NGSS Life Science

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Topic: Cellular Respiration Activity

Summary: Students will model the biochemistry behind cellular respiration by acting out the steps of cellular respiration.

Goals & Objectives: Students will be able to model aerobic and anaerobic respiration. Students will be able to demonstrate how glucose and O_2 are used to make ATP. Students will be able to explain how each of the steps of oxidative respiration work.

NGSS Standards: *HS-LS1-7.* Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

Time Length: 60 minutes (depending on class size)

Prerequisite Knowledge: Structure of the cell, glucose, and plasma membrane, what are active and passive transport, concentration gradients, ions and electrons, and enzymes.

Materials:

- Student drawn poster of the structure of the electron transport chain. Membrane must include the three proton pumps, two smaller proteins in between them and ATP synthase.
- Student drawn poster of the Calvin cycle with carbon, NAD^+ and FAD in their associated places.
- Tape
- Photocopy handouts, 7 pages of ADPs, 20 pages of O_2, 10 pages of glucose molecules, 1 page of Phosphates, 1 page of Hydrogen ions and electrons, and 1 page for each sign.

Set-up:

1. You will need three tables with easy access, preferably in the front of the room. Put the electron transport chain poster on top of the left table and tape the tape the labels on each desk so the students can read it. Put the Krebs cycle poster on the center table. Place the Glycolysis label on the right table and the glucose cutouts at the beginning (far right) of the table.
2. Cut out the H^+ ions, O_2, P as squares.
3. Place two ADP papers on the glycolysis table, two in the Krebs cycle, and three on the electron transport chain. Place the P cut out next to the corresponding ADP papers.
4. Place large quantities of O_2 papers in three different places on the table for the Krebs cycle. 1st is the citric acid production (Acetyl-CoA), 2nd is the first stage of Krebs cycle, and 3rd on the second stage of Krebs cycle.
5. Place the hydrogen ions on the bottom of the electron transport chain.

Procedures:

1. Review with students about the purpose of cellular respiration, the active transport with hydrogen pumps, ATP synthase, and how NADH and $FADH_2$ are electron carriers for the electron transport chain.

2. Demonstrate to the students the activity. Ask for one student volunteer. Have that student be to the right of all the tables. Give the student a glucose. Then explain to the class that the tables are inside of the cell and that the volunteer is outside of the cell. The first table (glycolysis) is the cytosol and the other two tables are inside a mitochondria.

3. Then ask the volunteer how he can get the glucose molecule inside the cell? "carrier proteins". Then the students walks up to the glycolysis table with their glucose. Then ask the student what happens to the glucose. The student then rips the glucose paper in half so they have two pyruvic acids (pyruvate). Ask students what is that three carbon molecule? Then the student places the two Ps onto the ADP to form ATP. The students also tell you that the form 2 NADH. If you want to get technical, in order for the glucose to split, have the students take two Ps off the ATP to power glycolysis. After the split, students then make four ATP for a net gain of 2 ATP.

4. Students then walk to the mitochondria. Ask the students what they are bringing into the mitochondria. (pyruvic acids). Ask the students if oxygen is present. If yes, precede.

5. The first step is citric acid production. Students rip off one carbon from each pyruvic acid and combine it with the O_2 molecule one the table. They tell you the just made CO_2. Then they throw the CO_2 over their shoulders as if it is going into the air. Next they tell you they also make two NADH. Last, the two carbon acetyl group is added to the 4 carbon molecule of the Krebs cycle by an enzyme called Coenzyme A. This process is called Acetyl-CoA. Remind students that they have two acetyl groups, not one.

6. The students place their two carbon acetyl group on the side of the four carbon chain to show they just made citric acid. Next, the students rip off one carbon from their piece of paper, not the four carbon molecule and combine it with an O2 molecule. They throw the CO_2 behind them and they tell you the make two NADH (one for each). The four-carbon molecule goes through all four steps of the Krebs cycle and is recycled to start the cycle all over.

7. In the second step, students take their last C and combine it with O_2 to form CO_2. They throw them behind them and they make two ATP by place the phosphate group on top of the ADP. They also tell you that make two NADH.

8. In the third step of the Krebs cycle, students tell you that they make two $FADH_2$.

9. In the last step, students tell you that they make two more NADH.

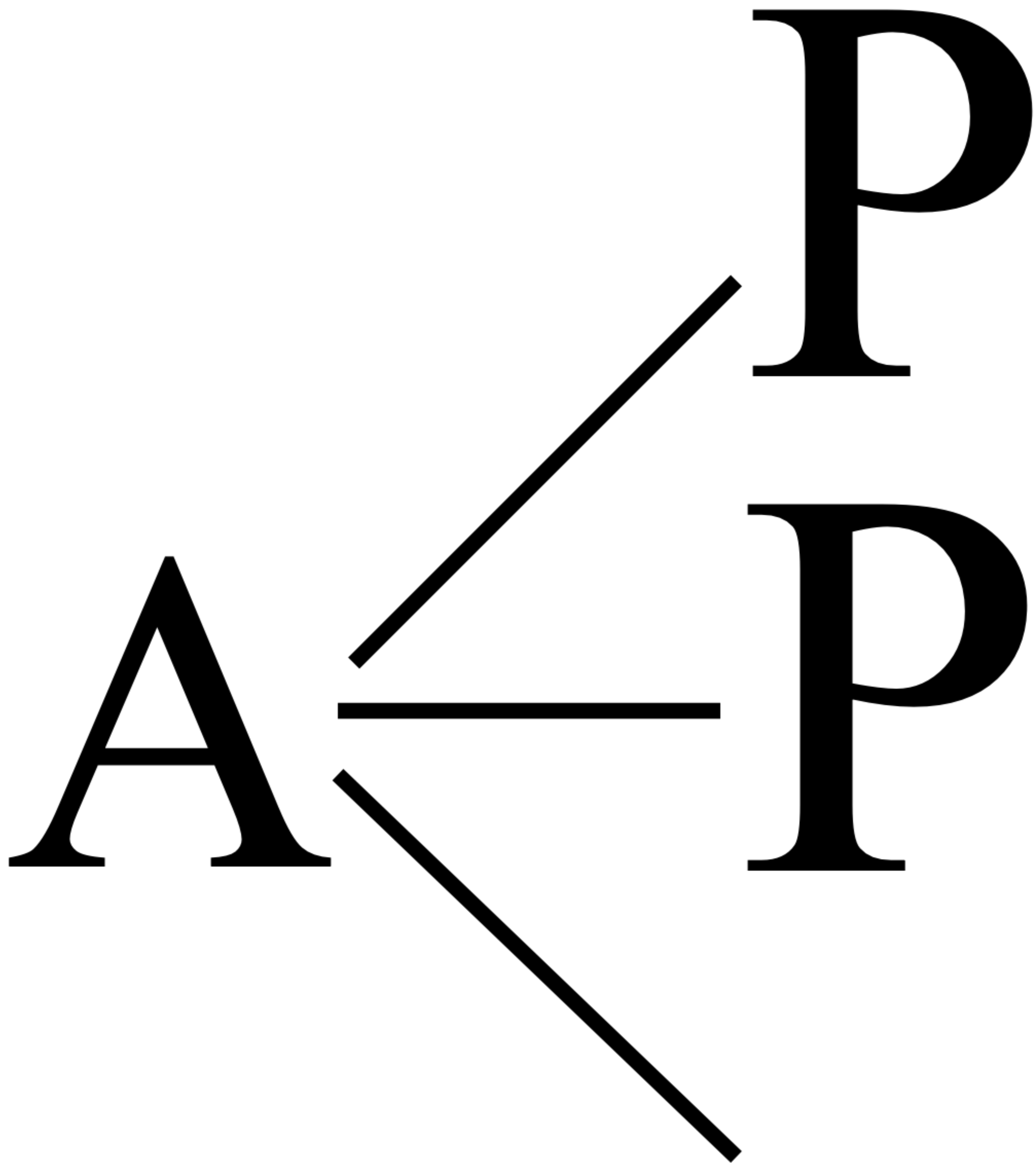
10. Students then go to the electron transport chain table. They need to tell you that all the NADH and $FADH_2$ made before will now be used to power the electron transport chain. For NADH, the students then slides one electron past three proton pumps. The electron then ends up in a water molecule. The student then needs to push the H^+ through each of the pumps to create a concentration gradient. You can also show how $FADH_2$ work by the student moving the electron across two proton pumps and ending in water. The students now move the H^+ ions back across the membrane though ATP synthase. Each time a H+ come through, an ATP is made. The student place a P onto the ADP paper.

11. The process repeats. You can usually have the two students doing the activity at one point in time. All other students who are waiting their turn or have finished the activity work on the handout individually. The handout is collected at the end of the class.

Accommodations: Students who have difficulty walking can move their seat to the opposite side of the table and watch other students perform the activity. Students with an IEP can say much simpler versions like "Sugar is broken apart and ATP is made". If a student with an IEP needs extra time, they can take the handout home.

Editable DOCX File and Answer Key:

Available at www.ngsslifescience.com


P
A
P

O_2 O_2

O_2 O_2

O_2 O_2

O_2 O_2

CCCCCC

Glucose

CCCCCC

Glucose

CCCCCC

Glucose

H^+ H^+

H^+ H^+

H^+ H^+

e^- e^-

Acetyl-Co A

Break down pryuvic acid by removing aCaron to form CO2.

Electrons are also removed to form NADH.

Coenzyme joins the two carbons to form Acetyl CoA.

Glycolysis

Glucose is broken in half to form two pryuvic acids

2 ATP

2 NADH.

Kreb Cycle

During the Krebs cycle, pyruvic acid from glucose is used to make carbon dioxide, NADH, ATP, and $FADH_2$

Electron Transport Chain

NADH, $FADH_2$ donate their electrons to pump hydrogens across the concentration gradient.

Hydrogen then diffuses through ATP synthase and ADP is converted into ATP.

C-C-C-C

4-Carbon compound recycled in Krebs Cycle

C-C-C-C

4-Carbon compound recycled in Krebs Cycle

P P

P P

P P

P P

Name: ______________________ Row: _______

Date:_____________ Period:______

Cellular Respiration Activity

1. What is the chemical formula for oxidative cellular respiration?

6___________+ ____________→ 6____________+ 6______________+ 36 ________

2. In what organelle does oxidative respiration take place? ___________________________

3. Where does glycolysis take place? ____

4. Is oxygen required for glycolysis to happen? ___________________________________

5. How many net ATPs are created in glycolysis? __________________________________

6. What type of acid is created in glycolysis? _____________________________________

7. When _____________ acid enters the mitochondria, what gas is formed? ______________

8. Then an enzyme joins the two carbons to form what? ______________________________

9. How many ATPs are made in Krebs Cycle? _____________________________________

10. What does NADH and $FADH_2$ power? ____

11. Each NADH powers how many proton pumps? __________________________________

12. Each $FADH_2$ powers how many proton pumps? __________________________________

13. The high-energy electron that powers the electron transport chain is stored by forming what molecule? ____

14. What causes the hydrogen ions to go through ATP synthase? _______________________

15. How many total ATPs are made during oxidative respiration? _______________________

16. If oxygen is not present, what happens? _____________________________________

17. What does anaerobic mean? _____________________

18. Anaerobic respiration in plants makes what? ____________in animals? ______________

19. How many net ATPs are created in anaerobic respiration? ___________________________

20. Does anaerobic respiration take place inside the mitochondria? _____________________