Pat Lamb   1
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

A Concrete Lab for
Aerobic & Anaerobic Respiration

<u>Subject Area:</u> High School Biology / Anatomy & Physiology

<u>Grade Level:</u> 10 - 12

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

<u>Engineering Connection:</u> Application of sensor technology to molecular biology.

<u>Learning Objectives:</u>
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.

<u>Materials:</u>
* Blood Pressure Cuffs
* Finger Pulse Oximeters
* Dumbbells
* Stop Watch
* Meter Stick
* Jolly Rancher Candy (Extension)

<u>Lab Extension:</u> See end of the lab for an extension.

<u>Safety & Precautions:</u> 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.

<u>Acknowledgments:</u> A special thank you to my STEM fellow, Mr. Joseph Lancaster, for the hours of collaboration on multiple labs using computers & sensors.

Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

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 diffence 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 dumbell that is "heavy" for you personally.
    3. Place your arm <u>flat</u> on the desk with your wrist, hand,
      and dumbell extending over the edge.
    4. Moving only your wrist, curl the dumbell one time so that
      your partners can measure the vertical distance (in cm)
      the dumbell 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 dumbell,
          measure its highest and lowest points during one
          curl.
    5. Using only your wrist, curl the dumbell as manuy 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 concentraqte only on curling the dumbell.
      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 O_2.

Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

PART B:

1. <u>Immediately</u> 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

Pulse before exercise	Pulse after exercise
/ minute	/ minute

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

Table 2

Dumbell's Weight	Distance Dumbell Moved
lb	cm
kg	m

Pat Lamb
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

Table 3

_____ Right Arm or _____ Left Arm	Aerobic (without blood pres. cuff)	Anaerobic (with blood pres. cuff)
Number of Curls		

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

Table 4

Energy Used	Aerobic Curls	Anaerobic Curls
Number of calories		
Number of ATPs		

Table 5

	Push Ups	Heart Rate	Oxygen Level
Initial	0		
Final			

CALCULATIONS:

To lift the dumbell, we must overcome the gravitational force on that dumbell. The gravitational force on that dumbell equals the dumbell'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 dumbell = mass of dumbell x 9.81 m/s^2

Force = _____ kg x 9.81 m/s^2

Force = _____ kg m/s^2

Pat Lamb   5
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

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

Work = Force x Distance

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

Work = _____ joules   (joules = kg m^2/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.

Pat Lamb   6
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

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 (6.02×10^{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:

$$\frac{(\underline{\hspace{4cm}} \text{calories})}{(7300 \text{ calories / mole of ATP})} = \underline{\hspace{3cm}} \text{moles of ATP}$$

FOR ANAEROBIC CURLS:

$$\frac{(\underline{\hspace{4cm}} \text{calories})}{(7300 \text{ calories / mole of ATP})} = \underline{\hspace{3cm}} \text{moles of ATP}$$

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

$$(\text{\# of moles of ATP}) \times \frac{6.02 \times 10^{23} \text{ ATPs}}{\text{moles of ATP}} = \text{\# of ATPs used}$$

Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

FOR AEROBIC CURLS:

_____ moles ATP x $\underline{6.02\text{x}10^{23}\text{ ATPs}}$ = _____ ATPs used
                         moles of ATP

FOR ANAEROBIC CURLS:

_____ moles ATP x $\underline{6.02\text{x}10^{23}\text{ ATPs}}$ = _____ ATPs used
                         moles of ATP

    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.

Pat Lamb
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

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.

$$\% \text{ Difference} = [(\text{Predicted amount - calculated amount}) / \text{calculated amount}] \times 100$$

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:

Pat Lamb
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

Student Questions Instead of a ATP Lab Conclusion

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?

Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

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?

_____

Pat Lamb   11
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

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, $NADH_2$, etc.)

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?

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?

Pat Lamb
Manhattan High School
2100 Poyntz Ave.
Manhattan, Kansas, 66502
email: patl@manhattan.k12.ks.us

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.