each complex. (b) The sequential oxidation-reduction of each component in the four complexes

IV. ORGANIZATION OF ELECTRON-TRANSPORT CHAIN

The components of the electron transport chain can be purified from the mitochondrial inner membrane as four distinct of protein complexes:

(i) NADH – Coenzyme Q Reductase.
(ii) Succinate – Coenzyme Q Reductase.
(iii) Coenzyme Q – Cytochrome c Reducatse.
(iv) Cytochrome c Oxidase.

In complexes I, II and IV electron transfer drives the movement of protons from the mitochondrial matrix to the intermembrane space.

Complex I (NADH Dehydrogenase) involves more than 45 polypeptide chains, 1 molecule of flavin mononucleotide (FMN), and as

Many as nine Fe-s clusters, together containing a total 20 to 26 iron atoms.

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Complex II (Succinate – Dehydrogenase) oxidized succinate to fumarate, with concomitant reduction of bound FAD TO $FADH_2$. This $FADH_2$ transfers its electrons from immediately to Fe-S centers, which pass them on to UQ. Electrons flow from succinate to UQ.

Complex III drives electron transport from Coenzyme to Cytochrome c via a unique redox pathway known as the cycle. UQ Cytochrome c Reductase (UQ–cy+ e Reductase) as this complex is known, involves three different cytochromes and an Fe-S protein. In the cytochromes of these and similar complexes between the reduced Fe^{2+} ferrous) and oxidized Fe $^{3+}$ (ferric states).

Complex IV transfer electrons from cytochrome c to reduce oxygen on the matrix side. Complex IV (cytochrome c oxidase) accepts electrons from and directs them so the four-electron reduction of O_2 to form $2H_2O$ via CuA sites, the heme iron of cytochrome a, Cu_3 and the heme iron of a_3.

V. CONCLUSION AND RECOMMENDATION

In the electron transport process, the free energy of electron transfer from NADH and $FADH_2$ via protein - bound redox centres is coupled to ATP synthesis. The free energy necessary to generate ATP as extracted from the oxidation of NADH and $FADH_2$ by the electron transport Chain, a series of four protein complexes, through which electrons pass from lower to higher standard reduction potentials. Electrons are carried from complexes I and II to complex III by coenzyme Q (Co-Q or uniquione; so named because of its ubiquity in respiring organisms) and from complex III to complex IV by the peripheral membrane protein cytochrome.

Since the life sciences along with the physical sciences have received much more attention to revise and refresh course there is an urgent need now to lay emphasis on the protection of environment all over the world and to provide a better life to the living beings of this planet in order to maintain a proper balance between the environment and human survival it becomes imperative to incorporate concepts of immediate concern that have direct complications not only to theory but practical work and their subsequent application for environmental protection and human Survival and then to maintain the ecological and biochemical balance.

The study of such concept as electron transport should be specifically introduced in the course of study related to the biological Sciences at various levels,

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