# Lab 7: Aerobic Cellular Respiration

## Purpose

The purpose of this activity is to explore the effects of exercise intensity on aerobic cellular respiration rates.

## Learning Objectives

At the conclusion of this exercise, students will be able to:

* Recite the inputs and outputs of the aerobic cellular respiration chemical reaction.
* Design an experiment to analyze the effects of exercise intensity on aerobic cellular respiration rate.
* Describe and interpret aerobic cellular respiration inputs/outputs and their relationship to exercise intensity.
* Justify the effects of exercise intensity on aerobic cellular respiration rates with an evidence-based argument.

## Why It’s Relevant

Just as gasoline fuels a car, all living organisms require an energy source to sustain essential cellular functions such as breathing, running a marathon, or learning in school. Cellular respiration is the chemical process that generates adenosine triphosphate (ATP), the primary energy source for cells.

By understanding aerobic cellular respiration, we can apply its principles to enhance our well-being—for example, optimizing nutrition to meet dietary needs, selecting exercises that benefit our physiology, and understanding fundamental biochemistry for medical treatments and pharmacology. Beyond ourselves, this process plays a crucial role in chemical cycling within food webs and energy transfer pathways in ecosystems.

## Introduction

All living organisms require energy to carry out their daily **cellular** activities. For example, humans consume a nutritious diet to sustain daily functions and optimize physical performance. At the cellular level, **adenosine triphosphate (ATP)** serves as the primary usable energy source, generated through a series of cellular processes collectively known as **cellular respiration**.

Cellular respiration is the process by which cells convert chemical energy from **glucose (C6H12O6)** into usable energy (ATP). In the presence of **oxygen (O₂)**, this process is known as **aerobic cellular respiration** or **aerobic respiration**. During the conversion of glucose into ATP, heat, **carbon dioxide (CO₂)**, and water (H₂O) are released as **byproducts**. This process can be represented by the following **chemical equation**: C6H12O6 + O₂ → CO₂ + H₂O + ATP

In humans, glucose is derived from the diet or from stored **macromolecules** such as carbohydrates, fats, and proteins. **Enzymes** break down these macromolecules into glucose, which then undergoes a series of **chemical reaction**s, including **glycolysis**, the **citric acid cycle**, and the **electron transport chain**. The O₂ we inhale facilitates these reactions, enabling our cells to produce ATP for cellular activities. Additionally, the CO₂ generated as a byproduct is exhaled and can be utilized by **photosynthetic** organisms in the environment.

You and your lab partner (if applicable) will design and perform a quick and simple scientific experiment to explore the concepts of cellular respiration.

## Materials for In-Person Courses

The lab has the following equipment for you to collect your data:

* Venier carbon dioxide (CO2) sensor: This probe can detect and collect CO2 levels
* Refer to Appendix 2 for instructions on using the probe and collecting data on Venier data acquisition software.

## Alternative Materials for Online Courses

Your instructor will provide a recording of someone collecting data using the Venier carbon dioxide (CO2) sensor.

## Curiosity and Inquiry

You and your lab partner (if applicable) are going to explore the relationship between exercise levels and aerobic cellular respiration. With this in mind, the question you are asking is:

“Does intensity (moderate versus strenuous) of exercise affect the CO₂ levels exhaled out of the human body and thus aerobic cellular respiration?”

## Formulating a Hypothesis

1. What is your hypothesis? Explain how and why moderate versus strenuous exercise may affect aerobic cellular respiration rate in humans.
2. Prediction #1: Will your data suggest a difference of CO2 levels between moderate and strenuous exercise?

## Testing the Hypothesis: Designing an Experiment

1. Design an experiment to test your group’s hypothesis/prediction. Below are things to consider when designing your experiment:
* What types of exercise are considered moderate? Strenuous?
* Should you do the exercises for the same duration of time?
* Should you collect CO2 for the same duration of time?

## **Safety note**

**Students with health conditions should modify the activity or refrain from participating. Please use your own discretion to determine what is considered moderate or strenuous for you.**

1. What are the **independent** and **dependent variables**?
2. What is the **control group**?
3. What is the **experimental group**?
4. What are reasonable (due to limited class time, resources, etc.) **sample sizes** for your control and experimental groups?
5. How many replications are reasonable in the control and experimental groups?
6. What are some physiological measures to record to ensure your subject is performing moderate or strenuous activity? In other words, what are some changes you notice in your body while you exercise?
7. Why does **heart rate** change during exercise and which organs are important for O2 acquisition?

Before moving on, check your experimental design with your instructor to gain feedback and edit the steps of your experiment.

## Testing the Hypothesis: Data Collection

Once your instructor approves your experimental design, execute the experiment and collect data in the data tables provided below.

## Alternative Procedure for Online Courses

Watch the recording of data collection and record the subject’s data in the data tables provided below.

1. Subject 1 Data Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| TRIALS | Resting CO2 (PPM) | Resting beats per minute (BPM) | Moderate CO2 (PPM) | Moderate beats per minute (BPM) | Strenuous CO2 (PPM) | Strenuous beats per minute (BPM) |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |

1. Subject 2 Data Table (If time permits, collect data on another subject)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| TRIALS | Resting CO2 (PPM) | Resting beats per minute (BPM) | Moderate CO2 (PPM) | Moderate beats per minute (BPM) | Strenuous CO2 (PPM) | Strenuous beats per minute (BPM) |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |

## Interpreting and Visualizing Your Data

Once data collection is over, complete the simple statistical analysis table below.

1. What are the **mean, mode, median**, and **standard deviation** of Subject 1’s data? (Your instructor will inform you if they wish for you to manually or automatically calculate the measures. Refer to Appendix 1 for instructions on using Google Sheets to calculate statistical measures to automatically calculate. However, you can use any program that you are most comfortable with.)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Resting CO2(PPM) | Resting beats per minute (BPM) | Moderate CO2 (PPM) | Moderate beats per minute (BPM) | Strenuous CO2 (PPM) | Strenuous beats per minute (BPM) |
| Mean |  |  |  |  |  |  |
| Mode |  |  |  |  |  |  |
| Median |  |  |  |  |  |  |
| Standard Deviation |  |  |  |  |  |  |

1. What are the mean, mode, median, and standard deviation of Subject 2’s data?

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Resting CO2(PPM) | Resting beats per minute (BPM) | Moderate CO2 (PPM) | Moderate beats per minute (BPM) | Strenuous CO2 (PPM) | Strenuous beats per minute (BPM) |
| Mean |  |  |  |  |  |  |
| Mode |  |  |  |  |  |  |
| Median |  |  |  |  |  |  |
| Standard Deviation |  |  |  |  |  |  |

1. Which evidence would you use to determine whether the subject(s) performed moderate vs. strenuous exercise? Why?
2. Are the resting rates similar or different between the two subjects? Explain why there may be a difference, even if you are both resting.
3. Now plot the data that your group collected. Label the **X** and **Y axes** and choose the appropriate number scale for each axis. Graph the mean and the standard deviation bars. our instructor will inform you if they wish for you to manually or automatically create the graph. Refer to Appendix 1 for instructions on using Google Sheets to graphs with standard deviation bars. However, you can use any program that you are most comfortable with. *Helpful Tip: Apply your knowledge about****independent****and****dependent variables****when labeling the axes.*



1. Do you notice patterns between the independent and dependent variables? Explain the relationship.

## Interpreting and Visualizing Class Data

### Class Data Spreadsheet Entry

Once you have collected all your data, enter your data in the class spreadsheet on Google Sheets. Your instructor will provide you with the link.

### Class Data Analysis and Graphing

In your data collection (see question 16) as well as the class data, you may find variability in resting conditions. Additionally, you may or may not see evidence of moderate versus strenuous exercise (see question 15). To normalize the data, the **percentage (%) change** from rest to exercise intensity is automatically calculated in the class spreadsheet**.**% change will allow you to see how measurements change from resting to exercise (at moderate or strenuous intensity).

1. Now plot the data that the class collected. Label the X and Y axes and choose the appropriate number scale for each axis. Graph the % change mean and the standard deviation bars.



1. Do you notice patterns between the independent and dependent variables? Explain the relationship.

## Making a Conclusion

1. Do your results validate or reject your group’s hypothesis? Why?
2. What are some strengths and weaknesses of your experiment?
3. If you were to repeat this experiment, what would you do differently? If there were any inaccurate results, how would you avoid those next time?
4. Do your data display the same relationship as the class data? If not, describe the difference(s).
5. When analyzing the data, would you use your individual data or the class data to formulate your conclusions? Why?
6. Does the class data validate or reject your group’s hypothesis? Why?
7. If the purpose of aerobic cellular respiration is to convert chemical energy into usable energy, what is the significance of CO2 and O2 to aerobic cellular respiration in this experiment?
8. Based on the class data, what do you conclude about the effects of exercise intensity on CO2levels exhaled out of the body?
9. Based on the class data, what do you hypothesize are the effects of exercise intensity on aerobic cellular respiration rate in this experiment? Justify the hypothesis with an evidence-based argument.
10. In which organelle in the eukaryotic cell does aerobic cellular respiration occur?
11. Which of the following processes, glycolysis, citric acid cycle, or electron transport chain, produces the most ATP to support the muscles to perform different levels of exercise intensity?