Electron transport and Oxidative phosphorylation or
As the electron turns

Introduction:

The complete oxidation of glucose carbons by glycolysis and the citric acid cycle can be written as

$$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$$

The reducing equivalents (electrons) are captured in the form of reduced co-enzymes (NADH and $FADH_2$) which eventually transfer electrons to molecular oxygen

$$6O_2 + 24H^+ + 24e^- \rightarrow 12\ H_2O$$

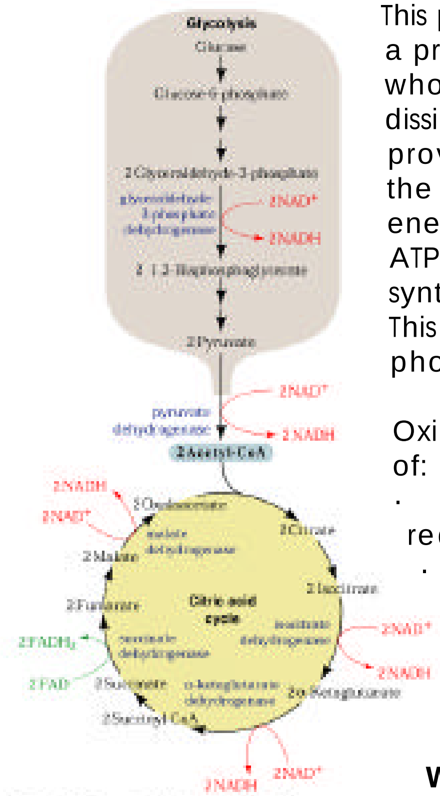
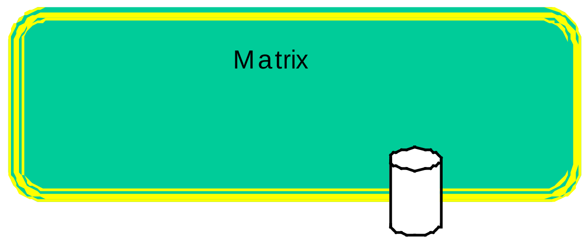


Figure 17-1. The sites of electron transfer that form NADH and $FADH_2$ in glycolysis and the citric acid cycle.

This process regenerates NAD^+ and FAD and generates a proton gradient across the inner mito membrane, whose dissipation provides the free energy for ATP synthesis.



This process is known as oxidative phosphorylation.

Oxidative phosphorylation - the combined actions of:

- Electron transport - ETS - (the transport of e^- from reducing equivalents to O_2)
  - Harnessing the chemical and electrical potential produced by the ETS
    - O_2 is ultimate e- acceptor and drives ATP formation thus oxphos

Where do the equivalents come from?

- glycolysis
- TCA
- ß oxidation of fatty acids

ETS and Oxphos tightly coupled via the H^+ gradient - can be uncoupled by poisons and inefficient coupling leads to heat

Mitochondria

- Outer membrane is very porous
- Inner membrane very tight. Transfer into and out of matrix is controlled - important in H^+ and shuttling reducing equivalents.
- membranes are topologically sided - different charge, lipids and proteins

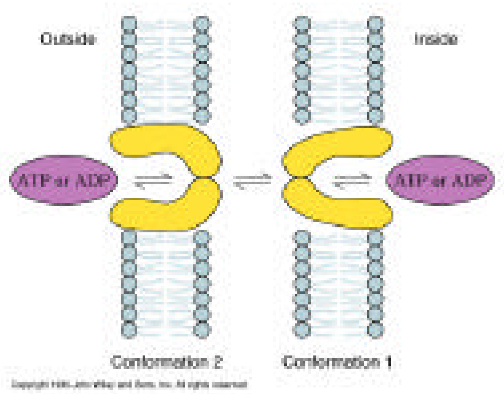
NADH shuttle

Much of the reducing equivalents is produced in the cytosol and needs to be shuttled into the mitochondria - this happens by one of two means

- The malate-aspartate shuttle allows NADH to be indirectly transported into the mitochondrion by reducing OAA to malate and transporting malate across the inner mitochondrial membrane. OAA is then transaminated to asparate and then shuttled back to the cytosol

- The glycerophosphate shuttle first reduces cytosolic dihydroxyacetone phosphate (DHAP) to 3-phosphoglycerate and NAD+. The 3-phosphoglycerate is oxidized by an inner mitochondrial membrane enzyme, flavoprotein dehydrogenase, which introduces electrons directly into the ETS via $FADH_2$.

ATP Translocation



Most of the ATP generated in the mitochondria is used in the cytosol. The ADP-ATP translocator exports ATP out of the matrix while importing ADP.

- ATP has one more negative charge than ADP thus the transport is based on membrane potential. - electrogenic transport.
- Transport is driven by the electrochemical potential of the proton concentration gradient (positive outside)

Redox potential / free energy changes:

In an electron transfer reaction electrons flow from a substance with a lower reduction potential to a substance with a higher reduction potential.

- Thus redox potential is a measure of a molecule's affinity for electrons

Redox potential give a measure of oxidizing and reducing strengths of the different electron carriers

- Oxidized form NADH -> Reduced form NAD^+
- The reaction potential for a reaction is the sum of the voltage potentials

  $\Delta E^{o\prime} = E^{o\prime}$ (e^- acceptor) - $E^{o\prime}$ (e^- donor)

- The voltage potential for the electron transfer from NADH (-0.315) to O_2 (0.815)is:

  $\Delta E^{o\prime}$ =

  Or for two half reactions

  $1/2\ O_2 + H^+ + 2e^- \rightarrow H_2O$

  $NAD^+ + H^+ + 2e^- \rightarrow NADH$

  $\Delta E^{o\prime}$ =

MDH reaction: Malate + $NAD^+ \rightarrow$ OAA + NADH + H^+

$NAD^+ + 2e^- \rightarrow NADH^+ + H^+$ $\quad E^{o\prime} = -0.32$ V

$OAA + 2e^- \rightarrow$ Malate $\quad E^{o\prime} = -0.17$ V

$\Delta E^{o\prime}$ = change in redox potential = oxidant Eo' - Reductant $E^{o\prime}$

$\Delta E^{o\prime} = -0.15$ V $\rightarrow$ from this we can determine the spontaneity of the reaction

$$\Delta G^{o\prime} = -nF\Delta E^{o\prime}$$

n = # of electrons transferred

F = faraday's constant = 23.06 kcal/volt · mol

$$\Delta G^{o\prime} = -2 \times 23.06 \text{ kcal/volt . mol} \times -0.15 \text{ V}$$

$$\Delta G^{o\prime} = +6.92 \text{ kcal/mol}$$

- A reaction will proceed spontaneously when $\Delta E^{o\prime} > 0$
- Just like the Gibbs function, changes in actual concentration will shift the reaction

Physical contact need not occur for redox reactions to take place

Transfer of e^- starts at NADH (or $FADH_2$) and ends with $O_2 \rightarrow H_2O$

$\Delta E^{o\prime}$= +1.13 V , $\Delta G^{o\prime}$ = - 56.52.6 kcal/mol