Electron-Transport Chain and ATP production

Occurs in the inner mitochondrial membrane where NADH and $FADH_2$ are oxidized back to NAD^+ and FAD. They transfer their e^- in a series of steps and ultimately to O2:

$$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$$

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

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

1b. $FADH_2$ is oxidized (transfers its e^-) 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^- are transferred between proteins and then to cytochrome c. Protons are pumped.

3. Cytochrome c travels to the enzyme complex IV where the e^- are transferred between proteins and then to O2 to form water. More protons are pumped.

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

$$ADP + P_i \rightarrow ATP + H_2O$$

(oxidative phosphorylation[1])

Each NADH that enters the electron transport chain produces 3 ATP molecules (i.e H^+ ions are pumped at complexes I, III and IV) whereas each $FADH_2$ (that joins the "chain" at complex two) produces 2 ATP molecules (i.e H^+ ions are pumped only at complexes III and IV)

[1] 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
1. From Glycolysis (in cytoplasm)			
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
		Total	**6**

2. 2 Pyruvate → 2 acetyl-CoA			
2 NADH molecules formed	(*3 ATP)		+6
(This NADH is already in the mitochondria and no transport is necessary.)			
		Total	**6**

3. Citric Acid Cycle (and Electron transport chain)

From each acetyl-CoA we get 3 NNADH, 1 $FADH_2$ and 1 ATP.
Two acetyl-CoA enter the cycle (if we started with 1 glucose).

6 NADH	(*3 ATP)	+18
2 $FADH_2$	(*2 ATP)	+4
2 ATP		+2
	Total (for two)	**24**

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.