

Gas Exchange and Cellular Respiration 5E

Did the marathon runner run out of breath or not get enough oxygen? Why do we breathe faster when we exercise?

Performance Expectations
HS-LS1-2, HS-LS1-3,
HS-LS1-7

Investigative Phenomenon
Humans breathe faster when exercising.

Time
6-8 days

In this 5E instructional sequence, students are investigating the questions about breathing that surfaced during the Driving Question Board launch: Did the marathon runner run out of breath? Did the marathon runner not get enough oxygen? This leads to questions about why humans breathe faster when exercising. Students investigate the interaction between the respiratory and circulatory systems that are both required to work properly, as well as the feedback mechanisms that regulate all of this, to ensure that we can carry out cellular respiration and keep exercising. Students figure out that the marathon runner probably did not collapse due to being out of breath.

Engage	Why do we breathe (ventilate) faster when exercising?	Connecting to their earlier questions about the marathon runner's breathing and oxygen, students share their initial ideas about why we breathe faster when we exercise and use our muscles. This leads students to express a need to investigate gas exchange in the human body further.
Explore 1	How do organisms generate ATP to use as an energy source for life processes?	Students conduct an investigation on how sugar impacts cellular respiration in a model organism, yeast, in order to generate initial ideas on the inputs and outputs of the process , and to start to understand the phenomenon introduced in the Engage phase. In this phase, students are starting to figure out how organisms, including humans, generate ATP to use as an energy source, and the materials that cells need to do so.
Explain 1	Developing an understanding of how cells generate ATP in the process of cellular respiration.	Students engage with data collected and a complex text about cellular respiration in yeast in order to modify and refine a model that shows inputs and outputs in the system .
Explore 2	How does the body regulate O ₂ levels in the blood?	In the previous Explore/Explain, students surface the importance of oxygen in generating ATP. By analyzing secondary data sets on CO ₂ and O ₂ levels in the blood, students surface the concept of dynamic equilibrium , and the interaction of body systems in regulating oxygen levels in the blood.
Explain 2	Using visual texts to construct an explanation of how interacting systems regulate gas exchange.	Students partner-read a visual text in order to construct a sequence chart that explains how feedback mechanisms work to maintain homeostasis and regulate gas exchange through the coordinated effort of multiple body systems at the cellular, organ, and body system levels .
Elaborate	How do different plants regulate gas exchange?	Students extend their ideas about gas exchange by constructing a model to demonstrate how plants regulate gas exchange.
Evaluate	How does the regulation of gas exchange connect to changes we see during intense exercise?	Students use their input/output model , and their new understanding of cellular respiration and the regulation of gas exchange through the interaction of multiple body systems in order to address the Marathon Runner problem. Students evaluate the relevance of new evidence, such as the O ₂ saturation of the runner.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

Why do we breathe (ventilate) faster when exercising?

Connecting to their earlier questions about the marathon runner's breathing and oxygen, students share their initial ideas about why we breathe faster when we exercise and use our muscles. This leads students to express a need to investigate **gas exchange** in the human body further.

Preparation

Student Grouping

☐ Pairs

Routines

☐ Rumors

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

- ☐ sticky notes
- ☐ chart paper or whiteboard
- ☐ image of an athlete breathing heavily (video or GIF)

Launch

1. Remind students that during the Driving Question Board launch, one category of questions that emerged was related to breathing and/or if sufficient oxygen was available (for example: Did the marathon runner run out of breath or not get enough oxygen?). Ask students to share more about why they asked questions about breathing. Listen for the observation that when running or exercising, your breathing increases.
2. Use students' questions and observations about breathing to transition to the guiding question: Why do we breathe faster when we are exercising?

Access for All Learners



All students have some background knowledge on the topic of exercise and respiration. Be sure to provide

3. Prompt students to consider the body models they generated during the anchor phenomenon launch, and their own experiences running or exercising heavily. If students need support generating ideas, provide a brief video, image, or GIF of an athlete breathing heavily.
4. Individually, students respond to the prompt, brainstorming as many ideas as possible.

opportunities for students to articulate those ideas at this point, by selecting examples that make sense to them.

Surfacing Student Ideas

1. Each student reads through their ideas, and decides on their most important idea, writing that one idea on a sticky note. Remember, this should be a response to the question: Why do we breathe faster when we are exercising?
2. Use the group learning routine **Rumors** to surface student ideas.
3. After students have shared their ideas through Rumors, categorize student ideas to address during the instructional sequence.

Routine

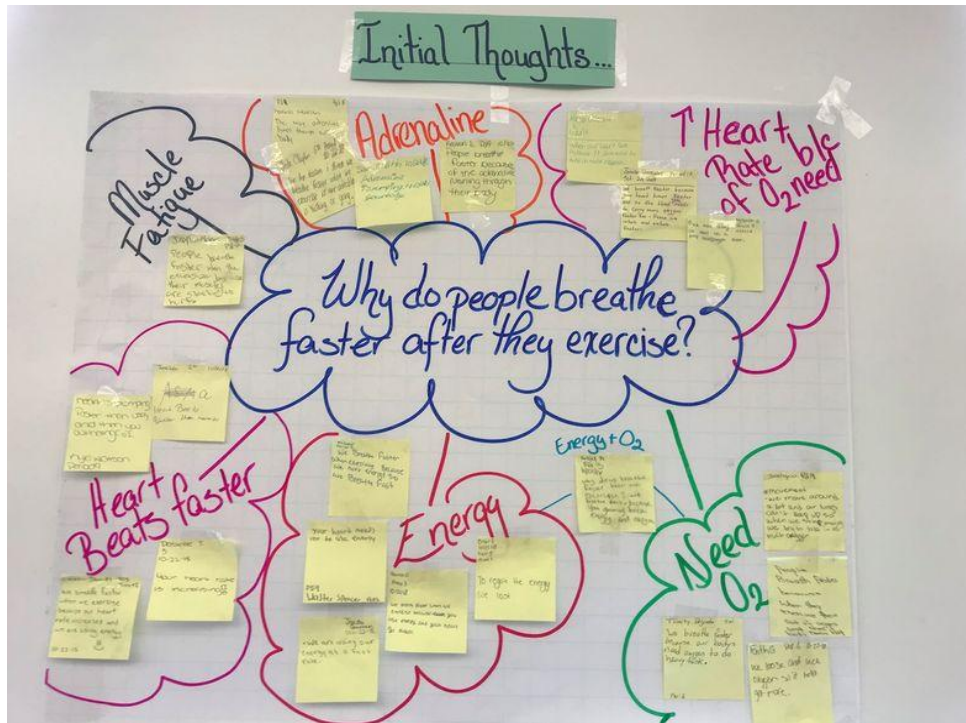


The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during the Engage phases. This is the first time the routine **Rumors** appears in this unit. Please read the Biology Course Guide for detailed steps about this routine.

Classroom Supports



Create a poster or space on a whiteboard for categories of student ideas that have come up. Use the title: Why do we breathe faster when we are exercising? You can refer back to the poster throughout this 5E plan.



Gas Exchange initial questions

4. Prompt students to think about why they might need air or oxygen.
5. End the discussion by asking students how they might investigate the need for air or oxygen.

Look & Listen For



Students have background knowledge (and have thought about this using their body models during the Anchor Phenomenon Launch). In the discussion they may surface ideas around:

- the need for oxygen
- excreting carbon dioxide
- the need for energy
- alternative conceptions such as “We breathe to cool down.”

Explore 1

How do organisms generate ATP to use as an energy source for life processes?

Students **conduct an investigation** on how sugar impacts **cellular respiration** in a model organism, yeast, in order to generate initial ideas on the **inputs and outputs of the process**, and to start to understand the phenomenon introduced in the Engage phase. In this phase, students are starting to figure out how organisms, including humans, generate ATP to use as an energy source, and the materials that cells need to do so.

Preparation

Student Grouping

- ☐ Table groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Surfacing Ideas for Experimental Design
- ☐ Cellular Respiration in Yeast Investigation - Basic Protocol
- ☐ Cellular Respiration in Yeast Investigation
- ☐ Graphing Support - Scaffold
- ☐ Making Sense of Investigation Design
- ☐ Yeast Respiration Investigation Rubric

Lab Supplies

- ☐ 3 plastic water bottles (disposable) or erlenmeyer flasks
- ☐ 3 packets yeast
- ☐ 3 balloons
- ☐ 300 mL warm water
- ☐ 3 sugar packets
- ☐ measuring tape

Other Resources

- ☐ *Characteristics of a Model Consensus List (Example)*

Launch

1. Ask students to remind us what we are trying to figure out (whether the marathon runner ran out of breath). Tell students that so far, we have a lot of ideas about our own breathing; point to Rumors patterns if still visible in the classroom. At this point the class should have some ideas surfaced around that we might need oxygen and that it connects to needing energy for exercise (or to exercise in some

Classroom Supports

way). Have students recall their earlier discussion about how we might investigate our need for oxygen, with emphasis on the fact that we want to investigate this here in the classroom.



Post the class consensus list on characteristics of a scientific model as a tool to support students with this important idea, which they will develop over the course of the unit.

2. Introduce the idea that you will use a model organism to begin to collect data on what is happening in human muscle cells. Prompt students to provide some ideas on why we would study yeast, when we are really interested in investigating humans and why they breathe quickly during exercise.
3. Remind students that they have already interacted with and generated a scientific model, the human body outline. Point out that model organisms are also scientific models.
4. Using what they know about generating their first model (the human body outline), prompt students to generate characteristics of a scientific model. Give students an opportunity to brainstorm their initial ideas of what a scientific model is and then confer with a partner about their thoughts.
5. Generate a class consensus list, and post it in the room. See the *Characteristics of a Model Consensus List (Example)*.

Note: At this point, it is fine if students do not have a completely clear or accurate definition of a scientific model! They will return to this class list throughout the unit.

Look & Listen For



Students may generate ideas such as:

- A model organism is cheaper and easier to manipulate
- Using a model organism is more humane
- We can't see inside a human easily
- Humans and yeast both need to complete life processes

Investigation: Cellular Respiration in Yeast

1. Provide each student with the *Cellular Respiration in Yeast Investigation*. In each group, students set up 3 beakers:
 - Beaker 1: 0 sugar packets
 - Beaker 2: 1 sugar packet
 - Beaker 3: 2 sugar packets

Lab Safety Note: Do not allow students to handle broken glass at any time. An adult should use forceps, tongs, scoops, or other mechanical devices for removing broken glass from the work area. Goggles should be worn by everyone during labs that involve glassware and / or any substances.

2. After setting everything up correctly, students start on the data collection.
3. Once students have collected their groups' data, have them enter it into a shared spreadsheet, so that they can aggregate the data and make sense of trends.
4. Have students work in groups to record their ideas about the data in the Analysis of Classwide Data in *Making Sense of Investigation Design*.

Conferring Prompts



Confer with students as they work in collaborative groups to collect data and complete the See-Think-Wonder chart.

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- Why are we studying yeast, if we are really interested in humans?
- What is your group's experimental question?
- What is your group's hypothesis? What made you develop this?
- What are you measuring? How are you measuring it?
- What is (are) the thing(s) that stay the same (controls) in the experiment? Why do we need most things to stay the same?
- What would be the best way to organize the data you are collecting?
- What is happening in the bottle? Why is it happening?
- What are you able to see, and what aren't you able to see, in this process?

Look & Listen For



While students work on the See-Think-Wonder look for the following ideas:

- The trend that as sugar increased, circumference of the balloon and height of the foam increased (that the rate of cellular respiration increased)
- Sugar and water (used to activate the yeast) were added as inputs
- Gas (in the balloon and in the foam) was an output
- Energy is an output (not seen, but discussed in the prelab)

- Gas may be an input (as it is in the system) but no evidence yet that a gas entered the yeast cell)

Differentiation Point



Experimental Design



Some students may already be familiar with the practices related to experimental design. To challenge students further, provide only the basic protocol (most of the details are removed), and ask students to generate their own procedure or use the procedure to investigate a similar question, such as: What is the impact of different sugar types (honey, brown sugar, etc) on cellular respiration in yeast?

Data Interpretation

Set up the lab and data collection in the same manner as outlined above. After students have collected their data, pause to surface and review experimental design as necessary, using the Same-Different Chart as a scaffold to support students in thinking about the difference between variables. Allow students to revise the portion of the lab that asks them to identify these variables. When graphing, use the graphing decision chart before students graph data and the peer-to-peer graphing rubric after graphing. Both materials are a part of *Cellular Respiration in Yeast Investigation* and will help surface which student may need additional graphing support.

Whole-Class Investigation Summary

1. Ask students to work independently to complete the Investigation Summary section in *Making Sense of Investigation Design*, then use these completed pages to discuss the findings from the investigation.
2. Ask groups to come up with one important idea to share with the whole class, from their Summary notes.
3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the phenomenon.

Integrating Three Dimensions



Each question in the Summary targets a different element in the standards for this unit, so make a determination about the ideas that are most important to surface in the classroom to set the stage for the Explain phase.

Look & Listen For



Possible student ideas from the Summary page:

- Yeast are useful model organisms, but yeast (and the system they are found in) is different and less complex than muscle cells and a human body.
- Sugar is a source of energy for the yeast, but students may still wonder how it is used to fuel activities in the cell.
- Gas is an important component, but students may wonder which gas(es) and if it is an input or just an output (or both).
- Students may still wonder how breathing is connected to cellular respiration and/or working muscle cells.

Routine



This is the first time **Domino Discover** is being used in this unit. This routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Biology Course Guide for support with this routine.

Access for Multilingual Learners



Domino Discover provides receptive language opportunities for students who are **entering and emerging** language learners. For those who are **transitioning and expanding**, this routine provides time to rehearse language with peers, so that students are not responsible for on-the-spot responses before they are ready.

Self and Peer Assessment

1. Ask students to work independently to complete the Investigation Discussion prompts in *Graphing Support - Scaffold*, then discuss the findings with their group.

2. Provide time for students to use the *Yeast Respiration Investigation Rubric* to reflect on their own participation in the investigation, and that of their peers.

Explain 1

Developing an understanding of how cells generate ATP in the process of cellular respiration.

Students engage with **data collected and a complex text** about **cellular respiration** in yeast in order to **modify and refine a model that shows inputs and outputs in the system**.

Preparation

Student Grouping

- ☐ Triads

Routines

- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ Input-Output Model for Cellular Respiration
- ☐ Cellular Respiration in Yeast Text
- ☐ Summary Task

Lab Supplies

None

Other Resources

- ☐ *Characteristics of a Model Consensus List (Example)*
- ☐ *Class Consensus Discussion Steps*
- ☐ *Biological Levels of Organization*
- ☐ Driving Question Board (questions related to this 5E)
- ☐ Chart from Engage of students' ideas related to breathing and exercise

Refine Class Consensus on Scientific Models

1. Using the example of yeast, prompt students to come up with additions to the class wide list of the characteristics of a scientific model.
2. Through class discussion, surface new ideas, as well as ideas students are finding particularly helpful

Classroom Supports

or important, and record those on the class consensus list. At this point, it is fine if students do not have a completely clear or accurate definition of a scientific model. They will return to this class list throughout the unit.



Continue to develop the class consensus list, as this will support student thinking about scientific models throughout the unit.

Integrating Three Dimensions



Throughout this Explain phase, students are addressing and making sense of data using **CCC #4 - Systems and System Models**; keep in mind that the Explain phase is not only about figuring out core ideas, but about using crosscutting concepts to do that figuring out.

Generate Input-Output Models

1. Prompt students to work in pairs on handout *Input-Output Model for Cellular Respiration*, based on the data collected in the investigation and the lists of inputs and outputs they created in the Explore 1 phase. These do not need to be polished pieces of work, but they should represent the current thinking of each group.

Look & Listen For



While students are engaged in Think-Talk-Open Exchange, circulate and listen for these ideas, to provide a bridge to the text:

- Trying to figure out why carbon dioxide is created through respiration
- Trying to make a connection between respiration and the work or activities that cells do

Access for Multilingual Learners



Think-Talk-Open Exchange is a routine that provides access to **transitioning** language learners. While students might not realize they need the think time, this silent planning time provides the additional processing time transitioning students need. As an added bonus, this time is helpful for many other students as well!

- Grappling with questions about where the sugar actually goes during respiration

Identifying Components to Add to Models

1. Provide students the handout *Cellular Respiration in Yeast Text*. Frame the rationale for reading this text by naming some specific point(s) that came up in the **Think-Talk-Open Exchange**. For example:
 - “When your groups were talking just now, I noticed that some groups were trying to figure out how yeast relate to humans. This is really interesting! As we read this, we can try and fill in gaps or problems with our group models.”
 - “During the TTOE just now, I heard Kameelah asking her group about what was in the bubbles in the yeast experiment. I’ve heard a lot of ideas about this. Let’s try to figure this out in today’s lesson.”
2. Prompt students to read and annotate individually for the following, using the annotation guide in their handouts:
 - points that confirm your group’s model
 - points that contradict your group’s model
 - points that help to modify or add to your group’s model
3. Pause the class to ensure that students have a strong understanding of the hierarchical organization of the levels of the human body by showing *Biological Levels of Organization*.
4. Ask students to return to their group models, to add or modify components that were not in the earlier version.

Differentiation Point



Here are some options for ensuring that all students have access to the information in the Cellular Respiration text, since there is one version of the text.

1. Shared reading group: support students by having them read the text along with a teacher, in a small group setting.
2. Anticipation guide: provide students with statements that the text will either confirm or negate. Then have them read the text with an eye for these points.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:

"We have a lot of different ideas circulating in the room right now, and they are in the form of different models. It is really important for us to get to some agreement on how we represent what we know about respiration, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to do something called a **Class Consensus Discussion**. First I will select a few different groups to share their ideas. Then, we will let each group share their model, and discuss what we can agree to as a class."

2. You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. we select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

3. Select two or three groups' models to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of cellular respiration. The decision about which models to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas.

This is the first time doing such a discussion in this unit, so focus more on the steps and the process. In future parts of this unit, you will use this format to do more in-depth discussions and consensus building. Refer to the Biology Course Guide for support with this routine.

Classroom Supports

4. Ask the first group to share their model. You can do this by:
 - Projecting using a document camera; OR
 - Copying the models to be shared and passing them out to the class; OR
 - Taking a picture of each model and projecting them as slides.
5. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.
6. Return to student questions from the start of the 5E (Engage), in order to bring up lingering issues not yet resolved, such as:
 - How does our body sense that we need to breathe faster?
 - How much oxygen do we need?
 - How does oxygen get to our muscles?
 - Did the marathon runner not obtain enough oxygen? Or was her body unable to properly regulate oxygen levels?

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- The role of oxygen in generating energy through cellular respiration; without oxygen, cellular respiration cannot happen.
- The idea that humans breathe faster during exercise, in order to deliver more oxygen for cellular respiration.
- All organisms, including humans, need oxygen to generate ATP to use as an energy source, and during exercise we use more energy.

Note: We haven't addressed the mechanisms behind gas exchange, so there is no need to clarify this if students still have questions!

Implementation Tip



Post the steps to the class consensus discussion in the room, as a reference to which you can return to future lessons.

Access for Multilingual Learners



Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context, which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.



The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #4 - Systems and System Models** explicit for students by elevating and probing for ideas related to the idea that models can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. This is an important element **CCC #4 - Systems and System Models** at the high school level.

Summary Task

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to circle back to the ideas in this text, in the coming parts of the 5E lesson.

Summary Task

How did the class consensus discussion go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:
What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:
Why do people breathe harder or faster when exercising?

Words	Input-Output Model

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) understanding how they are using the three dimensions to make sense of a phenomenon, breathing in 2) ideas about how they and their peers are building knowledge together; and 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Explore 2

How does the body regulate O₂ levels in the blood?

In the previous Explore/Explain, students surface the importance of oxygen in generating ATP. By **analyzing secondary data sets** on CO₂ and O₂ levels in the blood, students surface the concept of **dynamic equilibrium**, and the **interaction of body systems** in regulating oxygen levels in the blood.

Preparation

Student Grouping

☐ Pairs

Routines

☐ Questions Only

Literacy Strategies

☐ Three-Level Guide

Materials

Handouts

- ☐ Blood Oxygen Graphs
- ☐ Blood Oxygen Graphs Three-Level Guide
- ☐ Analyzing Blood Oxygen Levels Investigation Rubric

Lab Supplies

None

Other Resources

☐ Colored pencils

Launch

1. Begin by asking students to remind us what we are trying to figure out, (such as: Did the marathon runner run out of breath or oxygen?). In this investigation, students will begin to figure out answers to their unanswered questions from the previous Explore and Explain phases:
 - How does our body know to breathe faster or slower?
 - How much oxygen do we need?
 - How does oxygen get to our muscles?
 - How does CO₂ get out?

- Did the marathon runner not obtain enough oxygen? Or was her body not able to properly regulate oxygen or carbon dioxide levels?
2. Ask if students know the difference between arteries and veins, and explain that arteries take blood away from the heart, while veins return blood to the heart. This background information serves as framing for the rest of the Explore phase, and it does not detract from the ideas students are intended to construct together.

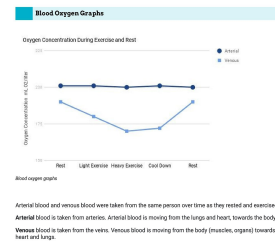
Implementation Tip



When returning to the Driving Question Board, be sure to change these suggested teacher notes so that they match your class's actual questions!

Investigate Data Using a Three-Level Guide

1. Launch students into interacting with the complex graph: *Blood Oxygen Graphs*.
2. Students use the **Three-Level Guide** strategy and the steps in the *Blood Oxygen Graphs Three-Level Guide*; to interpret the graph and determine patterns.
3. Confer with students as they work in pairs to complete the three-level guide.



Conferring Prompts



Confer with students as they work in pairs to complete the three-level guide. Surface student thinking about the differences between arterial and venous blood.

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- How do gas levels differ during light exercise as compared to intense exercise?
- Why would there be differences in each gas at different places in the body?

Access for All Learners



Visual texts can be a great tool to provide access in science classrooms for students who are not strong readers. Three-level guides build in time to think about and interpret a visual text, in order to get as much meaning as possible from the materials.

- Why are there different levels of each gas?

Implementation Tip



Since this is students' first time doing a **Three-level Guide**, consider facilitating this as a pair activity, with whole-class check-ins to make sure everyone is following the process. It is okay to take additional time on the first instance of using a Three-Level guide.

Whole-Class Investigation Summary

1. In pairs, students use the group learning routine **Questions Only** to generate a set of questions about the relationship between oxygen, carbon dioxide, and the body.
2. Pairs share out their questions, in order to generate a comprehensive class list of ideas.
3. At the end of the routine, each group should select and add to an agreed-upon input-output model. These do not need to be polished pieces of work, but they should represent the current thinking of each group.

Look & Listen For



In the class share out, highlight questions similar to the following:

- Where do these gases come from?
- How do they get into and out of the body?
- How does the body "know" when to bring in more oxygen from the environment?
- Why does the amount of oxygen in arterial blood stay almost constant, even when exercising?

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
5. Provide students with *Analyzing Blood Oxygen Levels Investigation Rubric*. Ask students to use the

Routine



The **Questions Only** routine offers students an opportunity to generate questions that can guide their investigations about a phenomenon. This is the first time this routine appears in this unit! Please read the Biology Course Guide for detailed steps about this routine.

investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Explain 2

Using visual texts to construct an explanation of how interacting systems regulate gas exchange.

Students partner-read a **visual text** in order to **construct a sequence chart that explains** how **feedback mechanisms work to maintain homeostasis and regulate gas exchange through the coordinated effort of multiple body systems at the cellular, organ, and body system levels.**

Preparation

Student Grouping

- ☐ Lab groups

Routines

- ☐ Domino Discover

Literacy Strategies

- ☐ Sequence Chart

Materials

Handouts

- ☐ Summary Task

Lab Supplies

None

Other Resources

- ☐ *Gas Exchange Card Sequence*
- ☐ [MedlinePlus text: Gas exchange](#)
- ☐ [BBC diagram: Respiration](#)
- ☐ *Sequence Chart*
- ☐ [Video of ventilation and gas exchange in the lungs](#)

Launch

1. Introduce the guiding question for this Explain phase activity, connecting to one or more questions from the end of the Explore phase: How does the body regulate gas exchange?

Integrating Three Dimensions



Throughout this Explain phase, students are addressing and making sense of data using **CCC #7 - Stability and Change**; at the high school level this CCC addresses feedback mechanisms, which are an underlying way of thinking about biological systems that cuts across topics and is explicitly taught as a lens in this 5E.

Use Cards and Text to Build a Sequence Chart

1. Provide student groups with the cards for the **Sequence Chart** activity. Explain the directions for the activity, making it clear that this task is not a simple matching activity. For example:

"I have just given every group a set of cards. There are some ideas on these cards that we've already thought about in this unit. Other ideas might be new. Your job is to work with your group to come up with a sequence for these cards that makes sense. There are different ways to piece together the information, so don't worry about getting the one right answer."

2. Provide student groups with the text and video as resources, once they get stuck or are clear about what they need to figure out next. These resources provide information for modifying the card sequence.

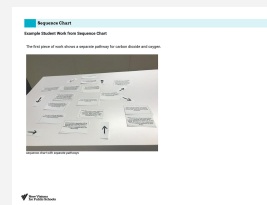
Look & Listen For



While students are engaged in completing the **Sequence Chart** activity, circulate and listen for or ask about these key ideas:

- Trying to make a connection between respiration and the work or activities that cells do.
- Grappling with questions about where the sugar actually goes during respiration.

Use the *Sequence Chart* to guide how you support students.



Access for All Learners



We found that students need support and facilitation to do this sequence chart well. Keep in mind that this is not a simple matching game. Instead, be available to help students make sense of the material and work together to create a sensible sequence. There are many valid answers or pathways. Prompting students to sequence or reorganize information provides access to learners who need additional time to process and make sense of the learning.

Differentiation Point



Here are some options for ensuring that all students have access to the **Sequence Chart** activity.

- Have students who are struggling to get started go through the cards and annotate all of the ones that relate to Carbon Dioxide and all the ones that relate to Oxygen, as a way to start categorizing the cards.
- Start a group with a smaller set of cards, then adding others in later in the class.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:

"We are going to use a **Class Consensus Discussion**, just like we did a few days ago, to learn about all the thinking in the room and come to some decisions about how the human body "knows" how to have the right amount of different gases at all times."

2. You may decide to walk students through the entire poster again, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. we select a few different groups' ideas.
2. The first group shares out their work.
3. one person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Refer to the Biology Course Guide for support with this routine.

Integrating Three Dimensions



Make sure this idea of a feedback mechanism is treated as a concept, not just as a vocabulary word. This is students' first time in the unit considering this complex idea, but they will come back to it multiple times. If many students note that the sequence charts all look the same, then go ahead and name that pattern as a *feedback mechanism*. But there is no need to rush into definitions.

Access for Multilingual Learners



Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context. This approach is particularly helpful for **transitioning** English Language Learners.

3. Select two or three groups' sequence charts to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of gas exchange. The decision about which models to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
4. Ask the first group to share their model. You can do this by:
 - Projecting using a document camera; OR
 - Copying the models to be shared and passing them out to the class; OR
 - Taking a picture of each model and projecting them as slides.
5. With each group that presents, pause and reflect on which components are happening at the cell, organ, or body system level. You can keep a chart paper with this information, or just ask students to note which levels are implicated in the different sequence charts. Begin to set up the idea that there are systems at different levels interacting here.
6. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk, so be sure to facilitate the conversation so that key ideas emerge.
7. Return to student questions that bring up lingering issues not yet resolved, such as:
 - Is it possible just to run out of oxygen?
 - Is it possible to have too much carbon dioxide in our blood? What would happen?
 - Did the marathon runner not obtain enough oxygen? Or was her body unable to properly regulate oxygen levels?
 - Do all living things regulate gas in the same way?

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- Oxygen moves easily into the bloodstream from the air in the lungs.
- The brain detects increased carbon dioxide in the blood, and that makes you breathe faster.
- Carbon dioxide is a product of respiration, and it ends up in blood in order to be breathed out.

- These sequence charts show a *feedback mechanism*.

Note: Dynamic equilibrium and homeostasis do not need to be introduced as vocabulary at this point. Instead, provide students time to observe this pattern and articulate what they are seeing. This concept will return in the two subsequent 5E plans.

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about how the body regulates gas exchange.

Summary Task

Today we completed a class consensus discussion after looking at a few different sequence charts. How did it go?

1. One thing that went well in the discussion:
2. One thing we can improve the next time we have a discussion:
3. One person who helped me learn today:
What did you learn from this person?
4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today.

1. How does the body regulate gas exchange?
2. Why do we say that gas exchange is a feedback mechanism?
3. How is gas exchange regulated at the cell, organ, and body system level? Give one example of each.

Cellular level

 New Visions for Public Schools

Integrating Three Dimensions



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) understanding how they are using the three dimensions, including the concept of gas exchange, to make sense of a phenomenon, breathing faster; 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

How do different plants regulate gas exchange?

Students extend their ideas about **gas exchange** by **constructing a model** to demonstrate how plants **regulate** gas exchange.

Preparation

Student Grouping

☐ Table groups

Routines

☐ Read-Generate-Sort-Solve

Literacy Strategies

None

Materials

Handouts

- ☐ Comparing Gas Exchange Text
- ☐ Comparing Gas Exchange R-G-S-S

Lab Supplies

None

Other Resources

Text-Based Task

1. Organize students into triads. Highlight for students that in the previous Explore & Explain, they figured out how humans regulate gas exchange in order to generate ATP to use as an energy source for life processes (like exercise) and to expel waste products.
2. If this question has not surfaced yet, prompt students to consider whether they think other organisms regulate gas exchange the same way humans do. Ask them to list reasons why this might be helpful to figure out. Note: It is possible that students may have asked whether this process of gas exchange is the same for all living things. If so, let them know this is the question they will be figuring out in this Elaborate.
3. Provide the guiding prompt for working through *Comparing Gas Exchange*

Comparing Gas Exchange R-G-S-S
Directions for Read-Generate-Sort-Solve

Access for All Learners



In the Explain phase, the teacher was able to assess student learning around how the human body regulates gas exchange. This phase of the 5E allows for students who are still unsure of that idea to develop it

Text: How do plants regulate gas exchange, and how is that similar to or different from how humans do so?

4. Provide the text on plants students.
5. Facilitate the group learning routine **Read-Generate-Sort-Solve** using the handout *Comparing Gas Exchange R-G-S-S* as a way for students to synthesize and extend their thinking.

Look & Listen For



Students may generate ideas such as:

- Plants exchange gas with their environment.
- Plants regulate gas exchange through a set of feedback mechanisms.
- Diffusion is an important, key process for the movement of gas.
- Plants have cells that enable gas exchange and transport between components of the leaf system at different scales

further through learning about other organisms.

Routine



The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. This is the first time the class has engaged in this routine, so be sure to refer to the Biology Course Guide for planning support.

Evaluate

How does the regulation of gas exchange connect to changes we see during intense exercise?

Students **use their input/output model**, and their new understanding of **cellular respiration and the regulation of gas exchange** through the **interaction of multiple body systems** in order to address the Marathon Runner problem. Students evaluate the relevance of new evidence, such as the O₂ saturation of the runner.

Preparation

Student Grouping

☐ Table groups

Routines

☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Gas Exchange & Cellular Respiration Model
- ☐ Gas Exchange & Cellular Respiration Model Rubric

Lab Supplies

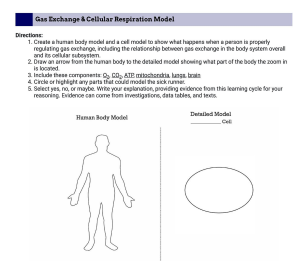
None

Other Resources

- ☐ Class wide scientific model characteristics
- ☐ Driving Question Board from the start of the unit should be available

Revisit the Performance Task

- Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence (for example: Did the marathon runner run out of breath or not get enough oxygen?).
- Students work individually on *Gas Exchange & Cellular Respiration Model*, in the Performance Task Organizer. They should make choices on how to represent their ideas using the model they are developing. In the models,



students are representing how a human normally regulates gas exchange at different scales and how the components of the body and the body as a system overall relate to each other.

3. Confer with students while they are working.

Conferring Prompts



Confer with students as they work to develop their models. Prompt students to return to the class wide scientific model characteristics, posted in the room.

Suggested conferring questions:

- Can you confirm, contradict, or modify anything on the list based on your interactions with models throughout these investigations on gas exchange and cellular respiration?
- How can you use the characteristics on the list to inform the development of your own model?

4. Provide students with the normal oxygen saturation level 95-100%, or refer them to the graph from Explore 2. This information should be recorded in their organizer.
5. Students individually use their model to evaluate the claim on whether or not the runner was not able to regulate oxygen, and collapsed because of this (*Did the runner run out of oxygen?*). Prompt students to use the medical tent data to support their claim. They should also consider data and evidence gathered during the investigations completed during this instructional sequence, as well as their new understandings.
6. Use the *Gas Exchange & Cellular Respiration Model Rubric* for students to self-reflect on their progress and to provide individual feedback towards the final task.

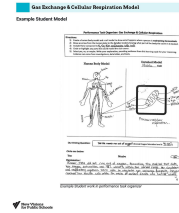
Implementation Tip



When returning to the **Driving Question Board**, be sure to change these suggested teacher notes so that they match your class' actual questions!

Document Class Thinking

1. Prompt students to discuss, with their groups, their decision on the question: Did the marathon runner run out of oxygen? Students can use the notes in their Performance Task Organizers in these discussions.
2. Each group comes to a consensus answer to the question—Yes, No, or Maybe—and should be able to articulate their reasoning.
3. Use the *Gas Exchange & Cellular Respiration Model Rubric* for students to self-reflect on their progress and to provide individual feedback towards the final task. As a teacher, use the sample student work, *Gas Exchange & Cellular Respiration Model* to guide feedback to students.
4. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point. Based on the investigations in this 5E instructional sequence, most groups will say No. Groups that shared Yes or Maybe may need some additional support during the next 5E instructional sequence when ideas related to cellular respiration and feedback mechanisms repeat.



Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Biology Course Guide for support with this routine.

Revisit the Driving Question Board

1. Use the **Driving Question Board** routine to discuss which of their questions have been answered.
2. Have students identify which categories/questions they have not figured out yet. Students should share out these questions, and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.
3. One question category still unanswered should relate to questions about muscles and energy (for example, questions about: Did the marathon runner's muscles just get tired or did she run out of energy?). Tell students that in the next sequence of lessons, they will investigate what it means when our muscles get tired. Some students may already anticipate connections to what they were learning in this Gas Exchange instructional sequence, which should be noted, and revisited during the Muscles and Energy sequence.

Implementation Tip



Use the **Driving Question Board** unit routine to document students' evolving questions.

Standards in Gas Exchange and Cellular Respiration 5E

Performance Expectations

HS-LS1-2 **Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.**

Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.

Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.

In NYS the clarification statement has been edited as follows: Emphasis is on functions at the organism's system level such as nutrient uptake, water delivery, immune response, and organism response to stimuli.

HS-LS1-3 **Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.**

Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.

Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.

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.**

Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration

Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.

In NYS, all occurrences in this PE of the phrase "cellular respiration" have been replaced with the phrase "aerobic cellular respiration."

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3)

LS1.A Structure and Function

- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. LS1.A(3)

Systems and Systems Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.
-

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. LS1.A(4) LS1.C Organization for Matter and Energy Flow in Organisms - As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. LS1.C(3) - As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. LS1.C(4)	CCC4(3) Stability and Change Feedback (negative or positive) can stabilize or destabilize a system. CCC7(3)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Developing and Using Models		<i>Input-Output Model for Cellular Respiration Summary Task</i>	<i>Blood Oxygen Graphs Three-Level Guide Summary Task</i>	<i>Comparing Gas Exchange R-G-S-S</i>	Cell and Body Model in Gas Exchange & Cellular Respiration Model Gas Exchange & Cellular Respiration Model Rubric
LS1.A Structure and Function	Rumors: students' post-its and the emergent categories		Questions Only Gas Exchange Card Sequence; Summary Task Summary Task	<i>Comparing Gas Exchange R-G-S-S</i>	Cell and Body Model in Gas Exchange & Cellular Respiration Model Gas Exchange & Cellular Respiration Model Rubric Yes-No-Maybe Explanation in Gas Exchange & Cellular Respiration Model
LS1.C Organization for Matter and Energy Flow in Organisms	Rumors: students' post-its and the emergent categories	<i>Input-Output Model for Cellular Respiration Summary Task</i> Cellular Respiration in Yeast Investigation			Cell and Body Model and Yes-No-Maybe Explanation in Gas Exchange & Cellular Respiration Model
Systems and Systems Models		Making Sense of the Cellular Respiration in Yeast Investigation <i>Input-Output Model for Cellular Respiration Summary Task</i>		<i>Comparing Gas Exchange R-G-S-S</i>	Cell and Body Model in Gas Exchange & Cellular Respiration Model Gas Exchange & Cellular Respiration Model Rubric
Stability and Change			Gas Exchange Card Sequence; Summary Task	<i>Comparing Gas Exchange R-G-S-S</i>	Yes-No-Maybe Explanation in Gas Exchange & Cellular Respiration Model Gas Exchange & Cellular Respiration Model Rubric

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP2 MP3 HSF-IF.B.5 8.F.B.5	MP2 MP3 HSF-IF.B.5 8.F.B.5	MP2	MP2
ELA/Literacy		RST.9-10.1 RST.9-10.7 SL.9-10.4 SL.9-10.5	RST.9-10.1 RST.9-10.7 SL.9-10.4 SL.9-10.5	WHST.9-10.9	WHST.9-10.2 WHST.9-10.9 SL.9-10.4