A Concrete Lab for
Aerobic & Anaerobic Respiration

Subject Area: High School Biology / Anatomy & Physiology

Grade Level: 10 - 12

Time Required: One lab period (approximately 1 hour). However, the extension will require at least ½ of another period.

Engineering Connection: Application of sensor technology to molecular biology.

Learning Objectives:
1. Students will concretely experience the effects of anaerobic respiration.
2. Students will be able to use a pulse oximeter to note changes in heart rates.
3. Students will be able to use a pulse oximeter to note changes in blood oxygen levels.
4. Students will be able to determine the amount of energy (ATPs) used in the activity.
5. Students will be able to relate changes in their physiology to anaerobic exercise.

Materials:
• Blood Pressure Cuffs
• Finger Pulse Oximeters
• Dumbbells
• Stop Watch
• Meter Stick
• Jolly Rancher Candy (Extension)

Lab Extension: See end of the lab for an extension.

Safety & Precautions: Blood pressure cuffs should be used as directed. Also if a towel is used under the wrist, it protects the arm from the edge of the table.

Acknowledgments: A special thank you to my STEM fellow, Mr. Joseph Lancaster, for the hours of collaboration on multiple labs using computers & sensors.
The Actual Difference in Aerobic and Anaerobic Respiration

PRE LAB PREDICTIONS:
1. How many curls do you think you can do?
   Aerobically = _______, anaerobically = ________.
2. How many total ATPs do you think you will expend in 30 seconds of wrist curling the dumbbell?
   Aerobically = _______, anaerobically = ________.

OBJECTIVE:
To actually physically experience the difference in muscle performance when using both aerobic and anaerobic respiration.

PROCEDURE:

PART A:
1. Place sphygmomanometer on "curler's" arm. **Do not pump it up!**
2. Select a dumbbell that is "heavy" for you personally.
3. Place your arm flat on the desk with your wrist, hand, and dumbbell extending over the edge.
4. Moving only your wrist, curl the dumbbell one time so that your partners can measure the vertical distance (in cm) the dumbbell covers.
   To measure the vertical distance:
   A. Place a meter stick on a chair to eliminate movement.
   B. Using the bottom of one side of the dumbbell, measure its highest and lowest points during one curl.
5. Using only your wrist, curl the dumbbell as many times as you can for 30 seconds.
6. Your partners will:
   A. Keep track of time
   B. Count the number of curls
   C. Make sure you cover the full distance in each curl (without raising your forearm off the desk).
7. You need to concentrate only on curling the dumbbell. However, do note different physiological changes in your body (getting hot, sweating, increased respiration, increased blood circulation to area, etc.) Also try to determine when, and if, your forearm runs out of oxygen.
PART B:

1. **Immediately** after curling for 30 seconds, your partner should pump up the sphygmomanometer to 140 mmHg. Since we only want to slow down the circulation and not stop it, pump it up only to 140. On more muscular individuals be sure to have them use heavier weights. If you don't start immediately they will replenish their stored ATPs and myoglobin.

2. Repeat steps 5 - 7.

PART C:

1. Select one member of your group for push ups.
2. Place a finger pulse oximeter on his ring finger.
3. Take the initial oxygen reading and record it in table 5.
4. Have group member start push ups until they can no longer do any (failure).
5. Record number of push ups and final oxygen reading in table 5.

RESULTS:

Table 1

<table>
<thead>
<tr>
<th>Pulse before exercise / minute</th>
<th>Pulse after exercise / minute</th>
</tr>
</thead>
</table>

Conversions:
1.000 pound = .4536 kilograms
100.0 centimeters = 1.000 meter

Table 2

<table>
<thead>
<tr>
<th>Dumbell's Weight</th>
<th>Distance Dumbell Moved</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb</td>
<td>cm</td>
</tr>
<tr>
<td>kg</td>
<td>m</td>
</tr>
</tbody>
</table>
Table 3

<table>
<thead>
<tr>
<th>Right Arm or Left Arm</th>
<th>Aerobic (without blood pres. cuff)</th>
<th>Anaerobic (with blood pres. cuff)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Curls</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

You must perform the calculation portion of this lab before you can complete table 4.

Table 4

<table>
<thead>
<tr>
<th>Energy Used</th>
<th>Aerobic Curls</th>
<th>Anaerobic Curls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of calories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of ATPs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5

<table>
<thead>
<tr>
<th></th>
<th>Push Ups</th>
<th>Heart Rate</th>
<th>Oxygen Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALCULATIONS:

To lift the dumbbell, we must overcome the gravitational force on that dumbbell. The gravitational force on that dumbbell equals the dumbbell's mass (determined earlier) times the acceleration of gravity. The acceleration of gravity is equal to 9.81 meters / second^2.

Force needed to lift dumbbell = mass of dumbbell x 9.81 m/s^2

Force = _____ kg x 9.81 m/s^2

Force = _____ kg m/s^2
Energy is used to perform work. In our case, chemical energy from ATP's are used by your forearm muscles to overcome the dumbbell's gravitational force (found above). By moving the dumbbell (the distance it moved was measured earlier), the muscles are performing "work" on the dumbbell.

Work = Force x Distance

Work = _____ kg m/s^2 * _____ m

Work = _____ joules (joules = kg m /s^2)

This is the amount of work needed to raise the dumbbell one time. Therefore the above equation can be written as:

Work = _____ joules/curl

To find the total work expended by your arm, multiply the amount of work needed to raise the dumbbell by the number of times the dumbbell was curled (see results for number of curls).

Total Aerobic Work = (_____ joules/curl) x (_____ curls)

Total Aerobic Work = _____________ joules

Total Anaerobic Work = (_____ joules/curl) x (_____ curls)

Total Anaerobic Work = _____________ joules

Joules are units of measure for both work and energy. They can be converted into other units of measure for energy, such as calories.

1 joule = .24 calories

To convert the joules (those produced during total anaerobic and aerobic work) to calories, use the following equation:

_____ aerobic joules x .24 calories/joule = _____________ cal

_____ anaerobic joules x .24 cal/joule =__________ calories

Record in your table 4 results the total number of calories determined for the energy used during the aerobic and anaerobic curls.
Number of ATPs Used:

It requires 7,300 calories to create 1 mole of ATPs. One mole of ATPs can also use 7,300 calories to perform work (in our case, the movement of muscles and therefore, of a dumbbell).

Remember that the word "mole" is referring to a specific amount; 602,000,000,000,000,000,000,000 (6.02 x 10^{23}).

To determine the actual number of moles of ATPs used in moving the dumbbell for 30 seconds, complete the following equation:

\[
\frac{\text{(\# of calories used to move dumbbell)}}{7300 \text{ calories/mole of ATP}} = \text{moles of ATP used}
\]

For Aerobic Curls:

\[
\frac{\text{calories}}{7300 \text{ calories/mole of ATP}} = \text{moles of ATP}
\]

For Anaerobic Curls:

\[
\frac{\text{calories}}{7300 \text{ calories/mole of ATP}} = \text{moles of ATP}
\]

To determine the actual number of ATPs used in moving the dumbbell, complete the following equation:

\[
\frac{\text{(# of moles of ATP) \times 6.02x10^{23} ATPs}}{\text{moles of ATP}} = \text{# of ATPs used}
\]
FOR AEROBIC CURLS:

\[
\text{moles ATP} \times 6.02 \times 10^{23} \text{ ATPs} = \text{ATPs used}
\]

FOR ANAEROBIC CURLS:

\[
\text{moles ATP} \times 6.02 \times 10^{23} \text{ ATPs} = \text{ATPs used}
\]

In table 4 record the total number of ATPs that you used to curl your arm both aerobically and anaerobically.

Since the production of ATPs in aerobic respiration requires the use of oxygen, your group should see a fall in the blood oxygen level as the muscles of your group member created ATPs while doing push ups.
Questions to Help Students With Their Conclusions

How close was your prediction on ATPs expended in 30 seconds to the amount you actually used? Find the % difference between your prediction and your calculated amount.

\[
\% \text{ Difference} = \left(\frac{\text{Predicted amount} - \text{calculated amount}}{\text{calculated amount}}\right) \times 100
\]

You were only using half of the muscles (wrist flexors) in one forearm. What if you were in some sport and using most of the muscles in your body? How many ATPs would you be going through in 30 seconds?

What is the physiological purpose of coaches conditioning you?

Research what % of the energy used from the destruction of a glucose molecule is used to make ATPs? What happens to the rest of the energy?

After the lifting the dumbbell did you feel hot? Why? Did you sweat? Why does the body perspire? How is evaporation important in this process? Did your face turn red? What caused your face to turn red and how does that cool your entire body down?

How many glucose molecules must have been expended in the aerobic portion of this lab?

Did your pulse rate go up after exercising? Did you breathe harder after lifting the weights? Why?

Could you tell when most of your muscles went into anaerobic respiration? Did they respond to your commands? What happened and why (physiologically) did it happen?

Did you notice any lactic acid build up? Why was it made? What would happen if your entire body ran out of O\(_2\) and could only make 2 ATPs / glucose molecule? Can you support your hypothesis with evidence?

Possible Extension:
Predictions:
Could you have lifted the dumbbell (without the blood pressure cuff) for 2 minutes? _____ Why or why not? (use cell respiration information in your answer)

Predict how you would have felt after lifting a heavy dumbbell for two minutes.

1. Breathing?

2. Body temperature?

3. Muscle performance?

4. Soreness?

5. Pulse (heart rate)?

6. Perspiration?

According to your notes what % of the energy used from the destruction of a glucose molecule is used to make ATPs?

What happens to the rest of the energy?

When you lifted the dumbbell for 30 sec. did your face and/or arm turn red? _____ If you lifted the dumbbell for 2 minutes, do you think that your face and/or arm would turn red? _____

What do you think causes your face to turn red?
According to your enzyme notes what will happen if your body gets too hot?

How are enzymes involved in the process?

How does your body try to prevent overheating?

How can blood help cool down the interior of your body? How does that help to cool your entire body down?

Why does the body perspire?

Write down the definition for evaporation from your first chapter notes.

How is evaporation important in your body's cooling down process?

How many glucose molecules did you calculate were expended in the aerobic portion of this lab?
Did your pulse rate go up after exercising? Why or why not?

Why does your pulse rate go up after exercising?

Did you breathe harder after lifting the weights? Why or why not?

Why do you breathe harder after exercising? What does this have to do with the ETS?

Could you tell when most of your muscles went into anaerobic respiration? Did they respond to your commands? What happened and why (physiologically) did it happen?

Did you notice any lactic acid build up? How could you tell?

Why was lactic acid made? (Include ETS, Kreb's Cycle, Glycolysis, \( O_2 \), NADH, etc.)
What would happen if your entire body ran out of \( \text{O}_2 \) and could only make 2 ATPs / glucose molecule? Can you support your hypothesis with evidence?

Ask Mr. Lamb for a piece of candy. Weigh the candy.

Weight of candy + wrapper = _________ grams

Weight of wrapper = _________ grams

Weight of candy = _________ grams

The candy is made mostly of sucrose. Sucrose is a disaccharide. What are the two monosaccharides that make it?

1. _____________

2. _____________

One mole of sucrose weighs about 360 grams. How many moles of sucrose were in the candy you ate?

How many molecules of sucrose (or anything) are in one mole?
How many molecules of sucrose (or anything) are in the candy?

How many glucose and fructose molecules are in the candy?

How many ATPs would be made from these sugars if you had plenty of oxygen?

Select an exercise from the chart and figure how much you would have to do to burn off the candy you just ate.