Lesson 4: Explaining How Animals Move and Function

Overview

Students learn and use a scientific model to explain cellular respiration using the Three Questions. They relate the rearrangement of atoms in cellular respiration to energy release.

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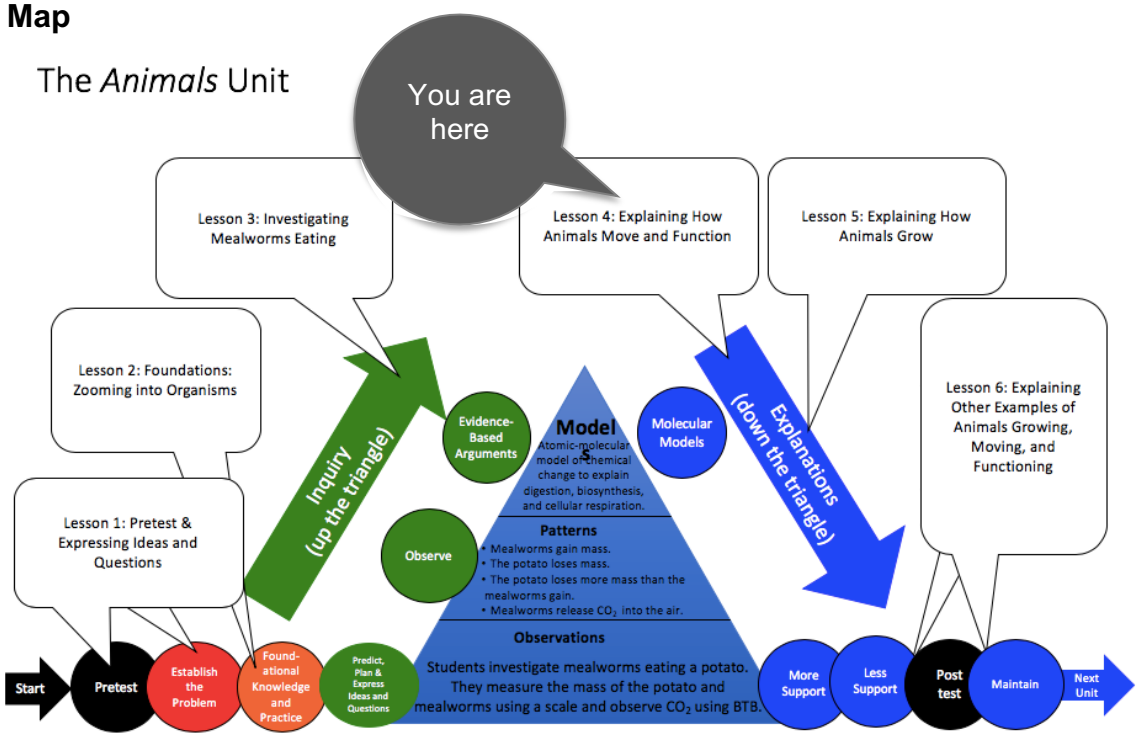
Guiding Question

How do animals use food to move and function?

Activities in this Lesson

- Activity 4.1: Molecular Models for Cows Moving and Functioning: Cellular Respiration (40 min)
  - *Note: The steps that have students construct molecular models in this activity are optional if students did molecular modeling for cellular respiration in another unit and performed well on the pretest for items related to cellular respiration.*
- Activity 4.2: Explaining How Cows Move and Function: Cellular Respiration (40 min)

Unit Map



Learning Goals

Target Performances

Lesson 4 –Explaining How Animals Move and Function	
Activity 4.1: Molecular Models for Cows Moving and Functioning: Cellular Respiration	Students use molecular models to explain how carbon, oxygen, and hydrogen atoms are rearranged into new molecules in a cow's cells.

Activity 4.2: Explaining How Cows Move and Function: Cellular Respiration	Students explain how matter moves and changes and how energy changes during cellular respiration in a cow's cells (connecting macroscopic observations with atomic-molecular models and using the principles of conservation of matter and energy).

NGSS Performance Expectations

Middle school

- MS. Matter and its Interactions. MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
- MS. Matter and its Interactions. MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

High school

- HS. Matter and its Interactions. HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- HS. Matter and its Interactions. HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- HS. From Molecules to Organisms: Structures and Processes. 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.
- From Molecules to Organisms: Structures and Processes. HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Background Information

Three-dimensional Learning Progression

This lesson also focuses on the second use of food—as a source of energy—and on the carbon-transforming process that makes food energy available to animal cells—cellular respiration. Every living organism, from the smallest bacteria to the largest tree in the forest, needs to acquire a source of chemical energy, which is found in the C-C and C-H bonds in organic matter. Once organic matter is oxidized, the chemical energy found in the high-energy bonds is made available for cell functions such as movement, chemical work, and transport of materials. Ultimately all of this energy becomes body heat. The atoms once tied up in organic molecules are rearranged into inorganic water and carbon dioxide. Cellular respiration helps to explain why we breathe out CO_2 and water, and why our body temperature stays a toasty 98.6 degrees. Unfortunately, many students incorrectly see cellular respiration as the way we convert food or stored biomass (fat) into *energy* to move and exercise. Students even make these matter-energy conversions at the atomic-molecular scale when they learn about ATP (another organic molecule). Students need to develop an explanation of cellular respiration that conserves both matter and energy and makes the connection between atomic-molecular transformations and macroscopic observations.

We will consistently focus on the idea that understanding carbon-transforming processes involves answering the Three Questions:

- **The Matter Movement Question: Where are molecules moving?** (How do molecules move to the location of the chemical change? How do molecules move away from the location of the chemical change)
- **The Matter Change Question: How are atoms in molecules being rearranged into different molecules?** (What molecules are carbon atoms in before and after the chemical change? What other molecules are involved?)
- **The Energy Change Question: What is happening to energy? (**What forms of energy are involved? What energy transformations take place during the chemical change?)

Matter (Matter Movement and Matter Change). We find that even students who have learned how to balance chemical equations do not appreciate the meaning of the procedure:

- Conservation of atoms (the Matter Change Question): The numbers of atoms on the left and right side of a chemical equation have to be the same because they are THE SAME ATOMS! A chemical equation just shows how they are being rearranged into new molecules.
- Conservation of mass (the Matter Movement Question): ALL the mass of any material is in its atoms (and none of the mass is in the bonds, which are just attractive forces between atoms). So, the mass of the products is always the same as the mass of the reactants.

Energy (the Energy Change Question). Chemists, physicists, and biologists have many different conventions for describing and measuring chemical energy. We have a deeper explanation of the conventions used in *Carbon TIME* units and how they relate to conventions used in different scientific fields on the BSCS website in a document called *Carbon TIME* Content Simplifications. Here are some key points:

- All bond energies are *negative* relative to individual atoms. So, during a chemical reaction, it always takes energy (the activation energy) to break bonds. Then, energy is released when new bonds are formed.
- Whether a chemical reaction releases energy or not depends on the total energy of the reactants, compared with the total energy of the products. So, energy is released when the total bond energy of the products is lower (i.e., more negative relative to individual atoms) than the energy of the reactants.
- In systems like our atmosphere, where excess oxygen is always present, the most abundant sources of chemical energy are substances that release energy when they are oxidized (e.g., substances with C-C and C-H bonds).

The two activities in this lesson represent the **Explanations Phase** of the *Animals Unit*. This involves modeling and coaching with the goal of helping students develop atomic-molecular scale accounts of cellular respiration that was one driver of the macroscopic changes they observed in their Mealworms Eating Investigation in the previous lesson.

Key Ideas and Practices for Each Activity

Activity 4.1 is the first part of the **Explanations Phase** of the instructional model (going down the triangle) for cellular respiration. Students construct molecular models of the chemical change that took place during the investigation to help them develop an atomic-molecular explanation for how animals use food to move, breathe, and function. Activity 4.1 also simplifies the full story of what happens to matter during the multi-step process of cellular respiration. The activity uses a standard but simplified formula for the overall chemical change:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

This incorrectly suggests that some of the oxygen atoms O_2 in end up in CO_2, which is not actually the case. A more accurate formula to represent the multi-step process would be as follows:

$$C_6H_{12}O_6 + 6\ \mathbf{O_2} + 6\ H_2O \rightarrow\ 6\ CO_2 + 12\ H_2\mathbf{O}$$

Thus, all of the oxygen atoms in O_2 (**bolded** in the equation above) end up in H_2O, while the oxygen atoms in CO_2 all come from glucose or water.

In practice biochemists often do not try to trace individual H and O atoms through biochemical processes, since the processes always take place in environments where water provides H and O atoms.

In *Carbon TIME* Units we explain that the chemical energy released during cellular respiration is used for cell functions and ultimately converted to heat. In more advanced classes, you may choose to include another intermediate step in this story: the energy released by oxidation of glucose is used to convert ADP (adenosine diphosphate) and phosphate into ATP (adenosine triphosphate), which is the immediate source of energy for cell functioning. Some of your students may believe that ATP is a form of energy and not a form of matter or that the matter in glucose is converted to ATP, so pay particular attention to how students describe ATP when learning about cellular respiration. ATP is matter with chemical energy stored in its bonds.

Our research has consistently showed that these ideas are extremely difficult for students who have not formally studied chemistry. We therefore use the convention of twist ties to identify bonds that release energy when they are oxidized.

Activity 4.2 is the second part of the **Explanations Phase** of the instructional model (going down the triangle) for cellular respiration. Students use the **Explanations Tool** to construct final explanations of what happens when animals oxidize small organic molecules to release energy to move and function, and then release water and carbon dioxide. Ideally, at this phase their explanations will combine evidence from macroscopic-scale observations during the investigation with their new knowledge of chemical change at the atomic-molecular scale.

Note: Activities 4.1 and 4.2 focus on the fact that animals remove oxygen atoms in glucose and fat molecules from their bodies through cellular respiration in the form of H_2O and CO_2 molecules. Although the curriculum does not go into this amount of detail, it should be noted that most of the oxygen atoms from fat and glucose are expelled from the body in CO_2 molecules (approximately 84%) and some of the oxygen atoms leave the body in H_2O molecules as well (approximately 16%).

Key Carbon-Transforming Processes: Cellular Respiration

Content Boundaries and Extensions

Talk and Writing

At this stage in the unit, the students will be **developing Explanations**. The table below shows specific talk and writing goals for this phase of the unit

Talk and Writing Goals for the Explanations Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Examine student ideas and correct them when there are problems. It's ok to give the answers	*Let's think about what you just said: air molecules. What are air molecules?* *Are you talking about matter or energy?*	Molecule Poster Three Questions Poster

away during this phase! Help students practice using **precise language** to describe **matter and energy**.	*Remember: atoms can't be created. So that matter must have come from somewhere. Where did it come from?* *Let's look at the molecule poster again… is carbon an atom or a molecule?*	
Focus on making sure that explanations include multiple **scales**.	*The investigation gave us evidence for what was happening to matter and energy at a macroscopic sale. But what is happening at an atomic-molecular scale?* *What is happening to molecules and atoms?* *How does energy interact with atoms and molecules during chemical change?* *Why doesn't the macroscopic investigation tell us the whole story?* *Let's revisit our scale poster… what is happening to matter at the molecular scale?*	Molecular Models Molecular Modeling Worksheets **Explanations Tool** PPT Animation of chemical change Powers of Ten Poster
Encourage students to recall the investigation.	*When did this chemical change happen during our investigation?* *How do we know that? What is our evidence?* *What were the macroscopic indicators that this chemical change took place?*	**Evidence-Based Arguments Tool** Investigation Video
Elicit a range of student explanations. Press for details. Encourage students to examine, compare, and contrast their explanations with others'.	*Who can add to that explanation?* *What do you mean by _____? Say more.* *So, I think you said _____. Is that right?* *Who has a different explanation?* *How are those explanations similar/different?* *Who can rephrase _____'s explanation?*	**Explanations Tool**

Activity 4.1: Molecular Models for Cows Moving and Functioning: Cellular Respiration (45 min)

Overview and Preparation

Target Student Performance

Students use molecular models to explain how carbon, oxygen, and hydrogen atoms are rearranged into new molecules in a cow's cells.

Resources You Provide

- (From previous lesson) Students' unanswered questions they shared in Activity 3.3 Evidence-Based Arguments about Mealworms Eating
- (From previous lesson) 3.3 Evidence-Based Arguments Tool for Mealworms Eating
- molecular model kit (1 per pair of students)
- scissors (1 per pair of students)
- twist ties (at least 12 per pair of students)
- video of a cow moving, such as here: https://youtu.be/onWzeDElz6w

Resources Provided

- 4.1 Molecular Models for Cellular Respiration Worksheet (1 per student)
- 4.1 Grading the Molecular Models for Cellular Respiration Worksheet
- 4.1 Molecular Models for Cow Cellular Respiration PPT

Recurring Resources

- Molecular Models 11 x 17 Placemat (1 per pair of students)
- Molecule Diagram 11 x 17 Poster (1 per class)
- Three Ways to Represent Glucose 11 x 17 Poster (1 per class)
- Forms of Energy Cards (1 set per pair of students)
- Cow 11 x 17 Poster (1 per class)

Setup

Prepare one model kit, one Molecular Models 11 x 17 Placemat, one pair of scissors, and one Forms of Energy Cards for each pair of students. Print one copy of the 4.1 Molecular Models for Cellular Respiration Worksheet for each student. Prepare a computer and a projector to display the PPT. Retrieve the materials from Activity 3.3. This may include PPT slides from the lesson in which you typed students' unanswered questions or a photograph of their unanswered questions. Print and hang the Cow 11 x 17 Poster, Molecule Diagram 11 x 17 Poster, and Three Ways to Represent Glucose 11 x 17 Poster.

Directions

1. Use the instructional model to show students where they are in the course of the unit. Show slide 2 of the 4.1 Molecular Models for Cow Cellular Respiration PPT.
2. Remind students of their unanswered questions from Activity 3.3. Tell students that in today's activity we will use molecular modeling to begin to answer some of their unanswered questions about what happens when a mealworm eats.

- Return students' completed 3.3 Evidence-Based Arguments Tool for Mealworms Eating and ask them to review their unanswered questions from the last lesson.
- You may have typed and saved students' unanswered questions on the 3.3 Evidence-Based Arguments Tool for Mealworms Eating PPT or you may have taken a picture of students' unanswered questions. Display the visual and review what students shared.
- We are transitioning from mealworms to cows because it is simpler to track the carbon-transforming processes (cellular respiration, digestion, and biosynthesis) in a cow than in a mealworm.

3. Make connections among processes at different scales.

Display slide 3 in the PPT.

- Show students the short clip of a cow moving. Follow the link in the PPT, in the materials list, or here (https://youtu.be/onWzeDElz6w). Thirty seconds of the clip should be sufficient.
- At the macroscopic scale, we wonder: *How do cows move*?
- At the microscopic scale, we thinka bout this question in terms of a cow's muscle cells: *How do a cow's muscle cells get energy to contract the muscles and move?*
- At the atomic-molecular scale, we think about this question in terms of atoms and molecules in chemical changes: *What chemical change provides energy to the muscle cells?*
- Assure students that we will be able to answer several of their unanswered questions by the end of today's activity.

4. How do a cow's muscle cells get energy to move?

- Use Slide 4 to show students that animals use food in two ways.
- Today we'll be focusing on energy as one of those uses (cellular respiration).

5. Use the cow animation to connect the atomic-molecular scale to the macroscopic scale

Show slide 5 of the PPT.

- Use the animation to support students in connecting the atomic-molecular scale to the macroscopic scale.
- Tell students they will be modeling the change that occurs during cellular respiration at the atomic-molecular scale.

6. Introduce students to the three different ways we represent molecules in the *Carbon TIME* units.

Post a copy of the Three Ways to Represent Glucose 11 x 17 Poster in your classroom and display slide 6 in the PPT. Have students discuss the differences in the three different images we use in the *Carbon TIME* Units to represent molecules.

- The first form uses letters and numbers. Each letter represents a type of atom and each number indicates how many of that atom are in the molecule.
- The second form uses letters and sticks. Each letter represents an atom, and each stick represents a bond.
- The third form uses balls and sticks. Each ball represents an atom, and each stick represents a bond.

7. Prepare for building molecular models.

Divide the class into pairs and give each pair a molecular model kit, a set of Forms of Energy Cards, and Molecular Models 11 x 17 Placemat. Pass out one copy of 4.1 Molecular Models for Cellular Respiration Worksheet to each student.

- Tell students that they'll be using molecular models to model the process of cellular respiration, which will help them answer several of their unanswered questions.
- Show students slide 7 to explain the bonding of atoms in molecules. Tell students that the rules on this slide are important because they apply to all molecules that they will make in all *Carbon TIME* units.

8. Have students use the molecular model kits to construct the reactants.

Use slide 8 to show instructions to construct the reactants: glucose and oxygen. Students can also follow instructions in Part B of their worksheet.

9. Check students' work for the reactants.

Show slide 9 in the PPT.

- Have students compare their own molecule with the picture on the slide.
- Slide 10 shows an **important message**: after students create their reactant molecules, make sure they put away all unused pieces of their molecule kits. This helps reinforce that the matter and energy in the reactants are conserved through the chemical change, and that only the materials from the reactants are used to build the products.

10. Have students construct a model of the product molecules.

Show slide 11 of the PPT and have students re-arrange the atoms to make molecules of CO_2 and H_2O. Tell students to follow the instructions in steps 3 and 4 in Part B of the worksheet to construct their products.

To do this, they will need to move their molecules from the reactants side to the products side of the placemat. Explain to students that atoms last forever, so they should not add or subtract atoms when they change the reactant molecule into product molecules.

11. Check students' work for the products.

Show slide 12 in the PPT.

- Have students compare their own molecule with the picture on the slide.
- Use slide 13 to compare the reactants and products.

12. Have students watch an animation of the chemical change.

Show slides 14-20 in the PPT to help students make connections between what is happening in the animation and the molecular models they made.

- For each slide, focus on different atoms and forms of energy and how they change. The animation draws attention to where they atoms begin and end in the reaction.

13. Have students record their results.

Show slide 21 in the PPT.

- Tell students to complete Part C of their worksheet to trace the atoms during the chemical change.

14. Have students record their results.

Show slide 22 in the PPT.

- Tell students to complete Part D of their worksheet to trace the energy during the chemical change.

15. Discuss results with the class.

Show slide 23 in the PPT.

- Complete the "check yourself" questions with the class in Part E.

16. Help students write a balanced chemical equation.

Tell students that now that they have represented a chemical change using molecular models and in animations, they will represent chemical change by writing the chemical equation.

- Show Slide 24 to guide students through the process of writing a balanced chemical equation for cellular respiration. Tell students that these rules apply to all chemical reactions.
- Tell students to write their equations in Part F of their worksheet.
- Have students write their own chemical equations before comparing them with the one on Slide 25.

17. Have students complete an exit ticket.

Show slide 26 of the 4.1 Molecular Models for Cow Cellular Respiration PPT.

- Conclusions: What happens to glucose and oxygen during cellular respiration?
- Predictions and Planning: Where do you think cellular respiration occurs?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The Predictions and Planning question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the Predictions and Planning question can be used as a lead in to the next activity.

Assessment

Listen for the students' sense of necessity to make sure that atoms last forever during chemical changes. Asking them about the "atoms are forever" rule during the molecular modeling and animation may give you a sense of how committed they are to conserving matter.

If you had students complete the molecular modeling part of this activity, use 4.1 Grading the Molecular Models for Cellular Respiration Worksheet to get a sense of students' initial ideas and explanations about cellular respiration in plants. Students should be able to follow instructions and complete the worksheet correctly, so it is reasonable to grade this worksheet.

Tips

- Laminate the Molecular Models 11 x 17 Placemats. These will be used multiple times in each unit.
- During the molecular modeling activity and animation, focus on how matter and energy are conserved through the chemical change. This is the main goal of the activity!

Differentiation & Extending the Learning

Differentiation

- Strategic grouping with strong speakers
- Build models for students to copy

Modifications

Extending the Learning

This TED Talk about “the mathematics of weight loss” provides an alternative way of looking at how cellular respiration drives weight loss: https://www.youtube.com/watch?v=vuIlsN32WaE

Activity 4.2: Explaining How Cows Move and Function: Cellular Respiration (40 min)

Overview and Preparation

Target Student Performance

Students explain how matter moves and changes and how energy changes during cellular respiration in a cow's cells (connecting macroscopic observations with atomic-molecular models and using the principles of conservation of matter and energy).

Resources You Provide

- (From previous lesson) 3.3 Evidence-Based Arguments Tool for Mealworms Eating

Resources Provided

- 4.2 Explanations Tool for Cow Cellular Respiration (1 per student)
- 4.2 Explaining How Cows Move and Function: Cellular Respiration PPT
- 4.2 Grading the Explanations Tool for Cow Cellular Respiration
- 4.2 How do Animals Get the Energy They Need to Move? Reading (1 per student)

Recurring Resources

- Learning Tracking Tool for Animals
- Assessing the Learning Tracking Tool for Animals
- Animals Matter Tracing Tool (1 per student)
- Assessing the Animals Matter Tracing Tool
- Cow 11 x 17 Poster (1 per class)
- (Optional) Example Animal Explanations Handout (1 per student or per group)
- Questions, Connections, Questions Student Reading Strategy
- Three Questions 11 x 17 Poster (1 per class)
- Three Questions Handout (1 per student)

Setup

Print one copy of the 4.2 Explanations Tool for Cow Cellular Respiration for each student. Return students' completed versions of the 3.3 Evidence-Based Arguments Tool for Mealworms Eating for review. In this activity, your students will need to use the Three Questions Explanation Checklist on the back of the Three Questions Handout. Be sure to have this available to students and see the notes in the Modifications at the end of the Activity for ideas about how to use it.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.2 Explaining How Cows Move and Function: Cellular Respiration PPT.

2. Revisit students' arguments about what happens when mealworms eat.

- Show slide 3 of the 4.2 Explaining How Cows Move and Function: Cellular Respiration PPT.
- Tell students that this activity's purpose is to develop explanations for how cows use food to move and function.

- Return each student's copy of 3.3 Evidence-Based Arguments Tool for Mealworms Eating and have them review their arguments before they completed the molecular modeling activity. Their arguments and unanswered questions should also apply to cows.
- Ask them to think about what they know now that they didn't know then.

3. Have students complete the front of the Explanations Process Tool.

Show slide 4 of the 4.2 Explaining How Cows Move and Function: Cellular Respiration PPT. Give each student one copy of 4.2 Explanations Tool for Cow Cellular Respiration.

Make sure students understand that they will use the information from the to help them construct their explanations paragraphs on the back.

Give students about 10 minutes to complete the front of the Explanations Process Tool.

Display slide 5. Then, have students compare their responses with a partner, with the goal of confirming that their responses are the same.

4. Have students check the front of the explanations tool using the PPT.

Use slides 6-12 in the PPT to have the students discuss what is happening to matter during cellular respiration and to have them check their answers to the Matter Movement Question on their 4.2 Explanations Tool for Cow Cellular Respiration.

- Show students slide 6 to have them think about where atoms are moving from and moving to during cellular respiration.
- Show slide 7 to explain that atoms and molecules are moving so that animals can get energy through cellular respiration: Animals need glucose and oxygen as reactants, and they must get rid of carbon dioxide and water as waste.
- Show slide 8 to explain a simplified version of movement of all these materials through the cow.
- Display slides 9-12 to have students compare their answers to the Matter Movement Question with the answers on the slide. Students only need to have arrows showing the movement of molecules into and out of the cell. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.

5. Have students think about how cellular respiration also answers the Matter Change Question.

Show slide 13 to zoom into a muscle cell in the cow's leg to illustrate cellular respiration at the cellular scale. Glucose and oxygen enter the cell; carbon dioxide and water leave—and cell gets energy to function!

- Display slides 14-15 to have students compare their answers to the Matter Change Question on the 4.2 Explanations Tool for Cow Cellular Respiration with the answers on the slide. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.

6. Discuss how cellular respiration helps to answer Energy Change questions, including unanswered questions about mealworms and cows.

Display slide 16 to have students compare their answers to the Energy Change Question on the 4.2 Explanations Tool for Cow Cellular Respiration with the answers on the slide.

- Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.
- Have students consider how these answers address Energy Change at macroscopic, atomic-molecular, and cellular scales.

7. Have students write paragraph explanations of the process of cellular respiration in cows.

Display slide 17. Ask students to write paragraphs explaining the process of cellular respiration on the second page of the 4.2 Explanations Tool for Cow Cellular Respiration.

- Refer student to the checklist and questions on the Three Questions Handout for reminders about what to include in their paragraph
- Remind students that they have the information they need in their responses to the questions on the front of the Explanations Tool.
- Remind students that the graphic organizer on the front has the information they need to write their explanations paragraphs.
- Remind students to refer to their Three Questions Handout and Explanations Checklist to review what should be included in a good explanation.

8. Have students share explanations with each other.

Show slide 18 of the 4.2 Explaining How Cows Move and Function: Cellular Respiration PPT. Divide students into pairs and have them compare explanations for the Three Questions and the final explanation on the process tool.

- Have students use the Three Questions 11 x 17 Poster (or Handout) as a reference. Have students check their explanations with the middle and right-hand columns of the poster to make sure they are following the "rules."

9. (Optional) Have students critique example explanations.

Display Slide 19 of the PPT. Have students look at two handouts: (a) The Three Questions Handout, and (b) the Animals Example Explanations Handout.

Ask students to evaluate the two example explanations of cow cellular respiration on the Animals Example Explanations Handout: Which explanation is better? Why?

Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to justify their critiques of the explanations.

10. Have students critique and improve their full explanations.

Display slide 19 of the PPT for the full explanation. Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to check that their story includes each of the parts (matter movement, matter change, energy change, and matter movement).

- If students don't have all four parts in their explanation, instruct them to add to their explanation using a different colored writing utensil.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

11. Have students read about how animals get the energy the need to move.

Pass out 4.2 How do Animals Get the Energy They Need to Move? Reading. The reading provides a summary explanation of cellular respiration and additional information about muscle fatigue. Have students read using the Questions, Connections, Questions Student Reading Strategy. See the Questions, Connections, Questions Reading Strategy Educator Resource document for information about how to engage students with this strategy.

After pairs are finished reading, have students share with the class what they found interesting and any questions they have.

12. Have students connect their atomic molecular explanations to the macroscopic scale by using the Animals Matter Tracing Tool.

Show slide 20. Give students the Animals Matter Tracing Tool. Have students individually:

- Choose a cell and draw arrows showing the carbon-containing molecules that go to the cell and leave the cell (first page)
- Use the steps in the Three Questions to explain how matter and energy move and change in the cell (second page
- Show slides 21 and 22. Have students compare their answers to the answers on the slides, discuss, and revise their answers if necessary.

13. Revisit unanswered questions

Show slide 23. Have students look at their 3.3 Evidence-Based Arguments Tool for Mealworms Eating. Display the class list of unanswered questions from Activity 3.3.

- Ask students which of their unanswered questions they can now answer with their understanding of Cellular Respiration. Which ones are left unanswered? Do they have any new questions to add to the list?
- One question that students should have is: if cows eat plants that are mostly carbohydrates, where does the glucose that enters the cell come from? This and other remaining questions will be answered in future lessons on digestion and biosynthesis.

14. Have students complete an exit ticket.

Show slide 24 of the 4.2 Explaining Cow Cellular Respiration PPT.

- Conclusions: How do matter and energy change during cellular respiration?
- Predictions and Planning: Where do you think the glucose for cellular respiration comes from?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.

The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The Predictions and Planning question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the Predictions and Planning question can be used as a lead into the next activity.

15. Have a discussion to complete the Learning Tracking Tool for this activity.

Show slide 25 of the 4.2 Explaining Cow Cellular Respiration PPT.

- Pass out a Learning Tracking Tool to each student.

- Explain that students will add to the tool after activities to keep track of what they have figured out that will help them to answer the unit driving question.
- Have students write the activity name, "Explaining How Cows Move and Function" and their role, “Explainer” in the first column.
- Have a class discussion about what students figured out during the activity that will help them in answering the unit driving question. When you come to consensus as a class, have students record the answer in the second column of the tool.
- Have a class discussion about what students are wondering now that will help them move towards answering the unit driving question. Have students record the questions in the third column of the tool.
- Have students keep their Learning Tracking Tool for future activities.
- Example Learning Tracking Tool

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Explaining How Cows Move and Function Explainer	Model the oxidation of glucose to carbon dioxide and water using molecular model kits and use the Explanations Tool to explain what happens when cows move and function.	Some matter leaves the body as urine and waste but most matter leaves the body as CO_2 during cellular respiration.	What happens to food when it is in the body?

Assessment

During the class, circulate while students are comparing their explanations. Listen to see if they are able to explain cellular respiration at both the macroscopic and atomic-molecular scales. Use 4.2 Grading the Explanations Tool for Cow Cellular Respiration to grade student responses. This worksheet has “grading” in the title (instead of “assessing”) because at this point, students can be held accountable for correct answers. If students are still struggling with these concepts, you may want to revisit parts of the activity they are finding difficult. Use Assessing the Animals Matter Tracing Tool to grade the tracing tool.

Tips

- Make sure students understand that the chemical energy in glucose (not glucose itself) is converted to heat and motion energy.
- Make sure that students discuss and understand all three columns of the Three Questions 11 x 17 Poster or Handout. They play a central role in all *Carbon TIME* units.

Differentiation & Extending the Learning

Differentiation

- Provide sentence stems for discussion and filling in the Explanations Tool
- Work through the tool as a class and provide sentence stems for final explanation
- Hand out and refer to Example Animals Explanation handout when working on the Explanations Tool
- Refer to the word wall for questions on Cellular Respiration related vocabulary
- Refer to the Animals Matter Tracing Tool to support students further

Modifications

The Three Questions Explanation Checklist on the back of the Three Questions Handout can be used to scaffold students' explanations in many ways.

- Students refer to the checklist as they are constructing their explanations.
- Students use the checklist as they are sharing and revising their explanations with a partner.
- Students use the checklist to critique and revise their final explanations.
- Students use the checklist to critique the example explanations for each unit.
- Students use the checklist to create and/or evaluate a whole-class consensus explanation.

We recommend using this checklist with a gradual release. As students improve in their ability to write their own explanations, they may rely on the checklist less.

Extending the Learning

If there are still unanswered questions about cellular respiration, watch this video.
https://www.youtube.com/watch?v=4Eo7JtRA7Ig
Many traditional biology curricula include more depth about the steps in cellular respiration, mitochondria, and the role of ATP in cellular metabolism. While this level of detail is not included in the *Next Generation Science Standards* and is not necessary for the storyline in this unit, this would be an appropriate time to add those lessons.