

There are four distinct stages in the oxidation of fatty acids. Fatty acid degradation takes place within the mitochondria and requires the help of several different enzymes. In order for fatty acids to enter the mitochondria the assistance of two carrier proteins is required, Carnitine acyltransferase I and II. It is also interesting to note the similarities between the four steps of beta-oxidation and the later four steps of the TCA cycle.

Entry into Beta-oxidation

Most fats stored in eukaryotic organisms are stored as triglycerides as seen below. In order to enter into beta-oxidation bonds must be broken usually with the use of a Lipase. The end result of these broken bonds are a glycerol molecule and three fatty acids in the case of triglycerides. Other lipids are capable of being degraded as well.

Key molecules in beta-oxidation: (left) A triglyceride molecule, (middle) Glycerol, (right) Fatty Acids (unsaturated)

Steps of Beta-oxidation

Activation

Once the triglycerides are broken down into glycerol and fatty acids they must be activated before they can enter into the mitochondria and proceed on with beta-oxidation. This is done by Acyl-CoA synthetase to yield fatty acyl-CoA.

After the fatty acid has been acylated it is now ready to enter into the mitochondria.

There are two carrier proteins (Carnitine acyltransferase I and II), one located on the outer membrane and one on the inner membrane of the mitochondria. Both are required for entry of the Acyl-CoA into the mitochondria.

Once inside the mitochondria the fatty acyl-CoA can enter into beta-oxidation.

Oxidation

A fatty acyl-CoA is oxidized by Acyl-CoA dehydrogenase to yield a trans alkene. This is done with the aid of an [FAD] prosthetic group.

Hydration

The trans alkene is then hydrated with the help of Enoyl-CoA hydratase

Oxidation

The alcohol of the hydroxyacyl-CoA is then oxidized by NAD⁺ to a carbonyl with the help of Hydroxyacyl-CoA dehydrogenase. NAD⁺ is used to oxidize the alcohol rather than [FAD] because NAD⁺ is capable of the alcohol while [FAD] is not.

Cleavage

Finally acetyl-CoA is cleaved off with the help of Thiolase to yield an Acyl-CoA that is two carbons shorter than before. The cleaved acetyl-CoA can then enter into the TCA and ETC because it is already within the mitochondria.

References

Garrett, H., Reginald and Charles Grisham. Biochemistry. Boston: Twayne Publishers, 2008.

Raven, Peter. Biology. Boston: Twayne Publishers, 2005.

Problems

Where does beta-oxidation occur?

What is the average net yield of ATP per carbon?

Where exactly is water formed during the process of fatty acid degradation? (Hint: H₂O is formed when when the one of the products of beta-oxidation is passed through another of the metabolic pathways)

During the process of beta-oxidation, why is it that [FAD] is used to oxidize an alkane to an alkene while NAD⁺ is used to oxidize an alcohol to a carbonyl

Draw out the entire process of the degradation of a triglyceride, include enzymes and products and reactants for each step.

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