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Question

Describe the mechanism in aerobic respiration.

Aerobic respiration requires oxygen (O2) in order to create ATP. Although carbohydrates, fats, and proteins are consumed as reactants, it is the preferred method of pyruvate breakdown in glycolysis and requires that pyruvate enter the mitochondria in order to be fully oxidized by the Krebs cycle. The products of this process are carbon dioxide and water, but the energy transferred is used to break bonds in ADP as the third phosphate group is added to form ATP (adenosine triphosphate), by substrate-level phosphorylation, NADH and FADH2

Simplified reaction: C6H12O6 (s) + 6 O2 (g) → 6 CO2 (g) + 6 H2O (l) + heat

ΔG = −2880 kJ per mol of C6H12O6

The negative ΔG indicates that the reaction can occur spontaneously.

The potential of NADH and FADH2 is converted to more ATP through an electron transport chain with oxygen and protons (hydrogen) as the "terminal electron acceptors". Most of the ATP produced by aerobic cellular respiration is made by oxidative phosphorylation. The energy of O2 released is used to create a chemiosmotic potential by pumping protons across a membrane. This potential is then used to drive ATP synthase and produce ATP from ADP and a phosphate group. Biology textbooks often state that 38 ATP molecules can be made per oxidized glucose molecule during cellular respiration (2 from glycolysis, 2 from the Krebs cycle, and about 34 from the electron transport system). However, this maximum yield is never quite reached because of losses due to leaky membranes as well as the cost of moving pyruvate and ADP into the mitochondrial matrix, and current estimates range around 29 to 30 ATP per glucose.

Aerobic metabolism is up to 15 times more efficient than anaerobic metabolism (which yields 2 molecules ATP per 1 molecule glucose) because the double bond in O2 is of higher energy than other double bonds or pairs of single bonds in other common molecules in the biosphere. However, some anaerobic organisms, such as methanogens are able to continue with anaerobic respiration, yielding more ATP by using other inorganic molecules (not oxygen) of high energy as final electron acceptors in the electron transport chain. They share the initial pathway of glycolysis but aerobic metabolism continues with the Krebs cycle and oxidative phosphorylation. The post-glycolytic reactions take place in the mitochondria in eukaryotic cells, and in the cytoplasm in prokaryotic cells.

Glycolysis

Out of the cytoplasm it goes into the Krebs cycle with the acetyl CoA. It then mixes with CO2 and makes 2 ATP, NADH, and FADH. From there the NADH and FADH go into the NADH reductase, which produces the enzyme. The NADH pulls the enzyme's electrons to send through the electron transport chain. The electron transport chain pulls H+ ions through the chain. From the electron transport chain, the released hydrogen ions make ADP for an end result of 32 ATP. O2 provides most of the energy for the process and combines with protons and the electrons to make water. Lastly, ATP leaves through the ATP channel and out of the mitochondria.

Glycolysis is a metabolic pathway that takes place in the cytosol of cells in all living organisms. Glycolysis can be literally translated as "sugar splitting, which functions with or without the presence of oxygen. In humans, aerobic conditions produce pyruvate and anaerobic conditions produce lactate. In aerobic conditions, the process converts one molecule of glucose into two molecules of pyruvate (pyruvic acid), generating energy in the form of two net molecules of ATP. Four molecules of ATP per glucose are actually produced, however, two are consumed as part of the preparatory phase. The initial phosphorylation of glucose is required to increase the reactivity (decrease its stability) in order for the molecule to be cleaved into two pyruvate molecules by the enzyme aldolase. During the pay-off phase of glycolysis, four phosphate groups are transferred to ADP by substrate-level phosphorylation to make four ATP, and two NADH are produced when the pyruvate is oxidized. The overall reaction can be expressed this way:

Glucose + 2 NAD+ + 2 Pi + 2 ADP → 2 pyruvate + 2 H+ + 2 NADH + 2 ATP + 2 H+ + 2 H2O + energy

Starting with glucose, 1 ATP is used to donate a phosphate to glucose to produce glucose 6-phosphate. Glycogen can be converted into glucose 6-phosphate as well with the help of glycogen phosphorylase. During energy metabolism, glucose 6-phosphate becomes fructose 6-phosphate. An additional ATP is used to phosphorylate fructose 6-phosphate into fructose 1,6-bisphosphate by the help of phosphofructokinase. Fructose 1,6-biphosphate then splits into two phosphorylated molecules with three carbon chains which later degrades into pyruvate.

Oxidative decarboxylation of pyruvate

Pyruvate is oxidized to acetyl-CoA and CO2 by the pyruvate dehydrogenase complex (PDC). The PDC contains multiple copies of three enzymes and is located in the mitochondria of eukaryotic cells and in the cytosol of prokaryotes. In the conversion of pyruvate to acetyl-CoA, one molecule of NADH and one molecule of CO2 is formed.

Citric acid cycle

This is also called the Krebs cycle or the tricarboxylic acid cycle. When oxygen is present, acetyl-CoA is produced from the pyruvate molecules created from glycolysis. Once acetyl-CoA is formed, aerobic or anaerobic respiration can occur. When oxygen is present, the mitochondria will undergo aerobic respiration which leads to the Krebs cycle. However, if oxygen is not present, fermentation of the pyruvate molecule will occur. In the presence of oxygen, when acetyl-CoA is produced, the molecule then enters the citric acid cycle (Krebs cycle) inside the mitochondrial matrix, and is oxidized to CO2 while at the same time reducing NAD to NADH. NADH can be used by the electron transport chain to create further ATP as part of oxidative phosphorylation. To fully oxidize the equivalent of one glucose molecule, two acetyl-CoA must be metabolized by the Krebs cycle. Two low-energy waste products, H2O and CO2, are created during this cycle.

The citric acid cycle is an 8-step process involving 18 different enzymes and co-enzymes. During the cycle, acetyl-CoA (2 carbons) + oxaloacetate (4 carbons) yields citrate (6 carbons), which is rearranged to a more reactive form called isocitrate (6 carbons). Isocitrate is modified to become α-ketoglutarate (5 carbons), succinyl-CoA, succinate, fumarate, malate, and, finally, oxaloacetate.

The net gain from one cycle is 3 NADH and 1 FADH2 as hydrogen- (proton plus electron)-carrying compounds and 1 high-energy GTP, which may subsequently be used to produce ATP. Thus, the total yield from 1 glucose molecule (2 pyruvate molecules) is 6 NADH, 2 FADH2, and 2 ATP.

Oxidative phosphorylation

In eukaryotes, oxidative phosphorylation occurs in the mitochondrial cristae. It comprises the electron transport chain that establishes a proton gradient (chemiosmotic potential) across the boundary of the inner membrane by oxidizing the NADH produced from the Krebs cycle. ATP is synthesized by the ATP synthase enzyme when the chemiosmotic gradient is used to drive the phosphorylation of ADP. The electron transfer is driven by the chemical energy of exogenous oxygen and, with the addition of two protons, water is formed.