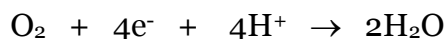


## Electron-Transport Chain and ATP production

Occurs in the inner mitochondrial membrane where NADH and FADH<sub>2</sub> are oxidized back to NAD<sup>+</sup> and FAD. They transfer their e<sup>-</sup> in a series of steps and ultimately to O<sub>2</sub>:



The energy released in these e<sup>-</sup> transfers is used to pump H<sup>+</sup> (protons) out of the matrix into the intermembrane space. This produces a proton gradient (different [H<sup>+</sup>] on each side) – a state of high potential energy.

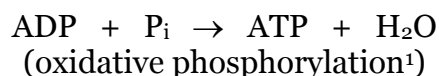
**1a.** At enzyme complex I, NADH is oxidized to NAD<sup>+</sup> and e<sup>-</sup> are transferred between different proteins in this cluster, then to coenzyme Q (CoQ or Ubiquinone). Protons are pumped.

**1b.** FADH<sub>2</sub> is oxidized (transfers its e<sup>-</sup>) to the CoQ at enzyme complex II. The reduced CoQ joins the rest of the “chain”.

**2.** The reduced CoQ travels to enzyme complex III where the e<sup>-</sup> are transferred between proteins and then to cytochrome c. Protons are pumped.

**3.** Cytochrome c travels to the enzyme complex IV where the e<sup>-</sup> are transferred between proteins and then to O<sub>2</sub> to form water. More protons are pumped.

The H<sup>+</sup> ions that have been pumped into the intermembrane space can only get back into the matrix through ATP Synthase. The energy released as H<sup>+</sup> flow back to the matrix is coupled with the formation of ATP:



Each NADH that enters the electron transport chain produces 3 ATP molecules (i.e H<sup>+</sup> ions are pumped at complexes I, III and IV) whereas each FADH<sub>2</sub> (that joins the “chain” at complex two) produces 2 ATP molecules (i.e H<sup>+</sup> ions are pumped only at complexes III and IV)

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<sup>1</sup> Notice that the name oxidative phosphorylation applies to the formation of ATP at the ATP Synthase in contrast with the substrate level phosphorylation.

## Energy obtained from a complete catabolism of glucose

1. Glycolysis
2. Pyruvate → acetyl-CoA
3. Citric Acid Cycle
4. Electron transport chain

	ATP count
<b>1. From Glycolysis (in cytoplasm)</b>	
For each glucose      2 ATP's used	-2
4 ATP's formed	+4
2 NADH produced      (*3 ATP)	+6
(Each NADH from glycolysis needs to be transported to the matrix in the mitochondria at a "cost" of 1 ATP each.)	-2
<b>Total</b>	<b>6</b>
 <b>2. 2 Pyruvate → 2 acetyl-CoA</b>	
2 NADH molecules formed      (*3 ATP)	+6
(This NADH is already in the mitochondria and no transport is necessary.)	
<b>Total</b>	<b>6</b>
 <b>3. Citric Acid Cycle (and Electron transport chain)</b>	
From each acetyl-CoA we get 3 NNADH, 1 FADH <sub>2</sub> and 1 ATP.	
<u>Two acetyl-CoA enter the cycle (if we started with 1 glucose).</u>	
6 NADH      (*3 ATP)	+18
2 FADH <sub>2</sub> (*2 ATP)	+4
2 ATP	+2
<b>Total (for two)</b>	<b>24</b>

### You have to be able to:

Calculate the total # ATP obtained, starting at any step of the metabolism (glycolysis, pyruvate → acetyl-CoA or the C.A.C.)

Describe the type of reaction in each step.