CHAPTER EIGHT

OXIDATIVE PHOSPHORYLATION

What is the energy released by an electron as it moves from carrier to carrier in the electron transport chain primarily used for ?

It is used to transport hydrogen ions from the mitochondrial matrix (i.e. the inside of the mitochondrion) across the inner mitochondrial membrane to the intermembranous space (i.e. to the outside of the *inner* mitochondrial membrane).

What is the result of this transmembrane hydrogen ion transport ?

There is an accumulation of hydrogen ions in the intermembranous space.

What is the buildup of hydrogen ions in the intermembranous space called ?

The chemiosmotic gradient.

Hydrogen ions are charged and water soluble and hence the membrane, which is composed of lipid, should be impermeable to them. How, therefore, do hydrogen ions cross the membrane?

The ions probably cross the membrane through specific transmembrane transport channels in the protein complexes that make up the electron transport chain (similar to the transmembrane transport channels for pyruvate mentioned above).

Why does this process of transporting hydrogen ions across the inner mitochondrial membrane require energy ?

As hydrogen ions move out of the mitochondrial matrix the concentration of hydrogen ions outside the membrane becomes greater than that inside the membrane. Therefore, the natural tendency of the ions would be to flow along their concentration gradient by simple diffusion from the **intermembranous space** of the mitochondrion to the **mitochondrial matrix**. In order to drive the hydrogen ions against this concentration gradient you must provide energy.

How is the energy released by electrons used to drive hydrogen ions out of the mitochondrion against the concentration gradient ?

The energy is probably used to form covalent bonds between the side chains of some of the amino acids that make up the transmembrane transport proteins. This leads to some amino acids moving closer together and therefore leads to a *conformational change in the three dimensional structure of the protein*. This movement in the molecule probably physically moves the hydrogen ions through the channel of the transmembrane transport channel.

What are the structures that project into the mitochondrial matrix from the inner surface of the inner mitochondrial membrane called ?

They are the ATP synthase proteins.

What are the two components of this ATP synthase protein ?

There is a transmembrane portion called Fo and a large spherical portion projecting into the mitochondrial matrix called F1 (see diagram later in chapter).

What is the function of the Fo portion of ATP synthase ?

Fo is a transmembrane hydrogen ion transport protein. (This is a different hydrogen ion transport protein to the one mentioned above through which H+ ions leave the mitochondrial matrix).

What is the function of the F1 portion of the ATP synthase ?

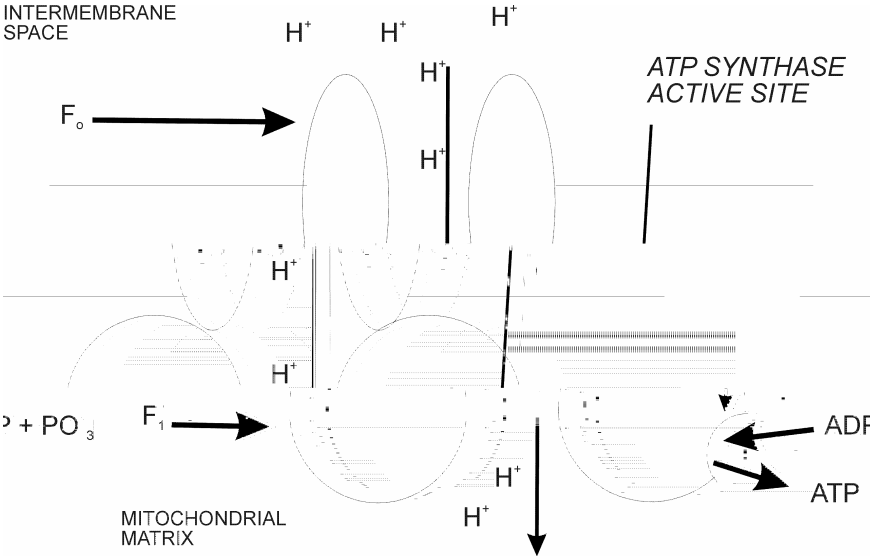
It is an enzyme. It has an active site that catalyzes the formation of a bond between ADP and an inorganic phosphate group to form ATP. *Finally, after all that we have started making some ATP !!*

Which direction do hydrogen ions move through the ATP synthase complex ?

They move from the intermembranous space (i.e. outside the inner mitochondrial membrane) to the mitochondrial matrix (along the hydrogen ion concentration gradient that has been created by the energy released in the electron transport chain).

What is the process by which ATP is synthesized by the ATP synthase enzyme called ?

Oxidative phosphorylation.



What determines if the ATP synthase enzymatic site is active ?

Hydrogen ions (which are positively charged) flowing through the transmembrane ion channel portion (Fo) of the of the ATP synthase complex interact with charges on the side chains of some of the amino acids in the ATP synthase complex (some amino acids have side chains with positively or negatively charged groups). This leads to a *conformational change* in the three dimensional structure of the whole protein complex, including the structure of the enzymatic site. This change in the conformation (or shape) of the protein means that the reagents (ADP and Pi) and products (ATP) can move into and out of the active site at a faster rate and so ATP is formed at a faster rate. *This is a similar process to one we described*

How does ATP get out of the mitochondrion to the cytoplasm to be used by energy requiring synthetic reactions ?

It passes through a special transmembrane transport channel in exchange for a molecule of ADP. (The ADP is therefore brought into the mitochondrion where it can be converted into more ATP).

How much additional ATP is synthesized from one molecule of glucose if all the NADH and $FADH_2$ molecules formed during glycolysis, conversion of pyruvate to acetyl CoA and the citric acid cycle are metabolized by the electron transport chain and oxidative phosphorylation ?

About 36 molecules of ATP are formed. Compare this with a net of 2 molecules of ATP formed per molecule of glucose if you could not use oxygen and relied on glycolysis to provide all your ATP requirements. Therefore oxidative metabolism can extract much more energy from a molecule of glucose than glycolysis can.

What are uncoupling proteins ?

Uncoupling proteins are a third type of transmembrane hydrogen ion transport protein in the inner mitochondrial membrane. Hydrogen ions can flow through uncoupling proteins instead of through the ATP synthase complex. This means that the hydrogen ion gradient can be dissipated *without forming ATP*.

What physiological process are uncoupling proteins thought to be important in ?

Uncoupling proteins are thought to be important in maintaining body temperature. When electrons move through the electron transport chain some of the energy they release is dissipated as heat. However, under normal circumstances, increased electron transport chain activity would lead to increased ATP production which would feed back to inhibit glycolysis. NADH production would therefore be reduced and there would be fewer electrons to pass through the electron transport chain

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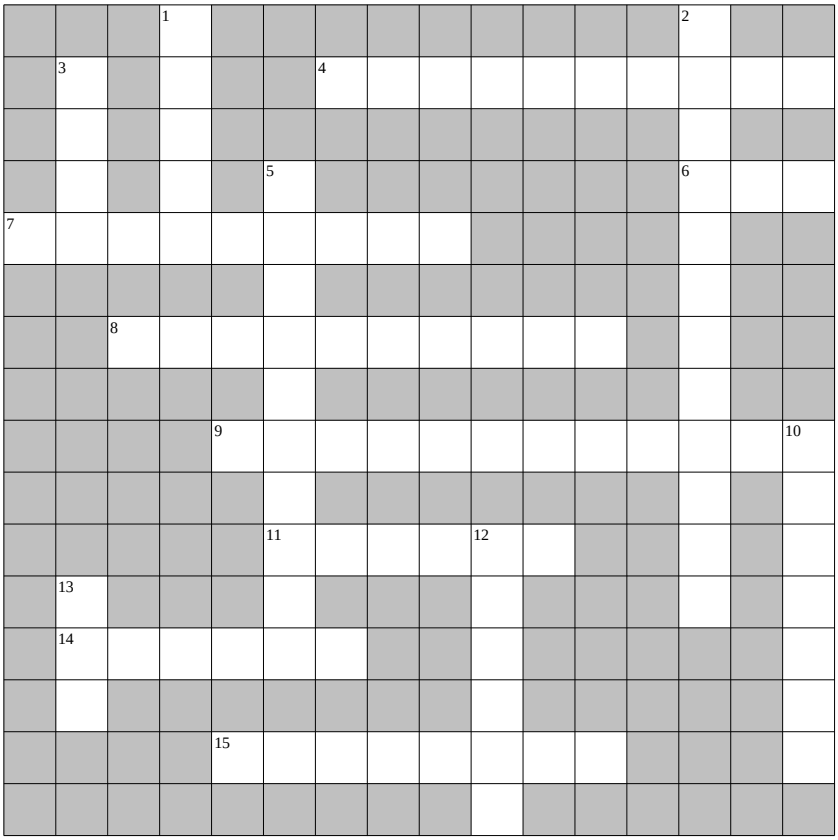
Electron Transport Chain and Oxidative Phosphorylation



Across

4. Electron carrier that is mobile in membrane (10)
6. Chemical formula for one of the electron carriers found early in the electron transport chain (3)
7. Approximate number of molecules of ATP synthesized by oxidative phosphorylation from one molecule of glucose (9)
8. Yellow coloured vitamin from which forms part of FAD and FMN molecules (10)
9. The name of the gradient formed by accumulation of hydrogen ions in intermembrane space of mitochondrion (12)
11. Final electron acceptor in the electron transport chain (6)
14. Metal ion found associated with cytochrome a/a3 (6)
15. Energy released by electrons is used to pump these ions into intermembrane space (8)

Down

1. Product of the final reaction in the electron transport chain (5)
2. Hydrogen ions moving through ATP synthase change the ---- of the protein (12)
3. Abbreviation for molecule that donates electrons to electron transport chain (4)
5. Iron containing electron carrier molecules in electron transport chain (9)
10. Poison that inhibits complex IV (7)
12. This is released as electrons move down along electron transport chain (6)
13. Order in which the different cytochromes (a.b and c) appear in the electron transport chain (1,1,1)

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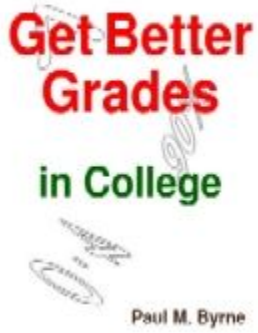

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