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CARBOHYDRATE METABOLISM - A CONSTANT SUPPLY OF ENERGY

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ABSTRACT

All living cells need the energy to carry out various cellular activities. This energy is stored in the chemical bonds of fundamental molecules (e.g. carbohydrates, fats, proteins) that we eat as food. These fundamental molecules are broken down by enzymatic reactions in cells to generate energy in the form of adenosine triphosphate (ATP). The ATP generated by these pathways in cells is used to run fundamental cellular processes. All major pathways of carbohydrate metabolism are linked to alterations of glucose. As glucose is the essential sugar in the blood and the main energy fuel in the body. The metabolic pathways are Glycolysis, Oxidation of Pyruvate, Citric Acid Cycle and Electron transport chain (ETC). The food we devour is mainly comprised of proteins, polysaccharides (carbohydrates) and fats. These are first confined into smaller units: proteins into amino acids, polysaccharides into sugars, and fats into fatty acids and glycerol. This process of digestion occurs outside the cell. The amino acids, simple sugars, and fatty acids then enter the cell and endure oxidation by glycolysis (in the cytosol) and the citric acid cycle (in the mitochondria) to generate ATP (from ADP and Pi).

KEYWORDS: *Living cells, Food, Pathways, Food, and Carbohydrates.*

INTRODUCTION

METABOLISM: The term metabolism stands for all the organized chemical activities performed by a cell. The chemical process that takes place inside the bacterial cell. Metabolic comprises energy production (Catabolism) and Energy Utilization (Anabolism).

The word metabolism derived from the Greek word “metabole” meaning change is suitably used to describe the chemical reactions within the cell -continuous changes with its life processes. Catabolism: Biochemical processes involved in the breakdown of organic or inorganic compounds leading to energy production. Anabolism: Biochemical processes involved in the synthesis of cell constituents from simpler molecules usually requiring energy. Anabolism is also called Biosynthesis: It is an energy consuming process. Anabolism and Catabolism collectively termed metabolism (Food consists of various substances - Nutrients)

Chemicals from the environment of which a bacterial cell is built are called “NUTRIENTS”. Nutrients are taken up into the cell and are changed into cell constituents. Cells must have a means of obtaining energy for biosynthetic processes (ANABOLISM). And also energy needed for cell movement, transport of nutrients. An energy source is obtained from the environment as light or chemical energy. The overall process of metabolism in microorganisms which include anabolism and catabolism.

A common biochemical pathway for the fermentation of glucose is Glycolysis. Fermentation pathway includes Homofermentation and Heterofermentation. Glycolysis is an almost ubiquitous pathway for catabolism of glucose in animals and plants. It occurs in all cells of our body. The process is partial oxidation of glucose where the 6-C molecule is dissected to form two 3-C units (pyruvate), and the energy released is conserved in the form of ATP and NADH. The objective of glycolysis is to provide (i) energy and (ii) intermediates for other metabolic pathways (Yadav *et al.,* 1993).

The citric acid cycle is the final common pathway for oxidation of carbohydrates, lipids, and many amino acids. It occurs in aerobic organisms within cells that have mitochondria. Its main purpose is to oxidize acetyl-CoA and concomitantly reduce NAD+ and FAD. Under aerobic conditions, the end product of glycolysis is pyruvic acid. The next best is the formation of acetyl coenzyme A (acetyl CoA) - this step is technically not a component of the citric acid cycle but is shown on the diagram on the top left. Acetyl CoA, whether from glycolysis or the fatty acid spiral, is the founder of the citric acid cycle. In carbohydrate metabolism, acetyl CoA is the channel between glycolysis and the citric acid cycle. The initiating step of the citric acid cycle occurs when a four-carbon compound (oxaloacetic acid) condenses with acetyl CoA (2 carbons) to form citric acid (6 carbons). The full desire of a “turn” of the citric acid cycle is to produce two carbon dioxide molecules. This general oxidation reaction is consort by the loss of hydrogen and electrons at four specific places. These oxidations are linked to the electron transport chain where many ATP are produced.

METHODOLOGY

Glycolysis (Embden-Meyerhoff Pathway)

Definition: Glycolysis means oxidation of glucose to give pyruvate (in the presence of oxygen) or lactate (in the absence of oxygen) (Voet, D. and Voet, J.G. 1995).

The site of reaction: All the reaction steps ensue in the cytoplasm.

The process of Glycolytic Pathway: Glucose is phosphorylated to glucose -6-phosphate. The enzyme is hexokinase, which fissures ATP into ADP and the Pi is added on to the glucose. The energy released by hydrolysis of ATP is idolized for the forward reaction. Hexokinase is the main glycolytic enzyme and the reaction is irreversible. Glucose-6-phosphate is isomerized to fructose-6-phosphate by phosphohexose isomerase. Fructose-6-phosphate is another phosphorylated to fructose-1,6-bisphosphate. The enzyme is phosphofructokinase, it is an important key enzyme and the reaction is irreversible. Fructose-1, 6-bisphosphate is hacked into two 3 carbon atoms; one glyceraldehyde-3 phosphate and another molecule of dihydroxyacetone phosphate. The enzyme is aldolase. Dihydroxyacetone phosphate is isomerised to glyceraldehyde-3-phosphate by the enzyme phosphotriose isomerase. Glyceraldehyde-3-phosphate is dehydrogenated and simultaneously phosphorylated to 1,3-bisphosphoglycerate with the help of NAD+. The enzyme is glyceraldehyde-3-phosphate dehydrogenase. 1, 3-bisphosphoglycerate is converted to 3-phosphoglycerate by the enzyme 1, 3-bisphosphoglycerate kinase. Here one molecule of ATP is organized and this reaction is an example for Substrate level phosphorylation. 3-phosphoglycerate is isomerized to 2-phosphoglycerate by shifting the phosphate group from 3rd to 2nd carbon atom (Boyer, R. 1999). The enzyme is phosphoglucomutase. 2-phosphoglycerate is changed to phosphoenolpyruvate by the enzyme enolase. One water molecule is removed. A high energy phosphate bond is produced. This enzyme requires Mg++and inhibited by fluoride. Phosphoenolpyruvate is disaffiliated to pyruvate, by pyruvate kinase. One molecule of ATP is generated. This step is irreversible. In anaerobic condition, pyruvate is decreased to lactate by lactate dehydrogenase. In aerobic conditions, pyruvate enters the citric acid cycle for entire oxidation. The lactate from the anaerobic cycle enters Cori’s cycle (Berg *et al.*, 2002).

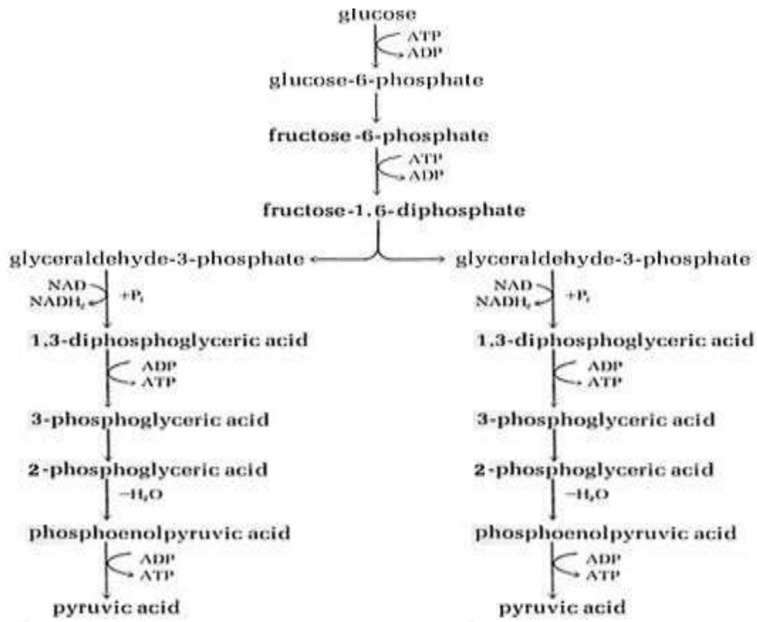


Figure: Glycolysis Pathways

Differences between Aerobic and Anaerobic Glycolysis

Process	Aerobic	Anaerobic
1. End product	Pyruvate	Lactate
2 .energy	6 or 8 ATP	2 ATP
3. Regeneration of NAD^+	Through respiration chain in mitochondria	Over Lactate formation
4. Availability to TCA in mitochondria	Available and 2 Pyruvate can oxidize to give 30 ATP	Not liable as lactate is cytoplasmic substrate

The signification of the Glycolysis Pathway: It is the only pathway that is taking place in all the cells of the body. Glycolysis is the single source of energy in erythrocytes. In strenuous exercise, when muscle tissue default enough oxygen, anaerobic glycolysis forms the major source of energy for muscles. The glycolytic pathway may be contemplated as the preliminary step before complete oxidation. The glycolytic pathway affords carbon skeletons for the synthesis of non-essential amino acids as well as glycerol part of fat. Most of the reactions are reversible (Hall, John E.,2015)

Citric Acid Cycle (Kreb's cycle/TCA cycle)

Definition: It is the series of reactions in mitochondria, which oxidized acetyl CoA to CO2, H2O and reduced H2 carriers that oxidized through respiratory chains for ATP synthesis (Lowenstein J M, 1969).

The site of reaction: Mitochondria of all tissue cells except RBCs, which not contain mitochondria.

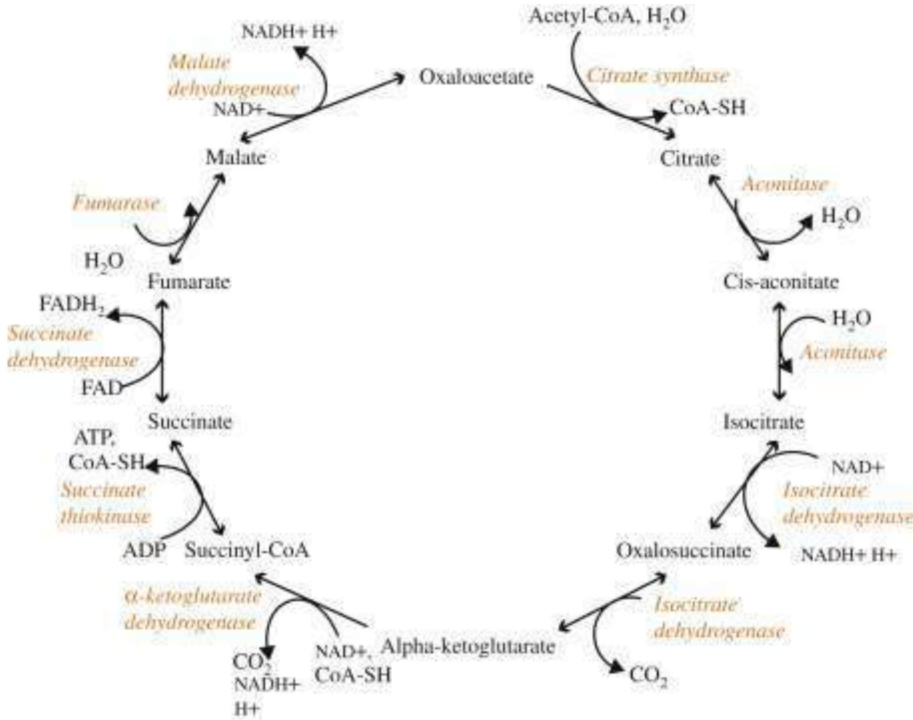


Figure: Citric Acid Cycle

According to Dashty, Monireh (2013) process of Citric Acid Cycle:

Step 1: The acetic acid subunit of acetyl CoA is connected with oxaloacetate to form a molecule of *citrate*. The acetyl coenzyme A operates only as a transporter of acetic acid from one enzyme to another. After Step 1, the coenzyme is released by hydrolysis so that it may connect with another acetic acid molecule to begin the Krebs cycle again.

Step 2: The citric acid molecule goes through an isomerization. A hydroxyl group and a hydrogen molecule are ejected from the citrate structure in the form of water. Two carbons form a double bond until the water molecule is joined back. Only now, the hydroxyl group and H molecule are reversed with respect to the original structure of the citrate molecule. Thus, *isocitrate* is formed.

Step 3: In this track, the isocitrate molecule is oxidized by a NAD molecule. The NAD molecule is decreased by the hydrogen atom and the hydroxyl group. The NAD binds with a hydrogen atom and captures the other hydrogen atom leaving a carbonyl group. This structure is very erratic, so a molecule of CO_2 is released creating *alpha-ketoglutarate*.

Step 4: In this track, coenzyme A, rebound to oxidize the alpha-ketoglutarate molecule. A molecule of NAD is decreased again to form NADH and leaves with another hydrogen. This instability motivates to a carbonyl group to be released as carbon.

Step 5**:** A water molecule discards its hydrogen atoms to coenzyme A. Then, a free-floating phosphate group relegate coenzyme A and forms a bond with the succinyl complex. The phosphate is then transferred to a molecule of GDP to make an energy molecule of GTP. It leaves behind a molecule of *succinate*.

Step 6: Succinate is oxidized by a molecule of FAD (Flavin adenine dinucleotide). The FAD eliminates two hydrogen atoms from the succinate and forces a double bond to form between the two carbon atoms, thus creating *fumarate*.

Step 7: An enzyme compute water to the fumarate molecule to form *malate*. The malate is composed by adding one hydrogen atom to a carbon atom and then adding a hydroxyl group to a carbon next to a terminal carbonyl group.

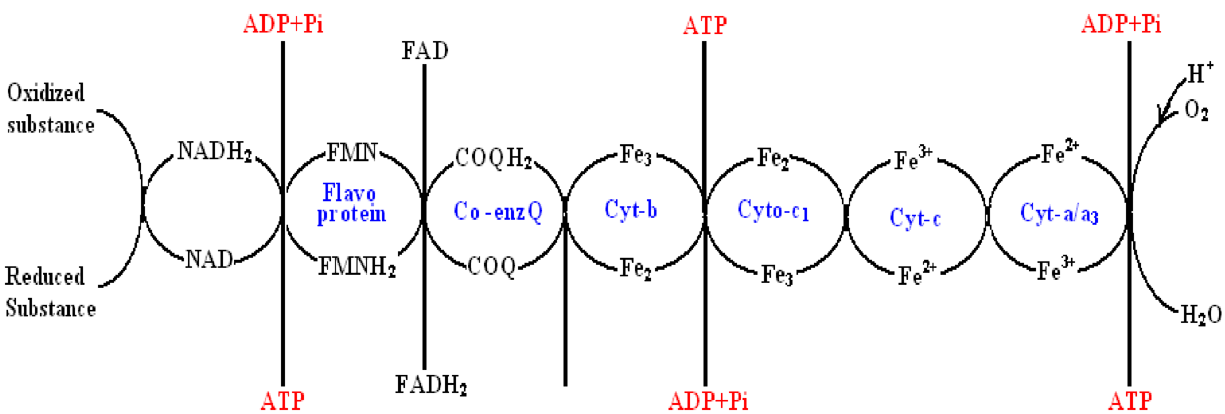
Step 8: In this step, the malate molecule is oxidized by a NAD molecule. The carbon that carried the hydroxyl group is now changed into a carbonyl group. The final product is *oxaloacetate* which can then combines with acetyl-coenzyme A and begin the Krebs cycle all over again

Energy (ATP) yield per Glucose molecule broken-down in Aerobic respiration

Glycolysis (Glucose)	Gateway step	Tri carboxylic acid
6 ATP ($2NADH_2$)		18 ATP ($6NADH_2$)
2 ATP	6ATP ($2NADH_2$)	4 ATP ($2FADH_2$)
2 ATP		2 ATP (2GTP)
8 ATP	6 ATP	24 ATP = 38 ATP

ransferred to O_2 or other terminal electron acceptors through the action of ETC. ETC composed of membrane-associated electron carriers (Maughan, Ron,2009). These have two basic functions.

The site of reaction: To accept electrons from an electron donor and transfer them to an electron acceptor. To conserve some of the energy released during electron transport for the synthesis of ATP.



The process of the Citric Acid Cycle:

ETC happens in the cytoplasmic membrane of prokaryotes (PKs) and inner mitochondrial membrane of Eukaryotes. End Products - H_2O, FMN- Flavin mononucleotide Co_2, FAD- Flavin Adenine di nucleotide, Energy - NAD – Nicotinamide Adenine Dinucleotide phosphate. NADH donates 2- hydrogen atom to FMN. Two hydrogen atoms are extended when FADH donates 2-electrons only to an iron-sulfur protein (FMN, FAD). 2-Protons are taken up from the dissociation of H_2O in the cytoplasm when non-heme iron reduces Co-enzyme "Q". Co-enzyme "Q" passes electrons one at a time to the cytochrome bc_1 – complex. Cytochrome transfers electrons from quinines to cytochrome 'C'. Electrons travel from cytochrome C to Cytochrome a/a_3 which serve as a terminal oxidase. Finally, reduction O_2 to H_2O occurs and ETC reactions are completed (Nelson, David L., 2013).

CONCLUSION

The food we consume is primarily comprised of proteins, polysaccharides (carbohydrates) and fats. These are first compressed into smaller units: proteins into amino acids, polysaccharides into sugars, and fats into fatty acids and glycerol. This process of digestion occurs outside the cell. More than 60% of our foods are carbohydrates. Starch, glycogen, sucrose, lactose, and cellulose are the main Carbohydrates in our food. Before intestinal absorption, they are hydrolyzed to hexose sugars. The food we consume is mainly constituted of protein, carbohydrate, and Fat.

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