TEACHER GUIDE
EXPLORE 1 LESSON 3

Food and Agriculture Center for Science Education

Module Question: *How is milk digested after it is consumed?*

What We Figure Out:

We figure out that the molecules in milk, such as proteins, carbohydrates, and fats, are broken down into smaller molecules in the different organs of the digestive system. Each organ has a set of specialized cells that produce molecules called enzymes that break down the molecules in milk into smaller molecules.

3D Learning Objective:

Students defend a claim about how multiple organs and their specialized cells produce enzymes to digest food molecules into smaller molecules, describing them using orders of magnitude.

Time estimate:

150 minutes

Materials:

Lesson 3 Student Guide
Lesson 3 Student Handout Chemistry of Milk
Lesson 3 Student Handout Enzyme Illustration
Lesson 3 Student Handout Size & Orders of Magnitude
Lesson 3 Student Handout Station Cards
Lesson 3 Teacher Resource Lab Guide
Lab Materials (see Teacher Resource Lab Guide)
Chart Paper
Meter Stick

Targeted Elements

SEP:

ARG-H5:
Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution **that**

DCI:

LS1.A-H1:
Systems of specialized cells within organisms help them perform the essential functions of life.

CCC:

SPQ-H4:
Using the concept of orders of magnitude allows one to understand how a model at

reflects scientific knowledge, and student-generated evidence.	**LS1.A-H3:** **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.**	**one scale relates to a model at another scale.**

Directions

Part 1: Our Motivation

USE OF PHENOMENA
Between Lessons 3-6, students will focus on the Module 1 Phenomenon. In Lesson 7, they will return to the Anchor Phenomenon and create presentations to help their peers understand how milk can help athletes recover from exercise.

Return to the Class Consensus Model from Lesson 2 that shows the role of different organs and cells in the digestion of milk. Ask students to share their ideas regarding the organs and cells they depicted as playing the most important role in digesting milk.

In student responses, listen for the following ideas:

- While the models show similar organs, we were not sure about the function of how the organs and cells digest milk.

Build off student responses to share that next, we will figure out how organs and cells function in the digestive system to digest milk. Point to the "How Does My Body Digest Milk?" category of the Driving Question Board. Ask students to identify a few selected questions that align with what they are still wanting to learn based on what they may have answered in the previous lesson.

Example student questions or ideas could include:

- We know that milk is being used in athletic recovery; what is in milk that makes it so good at doing this?
- What happens to milk after you drink it?
- How does milk get broken down in the body?
- Where does the digestion of milk occur?
- What do the mouth/esophagus, stomach, small intestine, and large intestine do in digestion?

Students can record these questions on their Lesson 3 Student Guide Part 1: Our Motivation. This will help students understand how this lesson connects to what they were trying to figure out about the Module Phenomenon.

TEACHER SUPPORT
Remember that the sample questions are just examples when returning to the Driving Question Board. Use the questions that your students have asked instead of the sample questions.

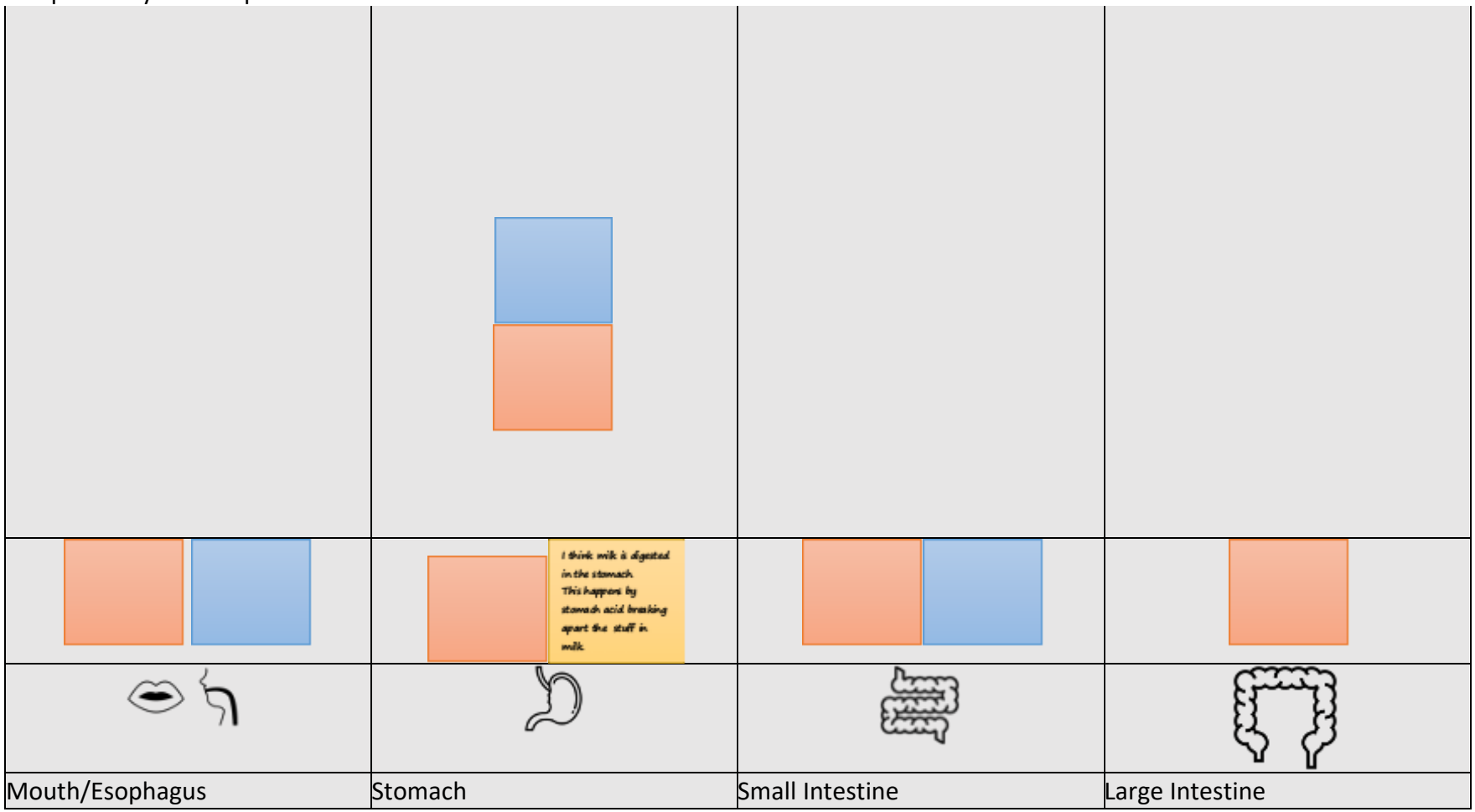
Part 2: Creating Initial Claims

Share with students that they will now make a claim that answers the question, *"What organs most help digest milk? How?"* They will choose between the mouth/esophagus, stomach, small intestine, and large intestine. They can choose one organ or more than one organ and write their responses on their Lesson 3 Student Guide Part 2: Creating Initial Claims.

Create a sticky-bar graph on the wall, similar to the example below, where columns represent an organ in the digestive system. Provide students sticky note(s), and have them record their response(s) from the previous question on the sticky note. Instruct students to place their sticky note(s) in the column on the chart representing the organ(s) they chose in the previous question. If students previously chose more than one organ, they can place more than one sticky note on the chart.

TEACHER SUPPORT
The "Sticky-Bar Graph" is a visual tool that provides an opportunity to quickly see the distribution of the class responses to a focus question. You can also have students add a written response to their sticky notes, which allows an additional formative assessment opportunity. Students can also put their names on their sticky notes so you can refer to and revisit their responses later.

Sample Sticky-Bar Graph:



After the class has placed their sticky notes on the chart, have students review the data that the chart is showing. Ask students what results they see in the chart. Select a few sticky notes from the organ with the most sticky notes and ask students to share their responses. Then, ask a few students to share about their sticky notes in the columns for the other organs. Have students write which claim is most favored by the class and record their classmates' reasons on their Lesson 3 Student Guide Part 2: Creating Initial Claims. Build off what students share

to emphasize that there are many different claims about how different organs play a role in the digestion of milk, so we will set out to gather new evidence to evaluate and defend these claims.

Part 3: Obtaining Evidence About What is in Milk

Distribute the Lesson 3 Student Handout Chemistry of Milk to students. Place students in pairs and instruct students to read the handout with their partners. They will identify the types of molecules present in milk. To support students in reading the handout together, you can suggest two roles: one student reads, and the other student annotates or highlights information that might be helpful in identifying the different types of molecules present in milk. They may switch roles throughout the text or stay with one role.

After students have finished reading, have student pairs nominate a spokesperson and use a Domino Share Routine to have students share the types of molecules they identified in milk.

1. Each group nominates a spokesperson.
2. As a student from group 1 shares, all other students serve in a "listener" role, noting patterns or ideas that emerge as the group continues to share.
3. Spokespersons from each group continue to share ideas until all groups have shared.
4. The facilitator holds a whole class discussion and invites the remaining students to share what they heard that was similar across all the responses or a unique response they want to elevate.

Facilitate the discussion to ensure that students identify molecules on their Lesson 3 Student Guide Part 3: Obtaining Evidence About What Is in Milk. Share with students now that they have identified the molecules that are in milk, they will be able to track what happens to these molecules as they are consumed and travel through the digestive system.

Part 4: Working With Orders of Magnitude

Share with students that to help figure out what happens to the molecules in milk as they move through the digestive system, it will be helpful to consider the scale at which this process is occurring in the body. To begin, show students a meter stick. Share with students that this tool is used to measure objects that are up to 1 m or 100 cm in length. Ask students to share objects they think are approximately this size. Acknowledge student responses and record them on the board in a table such as the one below. Examples may include a desk, a cabinet, a car wheel, a doorway, or a small child.

Object	Size (Max)	Scale Difference from Meter Stick	Scale Difference From Previous Object
Meter Stick, Desk, Car Wheel, Doorway	1 m in length	1	N/A

STUDENT SUPPORT
Students may bring forward a variety of ideas depending on their backgrounds. Accept and encourage different responses here.

Then, ask students what measurement on the meter stick would represent an object that is ten times smaller than the full meter stick and what kinds of objects are approximately this size. Acknowledge student responses, record them on the table on the board, and confirm that this measurement is 1/10th of the size of the full meter stick, which is 0.1 m or 10 cm. Examples of objects may include a small toy, a pen/pencil, a small bowl, someone's hand, or a book.

Object	Size (Max)	Scale Difference from Meter Stick	Scale Difference From Previous Object
Meter Stick, Desk, Car Wheel, Doorway	1 m in length	1	N/A
Small toy, Pen/Pencil, Small Bowl, Hand, Book	10 cm in width	1/10	1/10

Again, ask what measurement would be ten times smaller than this and what kinds of objects are this size. Acknowledge student responses and confirm that this measurement is 1/100th of the original meter stick size, which is 0.01 m or 1 cm. Brainstorm objects of this size again and acknowledge student examples such as the width of a grain of rice, a grain of salt, and a penny.

Object	Size (Max)	Scale Difference from Meter Stick	Scale Difference From Previous Object

Meter Stick, Desk, Car Wheel, Doorway	1 m in length	1	N/A
Small toy, Pen/Pencil, Small Bowl, Hand, Book	10 cm in width	1/10	1/10
Grain of Rice, Grain of Salt, Penny	1 cm in width	1/100	1/10

Share with students that when they are relating the size of objects by a factor of 10, they are working with a concept called **orders of magnitude.** Define orders of magnitude as the approximate size or quantity of something as measured in factors of 10. Add orders of magnitude to the table on the board, and fill in the order of magnitude column. Ask students to share what they notice about this column compared to the "Scale Difference" column.

Object	**Size (Max)**	**Scale Difference from Meter Stick**	**Scale Difference From Previous Object**	**Order of Magnitude Difference From Previous Object**	**Order of Magnitude Difference From Meter Stick**
Meter Stick, Desk, Car Wheel, Doorway	1 m in length	1	N/A	0	0
Small toy, Pen/Pencil, Small Bowl, Hand, Book	10 cm in width	1/10	1/10	1	1
Grain of Rice, Grain of Salt, Penny	1 cm in width	1/100	1/10	1	2

Build on student responses to confirm that for each factor of 10 in size difference, the order of magnitude changes by 1. Share with students that in the human body, the concept of orders of magnitude will be helpful in understanding how different parts of the body

relate to each other in terms of their size. Introduce the Size & Orders of Magnitude tool by distributing the Lesson 3 Student Handout Size & Orders of Magnitude. Ask students to share what they observe about the way the tool is set up. Build on student responses to confirm that the tool shows:

- Different units used to measure the size of objects.
- Each unit is related to the next by one or more factors of 10.
- Orders of magnitude are used to relate the size of objects to each other.
- There are a few objects listed on the tool that we are familiar with, such as a grain of rice or a grain of salt.

Allow students some time to label on the Orders of Magnitude tool a few of the objects that they brought up in the discussion. Ask a few students to share where they labeled the objects and how the tool shows their relative sizes by factors of ten. Confirm that as you move down each line on the scale, the size decreases by a factor of ten, and vice versa.

STUDENT SUPPORT

Depending on students' previous mathematics experience, you may need to review what scientific notation indicates and its relationship to orders of magnitude. Consider writing out the full fraction and/or decimal for several examples and demonstrating that each scientific notation number is ten times smaller than the previous number as you move down the scale.

CCSS SUPPORT

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
6.EE.A.1 Write and evaluate numerical expressions involving whole-number exponents.

This activity addresses both of these Common Core State Standards by actively involving students in working with multiple units and exponents and comparing one measurement to another. Utilize the student support suggestion above to support students in reaching this standard.

Introduce students to the first piece of evidence that they will observe to help figure out how molecules in milk are digested. Show the Lesson 3 Student Handout Enzyme Illustration. Share with students that this illustration shows multiple levels of scale in the human body to depict how the molecule sucrose, or table sugar, that is added to chocolate milk is broken down in digestion.

Allow students time to label each example of different structures, cells, and enzymes in the models on their Size & Orders of Magnitude tool. Invite students to share where they labeled these objects on the tool. You may want to project a version of this tool on the front board and label it together. Then, ask students to record the relative scale and orders of magnitude relationships for the objects in Lesson 3 Student Guide Part 4: Working With Orders of Magnitude.

As students work, circulate the room to ask questions such as:

- How can you mathematically determine the relative sizes?
- What does one order of magnitude difference indicate about size? Two? Three?

When students finish, invite a few students to share what they found and confirm the correct relationships that students share. Then, ask students how they think determining these size relationships can help them better understand the models. Summarize what students found by saying something like, "Based on the different sizes of objects in these diagrams, we can see that the structures in the human body that are involved in digestion are many different sizes, including sizes we can see, such as meters, to very small sizes, such as in micrometers or nanometers. Orders of magnitude are a useful way to see how the size of various small objects, like organs, cells, and molecules, relate to each other."

CCC SUPPORT

SPQ-H4: Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Throughout the unit, students will regularly observe and use models of each of the organs, tissues, glands, cells, and molecules involved in various body processes. The size relationships in these models may be difficult to interpret without making sense of the different scales depicted in each of the models. Therefore, the purpose of introducing orders of magnitude at this point in the unit is for students to begin to see the relative sizes of organs, tissues, glands, cells, and molecules so that students can begin to develop a sense of the scale relationships of these structures. Throughout the remainder of Module 1, students will continue to use SPQ-H4 as a focal element and will continue to use the Size & Orders of Magnitude tool to identify the relative sizes of different objects and structures in the body. In the remainder of the unit, students can return to this tool to remind themselves of the size relationships of different structures and molecules involved in other body processes.

Now that students have oriented themselves to the size depictions in the models, ask them to use a Think-Pair-Share to interpret what they see in the illustration. Students can first record a summary of what they see in the illustration on their Lesson 3 Student Guide Part 4: Working With Orders of Magnitude. Facilitate the share-out such that students agree that:

- The small intestine is made of structures at different scales, including m (1), cm (10^{-2}), and um (10^{-6}), and involves even smaller molecules called enzymes (nm, 10^{-9}).
- The epithelial cells in the small intestine have an enzyme that breaks apart sucrose.
- The enzyme takes the molecule sucrose and breaks it apart into two smaller molecules, glucose and fructose.

Build off student responses to confirm that at the surface of the small intestine, the epithelial cells release a small molecule enzyme to digest the sucrose in milk into two smaller molecules called glucose and fructose.
Share with students that they will gather more information on how additional molecules in milk are digested in the next activity.

Part 5: Obtaining Evidence About How Enzymes Digest Molecules in Milk

Share with students that the enzyme sucrase is just one of many involved in the digestive system and that students will investigate if and how different enzymes are involved in the digestion of the rest of the molecules in milk. Direct students' attention to each of the four lab stations around the room and share that students will now obtain information from texts and complete experiments to determine the role of different organs in the digestion of milk. Show students the Lesson 3 Student Handout Station Cards and associated lab materials at each of the four stations. Hold a Tool Talk in which you describe to students the relevant safety considerations and procedures for using the lab equipment without giving away the outcomes of what students observe at each station. Place students in small groups and share with students that they will rotate through four stations. Students may move, in groups, through the stations in any order.

Allow time for students to do so, recording their findings on their Lesson 3 Student Guide Part 5: Obtaining Evidence About How Enzymes Digest Molecules in Milk. Students should also record up to four different examples of the size of different body parts, cells, and molecules involved in digestion on their Size & Orders of Magnitude tool. As students work, circulate the room to ask probing questions such as the following to see how students are making sense of the texts and the results of the experiments:

- What is the function of this organ in digestion?
- What enzymes are produced by the cells in this organ?
- What are the sizes of the different objects and molecules involved in digestion in this organ? How do they relate to one another?
- How do the cells of this organ help in digestion? What enzymes do they produce?
- What results did you see from your experiment? Do the enzymes from the cells of this organ play a role in digesting the molecules in milk? What evidence shows you that?

After students have completed each station, hold a whole-class discussion for students to share out what they found at each station. Use the Domino Share Routine:

1. Each group nominates a spokesperson.
2. As a student from group 1 shares, all other students serve in a "listener" role, noting patterns or ideas that emerge as the group continues to share.
3. Spokespersons from each group continue to share ideas until all groups have shared.
4. The facilitator holds a whole class discussion and invites the remaining students to share what they heard that was similar across all the responses or a unique response they want to elevate.

Facilitate the discussion such that students agree that:

- The epithelial cells of the mouth produce an enzyme called amylase that breaks down starch into glucose. The mouth also chews solid food. The experiment showed us that the mouth is not involved in the breakdown of the molecules in milk.
- The parietal cells of the stomach produce stomach acid, which helps enzymes function, and the chief cells produce enzymes like pepsin that digest proteins such as whey into amino acids. The experiment showed us that pepsin is able to break down milk proteins into amino acids.
- The epithelial cells of the small intestine produce enzymes like sucrase, lactase, and lipase to break down fats and sugars. The experiment showed that lactase and lipase do break down fat and lactose in milk.
- In the large intestine, bacteria work with the epithelial cells to digest fiber. Goblet cells also form mucus to make the waste pass through the large intestine.

Then, ask students what general conclusions they can draw about how different kinds of cells help digest food. Facilitate the discussion such that students agree that:

- Different organs have different types of cells that each have a unique specialized function. In the digestive system, a series of **specialized cells** each create different types of enzymes to support the digestion of different types of molecules in foods.
- Each organ and their parts are made of cells that have functions and specialized structures for cellular functions to break down milks' nutrients into molecules.

Part 6: Defending Claims

After the discussion, share with students that now that they have gathered evidence about how each organ of the digestive system is involved in the digestion of the molecules in milk, they will return to the claims they made at the beginning of the lesson to evaluate their validity.

Ask students to choose two claims to evaluate. Individually, they will select evidence from the station activity (either from the reading or from the experiment) that is relevant to evaluating the claims they chose and then record a conclusion that supports or refutes the claim. Allow students time to record their evidence and conclusions on their Lesson 3 Student Guide Part 6: Defending Claims

FORMATIVE ASSESSMENT OPPORTUNITY

Students defend a claim about how multiple organs and their specialized cells produce enzymes to digest food molecules into smaller molecules, describing them using orders of magnitude.

Assessment Artifacts:

- Students' evaluation of the claims about how milk is digested in different organs (Lesson 3 Student Guide Part 6: Defending Claims).

Look Fors:

- Students evaluate claims using multiple pieces of evidence from the investigation and from the texts provided (ARG-H5).
- Students describe the role of various specialized cells in the digestion of the molecules in milk (LS1.A-H1).
- Students describe how the digestive system is a hierarchical system made of multiple interacting organs, which are made of multiple smaller-scale components such as specific cell types (LS1.A-H3).
- Students use orders of magnitude to describe the scale relationships between organs, cells, and molecules to evaluate the claims (SPQ-H4).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	Claim: I think milk is digested in the mouth. This happens by chewing food. Evidence: The mouth station reading states that the mouth uses amylase to break down	Claim: I think milk is digested in the mouth. This happens by chewing food. Evidence: The mouth station reading states that the mouth uses amylase from the acinar cells in the salivary glands to break down starch molecules.	Claim: I think milk is digested in the mouth. This happens by chewing food. Evidence: The mouth station reading states that the mouth uses amylase (10^{-9} m) from the acinar cells (10^{-6} m) in the salivary glands (10^{-3} m) to break down starch molecules. According to the Chemistry of Milk reading,

	starch molecules. Reasoning: Starch isn't digested in the mouth, but I'm still unclear if milk has starch in it. Conclusion: I think the claim is supported.	Reasoning: Because milk does not have starch in it, milk does not start to break down in the mouth. Instead, the different molecules in milk are digested in other parts of the digestive system by the enzymes released from cells like epithelial cells in the small intestine. Conclusion: Based on this evidence, I refute the claim that milk is digested in the mouth.	milk does not have starch as a chemical component. Reasoning: Because milk does not have starch in it, milk does not start to break down in the mouth. Instead, the different molecules in milk are digested in other parts of the digestive system by the enzymes released from cells like epithelial cells in the small intestine. Conclusion: Based on this evidence, I refute the claim that milk is digested in the mouth.
How to Achieve This Level	Student completes 0-1 out of 4 Look Fors	Student completes 2-3 out of 4 Look Fors	Student completes 4 out of 4 Look Fors

To Provide Additional Support For Students:

If students need additional support evaluating the claims, consider:

- Ask students questions as they work that press their thinking, such as:
  - What evidence is most relevant to this claim?
  - What role do cells and enzymes play in digestion in this organ?
  - What molecules are being digested in this organ?
  - What are the sizes of the organs, cells, and molecules involved in digestion? Which is the biggest? Which is the smallest?
- Focus students on a specific claim to evaluate or a specific piece of evidence to use.
- Provide students with a graphic organizer to help them sort evidence according to how relevant it is to each of the claims the class came up with.
- Engage students in a peer feedback session. Provide students with the Look Fors, and use a protocol such as Tell-Ask-Give or norms such as SPARK. Students can use the Look Fors to provide feedback to each other on how they can improve selected Look Fors in their work.

After students have individually evaluated the claims, do an activity to visualize how the class supported or refuted each claim. Place a piece of chart paper at each station that represents each of the organs of the digestive system. On each chart paper, write a claim from the class list in Part 2 that is relevant to that organ at the top of the page (e.g., at the Mouth station, record a claim that has to do with milk being

digested in the mouth). Then, below the claim, make a T-chart with two columns: Support the Claim and Refute the Claim. A sample of one of these charts for the mouth is shown on the next page.

Claim: I think milk is digested in the mouth. This happens by chewing food.	
Support the Claim	Refute the Claim

Students can then take a sticky note, write their name, and place it in the appropriate column on each chart to show if they think the evidence they obtained supports or refutes the claims on the different chart papers.

Allow students time to place their sticky notes on each of the chart papers for claims they evaluated. Then, visit the first poster, the Mouth, select a few sticky notes, and ask the owner to share how they think the evidence they obtained supports or refutes the claim. If students are divided on their support or refutation of a claim, spend some time allowing students to engage in argumentation. Ask students questions such as the following to support their argumentation:

- Can you share the evidence you found that would support or refute this claim?
- Can you say more about the evidence you found? Why is it relevant to this claim?
- What evidence do you have to argue against your peer who instead supported/refuted the claim? What evidence more clearly supports your conclusion?

Move to each poster and repeat this process. Facilitate the conversation at each poster so students agree that:

- Digestion of the lactase in milk primarily occurs in the small intestine when lactase breaks down lactose.
- Digestion of the proteins in milk primarily occurs in the stomach when pepsin breaks down proteins.
- Digestion of the fats in milk primarily occurs in the small intestine when lipase breaks down fats.

Transition to the next lesson by sharing that now that students have figured out how digestion functions in each of the different organs individually, students will next try to put together the different functions of the whole digestive system to see how they work together to digest milk.