Electron Transport and Oxidative phosphorylation

Electron Transport: transport of electrons from enzymatic cofactors (NADH,$FADH_2$) to oxygen.

Oxidative phosphorylation: used energy from transporting electrons from (NADH,$FADH_2$) to oxygen and produced ATP.

Hydrogen and electrons flow through the respiratory chain from NAD/NADH to O_2/H_2O. the respiratory chain consists of a number of redox carries that produce from NAD linked dehydrogenises systems, through flavoproteins and cytochromes to molecular oxygen.

Detail steps:

A- Oxidation of one molecule of NADH produced three molecules of ATP as in equation:

$$NADH + H + 3ADP + 3pi + \tfrac{1}{2} O_2 \longrightarrow NAD + 3ATP + H_2O$$

B- Oxidation of FADH2 molecule produces two molecules of ATP as in equation:

$$FADH_2 + 2ADP + 2pi + \tfrac{1}{2} O_2 \longrightarrow FAD + 2ATP + H_2O$$

The aim of the pathway:

1- Production of energy as (ATP) by oxidation of NADH and $FADH_2$.

2- Production of oxidize forces as NAD, FAD.

1- Electrons of NADH start to enter the respiratory chain from the NAD – specific dehydrogenises through flavoproteins and cytochromes to molecular oxygen.

2- Electrons of $NADH_2$ start to enter the respiratory chain from coenzyme Q forming hydroquinone QH_2 , after that these electrons transfer to other respiratory chain parts.

(fumarate/succinate) are linked directly to flavoproteins dehydrogenises, because their rodex potentials are more positive than the NAD – specific dehydrogenises .

3- ATP molecules produce in three sites in NADH molecules and in two sites in $FADH_2$ molecule, (as a result of phosphorylation of ADP molecules.

ADP + pi $\longrightarrow$ ATP

These sites contained:

1- The first site (between NADH and CoQ).

2- The second site (between cytochrome b and c).

3- The third site (between cytochrome c and oxygen).

In these sites ADP react with pi and from ATP molecule.

The hypothesis of oxidative phosphorylation

1- Chemical coupling hypothesis:

This hypothesis postulate that during electron transfer from redox forces to oxygen forms intermediate compound (a high-energy compound).

This compound is used as precursor to form phosphatic bond with high energy (to form ATP from ADP and phosphate).

2- Chemoiosomotic hypothesis:

This postulated that the mitochondria membrane is impermeable to protons, thus, electrons transporting from one carrier to another cause in transporting of protons to out, as a result, respiratory chain serve as a (pump) to transport H+ ions from the mitochondria and drive the synthesis of ATP.

3- Conformational Change In Protein:

Boyer postulated that electron transport is conserved in the form of a conformational change in an electron carrier protein molecule, and this change will yield energy as ATP.

Transporting of NADH in and out of mitochondria

NADH cannot penetrate the mitochondria membrane, but it is produced in the cytosol by 3- phosphoglyceraldehyde dehydrogenase in glycolysis.

The mechanism of transfer using the glycerophosphate shuttle and the malate shuttle.

Malate Shuttle:

In this shuttle the electrons transfer from NDAH to oxaloacetate which reduced to malate by malate dehydrogenase, then, malate enters to

mitochondria, after that, malate reduces NAD to NADH and covert to oxaloacelate by malate dehydrogenase, oxaloacetate convert to aspartate which transport through the mitochondria membrane and convert to oxaloacetate in the cytosol.

(oxaloacetate react with glutamate and produce aspartate and NADH by aminotransferase in cytosol).

NADH enters oxidation phosphorylation, oxidation of NADH in this shuttle produce three molecules of ATP. This shuttle take place in Heart, Kidney and liver.

Glycerol Phosphate Shuttle:

In this shuttle the electrons transfer from NDAH to Dihydroxyacetone-phosphate, which reduces to glycerol 3- phosphate by glycerol 3-phosphate dehydrogenase, after that, it inters to mitochondria (by specific receptors)

In mitochondria glycerol 3- phosphate react with FAD to produce FADH and dihydroxy acetone phosphate which transfer from mitochondria to cytosol. FADH enters respiratory chain, phosphorylation oxidation and produce (2) molecules of ATP. This shuttle takes place in muscles and brain.

Inhibitors

Effect of some compound in electron transport and oxidative phosphorylation may classify as follow:

1- Inhibitors of the respiratory chain.

2- Inhibitors of the oxidative phosphorylation.

In the two states they inhibit the formation of ATP from ADP.

1- Uncoupling reagents:

These compounds increased the entry of proteins to the inside of the enner membrane of mitochondria, thus, the energy of transporting of electron is used and then it dispersals and ATP don't form.

Exp. $\Longrightarrow$ (2 , 4 dinitrophenol , valinomycin , gramicidin)

2- Electron transport inhibitors:

Like: cyanide CN^-, CO , H_2S , actinomycin, barbiturate, the effect of these compounds is direct inhibition of electrons transportation , CN^- react with Fe of cytochrome (a_3+a) but CO inhibit Fe formation.

Total energy that produce from total oxidation of glucose

We can calculate the number of ATP molecules that produce from total oxidation of one mole of glucose by molecular oxygen to CO_2 and H_2O in (glycolysis, tricarboxylic acid, and oxidation phosphorylation)

Total reaction of oxidation of one mole of glucose

$$\text{Glucose} + 36ADP + 36pi + 36H + 6O_2 \longrightarrow 6CO_2 + 36ATP + 42H_2O$$

The ratio p:o defined as number of moles of inorganic phosphate which converted to organic phosphate (ATP) per one oxygen atom that consumed.

The ratio p:o is 3 because 36 moles of ATP molecules formed and 12 O_2 molecules consumed number of moles of ATP that formed from oxidative phosphorylation is 32 from 36 mole of ATP that formed from the total oxidation of glucose molecules.

Components of the Respiratory Chain

A- NADH dehydrogenase: is a protein which called flavoprotein, contains prosthetic group which is called flavin mono nuclutide.

B- Coenzyme Q: which is called ubiquinone, it is classified as lipid which contains side chain which is called isoprenoid.

C- Cytochromes: proteins contained prosthetic group (heme molecule which contains iron. This iron undergo from oxidation and reduction during transformation of electrons through cytochromes in the respiratory chain as in follow:

Cytb $\longrightarrow$ Cytc $\longrightarrow$ Cytc $\longrightarrow$ Cyt ($a + a_3$)

Electrons transfer across cytochromes to oxygen.