TEACHER GUIDE
EXPLORE 1B LESSON 17

Food and Agriculture Center for Science Education

Module Questions: ***Why are there so many changes to my body during exercise? How does milk help with recovery from these changes?***

What We Figure Out:

We plan and carry out an investigation to figure out that more carbon dioxide is exhaled during high-intensity exercise than when at rest.

3D Learning Objective:	**Time estimate:**	**Materials:**
Students plan and carry out an investigation, including controlling for confounding variables, to determine how exhaled carbon dioxide levels change during moderate versus intense exercise.	150 minutes	Lesson 17 Student Guide Lesson 17 Student Handout Experiment Design Tips Lesson 17 Teacher Resource Carbon Dioxide Lab Information Lab materials (per group of 3 students) ● Bromothymol blue ● Three glass or clear plastic containers (min 12 oz) ● Straws ● Aluminum foil (enough to cover each container) ● Stopwatch

Targeted Elements

SEP:	DCI:	CCC:
INV-H1:	**LS2.B-H1:**	**SC-H1:**

Plan an investigation or test a design individually and **collaboratively to produce data to serve as the basis for evidence as part of** building and revising models, **supporting explanations for phenomena**, or testing solutions to problems. **Consider possible variables or effects and evaluate the confounding investigation's design to ensure variables are controlled.**	Photosynthesis and **cellular respiration (including anaerobic processes) provide most of the energy for life processes.**	**Much of science deals with constructing explanations of how things change and how they remain stable.**

Directions

Part 1: Our Motivation

USE OF PHENOMENA
Between Lessons 16-20, students will focus on the topic of exercise from the Module Phenomenon. In Lessons 21-22, they will focus on the topic of recovery from the Module Phenomenon. In Lesson 23, they will investigate a related phenomenon. They will return to the Anchor Phenomenon in Lesson 24 and revise their presentations to help their peers understand how milk can help them recover from exercise.

Remind students that to help figure out why we breathe faster during exercise, in Lesson 16, they figured out that more oxygen is inhaled and delivered in the blood to muscles during exercise than when at rest. Remind students that they ended the lesson by making a prediction about what they think this means for the amount of carbon dioxide in the breath and how that might also help explain why we breathe faster during exercise. Ask students to recall their predictions and write them on their Lesson 17 Student Guide Part 1: Our Motivation. Build on student responses to share that they will test those predictions in this lesson.

Part 2: Planning and Carrying Out an Investigation

Share that students will plan and carry out an investigation to test if exhaled carbon dioxide levels increase from rest with intense exercise. Share the investigation question with students: “How does intense exercise impact the amount of carbon dioxide we breathe out?”

Prior to sharing more about the investigation, students can record the claim they are trying to test. This claim should come from their prediction of the relationship between the amount of carbon dioxide exhaled and high-intensity exercise. Students can record their claim on their Lesson 17 Student Guide Part 2: Planning and Carrying Out an Investigation.

Hold a brief discussion to introduce students to the materials they will use in their investigation. Share that there is a chemical compound common in biology and chemistry labs called Bromothymol Blue, typically referred to as BTB. BTB can be used to test for the presence and relative amount of carbon dioxide gas in a solution. Show students the beaker of blue BTB at one of the lab stations. Demonstrate that blowing into the beaker with a straw can change the color of the BTB. Ask students which color of BTB would indicate that more carbon dioxide is present in the beaker. Confirm that the yellow color indicates more carbon dioxide is present because there is carbon dioxide in the exhaled breath that went into the solution.

STUDENT SUPPORT

For the purpose of this investigation, a suggested starting ratio of BTB to water is 5 drops BTB per 30mL of water. The operator of the stopwatch should be prepared to stop and restart the timer if/when the student blowing bubbles into the water stops to take a breath or pauses for any reason.

Share that each small group will design an investigation using BTB and the supplies they see on the lab table, which are also listed in the Lesson 17 Student Guide Part 2: Planning and Carrying Out an Investigation. Introduce students to a basic procedure for how to use the lab supplies. Introduce students to any relevant safety considerations for these materials. Share with students that they should not, in any case, inhale or swallow the BTB solution. The Lesson 17 Teacher Resource Carbon Dioxide Lab Information has set-up description and additional notes regarding conducting the activity. Use this to ensure that students can easily access the materials they need and that you are comfortable troubleshooting investigation designs as students begin.

Next, show students the Lesson 17 Student Handout Experiment Design Tips. Read this table together with the class, and elaborate on any items you think are needed by your students. In particular, students may need extra support in determining what confounding variables or control groups are.

SEP SUPPORT

INV-H1: Plan an investigation or test a design individually and **collaboratively to produce data to serve as the basis for evidence as part of** building and revising models**, supporting explanations for phenomena,** or testing solutions to problems. **Consider possible variables or effects and evaluate the confounding investigation's design to ensure variables are controlled.**

In middle school, students planned investigations in which they identified independent and dependent variables and controls, what tools were needed to do the gathering, and how measurements would be recorded. Here, we are giving students an opportunity to both engage with this middle school practice and to build towards the high school-level practice by asking students to evaluate their investigation design to ensure variables are controlled and to include control groups. Depending on the previous experiences of your students with planning investigations, spend some time reviewing the various aspects of experimental design from middle school.

Allow students time to design their investigation and record it on their Lesson 17 Student Guide Part 2: Planning and Carrying Out an Investigation. As students work, circulate the room and support students with designing their investigation.

Use pressing questions such as:

- What did you plan to do at this step? Why?
- Can you tell me about how this plan ensures confounding variables are eliminated?
- What confounding variables may be present in this investigation plan?

FORMATIVE ASSESSMENT OPPORTUNITY

Students plan and carry out an investigation, including controlling for confounding variables, to determine how exhaled carbon dioxide levels change during moderate versus intense exercise.

Assessment Artifacts:

- Students' planning of an investigation to test if exhaled carbon dioxide levels increase with moderate and intense exercise (Lesson 17 Student Guide Part 2: Planning and Carrying Out an Investigation).
- Students' reflection on the quality of their experiment designs (Lesson 17 Student Guide Part 2: Planning and Carrying Out an Investigation).

Look Fors:

- Students create an investigation plan that describes independent, dependent, and controlled variables and how data will be collected (INV-H1).
- Students reflect on their investigation plan and how well it eliminates confounding variables (INV-H1).

- Students' investigation plans will help them figure out changes to the amount of carbon dioxide in the breath during rest versus intense exercise (LS2.B-H1, SC-H1).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	Experiment Design: I can measure if carbon dioxide is what I breathe out using the BTB chemical. If carbon dioxide is present, it goes from a blue color to more of a green-yellow color.	Experiment Design: For this investigation, the independent variable is the amount of exercise done, and I will be measuring to see if these affect the dependent variable, which is the amount of carbon dioxide. This will be indicated by the color of the indicator. I can measure if carbon dioxide is what I breathe out using the BTB chemical. If carbon dioxide is present, it goes from a blue color to more of a green-yellow color. I can compare the colors of the rest cup to the intense workout cup and both to the color of the control cup. This will tell me if rest or intense exercise made a change to the color of the BTB compared to the control. I will note my observations, and I could also take pictures of the cups to more-accurately show the colors after the lab has been completed. If anything changes during the procedure, I will write it down on my paper.	Experiment Design: For this investigation, the independent variable is the amount of exercise done, and I will be measuring to see if these affect the dependent variable, which is the amount of carbon dioxide. This will be indicated by the color of the indicator. I can measure if carbon dioxide is what I breathe out using the BTB chemical. If carbon dioxide is present, it goes from a blue color to more of a green-yellow color. A couple of variables I am controlling are the time and intensity I breathe into each cup, covering the cup to limit exposure to outside air, and carefully measuring materials to keep conditions as similar as possible between the three cups. I will use a control group to make sure my results are sound. This will be a cup with an indicator in it that I do not blow any air into. I will look for the color differences between the three cups. I can compare the colors of the rest cup to the intense workout cup and both to the color of the control cup. This will tell me if rest or intense exercise made a change to the color of the BTB compared to the control. I will note my observations, and I could also take pictures of the cups to more-accurately show the colors after the lab has been completed. If anything changes during the procedure, I will write it down on my paper. Reflection on Design: My investigation should be able to answer if I breathe out carbon dioxide and if I breathe out more of it after high-

			intensity exercise because I used a control to compare my results to, and I tried to control confounding variables. I think I am eliminating the major confounding variables by covering the cups when not blowing into them and following the exact same procedure for both. There could be small differences in the amounts of materials, but I will do my best to measure carefully.
How to Achieve This Level	Student completes 0-1 out of 3 Look Fors	Student completes 2 out of 3 Look Fors	Student completes 3 out of 3 Look Fors

To Provide Additional Support for Students

If students need additional support designing their investigations, consider:

- Encouraging students to sketch their experimental setup and use the sketch to plan their investigation.
- Redirecting students' attention to the planning investigation questions on the Lesson 17 Student Handout Experiment Design Tips that they may have overlooked.
- Prompting students to design their experiment backward from their prediction.
- Engage students in a peer feedback session. Provide students with the Look Fors, and use a protocol such as Tell-Ask-Give or norms such as SPARK. Students can use the Look Fors to provide feedback to each other on how they can improve selected Look Fors in their work.

STUDENT SUPPORT

In this experiment, be mindful of students with varying exercise abilities, and allow groups to modify the experimental design to fit the needs of those students.

As students plan their investigation, you may want to have them share their plans with each other to generate new ideas. You can use a Stay and Stray Strategy to do so.

1. Ask small groups to have one person "stay" at their table with their experiment design to explain it to classmates from other groups.
2. The rest of the team members "stray" to the other table groups to learn about the data collected by other groups, allot about 2 to 5 minutes per rotation.
3. During the rotation time, circulate the room to press students to explain the details of their investigation plan. Ask questions like:

a. "Are your data similar or different from each other?"
b. "How does the data you both collected support or refute the claim that carbon dioxide levels in breath would increase after exercise?"

4. At every signal to rotate to a new group, a different team member goes back to stay with the group's work, and everyone else (including the person who first stayed) moves on to view the next group's experiment design.
5. After visiting all groups, initial small groups regroup and share new information gathered.
6. Groups discuss new ideas and decide whether or not they will integrate them into their work.

TEACHER SUPPORT
Using the Stay and Stray Strategy allows students to compare and contrast their data and claims with other groups. This will help them self-evaluate the strengths and weaknesses of their claims before implementing edits.

When students are ready with their plans, have them check in with you to get approval to carry out the experiment. Ensure that students' plans follow recommended safety procedures and include appropriate experimental variables and controls, but do not prescribe one experiment design to all students. Variety in investigations will ensure students have a more meaningful share out of different approaches and results later in the lesson.

After checking in the plan, allow students time to carry out the investigation they planned and collect data. As students work, circulate the room to support students in using the materials properly, following their investigation plans, and recording data.

When students are finished collecting data, provide time for students to analyze the data they collected and determine if it supports or refutes their prediction/claim from Part 1. Hold a whole-class discussion for students to share what they found. Facilitate the discussion such that students agree:

- Exhaling at rest caused the BTB to change from a blue color to a green color after 15 seconds of blowing bubbles through the straw. A similar color change occurred in 7 seconds of blowing bubbles after intense exercise. Therefore, we can support the claim that the amount of carbon dioxide exhaled during high-intensity exercise is more than what is exhaled when at rest.

Part 3: Constructing Explanations

Next, to begin to navigate to the next lesson, ask students to try to explain any part of the Module Phenomenon (increased breathing rate, increased heart rate, and/or muscle burn and fatigue) using findings from the experiment in this lesson and the oxygen consumption data from Lesson 16. Students can record their ideas on their Lesson 17 Student Guide Part 3: Constructing Explanations.

Use a Think-Pair-Share Strategy to have students share their ideas. Student responses may vary.

1. Students are given time to think independently about their responses.
2. Students find an elbow partner.
3. Students take turns sharing their thoughts with their partner. Each student should be given time to respond.

Facilitate the conversation such that students agree that:

- To bring air into and out of the body, we have to breathe. If we are producing more carbon dioxide during exercise, we have to breathe more often to get it out of our body. The faster we breathe, the more carbon dioxide we have to exhale.
- We saw that there is more oxygen in our blood going to our muscles. If we are breathing faster, then we are also bringing in more oxygen. The heart pumps blood, so if there is more oxygen in the blood and it needs to get to our muscles, the heart would need to pump faster to get it to those places quicker.
- We aren't really sure yet what the increases in oxygen and carbon dioxide consumption would have to do with muscles burning and fatiguing, getting energy for exercise, or how milk helps in recovery.

Ask students what they think they should investigate next to make additional progress. Student responses may vary.

Acknowledge student responses and build off responses that indicate that students should investigate more about what is happening inside the body to figure out why muscles get fatigued and burn and how milk helps with recovery. Share that in the next lesson, students will investigate more about changes inside the body.