Unit 3: Bioenergetics
Content Outline: Cellular Respiration (3.2) – Part 1

I. Cellular Respiration
   A. This is the process of *releasing energy* contained in *organic molecules* (mainly Glucose) to do work. (This is an example of catabolism.)
      1. The process is for *making ATP* using oxygen, if available.
      2. The process releases heat (Remember, heat is *Low Quality E*) and free electrons. (Remember that electrons are a source of *Kinetic Energy*.)
   B. *With O_2 present* in the cell – Cellular Respiration can occur in the mitochondria.
   C. *Without O_2 present* in the cell – Fermentation will occur in the cytoplasm of the cell.
   D. 6H20 + C6H12O6 6CO2 + 6H2O + Free E +Heat E
      1. *The Free E is used to make ATP from ADP by phosphorylation*

II. Cellular Respiration is a *Three Step Process:*
   A. Step 1: **Glycolysis** (This is the *breaking* Glucose into 2 molecules of G3P.) (<u>All</u> organisms can do this process as it occurs in the *cytoplasm* of a cell.)
   A good visual for showing the two halves through out this process is to use a whiteboard marker. When capped it is Glucose. When "Broke" de-capped each piece then becomes a G3P. This helps when you are talking about two halves going through the same process.
   B. Step 2: **Kreb's Cycle** (This is all about *making Electron Carriers* in the continued breakdown.)
   C. Step 3: **e- Transport Chain** (This is where the *Free E of the electrons is used to help make ATP*.)
   D. The whole process yields a *maximum of 38 ATP*/ 95% of time only 36 produced though.

III. The Process of Glycolysis
   A. In this process, Glucose ($C_6 H_{12} O_6$) will be broken apart into 2 molecules of G3P. Each molecule of G3P will then be *converted* to a molecule of Pyruvate. At the end of the process, the cell will have 2 molecules of Pyruvate that can be put into the Mitochondria, if oxygen *is present* and it is a *Eukaryotic Cell*.
   B. There are two parts to Glycolysis:
      1. **E Investment Phase**
         a. Glucose is broken into 2 molecules of G3P.
         b. To break it in half *requires 2 ATP be used*. (One phosphate is put on *each* side of the Glucose molecule. This makes it *unstable* and Glucose breaks in half to make 2 G3P molecules.) (Whiteboard maker used to help visualize. A hand represents a single Phosphate being attached to one end. Show students that one phosphate cannot break (de-cap) the Glucose. When the second phosphate (hand) is attached, then it can be broken (de-capped).

      2. **E Payoff Phase**
         a. The 2 molecules of G3P will then be *converted* to 2 molecules of Pyruvate.
         b. This phase *will yield 4 ATP + 2 NADH* total.(2 ATP and 1 NADH per molecule.) The cell *pays back* the two it *used* for the first part. This leaves the cell with a *payoff* of two ATP. (What we refer to as **Net Gain**.) (Use each half of the marker to help make it visible. Each half will make 2 ATP and 1 NADH.
   C. Remember, this process *occurs with or without O_2 present in the cell.*
   D. <u>All</u> organisms do it as it occurs in the cytoplasm of a cell.

Cellular Respiration – Part 2

I. If Oxygen is present within the Eukaryotic cell ("**Aerobic**" means "With Oxygen"), the Eukaryotic cell *can* perform the other two parts of Cellular Respiration – Kreb's Cycle and Electron Transport Chain.

A. In order to enter the *inner* Mitochondrial space, where the Kreb's Cycle occurs, Pyruvate <u>must</u> be *converted* to Acetyl Coenzyme A. This is referred to as the **Pyruvate Conversion**. It occurs in the space *between* the outer membrane and the inner membrane of the Mitochondria. (Help students "see" that there are two separate areas within a Mitochondria. Hint at the ability to have a concentration gradient exist between the two spaces.

1. The final product is Acetyl Coenzyme A. (*Each* molecule is now located in the *inner* mitochondrial space.)

B. **Kreb's Cycle** (This occurs in the *inner* mitochondrial space where there is *room* to work.)

Remember, the *main purpose* of the Kreb's Cycle is to make Electron Carriers by tearing of Hydrogens and attaching them to the Electron carriers. Remember, each Hydrogen has one electron with it. See how many it makes per Acetyl Coenzyme put into the cycle.

1. **EACH** Acetyl Coenzyme A that goes through the cycle will produce:
   a. 3 NADH, 1 FADH2, 1ATP, and CO2.
   b. Each Electron carrier can carry 2 electrons to the Electron Transport Chain.
      i. The *first* negative electron cancels the positive charge on either NAD+ or FADH+.
      ii. The *second* negative charge makes the FADH or NAD negative.
      iii. So a *positive* H^+ will be able to attach to a *negative FADH or NAD.*

C. **Electron Transport Chain**

1. This occurs on the *inner Mitochondrial membrane.*
   a. This membrane is folded (*the folds increase surface area =more ATP can be produced as there is room for more Electron Transport Chains.)*
2. The Electron Transport Chain is <u>always</u> in a membrane.
   a. For Bacteria- It is the *plasma* membrane.
   b. For Eukaryotes – It is the *Mitochondrial inner membrane.*
3. The *whole* process is a *controlled release of E.*
   a. Electrons move 2 at a time *down* the chain toward *Oxygen*. *(Make H2O at end.)*
   b. *Energy (electrons) from NADH and FADH2 is used to produce ATP***.**
   c. *Free Energy*, from the electrons, fuels the *active transport* of H+ into the inner mitochondrial space. (Hint at "building" a concentration gradient.)
      i. H+ (ions/protons) are *pumped* into the space between the membranes *using the Free E released from electrons* as they go down the chain.
      ii. The concentration of H+ builds inside the space (like blowing up a balloon) to *create a concentration gradient.* High[ ] in between and low [ ] in the center. (A purple balloon and pinwheel are a great visual here.)
      iii. The *H+ are released* using ATP Synthesizing Complex. (It would be like pulling the cork in the sink.) (Let the air onto the pinwheel.)
      iv. The H+ rush out (going from High [ ]–>Low [ ]) allowing the **ATP Synthesizing Complex** to use the *Kinetic E* to turn ADP ATP in large amounts by *phosphorylation*.
      v. This is another example of **Energy Coupling** – two processes working together to make ATP. One process is Active transport and the other is facilitated diffusion. Also known as **Chemiosmosis.**
      vi. The Electron Transport Chain can *make 34 or 32 ATP*
      vii. *Add it all up now*:

2 Net ATP From Glycolysis
2 ATP from the Kreb's Cycle
<u>34 **OR** 32</u> from the Electron Transport Chain (Using all the NADH or FADH2)
38 Maximum OR 36 Normal

Cellular Respiration – Part 3

I. If *no Oxygen* is present within the cell ("**Anaerobic**" means "without oxygen"):

- A. **Fermentation** will occur to *free up the electron carriers* to keep at least Glycolysis going making ATP.
  - 1. Two types of fermentation can occur (It depends on the organism doing it.)
    - a**. Alcohol Fermentation** (This occurs in bacteria and Yeast –a fungus.)
      - i. They *convert* the two Pyruvate to 2 molecules of **Ethanol** by cutting off CO_2 and filling the open bond with H from the electron carriers. (This freed up the electron carrier to keep Glycolysis going and thereby making some ATP to *stay alive.)*
      - ii. Beer, wine, and bread are made by this type of fermentation.
    - b. **Lactic Acid fermentation** (This occurs in animals mainly.)
      - i. *Converts* Pyruvate into **Lactic Acid** by breaking a double bond with O_2 and adding H. The H comes from the electron carrier. Here again keeping the process of Glycolysis going to make a little amount of ATP to keep the cells *alive* in the absence of Oxygen.
      - ii. Cheese, yogurt, and muscle cramps (These force you to *stop* exercising.) are all created by this type of fermentation.

II. **Facultative Anaerobes**

- A. These organisms can perform *both* Aerobic and Anaerobic Respiration, but *prefer* oxygen – because it produces more ATP.)