Chapter 9

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- Steps of Cellular Respiration:
  1. Glycolysis
  2. The Kreb's Cycle[1]
  3. Oxidative Phosphorylation
- Cellular Respiration – A set of metabolic reactions and processes that convert biochemical energy from nutrients into ATP, and then release waste products. The chemical reaction is:

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + 36\,ATP$$

- Catabolism (breakdown) of glucose to produce ATP occurs
- Energy is harvested by digesting large molecules into smallers ones (particularly glucose), where bonds are then broken, and electrons are move from one molecule to another. As the electrons move, they carry energy.
- When a molecule loses an electron, it is oxidized, while the molecule gaining an electron is reduced.
- Electron carrier molecules move electrons by shuttling H atoms around.
- $NAD^+ \longrightarrow$ NADH (reduced)
- $FAD^{2+} \longrightarrow FADH_2$ (reduced)
- In Glycolysis, glucose is broken into pyruvates
- In the Kreb's Cycle, pyruvates become carbon dioxide
- In the Electron Transport Chain, electrons are passed to oxygen by NADH

[1] Also referred to as the Citric Acid Cycle

- Step One − Glycolysis:

    1. Glucose broken down into pyruvates (1 6-carbon molecule to 2 3-carbon molecules)
    2. Transfers energy from organic molecules to ATP (generates only 2 ATP per glucose, as pyruvates still hold most of energy)
    3. Occurs in cytosol
    4. Happens with or without oxygen
    5. Process occurs as follows: $C_6H_{12}O_6 \longrightarrow 2\,\text{Pyruvate} + 2\,H_2O \longrightarrow 2\,\text{ADP} + 2\,P_i \longrightarrow 2\,\text{ATP} + 2\,\text{NAD} \longrightarrow 2\,\text{ATP} + 2\,\text{NADH} + 2\,H^+$
    6. Net yield of 2 ATP and 2 NADH

- Step Two − The Kreb's Cycle:

    1. Occurs in the mitochondrial matrix as an 8-step pathway
    2. It is aerobic (meaning it only occurs if O_2 is present)
    3. Happens twice, one for each pyruvate
    4. Pyruvate become Acetyl-CoA
    5. CO_2 comes from breakdown of pyruvates in the Kreb's Cycle
    6. NAD^+ becomes NADH, while FAD^{2+} becomes $FADH_2$
    7. Net yield of 2 ATP, 6 NADH, and 2 $FADH_2$ per glucose molecule
    8. This stage marks the oxidation of glucose to CO_2
    9. Although not much ATP is produced, the NADH and $FADH_2$ are more important, as they are used in the Electron Transport Chain
    10. Per pyruvate, 3 NAD^+ is reduced to NADH, 1 FAD^+ is reduced to $FADH_2$, and one ATP is produced

- Step Three − The Electron Transport Chain:

    1. The chain consists of series of proteins built into the inner mitochondrial membrane
    2. Electrons are released from NADH and $FADH_2$, and, as they are passed along the series of enzymes, they give up energy, which is used to fuel chemiosmosis
    3. This yields about 34 ATP per glucose
    4. Is an aerobic process (aerobic respiration)
    5. 6 water molecules are formed when the electrons unite with oxygen at the end of the electron transport chain
    6. NADH dehydrogenase convert NADH to NAD
    7. Hydrogen molecules are removed from NADH and $FADH_2$

8. Electrons are then stripped from hydrogen atoms causing them to become protons (H^+)
9. Electrons are then passed from one electron carrier to the next in mitochondrial membrane
10. Flowing electrons make energy do work
11. Transport proteins in membrane pump H^+ (protons) across inner membrane into intermembrane space
12. H^+ gradient causes flow of protons through ATP synthase, which synthesizes ATP ($ADP + P_i \longrightarrow ATP$)
13. Oxidative Phosphorylation is the process of Chemiosmosis and Electron Transport Chain combined

- Chemiosmosis − The diffusion of ions across a membrane (this is what links the ETC to ATP synthesis)
- Oxygen is the final electron acceptor in the ETC
- If O_2 is unavailable, the ETC backs up, which means nothing to pull electrons down, which causes a build up of NADH and $FADH_2$, which makes it impossible to unload H, and ATP production ceases. Ass a result, cells run out of energy and the organism dies.
- Anywhere between 30-38 ATP is produced in one cycle
- Without oxygen, anaerobic respiration, or fermentation occurs:

  1. Another molecule must accept H from NADH
  2. Depending on the organism, either alcoholic fermentation or lactic acid fermentation occurs. Humans have lactic acid fermentation.
  3. In lactic acid fermentation, lactate accepts H, whereas, in alcoholic, CO_2 is produced and H is accepted.