Aerobic Cellular Respiration

- Products of **Glycolysis** (Aerobic):
  
  2 NADH + H^+  
  2 ATP (Net Substrate Level Phosphorylation)  
  2 Pyruvate

- Products: Entering : Mitochondria

  1. **Pyruvate**: *Translocation* :

      * Transition Reactions
      a. Looses:
      b. Reduces:
      c. Combines with:

      ** NONREVERSIBLE :**

  2. **NADH + H^+** : *From*

      a. **Oxidized at**:

      * Electrons passed through mitochondrial membrane by :
        -
      * Electrons “caught” on mitochondrial coenzymes

          - Accepted by:

Within Mitochondria: **2 Sets of Rxns**

1. **Krebs Cycle (Citric Acid or TCA)**: Cyclical set of

   * **Function**: Cyclical set of mitochondrial reactions yielding:
   * **Products**: per Acetyl CoA – per “one turn”
a. 1 ATP : Substrate level phosphorylation:

b.

c.

☆ Significance: Energy re-diversion:

✓ Produce: “Reduced Coenzymes”:

Products: Krebs cycle – ONE TURN

CO
NADH + H⁻
FADH₂
ATP

nosis per Glucose:

2 x 2 CO₂ = 4 CO₂
2 x 3 NADH + H⁻ = 6 NADH + H⁻
2 x 1 FADH₂ = 2 FADH₂
2 x 1 ATP = 2 ATP

Total ATP produced per glucose: Glycolysis & Krebs Cycle

ATP : Glycolysis
ATP : Krebs Cycle
ATP

Overall Cellular Respiration:

Total cellular ATP =

Q: Where are the other 26-28 ATPs?
Q: Where is the energy needed to power the endergonic ATP production if ALL of the bonds in glucose are “broken”?

A: Reduced molecules:

☆ Each coenzyme carries:

Electron Transport / Oxidative Phosphorylation:

• REDOX reactions: Transport Electrons

☆ “Oxidative”: Oxidation of:

☆ “Phosphorylation”: Phosphorylate:

Location:

• Contents: Series of:
• 4 Main Functions:

1. **REDOX: Oxidize**: NADH and FADH₂
   - Transport:

2. **Proton Pump: Hydrogens**
   - REDOX reactions “power” the hydrogen pumps:
     - Electrons produce proton pump:
       - a. First Pump: 4 Hydrogens
       - b. Second Pump: 4 Hydrogens
       - c. Third Pump: 2 Hydrogens
   - Function: Active transport of $H^+$ from *Matrix into Inner Mitochondrial Space*
   - Creating a:

3. **Disposal of electrons: Reduce Oxygen into**: 
   - Oxygen Oxidizes last electron carrier
   - Last electron movement:
     - Oxygen pulls electron off:
     - Oxygen combines with:
       \[
       2H^+ + 2e^- + \frac{1}{2} O_2 \rightarrow H_2O
       \]
   - Final Electron Acceptor:
     - *Highest*:

4. **Produce ATP**
   - Potential energy of concentration gradient used to:
   - **Respiratory Assembly**: 2 part protein complex
     - a. H⁺ Channel:
     - b. **ATP Synthase** Enzyme
       - Function:
         - H⁺ flows down its:
         - H⁺ association causes:
• Causing spinning of the protein rotor and activation of the:
  
  ✡ Gradient lost =
  
  • 3 hydrogens =
  • 1 hydrogen =
  • 3 hydrogens =
  • 4 hydrogens =

http://www.youtube.com/watch?v=PjdPTY1wHdQ

• \( \text{NADH} = 4 \text{H}^+ + 4\text{H}^- + 2 \text{H}_2 = 10 \text{H}^-
\)
  
  \[ 10 \text{H}^- / 4 \text{H}^- \_\text{ATP} = 2.5 \text{ATP} \]

• \( \text{FADH}_2 = 4\text{H}^+ + 2 \text{H}^- = 6 \text{H}^-
\)
  
  \[ 6 \text{H}^+ / 4 \text{H}^+ \_\text{per ATP} = 1.5 \text{ATP} \]

ATP Check Sheet : Actual Yield

Results:

1. Glycolysis:

2. Transition rxns:

3. Krebs:

✓ 26 ATP if FADH\(_2\) is used for Mitochondrial transfer
✓ 28 ATP if NADH+H\(^+\) is used for Mitochondrial transfer
Study Questions:

1) What is the difference between substrate level phosphorylation and oxidative phosphorylation?

2) Why is Lactic Acid NOT produced in the presence of oxygen? Where does the oxidation of the reduced coenzymes occur?

3) What are the products of glycolysis? Which are shuttled (transported) into the mitochondria? Once in the mitochondria, how is pyruvate assisted into the Krebs Cycle? (hint: what organic “helper” can assist the enzymatic breakdown of the carbon skeleton? What are the products of this incorporation of pyruvate into the mitochondrion (what are the products of the “prep steps”?) What happens to each of the products?

4) What two sets of chemical reactions occur within the mitochondria in the process of ATP production? Which one uses substrate level phosphorylation and which one uses oxidative phosphorylation?

5) What are the products of the Krebs Cycle (per pyruvate)? Following the transport of pyruvate into the mitochondria and the movement into and through one “turn” of the Krebs Cycle, how many CO₂ molecules are produced? When the Krebs cycle is complete, are any bonds from the original glucose remaining from which to harvest energy? Where is the remaining energy located that is needed to power the remaining 26 – 28 ATPs?

6) What is the functional significance of the Krebs Cycle – is it to make ATP or is it to make something else?

7) What are the four main functions of the electron transport & oxidative phosphorylation processes?

8) What purpose do the reduced coenzymes of NADH and FADH₂ have in the electron transport chain? (What energy storing activity occurs because of the transfer of these electrons?)

9) What is the ultimate fate of the electrons (which originally came from the glucose) in the electron transport chain? What is the FINAL electron acceptor of the electrons and what results from the process?

10) How is the hydrogen concentration gradient formed? What is the concentration gradient used for?

11) What are the respiratory assemblies? What are there two parts and what is the primary function of each?

12) Cyanide is a poisonous gas that results in rapid death. Cyanide functions by binding to and adversely affecting the last electron transport in the chain so that the electrons can not be removed. Using your knowledge of the ETC, explain why cyanide results in death.

13) How much ATP is produced in glycolysis, How much ATP is produced in Krebs? How much ATP is produced by the oxidative phosphorylation at the ETC?

14) The theoretical ATP yield for the complete oxidation of glucose is 36 or 38 ATP. Why is the actual ATP yield slightly less (30 or 32ATP)? (Hint: What is the difference between mitochondrial AYP yield and cytoplasmic ATP?)

15) Why is the overall mitochondrial ATP production listed as either 30 or 32 (or theoretical as 36 or 38)? (Hint: What is the difference between the NADH oxidation of FADH₂ by the electron transport chain?)