Metabolic Reactions

Lesson 11-12

How do things inside our bodies work together to make us feel the way we do?
How do things inside our bodies work together to make us feel the way we do?

Metabolic Reactions: Inside Our Bodies

OpenSciEd Unit 7.3
How do things inside our bodies work together to make us feel the way we do?

Metabolic Reactions: Inside Our Bodies

OpenSciEd Unit 7.3

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UNIT OVERVIEW

How do things inside our bodies work together to make us feel the way we do?

This unit on metabolic reactions in the human body starts out with students exploring a real case study of a middle-school girl named M’Kenna, who reported some alarming symptoms to her doctor. Her symptoms included an inability to concentrate, headaches, stomach issues when she eats, and a lack of energy for everyday activities and sports that she used to play regularly. She also reported noticeable weight loss over the past few months, in spite of consuming what appeared to be a healthy diet. Her case sparks questions and ideas for investigations around trying to figure out which pathways and processes in M’Kenna’s body might be functioning differently than a healthy system and why.

Students investigate data specific to M’Kenna’s case in the form of doctor’s notes, endoscopy images and reports, growth charts, and micrographs. They also draw from their results from laboratory experiments on the chemical changes involving the processing of food and from digital interactives to explore how food is transported, transformed, stored, and used across different body systems in all people. Through this work of figuring out what is causing M’Kenna’s symptoms, the class discovers what happens to the food we eat after it enters our bodies and how M’Kenna’s different symptoms are connected.

Through these investigations, students:
- Develop and use a model to explain how food is rearranged through chemical reactions, forming new molecules that support growth and/or release energy as this matter moves through the human body.
- Develop and use a model to explain how different subsystems of the body work together to provide cells what they need to function.
- Construct and defend a scientific explanation of how M’Kenna’s condition (celiac disease) leads to weight loss and lack of energy.
- Construct a scientific explanation based on evidence for how environmental factors, such as food intake, influence the growth of animals.


Focal Science and Engineering Practices (SEPs): Developing and Using Models, Analyzing and Interpreting Data, Engaging in Argument from Evidence

Focal Crosscutting Concepts (CCCs): Systems and System Models, Structure and Function

Building Toward NGSS Performance Expectations

MS-PS1-1:
Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-2:
Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-LS1-3:
Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

MS-LS1-7:
Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

MS-LS1-5:
Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

How students will engage with each of the phenomena:
## UNIT STORYLINE

How do things inside our bodies work together to make us feel the way we do?

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<tr>
<td>What is going on inside M’Kenna’s body that is making her feel the way she does?</td>
<td><img src="Image" alt="M’Kenna’s Doctor’s Note describes the symptoms in different parts of her body." /></td>
<td>M’Kenna, a 13-year-old girl, seems to be really sick and we aren’t sure why. We notice she has symptoms in all different parts of her body and some symptoms started before others. We figure out:</td>
<td></td>
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<tr>
<td>Anchoring Phenomenon</td>
<td><img src="Image" alt="Diagram" /></td>
<td>We think that it has to do with her digestive system, but we have a lot of questions that we need to answer in order to figure out what is causing M’Kenna’s symptoms.</td>
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<tr>
<td><img src="Image" alt="Diagram" /></td>
<td><img src="Image" alt="Diagram" /></td>
<td>We have some ideas for possible investigations we could pursue.</td>
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**Navigation to Next Lesson:** We figured out that most of M’Kenna’s symptoms were coming from her digestive system and that those symptoms started happening first. Also, we wondered if we could “see” inside M’Kenna’s body in some way. So, we want to somehow see inside her digestive system next.

| **LESSON 2**    |                             |                          |                     |
| 2 days          |                             |                          |                     |
| Can we see anything inside M’Kenna that looks different? | ![Image](Image) | We examined M’Kenna’s endoscopy report and some graphs that show what happens to food as it travels through M’Kenna’s digestive system in comparison to a healthy one. We figure out: |
| Investigation   | ![Image](Image) | We think that the digestive system is made up of different parts called organs. The different organs have similarities and differences in their structures. |
| ![Image](Image) | ![Image](Image) | M’Kenna’s small intestine doesn’t look the same as a healthy one. |
| ![Image](Image) | ![Image](Image) | In a healthy person, many different substances in a graham cracker decrease as they travel through the small intestine. |
| ![Image](Image) | ![Image](Image) | Some substances in M’Kenna’s small intestine decrease, but others do not decrease as much compared to a healthy person. |

**Navigation to Next Lesson:** We have evidence that something is going on in M’Kenna’s small intestine. Also, the graphs showed that some food substances seem to disappear in a healthy small intestine. Where are they going? What is the small intestine doing with food molecules?
### Lesson 3

2 days

**Why do molecules in the small intestine seem like they are disappearing?**

**Investigation**

We plan and conduct an investigation to determine whether food molecules can pass through or travel across a surface with a structure similar to the small intestine. We argue for how our results and molecular models of the substances we used might help explain how some kinds of food molecules could be absorbed into the body by passing through openings in the wall of the small intestine and others could not. We figure out:

- The structure of the walls of the small intestine and dialysis tubing must have microscopic openings/gates in them that let small food molecules through but not large ones.
- Sugar molecules, such as glucose, are much smaller than molecules of complex carbohydrates, such as starch, but both are made up of the same types of atoms (carbon, hydrogen, and oxygen).

### Lesson 4

1 day

**What happens to food molecules as they move through the small intestine and large intestine?**

**Investigation**

We investigate food data from the mouth to the large intestine and determine that (1) most of the molecules are gone by the time they reach the large intestine, and only fiber and water remain, and (2) M'Kenna has other molecules in her large intestine. We examine poop data to confirm what molecules should be expected. We figure out:

- As food moves through a healthy digestive system, food molecules disappear. We think they might be getting absorbed.
- Fiber always stays the same in the digestive system and leaves the body as poop.
- Most other molecules are gone when they reach the large intestine in a healthy person. Only fiber and water remain.
- M'Kenna's poop contains some additional food molecules (glucose, starch, fatty acids), too, which are not found in a healthy person's solid waste.
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| LESSON 5        |                             | We make observations about what happens to complex carbohydrates, other than fiber, in the mouth. We analyze data from a graham cracker noting how the complex carbohydrates and glucose change in the mouth. We also notice that glucose molecules look like smaller pieces of complex carbohydrates. We plan and conduct an investigation to determine whether complex carbohydrates, other than fiber, undergo a chemical reaction when mixed with a substance in saliva to produce glucose. We figure out:  
- Some types of complex carbohydrates decrease in the mouth while glucose increases.  
- Chemical reactions that occur in the mouth break down some types of complex carbohydrates into glucose, and no matter disappears when this happens. | ![In the mouth, some types of substances seem to decrease, and new substances increase.](image) |

**Navigation to Next Lesson:** We figured out that chemical reactions can occur in the mouth to break most complex carbohydrates down into glucose. Now we are wondering, Do chemical reactions occur anywhere else in the digestive system to break large food molecules down into smaller food molecules?  

| LESSON 6        |                             | We analyzed food data, noting how the food changes in different parts of a healthy digestive system. We noticed patterns in which some molecules decreased by the same amount that other molecules increased. We argued that this is a sign of chemical reactions happening in the digestive system. We figured out:  
- Certain food molecules are broken down by different portions of the digestive system.  
- Different organs in the digestive system perform different functions. | ![The quantity of some types of molecules (complex carbohydrates, fats, and proteins) decreases by the same amount that the quantity of other types of molecules (glucose, fatty acids, and amino acids) increases.](image) |

**Navigation to Next Lesson:** We think that we have figured out a lot! We can now account for one kind of molecule changing into another throughout the digestive system; in some places, like the small intestine, smaller food molecules are getting absorbed, and, in other places, like the large intestine, large food molecules are excreted. We think we should try to put all of these pieces together.
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| 2 days         |                             | We developed a model to represent the inputs, processes, and outputs of the digestive system and the role that the system plays in breaking down matter through chemical reactions, absorbing food, and excreting unused matter. We constructed an argument, based on evidence, to eliminate two of five possible conditions that could be causing the symptoms that M’Kenna is experiencing in her digestive system. We figure out:  
- In a healthy digestive system, multiple subsystems, or organs, work together to help the body break large food molecules down into smaller food molecules.  
- Large food molecules are broken down into smaller food molecules through chemical reactions that occur in the mouth, stomach, and small intestine.  
- Each organ plays a different role in the breakdown of large food molecules.  
- In a healthy person, the small intestine absorbs the small food molecules that had been broken down in preceding organs in the digestive system. | |
| What is the function of the digestive system, and how is M’Kenna’s digestive system different? | Putting Pieces Together | All previous phenomena | |

**Navigation to Next Lesson:** We have eliminated two of the possible gastrointestinal conditions that could be causing M'Kenna's symptoms, but we need to know more about the small intestine to figure out what is causing M'Kenna's symptoms. We decide to look more closely at the small intestine.

| LESSON 8       |                             | We zoom in on the small intestine to better understand its structure and function. First, we take stock of where we are in the body by mapping M'Kenna's system to the organization of the human body systems. We identify structures called “villi” that line the small intestine and use an interactive simulation to learn more about the villi.  
- Body systems are organized by System > Subsystems > Tissues > Cells.  
- M'Kenna’s intestinal wall surface is flat and a healthy person’s is folded back and forth (forming villi).  
- Increased villi height results in more surface area that food molecules come into contact with as they flow through the small intestine; this results in a greater rate of absorption in a healthy small intestine than in M'Kenna’s. | |
| 2 days         |                             | We figure out:  
- Body systems are organized by System > Subsystems > Tissues > Cells.  
- M’Kenna’s intestinal wall surface is flat and a healthy person’s is folded back and forth (forming villi).  
- Increased villi height results in more surface area that food molecules come into contact with as they flow through the small intestine; this results in a greater rate of absorption in a healthy small intestine than in M’Kenna’s. | |
| What does the surface of M’Kenna’s small intestine look like up close compared with a healthy one? | Investigation | When you look closely at the lining of the small intestine, you see long finger-like projections. | |

**Navigation to Next Lesson:** We argued from evidence why M’Kenna is experiencing many of her digestive symptoms. Now we are ready to answer some questions on our Driving Question Board.
### LESSON 9

#### 1 day

**How can a problem in one body system cause problems in other systems?**

**Problematising**

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<td><strong>How can a problem in one body system cause problems in other systems?</strong></td>
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<td><strong>Problematising</strong></td>
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**M’Kenna’s Doctor’s Note shows symptoms in other body systems.**

**Navigation to Next Lesson:** In this lesson, we think that problems in M’Kenna’s digestive system are connected to her symptoms in other systems, such as brain fog, fatigue, and not gaining weight. This made us wonder if the fact that she is not able to get food molecules absorbed from her small intestine (digestive system) as quickly as a healthy person might be part of the reason she isn’t gaining weight.

### LESSON 10

#### 2 days

**Why is M’Kenna losing so much weight?**

**Investigation**

**Navigation to Next Lesson:** We do an experiment and light different types of fats on fire and see that they seem to disappear, too, just like when a person loses weight! This makes us wonder, what is actually happening to fat when it burns?
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| **What happens to matter when it is burned?** | ![Image](image1.png) | We conduct two investigations to trap the gases produced by burning food. First, we burn vegetable oil in a closed versus an open system and compare the masses of the systems. Second, we burn vegetable oil in a closed system and track carbon dioxide and water in the air within the system using a sensor. We figure out:  
  - Food goes through a chemical reaction when it is burned. This reaction provides energy.  
  - Foods require something from the air in order to make energy.  
  - When food reacts with air to release energy, carbon dioxide gas and water vapor are its products. | ![Image](image2.png) |
| Investigation  |                             |                          |                    |

Food is burned in an open system, and the mass decreases. However, when food is burned in a closed system, the mass does not decrease, while carbon dioxide and water vapor increase.

**Navigation to Next Lesson:** In this lesson, we figured out that a chemical reaction occurs when food is burned and that it uses air and produces carbon dioxide, water vapor, and gives off energy. This made us wonder—is this chemical reaction really happening in our bodies to provide us energy for the activities we do? Are we literally burning fat or other kinds of food inside our bodies?

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</table>
| **Does this chemical reaction to burn food happen inside our bodies?** | ![Image](image3.png) | We gather evidence showing that a chemical reaction happens in the cells of the body to provide them with energy. The reaction helps us explain why certain materials that we take into our bodies, like oxygen and food, are different from the materials that leave our bodies, like carbon dioxide and water. If our activity level increases, the chemical reaction happens faster to meet cells’ needs. We figure out:  
  - Oxygen is taken in (inhaled) through the lungs, and carbon dioxide is exhaled through them. These gases enter and exit the blood by passing through the lung membrane wall and are transported to and from the cells of the body.  
  - Chemical reactions that happen within cells inside the body rearrange glucose and oxygen into carbon dioxide, water, and energy that the cells in the body can use.  
  - This reaction, which we call cellular respiration, happens when we’re resting, but it happens even more when we exercise. | ![Image](image4.png) |
| Investigation |                             |                          |                    |

Percent saturation of gases in the blood changes throughout the body.

**Navigation to Next Lesson:** We figured out a lot about how our bodies get energy to do the things we need to do! We’re ready to put all these pieces together and connect what we’ve figured out to explain some of M’Kenna’s non-digestive symptoms.
LESSON 13

2 days

How does a healthy body use food for energy and growth, and how is M’Kenna’s body functioning differently?

Putting Pieces Together

We developed a model to show how food is rearranged in the body in terms of matter inputs, processes, outputs, and energy flows within a body system. We constructed an explanation to explain the relationships between differences in M’Kenna’s digestive system and a healthy digestive system to predict symptoms (effects), such as M’Kenna’s decreased growth rate. We figured out:

- The digestive system takes in food and breaks it down through chemical reactions, and the small food molecules get absorbed into the body’s circulatory system through the small intestine.
- The respiratory and circulatory systems work together to bring food molecules and oxygen to cells in the body and to remove carbon dioxide.
- Humans need to take in food. Food is a type of fuel, which means that it can react with other substances to release energy.
- Cells rearrange food and oxygen through a chemical reaction, which creates carbon dioxide and water and releases energy that cells can use.
- The body system’s inputs are food (molecules mainly with C,H,O’s) and oxygen. Outputs are mainly carbon dioxide, water, and energy (students might also include poop, which is mostly fiber and water).
- When the body takes in excess food, it can be stored for later in the form of fat molecules in the body.
- When the body doesn’t take in enough food, it can use the stored fat or food molecules dedicated for growth to burn as fuel. Most of the matter goes into the air when fat is burned.
- M’Kenna’s body used fat molecules stored in her body when she wasn’t getting enough matter from food.
- M’Kenna is absorbing less food through her small intestine, so the cells in all the tissues in her body aren’t getting enough energy, which is causing her non-digestive symptoms.

Navigation to Next Lesson: We’ve accomplished our mission to figure out what was causing M’Kenna’s symptoms, and we’ve learned a lot about how our bodies work along the way! We can now explain things like how our bodies can get energy from eating a piece of chicken, and that got us thinking...what if we fed a dog that piece of chicken? Would their bodies do the same thing as our bodies? Would their bodies do chemical reactions to break food down and burn it for energy?
LESSON 14

2 days

Do all animals do chemical reactions to get energy from food like humans?

Investigation

Readings about different animals show that they all seem to break down and burn food for energy using chemical reactions, even though they may have different structures inside of their bodies.

We investigate an organism of our choice to see if it does metabolic reactions similar to the way humans do. We argue from evidence whether (1) our organism does chemical reactions to break down and burn food molecules the same way as humans and (2) it has the same structures inside its body that work together to do those processes. Then we come together to share our findings with other groups to give and receive feedback. We figure out:

- Animals, aside from humans, rearrange matter in food through chemical reactions to release energy.
- In animals, besides humans, oxygen reacts with food to produce carbon dioxide and provide energy.
- Other living things, such as anaerobic bacteria, don’t need oxygen for chemical reactions to get energy.
- Animals might have different structures in their bodies that do the same functions.

LESSON 15

2 days

What questions on our Driving Question Board can we now answer?

Putting Pieces Together

Animals, such as bears, can do the same chemical reactions as humans do to get energy from food to use now, to use for growth, or to store for later.

We revisit the Driving Question Board and discuss all of our questions that we have now answered. Then we demonstrate our understanding by individually taking an assessment. Finally, we reflect on our experiences in the unit.

LESSONS 1-15

29 days total
TEACHER BACKGROUND KNOWLEDGE

What are the Disciplinary Core Ideas (DCIs) in the context of the phenomena?

“Disciplinary Core Ideas” are reproduced verbatim from A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. DOI: https://doi.org/10.17226/13165. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

In this unit, students are introduced to the anchoring phenomenon—a 13-year-old girl named M’Kenna who feels very sick. Key symptoms are introduced in Lesson 1, specifically, M’Kenna’s digestive symptoms, her weight loss, and lack of energy. Students map those symptoms onto which body system they think they are associated with. Then students are introduced to a second set of data that show key differences compared to a healthy person in (1) the structure of one of her organs and (2) the relative amounts of absorption for different substances in a sample of food she eats. Together these data sources suggest that there might be something different happening in M’Kenna’s body compared to a healthy body. Through investigating M’Kenna’s case, students figure out how the body processes, transports, and uses food molecules inside the body.

In the first lesson set, students figure out how a healthy digestive system breaks down food into smaller molecules, which are then absorbed into the blood in the small intestine. M’Kenna’s body is breaking down food into small molecules, but not all of those molecules are absorbed by her small intestine. This is because her small intestine has a major structural difference from a healthy small intestine. M’Kenna’s small intestine is smooth, and an intestine with proper function has many finger-like folds. Students figure out that the folds create more surface area through which food molecules can pass. Consequently, her solid waste contains not only fiber, like a healthy body’s waste does, but also useful molecules that were not absorbed by her body, including glucose, amino acids, and fatty acids.

In the second lesson set, students develop models of various pathways showing how food molecules are rearranged in the body through chemical reactions to create energy, store matter for later use, and use matter for growth within a body system. Then they apply these ideas back to M’Kenna’s case to connect to how different body systems work together and can explain the way that M’Kenna is feeling.

This unit builds towards the following NGSS Performance Expectations (PEs):
- **MS-LS1-3:** Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
- **MS-LS1-5:** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- **MS-LS1-7:** Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

This unit applies the following NGSS PEs in a new context:
- **MS-PS1-1:** Develop models to describe the atomic composition of simple molecules and extended structures.
- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

This unit reinforces these NGSS PEs that students should have previously developed. In the OpenSciEd Scope and Sequence, these are first built in Unit 7.1. In this new context of metabolic reactions, students will engage in the analysis and interpretation of various forms of data on how molecules change or do not change as they move through digestion. Chemical reactions starting in our mouths and stomachs and continuing throughout the rest of the digestive system drive this change, breaking down large food molecules into smaller ones. Some molecules, like fiber, stay the same throughout digestion and, therefore, do not undergo chemical reactions.

The current version of the unit expands students’ understanding of metabolic reactions, which include these Grade 6-8 DCI elements:

**LS1.A Structure and Function**
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

**LS1.B Growth and Development of Organisms**
- The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range.

**LS1.C Organization for Matter and Energy Flow in Organisms**
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.

**PS3.D Energy in Processes and Everyday Life**
Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

There is a slash through the pieces of the DCIs that are not developed in this unit. In the OpenSciEd Scope and Sequence, students will develop an understanding of genetic factors in the OpenSciEd Unit 8.5, how plants do chemical reactions to obtain and store energy in the subsequent OpenSciEd Unit 7.4 and interactions with other organisms in the ecosystem dynamics OpenSciEd Unit 7.5. In addition, this unit introduces the concept of food as fuel and lays the groundwork for future units in which students figure out that both food and other sources of fuels are sources of matter and sources of energy, drawing connections between chemical reactions that transfer and convert energy in living and nonliving systems. This connects to the idea identified on page 196 of Framework for K–12 Science Education (National Research Council, 2012): “By middle school, a more precise idea of energy—for example, the understanding that food or fuel undergoes a chemical reaction with oxygen that releases stored energy—can emerge.”

You can view the placement of this OpenSciEd Unit 7.3 and associated units within the OpenSciEd Scope and Sequence document.

What should my students know from earlier grades or units to be successful in this unit?

This unit uses Disciplinary Core Ideas (DCIs) that students should have previously learned by working on the following NGSS performance expectations MS-LS1-1 and MS-LS1-2.

- **LS1.A Structure and Function:**
  - All living things are made up of cells.
  - Cell membranes are a boundary that controls what enters and leaves the cell.

This unit builds on disciplinary core ideas that students should have developed in working on MS-PS1-1, MS-PS1-2, MS-PS1-3, and MS-PS1-5 related to chemical reactions and molecular structure:

- **PS1.A: Structure and Properties of Matter**
  - Atoms form molecules that range in size.
- **PS1.B: Chemical Reactions**
  - The total number of each type of atom is conserved, and, thus, the mass does not change.
  - In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

Students would benefit from having prior experience doing the following focal science and engineering practices (SEPs) at the 3-5 grade-band level. They include the following:

- **Developing and using models**
  - Identify limitations of models.
  - Develop and/or use models to describe and/or predict phenomena.
  - Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.
  - Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.
- **Analyzing and interpreting data**
  - Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
  - Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
  - Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- **Engaging in argument from evidence**
  - Respectfully provide and receive critique from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
  - Construct and/or support an argument with evidence, data, and/or a model.
  - Use data to evaluate claims about cause and effect.

Having students familiar with using focal crosscutting concepts (CCCs) for this unit at the 3-5 grade-band level would be helpful. They include the following:

- **Systems and system models**
  - Students understand that a system is a group of related parts that make up a whole and can carry out the functions that its individual parts cannot.
  - They can also describe a system in terms of its components and their interactions.
- **Structure and function**
  - Students learn different materials have different substructures, which can sometimes be observed; and substructures have shapes and parts that serve functions.
What are some common ideas students might have?

Students will likely bring prior ideas about digestion to this unit, including familiarity with some of the molecules found in food, such as proteins and carbohydrates. Students might have a general understanding that digestion breaks down food to make it available to our bodies. However, connecting the breakdown of some food molecules into other molecules will be new for most students. In particular, the idea that starches in food might all get turned into sugars will seem counterintuitive, since students may have heard that eating sugary foods is bad for us. Also, students may think that the proteins, fats, and carbohydrates we eat go directly to other parts of the body, from the mouth or stomach. This unit provides evidence that this may not be happening until the foods reach the small intestine, and that, instead, chemical reactions are occurring with the food before that point. The main thing this unit clarifies, which students likely take for granted, is that they know we need food to grow; but seeing that a chemical reaction is needed to rearrange the molecules of food to make materials the body can use is a key mechanism that will be new to them.

Though students may still have lingering ideas that matter can disappear, this unit will provide evidence that matter is moving from one system to another, or outside of the system. Therefore, most of the matter when losing weight leaves the body through the carbon dioxide in our breath, rather than disappearing. As in the prior unit on chemical reactions, students see that, even though the properties of the matter may change as it is rearranged through chemical reactions, all the components are still there, and mass is conserved.

Students may already know that we breathe in oxygen and breathe out carbon dioxide, although this can be leveraged in the unit. They may believe that a simple model of gas exchange happens in or near the lungs, but what happens to these gases beyond the lungs will largely be unknown to students. Some students may know that parts of the body need oxygen, like the brain, but may not connect this need for oxygen to a cellular process involving chemical reactions to burn food as fuel for energy. This unit helps students develop a richer understanding of these gases as reactants and products of a chemical reaction in cells. Students know that we need oxygen, but this unit helps students explain why we need oxygen to live.

If students have developed a model of selective permeability of cell membranes and know that organs are made of networks of interconnected tissues, this unit will help them deepen their understanding of why some, but not all, molecules can cross that surface. If they have not developed a model of selective permeability of cell membranes, this will lay the foundation for it and will be revisited throughout the unit.

What modifications will I need to make if this unit is taught out of sequence?

This is the third unit in 7th grade in the OpenSciEd Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier in the middle school curriculum. These include:

- Introducing the students to the concept of a Driving Question Board and a shared set of classroom norms. This would not be necessary if taught after other OpenSciEd units.
- Supplemental teaching of the nature of matter, so that students see matter as made of particles.
- Supplemental teaching of the foundations for chemical reactions in PEs: (1) **MS-PS1-1** Develop models to describe the atomic composition of simple molecules and extended structures and (2) **MS-PS1-2** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. This unit is designed to come directly after two units involved in the foundations of chemical reactions and explicitly builds on those understandings. It is critical to note that students need the idea of chemical reactions and the idea that matter can be rearranged through these reactions yielding resultant materials with different properties to develop the explanations in this unit.
- Supplemental teaching of PEs: (1) **MS-LS1-1** Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells and (2) **MS-LS1-2** Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function. This unit does not introduce cells to students. It uses that prerequisite knowledge to build understanding that the organization of the body goes from cells, to tissues, to organs, to subsystems to multiple subsystems working together in one body system.
What are prerequisite math concepts necessary for the unit?

In Lesson 8 students use a NetLogo simulation to discover the relationship between the rate of food absorption and the height of villi that line the small intestine. Prerequisite math concepts that may be helpful include:

- **CCSS.MATH.CONTENT.6.NS.C.8**: Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane.
- **CCSS.MATH.CONTENT.6.RP.A.2**: Understand the concept of a unit rate \(\frac{a}{b}\) associated with a ratio \(a:b\) with \(b \neq 0\), and use rate language in the context of a ratio relationship.
- **CCSS.MATH.CONTENT.7.SP.C.6**: Approximate the probability of a chance event by collecting data on the chance process that produces it and observing its long-run relative frequency, and predict the approximate relative frequency given the probability.
- **CCSS.MATH.CONTENT.7.SP.C.8.C**: Design and use a simulation to generate frequencies for compound events.

Students analyze and interpret M'Kenna's height and weight growth charts in Lesson 10. Prerequisite math concepts that may be helpful include:

- **CCSS.MATH.CONTENT.6.SP.B.5.C**: Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

In addition, within the domain of Measurement and Data in the Common Core Mathematics Standards, students will be drawing on what they have learned across a number of standards under the category of Represent and Interpret data for grades 1-5 when they are generating and interpreting the tables and graphs of their data collected from the simulation and during analysis of several food molecule graphs in many lessons across the unit.
ASSESSMENT SYSTEM OVERVIEW

Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the “Assessment Icon” in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

<table>
<thead>
<tr>
<th>When</th>
<th>Assessment and Scoring Guidance</th>
<th>Purpose of Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 1</td>
<td>Initial Model</td>
<td>Pre Assessment&lt;br&gt;The student work in lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn where students are coming in and what ideas they have that you can build on in this unit. The more ideas in your classroom the better. Use students’ initial models to highlight the range and diversity of ideas the class as a whole has. Also, use the Consensus Discussion about the initial class model to assess which ideas students are bringing up in their models to explain the cause or underlying mechanism of M’Kenna’s symptoms. Look for agreement on key components of the models, such as (1) the digestive system, (2) input of food, and (3) some connections to other body systems.&lt;br&gt;Students have opportunities to pose and build on other students’ questions during the construction of the Driving Question Board (DQB). Look for how or why questions about phenomena that seek to investigate interactions inside of the body, either within a system or between different systems.&lt;br&gt;Use your judgement on how to press students to form how and why questions. If a student struggles with sharing, choose to celebrate going public with questions over getting to a how or why question. If students do not ask questions about the phenomenon that seek to investigate how different body systems work together, that’s okay at this point. They will have another opportunity to add questions to the DQB in Lesson 9. Also, questions can be added to the DQB at any point throughout the unit. We recommend always having sticky notes or index cards on hand to capture students’ evolving questions.</td>
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<tr>
<td>Lesson 7</td>
<td>Student (group sensemaking) Formative Assessment Teacher Key</td>
<td>Formative&lt;br&gt;This lesson is a group or pair formative assessment. Its intent is to give you information about where students are at with using evidence to begin to reason about the cause and effect of M’Kenna’s illness. The key is meant to support you in facilitating students, there are no correct answers. In this formative lesson you should be listening for students use of evidence from the unit so far and students’ understanding of what that evidence can tell them and not tell them.&lt;br&gt;This lesson is also providing motivation for lesson 8, where students receive the definitive piece of evidence that helps them to make a confident diagnosis.</td>
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<td>Lesson 8</td>
<td>Student Assessment Teacher Key- Sample Student Response Argument Rubric</td>
<td>Summative+Formative&lt;br&gt;This lesson is a putting the pieces together lesson. It includes a summative midpoint assessment that can provide formative information for moving forward in the unit. There is an argument rubric specific to this unit that should be used to score student responses. The goal of this assessment is to get students writing complex arguments on their own. You can decide how much or how little scaffolding your students need. Some prompts are included in the assessment.&lt;br&gt;This midpoint assessment is important formatively to make sure the class is on the same page and ready to move forward in the unit. At this point, students should be comfortable with the evidence and reasoning laid out in the rubric for this assessment.</td>
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<td>Lesson 10</td>
<td>Initial Ideas Discussion</td>
<td><strong>Formative / Pre Assessment</strong>&lt;br&gt;This lesson connects Lesson Set 1 with Lesson Set 2. As a formative, pre-assessment for Lesson Set 2, use the Initial Ideas Discussion in the Navigation activity about what could be causing M’Kenna’s weight loss to see if students could connect to what was figured out in Lesson Set 1 when she could not get enough matter inside her body because her villi in her small intestine are damaged. If students do not make this connection, that’s OK. They will have the opportunity to do so later on.</td>
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<tr>
<td>Lesson 14</td>
<td>Self Assessment Argumentation rubric with Gotta-Have-It Checklist</td>
<td><strong>Formative and Self Assessment</strong>&lt;br&gt;Student have an opportunity to develop arguments using evidence from their Gotta-Have-It Checklists. Then students do a gallery walk to provide each other with specific feedback using an argumentation rubric. With feedback from their peers, students can revise their work with a group. Although students can use the self-assessment rubric for giving and receiving feedback at any time, this is a designated spot for having students reflect.&lt;br&gt;&lt;br&gt;&lt;strong&gt;Peer Assessment&lt;/strong&gt;&lt;br&gt;In this lesson, students use a general argumentation rubric paired with their co-constructed Gotta-Have-It Checklist from the previous lesson to provide peer feedback to small groups on their arguments.</td>
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<td>Occurs in most lessons</td>
<td>Progress Tracker</td>
<td><strong>Summative</strong>&lt;br&gt;This lesson includes a transfer task to give students an opportunity to use the 3 dimensions to make sense of a different phenomenon. This is meant to be a summative assessment task for the unit and it gives you a grading opportunity. The task includes a teacher reference with a scoring guide as well as a modeling rubric for scoring the modeling question. Scoring guides are meant to highlight important ideas students should be including in their responses to the prompts. They are listed as bullet points so you can decide how to score them appropriate to the norms in your classroom. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated.&lt;br&gt;&lt;br&gt;If your students are struggling or you think they will need support in creating the model, there is a modified student assessment that gives students the components and interactions they will need in their model.</td>
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<tr>
<td>Anytime after a discussion</td>
<td>Student Self Assessment Discussion Rubric</td>
<td><strong>Formative and Student Self Assessment</strong>&lt;br&gt;The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress Tracker can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative 'grade' other than for completion.</td>
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When Assessment and Scoring Guidance Purpose of Assessment


There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process.

Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

Lesson-by-Lesson Assessment Opportunities

Every OpenSciEd lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher’s discretion.

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For more information about the OpenSciEd approach to assessment and general program rubrics, visit the OpenSciEd Teacher Handbook.
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<td>Lesson 1</td>
<td><strong>Develop models</strong> based on evidence to predict the relationships between components of a system (organs and body systems) to explain what is causing M’Kenna to feel the way she does (effect). <strong>Ask questions</strong> that arise from careful observation of M’Kenna’s Doctor’s Note to clarify and seek additional information about what is going on inside the body of M’Kenna that is causing her symptoms (effect).</td>
<td>Developing and Using Models; Cause and Effect; Systems and System Models  Teachers can use students' initial models to highlight the range and diversity of ideas the class as a whole has. See more information about how to use initial models in the Overall Unit Assessment table above. Also, use the Consensus Discussion about the initial class model to assess which ideas students are bringing up in their models to explain the cause or underlying mechanism of M’Kenna’s symptoms. Look for agreement on key components of the models, such as (1) the digestive system, (2) input of food, and (3) some connections to other body systems. Do not worry if students do not know the function of each body system. There will be other opportunities to build understanding of other body systems. See the teacher guide in this section for some guidance to help students if they are struggling when developing their initial models. <strong>Asking Questions; Cause and Effect</strong> Students have opportunities to pose and build on other students' questions during the construction of the Driving Question Board (DQB). Look for how or why questions about phenomena that seek to investigate interactions inside of the body, either within a system or between different systems. Use your judgement on how to press students to form “how” and “why” questions. If a student struggles with sharing, encourage them to go public with questions rather than focusing specifically on forming a “how” or “why” question. If students do not ask questions at this point about the phenomenon that seek to investigate how different body systems work together, this is okay. They will have another opportunity to add questions to the DQB in Lesson 9. Also, questions can be added to the DQB at any point throughout the unit. We recommend always having sticky notes or index cards on hand to capture students' evolving questions.</td>
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<td>Lesson 2</td>
<td><strong>Analyze and interpret data</strong> to identify patterns in how the structures of the digestive system and relative amounts of substances in a food sample appear in a healthy person as compared to in M’Kenna.</td>
<td>Analyze and Interpreting Data; Structure and Function; Systems and  While students are examining the illustrations of the organs of the digestive system, circulate among them to listen to group and/or pairs conversations to determine the prior knowledge and the similarities and differences between the different organs. Listen for students noticing the similarity that each organ is hollow inside based on the illustrations. However, you should avoid taking this as an opportunity to grade students on their understanding of these structures. It is more important to begin to determine how well students can analyze and draw comparisons using the illustrations. Students are not using the term “subsystem” at this point, even while they are examining organs, which are subsystems, but they are beginning to make connections between the structure of an organ and its ability to perform a job inside of the digestive system. They are just seeing the body as one system that has a digestive system, and that digestive system is made up of different structures. This understanding will be critical for future discussions of subsystems. <strong>Analyze and Interpreting Data; Patterns</strong> Students should be examining the endoscopy images in an attempt to determine if there are any patterns in the images that will help support their idea that M’Kenna’s symptoms are centered in the digestive system. When attempting to determine if a cause and effect relationship exists, students need to realize that phenomena may have more than one cause and the fact that two events are happening at the same time doesn't necessarily imply causation. When students are analyzing the graph or food molecules in the small intestine, they will need to pay attention to the patterns in data that indicate that some of the molecules are not leaving M’Kenna’s small intestine. If some students are struggling with the data analysis, provide additional support by gathering them in a small group to facilitate a more structured analysis of the endoscopy images.</td>
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<td>Lesson 3</td>
<td>Plan and conduct an investigation in order to produce data to determine whether food molecules can travel from one side of a system to the other side separated by a solid structure with properties similar to the walls of the small intestine.</td>
<td>Planning and Carrying Out Investigations; Systems and System Models; Structure and Function During the Plan Our Investigation section, while students write individually in their notebooks, walk around and look for them to make connections between the inside of the dialysis tube system as a representation of the inside of the small intestine. Therefore, students should place the food molecules inside the dialysis tube. If students struggle to connect their system to the small intestine have them revisit their Lesson 2 data that showed differences in food within the small intestine. At the end of day 1, look at Part 2 of Dialysis Tube Investigation to see students make their predictions about which molecule(s) will go through the structure of the dialysis tube system. Look at the connections between student predictions and the reasoning they use to justify their explanations. Student answers will vary based on their ideas from Lesson 2. If students struggle to connect their predictions with reasoning, prompt them to think about why they set up the pieces of the dialysis tube system in the way they did. Developing and Using Models; Structure and Function When students make sense of the results (Part 6 of Dialysis Tube Investigation), look at questions 2 and 3 to see if students connect their results from the dialysis tube investigation. Students should add the idea of openings/gates to the dialysis tube structure and that there must be something different about the structure of food molecules that allows glucose to fit through but not starch. If students struggle with connecting the glucose moving through the dialysis tube to the openings, ask them if they have ever experienced one material going through a barrier of some kind while another material did not, such as when sifting sand. At the end of day 2, students argue from evidence with their partners about what to add to their models in their Progress Trackers. Look for students to argue that, because glucose went from the inside of the dialysis tubing to the outside of the dialysis tubing, this must imply that there are openings or gates in the dialysis tubing and, thus, the small intestine. Students will also argue from evidence that using the molecular representations of starch and glucose show that starch is the larger structured molecule, impacting it from functioning by moving through the gates of the small intestine. If students struggle with the use of evidence, you might provide sentence starters or fill in the blanks for the reasoning part. See the teacher reference for an example.</td>
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<td>Lesson 4</td>
<td>Analyze and interpret data to determine patterns and limitations of the relative amounts of different molecules in food as it moves through the digestive system of a healthy person versus M’Kenna.</td>
<td>Analyzing and Interpreting Data; Patterns During the Follow the Graham Cracker section, while students are using the I² sensemaking strategy to analyze and interpret data, circulate and guide students to look at one type of food molecule from one graph to the next, noting patterns in the quantities that change from one graph to the next in a healthy person versus M’Kenna. Support students in sensemaking by guiding them to look at one type of food molecule at a time to recognize any patterns. If students are struggling to notice patterns, use two sheets of paper to help them cover extraneous information so that they can isolate one type of food molecule on both graphs. Ask guiding questions to help students identify patterns, such as “What do you notice about the amount of ___ in the mouth compared to what it is in the small intestine?” Keep track of the patterns students notice on a chart that is visible to all students in the group. Breaking the information down into smaller chunks will make it easier for them to analyze. During the Add to Our Progress Tracker section, you’ll examine students’ Progress Trackers for evidence of the data analysis that they did earlier. Prompt students to refer back to the evidence presented in the graphs so that their models are based on evidence. If students’ models do not show conclusions from the data analysis, ask guiding questions, such as “What did X data tell us?” and “Where do you have that learning represented in your model?”</td>
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| Lesson 5 | **Analyze and interpret data to identify a relationship** within the data that shows that the amount of certain **food molecules** (complex carbohydrates) decrease, and other **food molecules** (glucose) increase as they move through the mouth, which is a **correlational relationship**. Students argue that we need more data to determine the **cause** of the observed increases and decreases in food molecules. | **Analyzing and Interpreting Data; Cause and Effect: Patterns**  
After analyzing data from eating a graham cracker on **Analyze Data from Eating a Graham Cracker**, students record their analyses in their science notebooks. Look for students’ ability to recognize the pattern in the data that shows that, as complex carbohydrates decrease in the mouth, glucose increases. In addition, students should note that the relative quantities of the other food molecules in the mouth do not change. Students should be able to argue that the relationships that they observe are correlations, but not causations. If students struggle to identify patterns in the data, consider providing additional support in reading the graph provided. If students struggle to distinguish between causal and correlational relationships in the data, consider taking the time to distinguish between causal and correlational relationships. |
| Plan and conduct an investigation to produce data to determine whether **food containing complex carbohydrates**, but not glucose, undergoes a chemical reaction in the mouth and that this reaction turns the complex carbohydrates into **glucose** when mixed with a substance found in saliva (amylase), which is identified by a **pattern change** in the color of the food indicator. | **Planning and Conducting Investigations; Patterns**  
Students record their plans and findings from an investigation that they have planned and conducted on **Chemical Reactions in the Mouth Data Table**. Prior to conducting the investigation, check student work to make sure that they have planned an investigation similar to the one provided on **Unknown material with identifier: mr.l5.tref**. After conducting the investigation and recording their results, check student work using **Unknown material with identifier: mr.l5.tref** to determine if students have identified the anticipated patterns in the data. During the Making Sense discussion, listen for students to connect their findings to their data analysis of the graham cracker graph. If students struggle to plan the investigation, consider spending more time framing the goals of the investigation. If students struggle to interpret their findings, consider returning to the investigation in Lesson 3 so that students can remind themselves about the use of the various indicators. |
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| Lesson 6 | **Analyze and interpret data to identify patterns in the amount that certain food molecules (complex carbohydrates, proteins, and fats) decrease and other food molecules (glucose, amino acids, and fatty acids) increase as they move through different organs in the digestive system.** | **Analyzing and Interpreting Data: Patterns**
Students will have the opportunity to use Progress Tracker to look for the idea that large food molecules are broken down into smaller food molecules through chemical reactions. This presents an opportunity to determine how well students understand and make connections to this key idea partially developed as part of Lesson 5.

If students are struggling with this key idea, consider pulling the class together to interpret the multiple lines of evidence identified in Lesson 5 to support this claim. The multiple lines of evidence include: observations from eating a cracker, data analysis from eating a graham cracker, reading about digestion and amylase, and an investigation to determine if chemical reactions occur in the mouth. Consider suggesting a way to represent this idea to students by showing several large boxes attached to one another being broken down into separate boxes. Understanding that large molecules can be broken down into smaller molecules is central to students' understanding of what is taking place in the digestive system.

**Analyzing and Interpreting Data: Structure and Function**
Use the analysis and interpretation of data on Data of Food Molecules for a Healthy Person in students' science notebooks to look for analysis and interpretation of the data that can serve as evidence for the claim that each organ in the digestive system performs a different function. If students are struggling to analyze the data, consider modeling analysis of the data with the whole class. Redirect student attention to the helpful tips for interpreting the bars in the graph found in Food Molecule Data for a Healthy Person and help students make sense of one organ in the digestive system.

As students are analyzing the graphs, circulate and support students as they look for patterns that can help them explain why the amount of one type of molecule (e.g., protein) might be decreasing by the same amount that another type of molecule (e.g., amino acids) is increasing in the graham cracker in the mouth.

**Analyzing and Interpreting Data: Patterns, Structure, and Function**
Use the Building Understandings Discussion at the end of the lesson to determine if students have come to key conclusions related to MS-LS1-3. First, students should have analyzed data to identify patterns in the functions of each of the organs in the digestive system. Second, students should have interpreted these data as evidence that the digestive system is a system of interacting subsystems that each perform different functions.

If students struggled to analyze the data, consider returning to the data analysis and providing more scaffolding to support students in the analysis. If students struggle to make the connection that the digestive system is a system made up of interacting subsystems, consider physically showing how a piece of food moves through the different organs in the digestive system. Stop the food at each "stop" along the way (as indicated by the graphs) and then analyze each graph. |
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| Lesson 7 | Develop a model based on multiple lines of evidence to represent the inputs, processes, and outputs of the digestive system and the role that the system, and the subsystems within it, play in breaking down matter inputs through chemical reactions, absorbing food, and excreting unused matter. | **Developing and Using Models: Systems and System Models**  
Students will develop models throughout this lesson individually, in small groups, and as a whole group. Students should identify the following ideas in their models:  
- The digestive system is a long tube with different parts to it.  
- In one part of the digestive system, the small intestine, small food molecules are absorbed, and large food molecules aren’t.  
- Absorption means that the molecules cross the lining of the small intestine.  
- Fiber is not digested at all and is excreted from the body.  
- Large food molecules can be broken down into smaller food molecules.  
- In another part of the digestive system, the mouth, some types of complex carbohydrates are broken down into smaller pieces through chemical reactions.  
- Other types of food molecules (proteins and fats) are broken down in other parts of the digestive system (stomach and small intestine).  

Respectively provide and receive critiques about small-group models developed to explain how various subsystems in a healthy digestive system interact to move food through a series of chemical reactions to break down large food molecules. | If students are missing ideas, prompt them to revisit their Progress Trackers or science notebooks for key ideas that they are missing. During small-group modeling time, there are suggested prompts to help students when develop their models. In addition to including ideas about the breakdown of food in the digestive system, make sure students are incorporating key ideas about systems and system models, specifically as they relate to the digestive system. Prompt students to include these ideas by asking questions, such as: “What are the inputs, processes, and outputs that you will need to include in your model?” and “How can we differentiate between the processes happening in different parts of the digestive system?” and “Why do the processes need to occur in different parts of the system?” After students develop their Gotta-Have-It Checklists, students use the ideas in the list to develop a model to describe what is happening in a healthy digestive system.  

Engage in an argument from evidence to eliminate two of the five possible gastrointestinal conditions that could be causing the symptoms that M’Kenna is experiencing in her digestive system, based upon how they affect the body as a whole system. | After students update their 3-column Progress Trackers at the end of day 1 of this lesson, collect their Progress Trackers to provide formative feedback to students on their ideas. First, look for all of the ideas from the Gotta-Have-It Checklist represented. Second, provide feedback on the DCIs LS1.A and LS1.C, the CCC systems and system models, and the SEP developing and using models. Specifically, look for students representing ideas that the digestive system is one system within the human body and that it is made up of smaller parts called organs, which are viewed as subsystems in the digestive system. Students should also show that food is digested through a series of chemical reactions that break large food molecules down into smaller food molecules. The chemical reactions involved in digestion occur in different parts of the digestive system. Students should also use the model to show which component they think may function differently in M’Kenna’s digestive system. Finally, students should show the inputs, processes, and outputs of the digestive system. This is a key moment to provide formative assessment. If students struggle to include all of the key ideas in the model, consider working individually or in small groups with struggling students to return to previous investigations and make sense of the findings.  

Engaging in Argument from Evidence: Systems and System Models  
Use Task Parts 1 and 2: Eliminate Possible Conditions and Identify Missing Evidence to assess students’ ability to construct an argument, based on evidence, to eliminate two of five possible gastrointestinal conditions that could be causing the symptoms that M’Kenna is experiencing in her digestive system. Look for students to share ideas referenced on Task Parts 1 and 2: Eliminate Possible Conditions and Identify Missing Evidence. If choosing from five possible conditions is overwhelming to students, consider eliminating one condition by modeling the process for students. If students struggle to back up their claims with evidence, consider revisiting Lessons 1–6 to provide more time for students to make sense of the ideas in those lessons. |
Lesson 8

Engage in an argument from evidence supported by scientific reasoning for how a healthy digestive system rearranges matter through chemical reactions and absorbs food, and how and why M'Kenna's digestive system is functioning differently.

Analyze and interpret data to identify the relationship that taller villi (structure) have more cells that work together to impact the rate of absorption (function) of food molecules into the bloodstream.

Engaging in an Argument from Evidence; Systems and System Models; Structure and Function

In the Part 3: Argue from Evidence What's Causing M'Kenna's Symptoms, students argue from evidence that M'Kenna’s symptoms can be explained by her having celiac disease. Look for students to argue that M'Kenna has celiac because the villi in M'Kenna's small intestine cause her to have a reduced number of cells since taller villi in the small intestine cause there to be more cells, and this does not allow her body to absorb food molecules as effectively as a healthy digestive system. Students combine this evidence with the understanding that the data from her large intestine indicated that food molecules, other than fiber and water, remained in the large intestine after digestion, while in a healthy large intestine only fiber and water remain. While the assessment should be completed independently, some students might benefit from assistance with the organization of their writing. Additional guidance is provided in regard to how to support students with this organization. Then, students exchange written arguments with a peer and provide a critique of their argument based on the sufficiency of evidence provided. Look for students who attend closely to the strength of the argument and identify key pieces of evidence that support it. Provide a review for a small group of students or for the whole class about the key features of a strong scientific argument using Argument Rubric - Part 3 - M'Kenna's Disease for guidance. In Revisit the Driving Question Board, students select three questions from the DQB that they have made progress toward answering. They argue the answer to those questions using evidence that they have collected throughout the unit.

Analyzing and Interpreting Data; Structure and Function

In Examine the Function of the Villi, students collect data from the NetLogo interactive simulation of the small intestine. Students organize data into a table and create graphical displays of the data to demonstrate that villi height increases the number of cells, which has a direct relationship to the rate of absorption of food molecules into the bloodstream. Circulate and observe students to determine whether they are drawing a connection between villi height and the rate of absorption of food molecules into the bloodstream. Listen for students who explain that the cause of the food molecules that remain in M'Kenna's large intestine are a result of her villi being flat and, therefore, having fewer cells. If students are not drawing a connection between villi height and the rate of absorption, gather them into a small group and adjust the simulation together, making the villi height 0, then 5, then 10. After each adjustment, count the number of cells together, writing them down in a public space for comparison. Ask students what they notice about the data, guiding them to see that taller villi have more cells. Have students run three trials—one for each of these villi height adjustments—and add the rate of absorption to the data table. Ask students what they notice about the relationship between the number of cells and the rate of absorption. Scaffolding the activity in such an explicit manner should help students come to the conclusion that taller villi = more cells = higher rate of absorption. Some students may struggle to visualize a data table, and, therefore, have trouble initiating the task of creating a data table to organize their data. Additional guidance is provided to support students who are not constructing an organized data table.

In Add to the 3-Column Progress Tracker, students use all that they have figured out to develop a model to represent what is happening in M’Kenna’s digestive system as compared with a healthy digestive system. Look for students who incorporate the items in the bulleted list into their models in words and pictures. If students do not include an element, ask a targeted question to help students recall something that they figured out in this lesson. For example, if a student does not include something about villi height affecting the number of cells and, therefore, the rate of absorption of food molecules into the bloodstream, ask, “Where can I find information in your model about the villi? How did you show what you learned about the height of the villi from the NetLogo simulation?” This should remind students without giving away key learning.
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| Ask questions to gather more information about how problems in one body system interact with other systems after revisiting M'Kenna's symptom list. | **Asking Questions and Defining Problems:** Teachers can collect *Let's Answer Questions from Our DQB!* after revising the DQB. Look for every student to select questions from careful observation of the phenomenon with M'Kenna's doctor's note that pertain to the initial digestive system cluster of symptoms (on the DQB) and use evidence from lesson investigations. If students are unable to select digestive system questions and connect them to collected evidence, help students pick one lesson and explain how what they figured out in that lesson helps explain one of the questions listed. Students can look at their Progress Trackers from each lesson to help them identify what was figured out in each lesson.

After revisiting M'Kenna's doctor's note and their mapping of her symptoms, students are problematizing M'Kenna’s symptoms in other systems. This is a place to formatively assess if they are able to see that not only is the digestive system a subsystem of other systems but that it is also interacting with other systems. Look for students to notice that there must be a connection between her digestive system problems with absorption and her other symptoms, since her symptoms seem to start in her digestive system. Students will return to this thinking throughout this lesson and in other lessons. If students are unable to come up with the idea that problems in one system could be caused by problems in another system have them look back at their system mapping. If students don't suggest that there might be a connection between systems that they haven't figured out yet, ask them to think about which systems we have we have collected evidence to explain and which symptoms remain unexplained.

At the end of the lesson, students individually fill out their Progress Trackers for Lesson 9. Look for students to explain that we have figured out why most of M'Kenna's digestive system symptoms occur (due to issues with absorption of food in her small intestine), but we can't yet explain how that is causing her symptoms in other body systems, such as brain fog, fatigue, and weight loss. If students struggle to make this connection between systems, have them walk over to the DQB and look at the clusters of questions that don't have any dots on them yet. If they are still not able to make the connection, take out M'Kenna's Doctor's Note to see which symptoms and systems are still not explained.
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| Lesson 10 | **Analyze and interpret data** using graphical displays and statistics to identify temporal relationships to provide evidence for how M’Kenna’s pattern of body growth and weight have changed over time compared with typical children her age.  
**Obtain, evaluate, and communicate information** to determine the central ideas in an article to help determine where fat (matter) goes when people lose weight.  
**Plan and carry out an investigation** to produce data to serve as the basis for evidence to answer the question, Where does matter go when people lose weight? | As a formative, pre-assessment for Lesson Set 2, use the Initial Ideas Discussion in the Navigation activity about what could be causing M’Kenna’s weight loss to see if students could connect to what was figured out in Lesson Set 1 when she could not get enough matter inside her body because her villi in her small intestine are damaged. If students do not make this connection, that’s OK. They will have the opportunity to do so later on.  
**Analyzing and Interpreting Data; Stability and Change** Students are introduced to using statistics in order to identify temporal relationships in M’Kenna’s growth chart. Look for students to identify that M’Kenna’s growth remained stable for about 11 years, and then began to slow down when she turned 13. If students don’t make this connection, you can pull them into small groups to do a more guided data analysis. Also, you might pull different student work samples of their WIS/WIM statements and have the whole class look at what classmates have written. Next, students examine DEXA scans of a human and/or a dog that have lost weight. Look for students to identify that fat was lost over time. This should prompt students to begin to think about where the fat goes when someone loses weight. If students are identifying this, you might ask a question like, “If the animal weighed 60 pounds in this photograph, but 45 pounds in the next photograph, what is the difference in weight? Let’s think about a 15-pound dumbbell you might lift at the gym—that’s quite heavy! Where do you think all that weight went?”  
**Obtaining, Evaluating, and Communicating Information; Energy and Matter** After the students read the article *Children Need More Fat in Their Diets Compared to Adults* for the second time, they answer questions with a partner and discuss those questions as a whole class. During that discussion, look for students thinking about one way people use fat is to “burn” it, but what does burning fat really mean? Students should be wondering where the matter really goes when fat is burned. If this idea does not come out, ask if they have ever heard people say that they are “burning calories” when they exercise, and what do they think that means?  
**Planning and Carrying Out Investigations; Energy and Matter** During part 3 of the investigation, students will be answering the “Making Sense” questions to start to think through what happens to the matter when fat is burned. Look for students being able to make connections from their understanding of chemical reactions from a previous unit with the data they collected during this experiment. For students who are having difficulty with the “Making Sense” questions in Part 3, you could ask additional questions, such as: “What do the changes in the substance color, odor, or state of matter indicate about what happened?” and “Where did the matter in the vegetable oil/animal fat go?” |
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| Lesson 11 | Construct an explanation using both qualitative and quantitative data and scientific reasoning (that burning food produces energy, in the form of heat and light, and products, such as carbon dioxide and water) to describe why the mass of oil burned in an open system changes, while it stays the same in a closed system. | Constructing Explanations; Stability and Change; Energy and Matter  
After burning fat in the closed and open systems, students turn and talk with their partner to make sense of their results. This is a great mid-point formative assessment for teachers to listen to small group discussions and see if students are putting together that, when burning fat and releasing energy, the mass of the open system is changing and the closed system is stable due to matter being trapped within the system.  
At the end of day 1, students will complete Making Sense of Burning Fat Investigation Results part 3 to make sense of their results from burning fat in open and closed systems and measuring changes in the composition of air during the burning of fat in a closed system. Look for students to be able to explain that, due to changes in the mass and amounts of different substances in a closed system and the production of energy, a chemical reaction must have occurred. For students who are having difficulty with the Making Sense questions in part 3, you could ask additional questions like, “How did what we started with compare to what we ended with?” and “Do you have any evidence from our investigation to support that a change has occurred in the system?”  
On day 2, after a Scientists Circle, students will return to their seats and individually process what they have figured out in their Consensus Discussion on their Progress Tracker. Look for students being able to make the connection that burning food undergoes a chemical reaction that produces energy. In order for the energy to be released, the reaction requires oxygen. If students do not make this connection, ask them to look back at Burning Fat in Open and Closed Systems. Remind students that using the evidence that they have collected helps support their arguments. When doing so, ask them to think about what changes they noticed from the beginning to the end of the investigation. Ask them to consider if this reminds them of any other chemical reactions they have seen (such as with the bath bombs and rusting iron) or the graphs of changing amounts of food molecules in M’Kenna’s digestive system. |
Lesson | Lesson-Level Performance Expectation(s) | Assessment Guidance
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Lesson 12 | **Analyze and interpret data to identify spatial and temporal relationships in order to determine causes for changes to blood glucose, oxygen, and carbon dioxide levels in the body.**<br><br>**Obtain, evaluate, and communicate information to clarify a claim that a chemical reaction that produces energy in the body is occurring in different parts of the body and that the body uses more glucose and oxygen to provide energy to cells (effect) during exercise (cause) than while resting.** | **Analyzing and Interpreting Data; Cause and Effect**<br>In the activity, Collect Evidence of a Chemical Reaction: BTB Investigation, students collect data to determine whether the air they breathe out contains carbon dioxide. They also collect data to answer questions about the presence of a chemical reaction in the body that may be related to the chemical reaction they experienced in Lesson 11. Look for students who interpret the data from the investigation to understand that, because we breathe in oxygen (reactant) and we breathe out carbon dioxide (product), a chemical reaction is taking place inside the body. If students do not draw this parallel to the chemical reactions from Lesson 11 during which they burned food, ask students to revisit the models they created in their Progress Trackers. Guide students to examine the reactants and products in their Progress Trackers for reactions that occurred when they burned food outside of the body. Then, ask “Do we have food as fuel? Do we have evidence of carbon dioxide being released as a product?”<br><br>In the activity, Analyze Oxygen and Carbon Dioxide Levels in the Blood for Evidence of a Chemical Reaction, students are given data that tracks oxygen and carbon dioxide levels at different locations coming to and from the heart and lungs. Look for students who notice that the point at which oxygen levels decrease is the same point at which carbon dioxide levels increase. Students should also note the significance of the location being between blood going to other parts of the body and returning back to the heart and lungs. Students should infer that oxygen that travels in the blood is being transferred to other parts of the body, which accounts for the decrease. Students use their knowledge of the products of chemical reactions to assume the increase in carbon dioxide is the result of chemical reactions occurring in other parts of the body. If students do not demonstrate this understanding then return again to the Progress Tracker from Lesson 11, which details the reactants and products of a chemical reaction. Work with students in a small group or individually to connect the decrease in oxygen with the concept of oxygen acting as an input in a chemical reaction. Do the same with carbon dioxide as an output of a chemical reaction. If students are unsure of how to answer question 7 on Oxygen and Carbon Dioxide in the Blood - Part 1, use a picture of the circulatory system to show students where the blood vessels travel in the body. Say, “If the blood is full of oxygen here (point to Location 1) and that amount decreases as it travels throughout the body (trace pattern that outlines where blood travels in the system before bringing it back to Location 4), where else in the body could the oxygen be going?”<br><br>**Obtaining, Evaluating, and Communicating Information; Cause and Effect**<br>In Interpreting Activity Data, students receive oxygen and glucose data over time they must interpret to determine that the body uses more oxygen and glucose to provide energy to different parts of the body when the body is active versus at rest. Look for students who notice that the muscles, brain, and digestive organs use the bulk of the oxygen when the body is at rest because, even when the body is not active, these parts of the body are necessary to keep you alive. Students may claim that increased activity causes the body to need more energy. They identify data they would need to analyze to clarify and support their claim and then interpret data that tracks glucose levels in the blood over a 24-hour period, both with and without exercise after every meal. Students should notice glucose levels drop significantly after exercise, indicating more glucose is needed to provide energy to the body when it is active than at rest. If students do not come to this conclusion, try connecting to students’ past experiences with exercise. Ask students to consider a time when they have exercised, such as during P.E. class or outside playing with friends. Ask students what they noticed about the way their breathing changed as compared to when they are sitting quietly, at rest. Help students understand that the body takes in more oxygen by breathing rapidly because the body needs it when active. Similarly, students may have experienced a time when they have worked very hard or been very active, and it has made them feel hungry. This is a signal the body is in need of glucose because it is used more quickly when the body is active. Review the claims that students have written after examining the data described above. Look for students who include specific data or refer explicitly to the data to write a clear claim. If students do not write a clear claim, provide a sentence stem as support, such as: “The parts of the body that use the most energy when active are ___. I know this because ___.”
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<td>Lesson 13</td>
<td><strong>Develop models</strong> of three possible pathways showing how food is rearranged in the body to create energy, store matter for later use, and use matter for growth within a body system. <strong>Construct an explanation</strong> to explain the relationships between differences in M’Kenna’s digestive system and a healthy digestive system in order to predict symptoms (effects), such as M’Kenna’s decreased growth rate.</td>
<td><strong>Developing and Using Models; Systems and System Models</strong> Students work in small groups to develop models of three different pathways that food entering a body system could take: (1) how the body uses food for energy, (2) how the body uses food not needed right now, and (3) how the body uses food for growth. As groups develop these models, look for them to identify different matter inputs, such as food and oxygen, processes, such as digestion, storage, growth, and cellular respiration, and matter outputs, such as carbon dioxide, water, and fat. Models should also identify different energy flows; for example, in pathway 1, food is broken down and used for energy by the body right away. In pathways 2 and 3, energy from food, and molecules, is stored for later use or to be used in the growth of new tissues. Look for groups to generalize the processes for how healthy bodies use food in each of the three pathways. In pathway 1, models should indicate that food and oxygen enter the body system and are broken down to be used for energy. In pathway 2, models should indicate that excess food is used to create storage molecules, like fat and glucose stored in muscle and liver, which can be used later for energy or growth. In pathway 3, models should indicate that molecules from food can be rearranged to create different tissues in the body like muscle and bone. If groups struggle to identify how food is used differently in each of the pathways, refer them back to their Progress Trackers for Lessons 10-12 when we figured out that the body needs food for growth and that food can be burned for energy. <strong>Constructing Explanations; Cause and Effect</strong> After developing a classroom consensus model, students write an explanation for how M’Kenna’s body is functioning differently than a healthy body. In addition, students return to their Progress Trackers to update them with a 3-column entry. In this update, students use the model they built as a class to develop an explanation for how the systems in a healthy body work together to process matter and energy inputs, processes, and outputs. Students add to their explanations about how M’Kenna’s digestive system is functioning differently and how her digestive condition contributes to the symptoms that she experiences in other systems of her body. Use this opportunity to look for students to identify the cause and effect relationship between decreased food absorption affecting M’Kenna’s energy levels. Students should also explain the relationship between decreased food absorption causing M’Kenna to rely on stored food, or fat, leading to her slowed growth rate or decrease in weight. If students are struggling to make these connections, refer them back to their Progress Trackers for Lesson 12 when they figured out that, when we are active, our body needs more energy, which requires more food.</td>
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| Lesson 14 | Engage in an argument from evidence that, in animals, oxygen reacts with carbon-containing molecules to provide energy and produce carbon dioxide and that organisms might have different structures that work together to do similar functions. | Engaging in Argument from Evidence; Energy and Matter; Structure and Function
Students will be constructing an argument from evidence in small groups and getting an opportunity to revise their arguments. Look for students seeing similarities between their organism and humans by using the evidence connected from the readings that their animal does basically the same chemical reactions as humans to get energy from food, but they might have different structures inside their bodies that are involved. If students are struggling with their arguments, look for the callout box in the activity section of “Research How Other Organisms Get Energy” for questions to help them get started. During the time for students to revise their arguments, if students are struggling to identify how similar and different structures are functioning, help them map those structures to the human structures that they have previously studied.

When students are giving and receiving feedback, you will have an opportunity for students to self assess their ability to give and receive feedback using a rubric. Look for students to honestly assess themselves and their growth throughout the unit. There is a place in Lesson 7 during which students could have used the rubric to self assess their peer feedback. |

| Lesson 15 | Develop a model to explain how bears can rearrange matter in food through chemical reactions to release energy and use stored food in the form of fat to survive during hibernation. Construct an explanation by applying scientific ideas and evidence to show how bears obtain energy to survive for several months without eating during hibernation. | Developing and Using Models; Energy and Matter
This lesson includes a transfer task to give students an opportunity to use the three dimensions to make sense of a different phenomenon. This is meant to be a summative assessment task for the unit and gives you a grading opportunity. The task includes a scoring guide, as well as a modeling rubric for scoring the modeling question. Scoring guides are meant to highlight important ideas that students should be including in their responses to the prompts. They are listed as bullet points, so you can decide how to score them appropriately to the norms in your classroom. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated.

If your students are struggling or you think they will need support in creating the model, there is a modified student assessment that gives students the components and interactions they will need in their models. Reviewing what the class has figured out through answering the questions on the Driving Question Board is one way to help students to prepare for the summative assessment. Reviewing these questions is also a good formative assessment to see if there are any pieces that need to be revisited. |
LESSON 11: What happens to matter when it is burned?

PREVIOUS LESSON
We analyzed trends in M’Kenna’s weight and height and looked at images of weight loss over time. Then, we read an article that says, when kids lose weight, the fat is being “burned.” We wondered if this is the same “burning” as when we light something on fire. We lit different types of fats on fire and saw that they seemed to disappear too.

THIS LESSON
INVESTIGATION
2 days

We conduct two investigations to trap the gases produced by burning food. First, we burn vegetable oil in a closed versus an open system and compare the masses of the systems. Second, we burn vegetable oil in a closed system and track carbon dioxide and water in the air within the system using a sensor. We use the results of these investigations to figure out that food needs to undergo a chemical reaction with oxygen to release energy and that carbon dioxide gas and water vapor are products of that process. We wonder if this reaction could happen inside our bodies.

NEXT LESSON
We will gather multiple sources of evidence to argue that a chemical reaction is occurring to burn food inside the cells of our body. We will consider the purpose of the reaction and analyze activity data to see that, if the activity level changes, then this chemical reaction will happen more or less depending on how much energy our cells need.

BUILDING TOWARD NGSS
MS-LS1-3, MS-LS1-5, MS-LS1-7, MS-PS1-1 (applied in a new context), MS-PS1-2 (applied in a new context)

WHAT STUDENTS WILL DO
Construct an explanation using both qualitative and quantitative data and scientific reasoning (that burning food produces energy, in the form of heat and light, and products, such as carbon dioxide and water) to describe why the mass of oil burned in an open system changes, while it stays the same in a closed system.

WHAT STUDENTS WILL FIGURE OUT
- When food is burned, it goes through a chemical reaction that releases energy.
- Fats require oxygen to release energy.
- When a fat or food reacts with oxygen to release energy, carbon dioxide gas and water vapor are products of that process.
<table>
<thead>
<tr>
<th>Part</th>
<th>Duration</th>
<th>Summary</th>
<th>Slide</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 min</td>
<td><strong>NAVIGATION</strong> Facilitate a discussion around the responses to the questions from the <em>What Happens to Fat When It Burns?</em> activity to support an argument from evidence that a chemical reaction is occurring and that some of the products of that reaction are going into the air.</td>
<td>A</td>
<td><em>What Happens to Fat When It Burns?</em></td>
</tr>
<tr>
<td>2</td>
<td>10 min</td>
<td><strong>PLAN AND CONDUCT A CLASS DEMONSTRATION TO CAPTURE THE PRODUCTS FROM BURNING FAT</strong> Have students brainstorm how we could capture the products of the reaction to examine them more closely. As a whole class, conduct the demonstration comparing the masses of a closed and an open system before and after burning vegetable oil, with students recording the weight of the systems before and after a burn.</td>
<td>B-C</td>
<td>tape, <em>Burning Fat in Open and Closed Systems</em> lab</td>
</tr>
<tr>
<td>3</td>
<td>8 min</td>
<td><strong>BUILDING UNDERSTANDING DISCUSSION: BURNING FAT IN OPEN AND CLOSED SYSTEMS</strong> Facilitate a Building Understanding Discussion to help students argue that (1) some matter must be going into the air; (2) the flame in the closed system went out sooner than the one in the open system because it ran out of something in the air that it needed; and (3) liquid appeared on the sides of the closed-system container walls when the burn was done, and this liquid might be water.</td>
<td>D</td>
<td><em>Burning Fat in Open and Closed Systems</em></td>
</tr>
<tr>
<td>4</td>
<td>4 min</td>
<td><strong>ANALYZE DATA TO DETERMINE WHAT IS IN AIR</strong> Students analyze data for the composition of air.</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10 min</td>
<td><strong>PLAN AND CONDUCT A CLASS DEMONSTRATION TO MEASURE THE CHANGING GAS CONCENTRATIONS WHEN BURNING FAT</strong> Show students how to construct part of the data table and make predictions about how the amount of gases in the air within the closed system will compare before and after a burn. Conduct the investigation by burning vegetable oil in a closed system, but this time, track the carbon dioxide and water levels and have students record the results. Discuss and record what the results show.</td>
<td>F-J</td>
<td><em>Burning Fat in Open and Closed Systems, Burning Fat in Closed Systems and Measuring Gases</em> lab</td>
</tr>
<tr>
<td>6</td>
<td>5 min</td>
<td><strong>MAKE SENSE OF OUR CLOSED VERSUS OPEN SYSTEM RESULTS</strong> Have students explain how this data compares to what they saw when they were tracking different types of molecules in the graphs of the food we ate as it moved from the mouth and into the stomach, and how this also connects to the claim that they made at the start of the lesson. Students also summarize any clues the claim gives them about what might be happening to food inside our bodies and M’Kenna’s body when it is used for energy, or whatever new questions this raises for them.</td>
<td>K</td>
<td><em>Making Sense of Burning Fat Investigation Results</em></td>
</tr>
<tr>
<td>7</td>
<td>10 min</td>
<td><strong>NAVIGATION</strong> Have students review the responses to the “Making Sense” questions that they recorded in their science notebooks from the last class to discuss what happens when food burns.</td>
<td>L-M</td>
<td><em>Making Sense of Burning Fat Investigation Results</em></td>
</tr>
<tr>
<td>8</td>
<td>10 min</td>
<td><strong>CONSENSUS DISCUSSION ABOUT WHAT HAPPENS TO MATTER WHEN IT’S BURNED</strong> Facilitate a Consensus Discussion around the ideas raised in groups in the previous step.</td>
<td>N</td>
<td>discussion norms poster, chart paper, markers</td>
</tr>
<tr>
<td>9</td>
<td>5 min</td>
<td><strong>ANALYZE NUTRITION LABELS TO DETERMINE IF OTHER FOODS PROVIDE ENERGY</strong> Students compare the nutrition labels of carbohydrates and proteins to fat to look for evidence of calories.</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Part</td>
<td>Duration</td>
<td>Summary</td>
<td>Slide</td>
<td>Materials</td>
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</tbody>
</table>
| 10   | 5 min    | **COMPARE CARBON DIOXIDE AND WATER TO FOOD MOLECULES**  
Students revisit structural representations of food molecules that decreased when burning fat in a closed system and compare that with structural representations of air molecules that increased. The molecular representations serve as evidence to explain that a chemical reaction is occurring between air and food when it releases energy. | P-Q   | Air Molecule Reference              |
| 11   | 10 min   | **ADD TO OUR PROGRESS TRACKERS**  
Pull students together to update their Progress Trackers to reflect all of the ideas that students have figured out over the last two lessons that help answer the question, “What happens to matter when it is burned?” | R     | Progress Tracker, markers, chart paper |
| 12   | 5 min    | **NAVIGATION**  
Ask students to brainstorm what sort of additional evidence we would need to figure out if a similar kind of chemical reaction is happening in our bodies to provide us with energy from food. | S     | End of day 2                        |
### Lesson 11 • Materials List

<table>
<thead>
<tr>
<th>Material Type</th>
<th>per student</th>
<th>per group</th>
<th>per class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burning Fat in Open and Closed Systems lab materials</strong></td>
<td>safety goggles</td>
<td></td>
<td>2 digital balances (with a range going up to at least 500 g) with 0.01 g accuracy or better</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 tea candleholders</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 pipette (for vegetable oil)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1/2 cup vegetable oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>timer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>long-handled lighter or matches</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 candle wicks on a metal stand (trimmed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>tape</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>airtight container with sealing lid</td>
</tr>
<tr>
<td><strong>Burning Fat in Closed Systems and Measuring Gases lab materials</strong></td>
<td>safety goggles</td>
<td></td>
<td>long-handled lighter or matches</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 pipette (for vegetable oil)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 candlewick on a metal stand (trimmed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>½ cup of vegetable oil</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>scissors or hobby knife</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>4.75 quart Pyrex bowl with rimmed plastic lid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>detector for both carbon dioxide and humidity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>tape</td>
</tr>
<tr>
<td><strong>Lesson materials</strong></td>
<td>What Happens to Fat When It Burns?</td>
<td></td>
<td>discussion norms poster</td>
</tr>
<tr>
<td></td>
<td>science notebook</td>
<td></td>
<td>chart paper</td>
</tr>
<tr>
<td></td>
<td>tape</td>
<td></td>
<td>markers</td>
</tr>
<tr>
<td></td>
<td>Burning Fat in Open and Closed Systems Making Sense of Burning Fat Investigation Results</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air Molecule Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Progress Tracker</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Materials preparation (75 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Let your front office know that you are burning materials in the lab and make sure that you have temperature-based, rather than smoke-based, fire detectors in the lab.

If your class has a no-flame policy, you can show students these videos: closed versus open system [https://youtu.be/B72ZvlewPoE](https://youtu.be/B72ZvlewPoE), [https://youtu.be/zt_zOeyvxtM](https://youtu.be/zt_zOeyvxtM), and measuring the gases [https://youtu.be/6rgVobTmF08](https://youtu.be/6rgVobTmF08), and they can make their observations and make sense from the data they collect by watching what happens when fat is burned.

**Day 1: Burning Fat in Open and Closed Systems Lab**

- **Setup:**
  - Lay out and test the lab materials as suggested in [https://youtu.be/ITfc-gLDn4s](https://youtu.be/ITfc-gLDn4s) and as outlined in this teacher guide.
  - **Per class:** Make 2 tea candle holders containing 0.5-inch wicks (as you did in Lesson 10) and 3 mL of vegetable oil.
• **Notes for during the lab:**
  - Make sure that your balance can hold at least 500 g and is accurate to 0.01 g.
  - You can cut *Burning Fat in Open and Closed Systems* in half so students get Part 1 and 2 separately.

**Safety:** Make sure you have an area in which you can safely conduct the burn tests. If you do these burn tests in class, make sure they are on non-flammable lab tables. The amount of smoke and ash that will go into the air is minimal, but let your front office know that you are burning things in lab today and make sure that you have temperature-based, rather than smoke-based, fire detectors in the lab. If you are concerned about any of these, you can relocate this lab to be done along a concrete surface outside. Again, let your front office know of this before you take students outside. Be sure to have a fire extinguisher available.

• **Disposal:** Allow the fats to cool completely after burning. Then, put them into a non-flammable container (e.g., a coffee canister) and place in the garbage. You can also put the oil into a freezer to cool before disposing.

• **Storage:** All non-perishable items can be stored for later use at room temperature. Opened oil can be stored on a shelf for one year.

**Day 2: Burning Fat in Closed Systems and Measuring Gases Lab**

**Setup:**
- Lay out and test the lab materials as suggested in [https://youtu.be/aI86XxC85s8](https://youtu.be/aI86XxC85s8) and as outlined in this teacher guide.
- Cut a small slot in the lid of the Pyrex bowl so that the cord of the carbon dioxide and humidity detector can just fit through:
- Make sure to test the carbon dioxide and humidity detector. It should turn on automatically and show readings for each condition.
- **Per class:** Make 1 tea candle holder containing a 0.5-inch wick (as you did in Lesson 10) and 3 mL of vegetable oil.

**Safety:** Make sure you have an area in which you can safely conduct the burn tests. If you do these burn tests in the lab, make sure they are on non-flammable lab tables. The amount of smoke and ash that will go into the air is minimal, but let your front office know that you are burning things in lab today and make sure that you have temperature-based, rather than smoke-based, fire detectors in the lab. If you are concerned about any of these, you can relocate this lab to be done along a concrete surface outside. Again, let your front office know of this before you take students outside. Be sure to have a fire extinguisher available.

• **Disposal:** Allow the fats to cool completely after burning. Then, put them into a non-flammable container (e.g., a coffee canister) and place in the garbage. You can also put the oil into a freezer to cool before disposing.

• **Storage:** All non-perishable items can be stored for later use at room temperature. Opened oil can be stored on a shelf for one year.
Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

In the OpenSciEd Scope and Sequence, the chemical reactions units addressing NGSS PEs MS-PS1-1, MS-PS1-2, MS-PS1-3, MS-PS1-5, and MS-PS1-6 come before this unit. In that prior instruction, students learned that the atoms that make up the molecules of the old substance break apart and rearrange to form new molecules made of the same atoms, only in different arrangements; these new substances have new properties, such as color and odor. Students learned that chemical reactions can release or absorb energy from the surroundings. These ideas are reinforced and built upon in Lessons 5-7, 10, and 11.

While in previous lessons students may have had lingering ideas that matter can disappear when it is burned, this lesson provides evidence that matter does not disappear in the chemical reaction during the burning process. This is due to the conservation of mass in a closed system. This also confirms that a chemical reaction has occurred due to the production of two gases—carbon dioxide and water (vapor).

This lesson solidifies the two ideas identified in the Framework for K–12 Science Education (National Research Council, 2012): “By middle school, a more precise idea of energy—for example, the understanding that food undergoes a chemical reaction with oxygen that releases stored energy—can emerge. (page 196)” This lesson also motivates students to think about how, by the end of grade 8: “...in most animals (and plants), oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce carbon dioxide” (page 148).

Where We Are NOT Going

In this lesson, students put together that food molecules have carbon, hydrogen, and oxygen atoms connected together. When food molecules break apart, the atoms in them rearrange to form new substances (different molecules), and energy is released to the surroundings. However, students do not need to know about bonds breaking and forming in this process, as this is above grade level. Additionally, this lesson and unit do not address the rearrangement of matter by plants. This will be addressed in the next OpenSciEd Unit 7.4.

This lesson addresses the conservation of matter after a chemical reaction. It explicitly confirms that, if these reactions occur in a closed system, the mass of the entire system does not change. In order to remain in the middle-school grade band, students are not asked to balance equations. As stated in the assessment boundary of NGSS MS-PS1-5: “Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.”
LEARNING PLAN for LESSON 11

1 · NAVIGATION

7 min

MATERIALS: What Happens to Fat When It Burns?

Ask students to share their ideas from the What Happens to Fat When It Burns?. Begin class by presenting slide A and having students share out their responses from Lesson 10.

Say, Last time we burned vegetable oil and duck fat and saw that, after several minutes of burning, the mass of both fats decreased. Look back at your responses to Part 3: Making Sense from What Happens to Fat When It Burns? and pick one question to explain your reasoning to your group before we share out as a class.

<table>
<thead>
<tr>
<th>Suggested prompts</th>
<th>Sample student responses</th>
<th>Follow-up questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on the property changes you observed, what can you explain about what happened to the fat in these containers beyond just saying “they burned”?</td>
<td>A chemical reaction must have occurred. Energy was produced because we saw the light and felt the heat.</td>
<td>Can someone remind me what we mean when we say “chemical reaction”?</td>
</tr>
<tr>
<td>Compare the mass of each container before and after each fat burned. If matter can’t disappear, how can you explain the patterns in your data?</td>
<td>If the mass of the container went down, that must mean the amount of fat is going down. The mass went down because some stuff probably went into the air.</td>
<td>Say more about what you mean by “stuff went into the air..”</td>
</tr>
<tr>
<td>What clues does this give you about what might be happening to food inside our bodies and M’Kenna’s body when it is used for energy? Or, what new questions does this raise for you?</td>
<td>(Answers may vary. Accept all responses.)</td>
<td>Who can add onto the idea that ________ is building?</td>
</tr>
<tr>
<td>We said stuff might be going into the air when fat is burned, and that might be the reason the mass was going down. But how would we know if this was true? What evidence could we collect to prove this was happening?</td>
<td>Maybe we could see something going into the air when stuff is being burned. Like sometimes we see some black stuff. Maybe we could collect stuff going into the air or capture it somehow.</td>
<td>How would doing that help us?</td>
</tr>
</tbody>
</table>

Summarize students’ questions. Say, Wow! Our investigations seem to have led us to have even more questions. How exciting! These are really interesting ideas about what might be happening when we burn fat. We have thought about the mass decreasing, a chemical reaction occurring, and energy being produced! Let’s take a few minutes to revise our investigation to help us figure out even more about what happens in the air when fat is burned.
2 · PLAN AND CONDUCT A CLASS DEMONSTRATION TO CAPTURE THE PRODUCTS FROM BURNING FAT

MATERIALS: Burning Fat in Open and Closed Systems lab, science notebook, tape

Brainstorm how to redesign the investigation to capture what is produced from burning the oil. Project slide B. Read the slide and have students turn and talk with a partner for a minute. Then ask for a few students to share their ideas with the whole group:

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
</table>
| What are some ideas that you and your partner had for redesigning this investigation? | We could try to trap the air around the thing we are burning in a container (or bag). 🎯  
We need to make sure that we can seal the bag or container so that nothing can get in or out of the system.  |
| What are some things we will need to keep similar? | We will need to put everything on the balance.  
We will want to use the same oil, wick, and little containers.  
We need to make sure to take the mass at the beginning and end of the investigation. |

Motivate the need to conduct a controlled experiment. Prompt students to think about whether we could do this investigation with only an experimental group (the closed system).

<table>
<thead>
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<th>Suggested prompts</th>
<th>Sample student responses</th>
<th>Follow-up questions</th>
</tr>
</thead>
</table>
| If we redid the burn investigation with just a closed system, would that be enough for us to be able to tell anything? | Yes, because we did an open-system burn last class.  
No, I disagree. If we just used a closed system, it wouldn’t be enough to draw any conclusions. | How would we tell if there is actually a difference in our closed system when doing it this time? What would we compare to our closed system? |

**ADDITIONAL GUIDANCE**

You may want to introduce the idea of running a control condition, which is a useful thing to do when conducting investigations, so that you have something to compare your results to. Emphasize that the open system is our control condition because a good control group should have results that are known. We know from previous experiments that the mass will decrease in the open system. What we are wondering is if matter is going into the air and if the mass will change in a closed system, so that’s our experimental group.

**SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER**

Students may refer back to closed-system experiments that they may have done in their prior work during the OpenSciEd Chemical Reactions units. Emphasize that closed-system experiments allow scientists and engineers to trap all the matter in the system so that they can verify that the matter is conserved in physical and chemical processes. Later in this lesson, students will make the connection that, as energy is transferred as light and heat during a chemical reaction, matter is literally moving into the air.
Have students discuss the following questions.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How could we measure if something is coming out in the closed and open systems?</td>
<td>We could do the same thing as last time, and measure how much they weigh before and after they burn.</td>
</tr>
<tr>
<td>What would that tell us?</td>
<td>We could see if the weight lost between the open and closed system are the same or different. It would tell us if something is going into the air if the mass stayed the same in the closed system. It also might tell us if a chemical reaction is happening.</td>
</tr>
<tr>
<td>Turn and talk with a partner. What do you predict would happen? Why?</td>
<td>We think the same thing would happen as last time with the open system. The mass should decrease. But I think the mass might stay the same in the closed system because I think something new is being produced and going into the air.</td>
</tr>
</tbody>
</table>

Suggest that we try to set this kind of condition up, take some measurements from it, and see whether that helps us figure anything out.

Say, So, some of us think that the fat could be going into the air and some of us are really interested in trying to “capture” the stuff around the fat before and after it burns. Let’s see if doing closed- and open-system experiments helps us figure out where the fat is going when the mass of the fat (oil) decreases when burned.

Have students set up their data tables. Present slide C. Hand out copies of Burning Fat in Open and Closed Systems and have students tape it onto a new page in their science notebooks.

Have students label the first row of the table in part 1 as an OPEN system and the second row of the table as a CLOSED system.

**SAFETY PRECAUTIONS**

Ensure student safety by:

- Have students get safety goggles and put them on.
- Have students collect their science notebooks and chairs and make a circle around the demonstration table. They should sit at least four feet away from it (for safety and so that everyone can see). Emphasize that the energy release in the demonstrations can be dangerous if they get too close.
- Students will be at a common demonstration area for the remainder of this investigation, which is why having seats with them will be helpful.

Perform the demonstration of the open and closed system burns as a class.

1. Take out two tea candle holders with vegetable oil and wicks already in them. Tell students that each has vegetable oil in it. 2. Zero the first electronic balance. Mass the tea candle holder, oil, and wick assembly. Have students record this initial mass of the open system in their data tables.
3. Light the wick and set the timer for 1.5 minutes. Leave the open system on the balance. Let this burn while setting up the closed system. Then record the mass of the open system.

4. Place a loop of tape on the back side of the lid of the airtight container. Stick the second tea candle holder assembly to this loop of tape on the lid. This helps secure the tea candle holder assembly to the lid so that it doesn't slip and spill when you seal the lid on the container. Light the wick. Have another person place the clear part of the airtight container over this.

5. Once the lid is seated into the container, press the button on the lid (which is now on the bottom) to seal the system.
After you press the button on the bottom of the lid should look flat.

6. Zero the second electronic balance. Then mass the entire closed system container with the food (vegetable oil) burning in the tea candle holder. Wait a few seconds for the numbers to stop changing and for the system to equalize on the balance. Have students record the initial mass of the closed system in their data tables. Leave the container on the balance.
7. In 1-2 minutes, the vegetable oil in the closed system will burn out. Have students start taking qualitative observations of this system and record them and the mass of the system now (it should have remained unchanged). Have students record the final mass of the closed system.

8. Suggest that we keep letting the oil burn for another couple of minutes and see whether we notice any mass changes (or additional mass changes, as it will have already probably dropped by 0.1-0.2 g by now). While this is happening, have students make additional observations of the closed-system container and record anything else interesting that they notice in it. After burning for about 4 minutes, blow out the flame and have students record the final mass of the open system.

**ADDITIONAL GUIDANCE**

This electronic balance goes to the 0.01 g. It is very sensitive to movement (even of the air). If the mass seems to be fluctuating, have the students stand back and make sure they are not touching the table or moving air around. If you notice the mass start to increase, give the balance a few seconds to get to an amount and stay there before recording the mass. If mass continues to fluctuate, take the entire system off the balance, zero it, and place the system back on. You should get the same mass as when you started.

**ALTERNATE ACTIVITY**

Students may suggest to let the wick-oil assembly continue to burn on the balance. This will get hot but it is OK to do and will support students in connecting the idea of the mass decreasing with the amount of fat decreasing.
3 · BUILDING UNDERSTANDING DISCUSSION: BURNING FAT IN OPEN AND CLOSED SYSTEMS

MATERIALS: science notebook, Burning Fat in Open and Closed Systems

Have students develop explanations for their results. Students can now remove their safety goggles, but have them keep them out for the next investigation.

Project slide D. Tell students that you are assigning pairs of students to Turn and Talk about one of three questions—A, B, or C—and then report what they discussed in a couple of minutes to the whole group.

Count off pairs of students standing next to each other, “A, B, C, A, B, C . . . ” Then have students find another student with the same letter. Give student pairs two minutes to discuss their question.

ADDITIONAL GUIDANCE

If nothing appears on the sides of the closed-system container, just count off pairs to discuss questions A and B. There should be some water condensation that appears, which is a product of burning oil. It’s OK if it doesn’t come up here. Students will see evidence of the humidity increasing in the next experiment.

Facilitate a Building Understandings Discussion. Have students who discussed question A share an idea that they heard their partner share. Encourage all students to work with and build off their ideas, adding on, offering alternate explanations, or restating the ideas shared so far. Give a couple of minutes to discuss each of the questions (six minutes total).

KEY IDEAS

Purpose of this discussion: Prompt students to share out what they think their results from burning fat in open and closed systems mean. Students should notice and wonder about why the flame went out so quickly in the closed system. This problematizes the next piece of the lesson during which students try to figure out what is being produced from this chemical reaction.

Listen for these ideas:

- The mass of the closed system did not change because we were able to trap whatever was going into the air. The open system mass still went down.
- The flame in the closed system went out sooner than the one in the open system because it ran out of something in the air that it needed.
- Liquid appeared on the sides of the closed-system container walls when the burn was done, and this liquid might be water.

Suggested prompt | Sample student response
--- | ---
A. When burning the fat, why did the mass of the closed system remain stable, while the mass of the open system changed? | In the open system, the stuff that used to be in the fat went into the air and spread out around the room, which is why the mass of the system decreased. So, since the mass decreased, that must mean the amount of fat left in the tea candle holder decreased. But even if stuff went into the air in the closed system, we had it trapped, so we could still detect its mass inside the container.
### Suggested prompt

<table>
<thead>
<tr>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>It ran out of air.</td>
</tr>
<tr>
<td>It ran out of oxygen.</td>
</tr>
<tr>
<td>The oxygen got used by the fire.</td>
</tr>
<tr>
<td>There wasn't enough oxygen left for the fire to keep burning.</td>
</tr>
</tbody>
</table>

### C. What did you see in the air and on the sides of the closed-system container walls when the burn was done? What do you think that substance might be?

(Accept all responses, such as water, smoke, condensation, etc.)

### ASSESSMENT OPPORTUNITY

This is a midway point in building towards the Lesson Level Performance Expectation of Construct an explanation using both qualitative and quantitative data and scientific reasoning (that burning food produces energy, in the form of heat and light, and produces carbon dioxide and water) to describe why the mass of oil burned in an open system changes but in a closed system stays the same. Students should be able to compare the different experimental systems and explain that the open system changed because matter was going into the air, but the mass of the closed system stayed the same because we were able to trap the matter; instead of leaving the system, the matter stayed in the container, and thus could be read by the scale. If students do not make this connection, have them draw where they think the matter went in both the closed and open systems.

Motivate students to look more closely at what is in the air around us.

#### Suggested prompt

<table>
<thead>
<tr>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>The fire in the closed system probably ran out of air, but the open system could use as much air as it needed.</td>
</tr>
<tr>
<td>Yeah, the flame went out because fire needs air (or oxygen), and it ran out of it in the closed system.</td>
</tr>
<tr>
<td>I'm not totally sure.</td>
</tr>
<tr>
<td>I think there is dust. I'm not really sure of everything that's in the air.</td>
</tr>
<tr>
<td>Maybe someone has a list of what's in the air.</td>
</tr>
</tbody>
</table>

Say, I've got some data that shows the most common substances found in the typical air around us. Let's take a look and see what we find.
## 4 • ANALYZE DATA TO DETERMINE WHAT IS IN AIR

**MATERIALS:** science notebook

Notice and wonder about the gases in air. Project slide E. Ask students if they recognize any of these gases shown in the table on the slide and what they know about them. Then ask which of the atoms in the chemical formulas for these gases are ones we have encountered before in our investigations.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What do you notice and wonder about the gases typically found in air?</td>
<td>There are a lot of different gases in the air! Wow! There is so much nitrogen, 78%. The humidity can vary. What does that mean? nitrogen, oxygen, carbon dioxide, water vapor. I haven't heard of argon; what is that? Nitrogen, oxygen, carbon, hydrogen.</td>
</tr>
<tr>
<td>Which of these gases have you heard of before?</td>
<td>nitrogen, oxygen, carbon dioxide, water vapor. I haven't heard of argon; what is that? Nitrogen, oxygen, carbon, hydrogen.</td>
</tr>
<tr>
<td>Notice the symbols for the atoms that make up the molecules, N, O, C, H, Ar. Which of these symbols have we seen in our previous investigations?</td>
<td>nitrogen, oxygen, carbon, hydrogen.</td>
</tr>
<tr>
<td>Does anyone recall what atoms those symbols stand for?</td>
<td>nitrogen, oxygen, carbon, hydrogen.</td>
</tr>
</tbody>
</table>

### ADDITIONAL GUIDANCE

Some students may notice that the possible percentages for water vapor in the air can range from 0 to 4 percent; but if it was 4 percent, then the other numbers wouldn’t add up to 100 percent. If this arises, emphasize that this is a good noticing and important mathematical thinking. Ask students what they think will happen to the other percentages of other gases in the air, in conditions in which the water vapor in the air reaches 4 percent. Students should say that these will drop.

### ATTENDING TO EQUITY

Depending on where you are located, students may be able to make connections to either low or high humidity based on familiarity with their local community. This is an opportunity to have your students come to a consensus definition to describe how much water is in the air and add to your word wall using their personal experiences with water vapor (or lack thereof) in the air.

Problematize what we could do to figure out what gases are changing in the air when burning fat.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>So, we think that this reaction might need oxygen from the air. We think that gases went into the air, which might be a result of the reaction. We think they did because the mass of the closed system did not change.</td>
<td>I don't know? Maybe nitrogen? Could oxygen also go into the air? Carbon?</td>
</tr>
<tr>
<td>So, what gases do you think went into the air when we burned the food?</td>
<td>I don't know? Maybe nitrogen? Could oxygen also go into the air? Carbon?</td>
</tr>
<tr>
<td>How could we figure out what gases went into the air?</td>
<td>Remember when we wanted to know what food molecules were in different foods? We used something (an indicator) to help us see molecules that were there but were too small to see. Is there something like that for gases in air?</td>
</tr>
</tbody>
</table>
Say, I have a device that can detect a couple of the gases in the air. We can use this to measure the changes in the amount of gases in the air as a result of burning the oil. Let's try this test again.

5 · PLAN AND CONDUCT A CLASS DEMONSTRATION TO MEASURE THE CHANGING GAS CONCENTRATIONS WHEN BURNING FAT

MATERIALS: Burning Fat in Closed Systems and Measuring Gases lab, science notebook, Burning Fat in Open and Closed Systems

Introduce the second investigation system. Tell students that we will do the test again for just a closed system, following a similar procedure, but this time, we will use a tool to measure the gas levels in each system so that we can see whether the amounts are changing. ✱

Make predictions for the second investigation system. Project slide F. Emphasize that there are detectors that can detect other types of gases, too, but this detector can only detect a subset of them (carbon dioxide and water vapor). If students wonder, “Isn’t it important to see if there are any changes in N₂ or Argon?” say that the detector you have can only measure CO₂ and water, but maybe they could think of a way to measure N₂ or Argon in our classroom.

Give students a minute to fill in the first column of the part 2 data table shown on the Burning Fat in Open and Closed Systems handout for the substances they have been investigating: something from the air, oil/fat, water vapor, and carbon dioxide.

Then project slide G. Demonstrate how to make predictions in column A by filling out what we think happens to the amount of something needed from the air in a sealed container as the flame burns and eventually goes out.

Ask students what they predict will happen to the mass of the food as it burns. Students will say, It decreases. Emphasize that, since we all agree on this prediction, we should fill in the first column with a down arrow ↓.

SAFETY PRECAUTIONS

Ensure student safety.

- Have students put their safety goggles back on.
- Students should still be in a circle around the demonstration table at least four feet away from it (for safety and so that everyone can see).

Take the initial measurements of the air and food in the closed system. If your school has a no-flame policy, play https://youtu.be/zt_zOeyvxtM.

Add a tea candle holder with a wick. Then put it on the electronic balance. Zero the balance. Add oil using a pipette until the bottom of the wick is covered. Record the initial mass of the tea candle holder assembly with the oil.

Show students the carbon dioxide and relative humidity detector. Show slide H to reference the different parts of the detector.

Tell students that we will be recording the values for the carbon dioxide and water vapor (humidity) in the air now and after the burn.

Practice running the investigation. Ask for a student volunteer to read the readings off of the detector for the amount of carbon dioxide and water vapor (relative humidity). Have them show the other students where they are getting the information on the detector. (The image above shows a carbon dioxide reading of 714 parts per million (ppm) and a relative humidity reading of 37 percent.)
Once values stabilize as much as possible, have students record the carbon dioxide and water vapor values on *Burning Fat in Open and Closed Systems* in column B before the burn. Project slide I.

A nonessential idea in this lesson is to understand what relative humidity measures. But it is worth pointing out that 100 percent humidity does not mean that the air is filled with only water vapor molecules. Here is a short summary you can share with students to explain what it is measuring. Say: **Relative humidity isn't a measure of the percentage of water in the air, but rather how close the amount of water in the air is to the maximum that can be in the air before it reaches the maximum that can be held in the air. For example, 100 percent relative humidity means that the air can't hold any more water vapor without it clumping together and coming out in little droplets. On some days, 100 percent relative humidity could mean that the air has reached that 4 percent value we saw in the range of possible amounts of water vapor found in the air from day-to-day and place-to-place.**

1. Place the tea candle holder with oil and wick on the upside-down cover for the Pyrex bowl. Place the detector next to the candle holder so that there is enough room to place the Pyrex bowl upside down over both things and still have the edge of it sitting on the cover. The cord of the detector should run through the slot that you have cut in the lid.
2. Have a couple of student volunteers get ready to read off carbon dioxide and humidity values from the monitor every 10 seconds when you say “Go.” Have one person read off carbon dioxide readings, one person read off relative humidity readings, and one person say “Now” every 10 seconds. Have another student record these on the board or on a piece of chart paper for the class to reference.

3. Have a piece of tape ready to tape over the hole where the cord enters the bowl, and seal the system closed.

4. Light the wick. Now place the Pyrex bowl upside down over both the tea candle holder assembly and detector and set it in the lid. Tape over the hole where the cord enters the bowl. This is not an airtight system, but it will suffice for capturing the buildup of gases from the burn. Say, “Go.” Now have students read off and record carbon dioxide readings every 10 seconds.

5. After about a minute, the carbon dioxide reading in the container will get above 4,000. This will be the last reading students will be able to report before the “high” warning light comes on.
In another minute the flame will burn out. Then place just the tea candle holder assembly on the balance and record the final mass of the tea candle holder assembly with the oil.

Refer to slide J and have students record the final values for each substance in their data tables. This is highlighted in the green cells in column C on the slide.

Have students individually add arrows in column D, showing them carbon dioxide and humidity going up ↑ (based on the results measured from columns B and C).

6 · MAKE SENSE OF OUR CLOSED VERSUS OPEN SYSTEM RESULTS

MATERIALS: science notebook, Making Sense of Burning Fat Investigation Results

Project slide K. Hand out Making Sense of Burning Fat Investigation Results.

Assign the “Making Sense of Your Results” questions (part 3) as home learning. If time permits, have students return their chairs to their regular tables and work on the questions on Making Sense of Burning Fat Investigation Results. If time is short, or some students are not done, assign the completion of these questions for home learning. Emphasize that sharing their responses to these questions will be what we do at the start of the next class.

End of day 1

7 · NAVIGATION

MATERIALS: science notebook, Making Sense of Burning Fat Investigation Results

Have students review and share their answers to Making Sense of Burning Fat Investigation Results. Present slide L, which has the four questions from the handout that students will discuss in small groups.

Once all students have found their responses and read through them once to themselves, present slide M, which outlines a small-group discussion protocol for students to share their ideas about the “Making Sense” questions.*

Assign students to groups of three and give them about seven minutes to share their ideas in small groups, following the protocol on slide M.

* ATTENDING TO EQUITY

The talking stick protocol is used to ensure equitable floor time for all students in the discussion. The later rounds of discussion encourages students to work with and build off of each other's ideas that are shared in the group.
Facilitate a Consensus Discussion. Project slide N. Gather the class in a Scientists Circle. Review the class created discussion norms and have students pick one to focus on during this Consensus Discussion. Use this opportunity to establish agreement on the ideas that groups were converging on related to the questions discussed in the previous step.

**KEY IDEAS**

Purpose of this discussion: See what we can agree upon regarding what happens to matter and energy when fat is burned in a closed system.

Listen for these ideas:
- Light and heat energy were produced.
- Water appeared on the walls of the container.
- Carbon dioxide increased.
- In order for some substances to increase, other substances had to decrease.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What connections about matter and energy did you make to other students’ ideas during the talking stick protocol?</td>
<td>My partner said that the matter of some substances went down, and I said the matter of other substances went up.</td>
</tr>
<tr>
<td>Can you be more specific?</td>
<td>My partner said that energy was produced.</td>
</tr>
<tr>
<td>How do we know energy was produced in this reaction?</td>
<td>We saw that the mass of the oil decreased, and the amount of carbon dioxide and water increased.</td>
</tr>
<tr>
<td>Where did that energy come from and what evidence do we have that there was energy there to start?</td>
<td>We could see the light and feel the heat.</td>
</tr>
<tr>
<td>So what about other foods we eat besides vegetable oil—can those be burned for energy, too?</td>
<td>The food! The energy was in the oil, and we saw in Lesson 10 that vegetable oil has a lot of calories from fat (which we can use to measure energy).</td>
</tr>
<tr>
<td></td>
<td>If we know that other foods have calories, then we should be able to burn those as well.</td>
</tr>
</tbody>
</table>
9. ANALYZE NUTRITION LABELS TO DETERMINE IF OTHER FOODS PROVIDE ENERGY

MATERIALS: None

Examine nutrition labels to determine if other foods also have energy in the form of calories. Project slide O. Ask students to make noticings about how the food labels for carbohydrates and proteins compare to fat as a source of energy. Ask students to recall the fat label from Lesson 10.

<table>
<thead>
<tr>
<th>Carbohydrate food label: Marshmallow</th>
<th>Protein food label: Tuna</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Marshmallow</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Nutrition Facts</strong></td>
<td><strong>Nutrition Facts</strong></td>
</tr>
<tr>
<td>Serving Size Pieces (28g)</td>
<td>Serving Size 2oz (56g/about 1/4 cup)</td>
</tr>
<tr>
<td>Servings Per Container about 10</td>
<td>Servings Per Container 245</td>
</tr>
<tr>
<td><strong>Amount per serving</strong></td>
<td></td>
</tr>
<tr>
<td>Calories 100</td>
<td>Calories 60</td>
</tr>
<tr>
<td>% Daily Value*</td>
<td>Calories from Fat 10</td>
</tr>
<tr>
<td>Total Fat 0g</td>
<td>% Daily Value*</td>
</tr>
<tr>
<td>Sodium 20mg</td>
<td>Total Fat 1g</td>
</tr>
<tr>
<td>%</td>
<td>0 %</td>
</tr>
<tr>
<td></td>
<td>2 %</td>
</tr>
<tr>
<td>Total Carbohydrate 24g</td>
<td>Saturated Fat 0g</td>
</tr>
<tr>
<td></td>
<td>0 %</td>
</tr>
<tr>
<td>Sugars 17g</td>
<td>Trans Fat 0g</td>
</tr>
<tr>
<td>Protein 0g</td>
<td>8 %</td>
</tr>
<tr>
<td></td>
<td>Cholesterol 25mg</td>
</tr>
<tr>
<td></td>
<td>8 %</td>
</tr>
<tr>
<td></td>
<td>Sodium 0mg</td>
</tr>
<tr>
<td></td>
<td>10 %</td>
</tr>
<tr>
<td></td>
<td>Total Carbohydrate 0g</td>
</tr>
<tr>
<td></td>
<td>0 %</td>
</tr>
<tr>
<td></td>
<td>Dietary Fiber 0g</td>
</tr>
<tr>
<td></td>
<td>0 %</td>
</tr>
<tr>
<td></td>
<td>Sugars 0g</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protein 13g</td>
</tr>
<tr>
<td></td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vitamin A 0%</td>
</tr>
<tr>
<td></td>
<td>• Vitamin C 0%</td>
</tr>
<tr>
<td></td>
<td>Calcium 0%</td>
</tr>
<tr>
<td></td>
<td>• Iron 4%</td>
</tr>
</tbody>
</table>

*Percent Daily Values are based on a 2,000 calorie diet.

**INGREDIENTS:** CORN SYRUP, SUGAR, DEXTROSE, MODIFIED CORNSTARCH, WATER, GELATIN, CONTAINS LESS THAN 2% OF TETRASODIUM PYROPHOSPHATE, NATURAL AND ARTIFICIAL FLAVOR, ARTIFICIAL COLOR.

**INGREDIENTS:** WHITE TUNA, WATER, VEGETABLE BROTH, SALT, PYROPHOSPHATE.

**ATTENDING TO EQUITY**

Add this working definition of fuel to your class word wall so that all students can have a consensus on what the class means when using the word ‘fuel.’ To support Emergent Multilingual learners, make sure to write and draw examples of different fuels. You can also ask students to say the names of fuels in their home language and add those words to the word wall.
<table>
<thead>
<tr>
<th><strong>Suggested prompt</strong></th>
<th><strong>Sample student response</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What food molecules are these mostly made up of?</td>
<td>Marshmallows are mostly made of carbohydrates. Tuna is mostly made of protein.</td>
</tr>
<tr>
<td>Do they contain other substances besides fat?</td>
<td>They have a few other things like sodium, but sodium isn’t a food molecule and neither are those weird chemical names we can’t pronounce in the marshmallow.</td>
</tr>
<tr>
<td>What else do you notice?</td>
<td>Both marshmallows and tuna have calories!</td>
</tr>
<tr>
<td>Can you remind us what you mean when you say “calories?”</td>
<td>Calories are the energy our bodies need to do things like play basketball. Like fat, it has a lot of calories.</td>
</tr>
<tr>
<td>So, do you think that, if we burn these foods, the same thing would happen as when we burned the oil?</td>
<td>We were able to burn the fat and transfer energy as light and heat. So maybe we could burn these foods and they would transfer energy as light and heat, too.</td>
</tr>
<tr>
<td>Do you think we could burn other non-food things and get energy from them?</td>
<td>Answers will vary. We could burn a candle. Gasoline is burned by cars and can catch fire. We burn fuel in our grill or on the stove. Wood.</td>
</tr>
<tr>
<td>So, you are saying that all of these food items, like marshmallows, duck fat, and vegetable oil, and non-food items, like wood and gasoline, have something in common? We could burn any of these things, and we would get energy out of the system?</td>
<td>Yeah, I guess that’s right!</td>
</tr>
<tr>
<td>So, these are all types of “fuels.” A fuel is any material/matter that can react with other substances so that it releases energy. If you burned these other foods as fuel, what do you predict would be the products?</td>
<td>Well, when we burned fat, we made carbon dioxide and water, so if we burn these foods, we might make those same things.</td>
</tr>
</tbody>
</table>

**ALTERNATE ACTIVITY**

Students may want to burn other specific foods (such as marshmallows or cheese puffs) to determine if they provide energy. If time permits, students can build a stand to burn food using a paper clip tapped to a piece of cardboard that is wrapped in tinfoil or in a chunk of clay.

There is also an optional home learning [https://www.mprnews.org/story/2008/04/16/frenchfry_bus](https://www.mprnews.org/story/2008/04/16/frenchfry_bus) or possible substitute day reading about using different fuels to power vehicles (such as a french fry bus) any time after Lesson 11.
**10 · COMPARE CARBON DIOXIDE AND WATER TO FOOD MOLECULES**

**MATERIALS:** science notebook, *Air Molecule Reference*

Revisit the molecular representations of food to look for evidence for the source of matter in the products of carbon dioxide and water. Use *Air Molecule Reference* and *Analyze Data from Eating a Graham Cracker*. Project slides P and Q.

Pose the question, *If carbon dioxide and water molecules are being produced when foods are transferring energy through burning, then the atoms that make them up must be coming from somewhere. Where are they coming from?*

Hand out *Air Molecule Reference* to each pair of students. Tell elbow partners to use this reference to help them discuss this question further.

After a minute, have students share their ideas with the whole class.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where do you think the atoms that make up the carbon dioxide and water molecules started appearing in the container came from as we burned the food?</td>
<td>They came from the food molecules that were burned! Maybe they came from the air, too.</td>
</tr>
<tr>
<td>How is that possible? Who can say more about that?</td>
<td>When we burned the food, the molecules that were part of the food got broken apart, and those atoms rearranged to make new molecules when they reacted with the air.</td>
</tr>
<tr>
<td>So, I hear you saying we started with one substance and ended up with more of other substances through a reaction?</td>
<td>Carbon dioxide and water are made of similar atoms to fat!</td>
</tr>
<tr>
<td>Can someone remind me what we call the stuff we start with in a chemical reaction?</td>
<td>We said that a chemical reaction must be occurring because the substances we ended up with are different than the ones we started with.</td>
</tr>
<tr>
<td>And what do we call the stuff we end up with at the end of the reaction?</td>
<td>We call what we have at the beginning of a reaction the reactants. We call what is left over or produced from a chemical reaction the products.</td>
</tr>
<tr>
<td>So what would be our reactants and products when we burn fat as a fuel?</td>
<td>We start with the air (oxygen) and fat/food as our reactants. During the reaction, light and heat are released and we end up with an increase in carbon dioxide and water as our products.</td>
</tr>
</tbody>
</table>

*ATTENDING TO EQUITY*

If your word wall from the OpenSciEd Unit 7.1 is still up, walk over to the definitions that your class created for reactants (the substances you start with in a chemical reaction) and products (the new substances that occur after a chemical reaction); if not, add “reactants” and “products” to the word wall for this unit.
10 min

**ADD TO OUR PROGRESS TRACKERS**

**MATERIALS:** science notebook, *Progress Tracker*, markers, chart paper

- Ask students to return to their seats to update their *Progress Trackers*. Hand out the three-column *Progress Tracker*.

Present slide R. Say, **Wow, we have really figured out a lot about changes in energy and matter when burning fat. Before we take a few minutes to individually capture our thinking in our 3-column Progress Trackers, let's summarize our consensus ideas. Can someone give me a 30-second speech summarizing everything we have figured out about burning fat today? The rest of the class will listen to make sure we have evidence to support those ideas and be ready to agree or disagree.**

Tell students that we have just spent a lot of time building understanding and then coming to a consensus on what we think is happening to food molecules when fat is burned. Now, we are going to individually construct an explanation in the form of a model (or some other representation) for showing how what we have figured out helps explain what happens to food molecules when they are burned.

Have students add what we have figured out to their Progress Trackers along with the lesson question and source of evidence that led to these findings.
Here is one representation of what students might write.

<table>
<thead>
<tr>
<th>Question</th>
<th>Source of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. What happens to matter when it is burned?</td>
<td>• Burning food in open and closed systems and measuring the mass of both systems.</td>
</tr>
<tr>
<td></td>
<td>• Burning food in a closed system and measuring the change in concentrations of gases in the air.</td>
</tr>
<tr>
<td></td>
<td>• Molecular composition of air.</td>
</tr>
</tbody>
</table>

What we figured out in words/pictures

- When food is burned, a chemical reaction occurs because energy is released in the form of heat and light, and different substances are made.
- The concentration of gases in the air changed when the oil was burned. Both carbon dioxide and water increased.
- Matter is also conserved when the new substances are made because the mass of the closed system remained the same before and after burning the oil.

![Diagram showing chemical reaction]

Reactants: Food + Something from the air (oxygen?)

Chemical reaction

Products: Carbon dioxide + Water

Releases energy
Have students brainstorm next steps with a partner. Have students return their chairs to their desks. Present slide S.

Say, But now we are wondering, how does this work in our body system? The data we observed shows this for burning fat in a dish, but is this how it happens in our bodies?

Ask students to turn and talk about ideas for the two questions on the slide for a couple of minutes.

Have students share out their ideas in the last three minutes.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think a similar kind of chemical reaction is happening in our bodies to provide us with energy from food to do things?</td>
<td>Maybe, since I have heard that you breathe these gases in and out.</td>
</tr>
<tr>
<td></td>
<td>Some sort of chemical reaction must be happening, but I don't know how similar it is to this one.</td>
</tr>
<tr>
<td>Are we having little fires to burn things, like fat, protein, and glucose, for energy inside our bodies?</td>
<td>No, because there isn't a flame inside of us, is there?</td>
</tr>
<tr>
<td></td>
<td>Wait, is this why we get hot when we exercise?</td>
</tr>
<tr>
<td>What additional evidence could we collect to help us investigate this?</td>
<td>We could measure the air we breathe out.</td>
</tr>
<tr>
<td></td>
<td>We could see if these gases are in our bodies.</td>
</tr>
<tr>
<td></td>
<td>We could get data from inside different parts of the body to see if a chemical reaction with food is happening there.</td>
</tr>
</tbody>
</table>
Last time, we burned vegetable oil and duck fat and saw that, after several minutes of burning, the mass of both fats decreased. Look back at your responses to Part 3: Making Sense from the Lesson 10 handout. Pick one question and explain your reasoning to your group.

**Redesigning Our Investigation**

If we now claim that some of the stuff produced by this chemical reaction escaped into the air during the burn, then...

...what could we do as we burn the foods to capture those products and examine them more closely?

**Plan and Conduct an Investigation to Capture the Products from Burning Fat**

<table>
<thead>
<tr>
<th>System</th>
<th>Mass of the entire system before the burn</th>
<th>Mass of the entire system after the burn</th>
<th>Additional Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1: Open System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System 2: Closed System</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tape the Lesson 11 - Handout into your science notebook.

**Building Understandings Discussion: What we figured out from burning fat in open/closed systems**

A. When burning the fat, why did the mass of the closed system remain stable while the mass of the open system changed?

A. Why did the flame in the closed system go out so much sooner than the one in the open system?

A. What did you see on the sides of the closed-system container walls when the burn was done? What do think that substance might be?
Analyze Data to Determine What Is in Air

What do you notice and wonder about the gases typically found in air?

<table>
<thead>
<tr>
<th>Substance</th>
<th>Relative amount of this in the air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen ($N_2$)</td>
<td>~78%</td>
</tr>
<tr>
<td>Oxygen ($O_2$)</td>
<td>~21%</td>
</tr>
<tr>
<td>Humidity Water Vapor ($H_2O$)</td>
<td>Varies from 0% to 4%</td>
</tr>
<tr>
<td>Argon (Ar)</td>
<td>Under 1%</td>
</tr>
<tr>
<td>Carbon Dioxide ($CO_2$)</td>
<td>Under 1%</td>
</tr>
</tbody>
</table>

Be ready to share your ideas in a few minutes.

Plan and Conduct an Investigation to Measure the Gases Produced from Burning Fat

Fill in the substance that we will keep track of in this investigation in the first column of your data table.

Part 2: Measuring the Products of Burning Fat in a Closed System

<table>
<thead>
<tr>
<th>Substance</th>
<th>A. What do we predict will happen to the amount of this substance in the system?</th>
<th>B. Amount of substance measured (before the burn)</th>
<th>C. Amount of substance measured (after the burn)</th>
<th>D. What happened to the amount of this substance in the system?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Something from the air</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable Oil (Fat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Vapor ($H_2O$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide ($CO_2$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictions: Plan and conduct an investigation to measure the gases produced from burning fat

<table>
<thead>
<tr>
<th>Column A</th>
<th>It will increase (iev)</th>
<th>It will decrease (ev)</th>
<th>It will stay the same (es)</th>
</tr>
</thead>
</table>

Part 2: Measuring the Products of Burning Fat in a Closed System

How to Measure the Gases in Air

A graph of carbon dioxide levels will update every 5 seconds.

The value of carbon dioxide levels is in parts per million (or ppm).

Relative humidity of 100% means it is at the maximum it can reach before condensing out (which is around 4% water vapor in the air).

This label says that the range of detection for carbon dioxide levels is limited to 0-5,000 ppm.

The sensor is located here.
Initial Measurements: Plan and conduct an investigation to measure the gases produced from burning fat

Part 2: Measuring the Products of Burning Fat in a Closed System

<table>
<thead>
<tr>
<th>Substance</th>
<th>A. What do we predict will happen to the amount of this substance in the system?</th>
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<tr>
<td>Carbon Dioxide (CO₂)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wear your goggles!

Make Sense of Our Closed Versus Open System Results

1. What state of matter is each substance? Describe what happened to the amount of the substance during the investigation.
2. Think about when we burned the vegetable oil. Where do you think the matter from this fat is going?
3. What do you think is causing these changes to occur when a food item is burned? Explain your reasoning.
4. What clues does the claim give you about what might be happening to food inside our bodies and M'Kenna's body when it is used for energy? Or, what new questions does this raise for you?

Navigation

Open your science notebooks to the Making Sense questions on your Lesson 11 - Handout 2.
Consensus Discussion: What happens to matter when burned? (Talking Sticks Protocol)

Small Group Talking Stick Round 1:
Pass around a pencil as a talking stick to take turns having each person share their response to question 1 [30 seconds per person].
As each person shares, think about how this connects to your response in the next question.

Small Group Talking Stick Round 2:
Pass around a pencil as a talking stick to take turns having each person share their response to question 2 [30 seconds per person].
As each person shares, think about how this connects to your response to the next question.

Small Group Open Discussion:
Each person shares a connection that they noticed about matter and energy in regard to something that was said by another group member.

- What connections about matter and energy did you make to other students’ ideas during the talking stick protocol?
- How do we know energy is provided to the system?
- How do we know energy was produced in this reaction?
- Where did that energy come from, and what evidence do we have that there was energy there to start?

Analyze Nutrition Labels

Look at the nutrition labels.

- Do these foods contain other food molecules besides carbohydrates and protein?
- Do they both have calories?
- Do you think that, if we burn these foods, the same thing would happen as when we burned the oil?

Compare Carbon Dioxide and Water to Food Molecules

If carbon dioxide and water molecules are being produced when foods are transferring energy through burning, then the atoms that make them up must be coming from somewhere.

Where are they coming from?

KEY
- carbon C
- oxygen O
- hydrogen H

13

14

15

16
The tail end of one kind of complex carbohydrate (starch) molecule

The tail end of one kind of protein molecule

Two kinds of fatty acid molecules

Two glucose molecules

Two kinds of amino acid molecules

Two kinds of fatty acid molecules

Before we take a few minutes to individually capture our thinking in our 3-column Progress Trackers, let's summarize our consensus ideas. Someone will give a 30-second speech summarizing everything we have figured out about burning fat today. The rest of the class will listen to make sure we have evidence to support those ideas and be ready to agree or disagree.

Add to Our Progress Trackers

Before hearing an explanation, add to your Progress Tracker.

New Ideas and Next Steps: Let's take what we have figured out and problematize where to go next.

- Do you think a similar kind of chemical reaction is happening in our bodies to provide us with energy from food to do things?
- Do we have little fires to burn things like fat, protein, and glucose, for energy inside our bodies?
- What additional evidence could we collect to help us investigate this?
Lesson 11: What happens to matter when it is burned?

Navigation

Last time, we burned vegetable oil and duck fat and saw that, after several minutes of burning, the mass of both fats decreased. Look back at your responses to Part 3: Making Sense from the Lesson 10 handout. Pick one question and explain your reasoning to your group.

With your group

1. Discuss the questions from What Happens to Fat When It Burns?:
   a. How does the color, odor, and hardness of the substances that you ended up with compare to what you started with?
   b. Based on the property changes you observed, what claim can you now make about what happened to the original substances in these containers beyond just saying “they burned”?
   c. Compare the mass of the substance in each container before and after it burned. If matter can’t disappear, how can you explain the patterns in your data?
   d. What clues does this give you about what might be happening to food inside our bodies and M’Kenna’s body when it is used for energy? Or, what new questions does this raise for you?

Redesigning our Investigation

Brainstorm how to redesign the investigation to capture what is produced from burning the oil. If we now claim that some of the stuff produced by this chemical reaction escaped into the air during the burn, then…

Turn and talk

2. What could we do as we burn the foods to capture those products and examine them more closely?
   a. What will we change?
   b. What will we need to keep similar?
Plan and Conduct a Class Demonstration to Capture the Products from Burning Fat

3. Tape *Burning Fat in Open and Closed Systems* into your science notebook.
   a. Label the first row of the table in part 1 as an OPEN system and the second row of the table as a CLOSED system.
   b. Record the initial mass of the entire system before the burn.
   c. Record the initial mass of the closed system before the burn.

4. Burn the oil in the closed and open systems.
   a. Record the final mass of the open system before the burn.
   b. Record the final mass of the closed system before the burn.
   c. Record any additional observations of each system.

Building Understandings Discussion: What we figured out from burning fat in open/closed systems

5. Your teacher will assign you one of the following questions to discuss with your partner.
   a. When burning the fat, why did the mass of the closed system remain stable, while the mass of the open system changed?
   b. Why did the flame in the closed system go out so much sooner than the one in the open system?
   c. What did you see on the sides of the closed-system container walls when the burn was done? What do think that substance might be?

Analyze Data to Determine What Is in Air

6. What do you notice and wonder about the gases typically found in air?
7. Which of these gases have you heard of before?
8. Notice the symbols for the atoms that make up the molecules—N, O, C, H, Ar. Which of these symbols have we seen in our previous investigations?

Predictions: Plan and conduct an investigation to measure the gases produced from burning fat

We will do the test again for just a closed system, following a similar procedure, but this time using a tool to measure the gas levels in each system so that we can see whether the amounts are changing.
9. Reopen your science journal to *Burning Fat in Open and Closed Systems*.

10. Prepare to conduct the investigation to measure the gases.
   a. Fill in the first column of the part 2 data table shown on *Burning Fat in Open and Closed Systems* for the substances we have been investigating: something from the air, oil/fat, water vapor, and carbon dioxide.
   b. Record your thinking (for each substance) in column A: What do we predict will happen to the amount of this substance in the system?

### How to Measure the Gases in Air

### With your group

10. Examine the device we will use to detect gases in the air.

### Initial Measurements: Plan and conduct an investigation to measure the gases produced from burning fat

### With your class

11. Before your burn the oil:
   a. Record your thinking (for each substance) in column B: Amount of substance measured (before the burn).
Final Measurements: Plan and conduct an investigation to measure the gases produced from burning fat

**With your class**

12. Burn the oil in the closed system with the carbon dioxide and humidity detector.
   a. Record your thinking (for each substance) in column C: Amount of substance measured (after the burn).
   b. Individually add arrows in column D, showing: What happened to the amount of this substance in the system (based on the results measured from columns B and C)?

**On your own**

13. What state of matter is each substance? Describe what happened to the amount of the substance during the investigation.
14. Think about when we burned the vegetable oil. Where do you think the matter from this fat is going?
15. What do you think is causing these changes to occur when a food item is burned? Explain your reasoning.
16. What clues does the claim give you about what might be happening to food inside our bodies and M’Kenna’s body when it is used for energy? Or, what new questions does this raise for you?

**Make Sense of Our Closed Versus Open System Results**

Return to your seats to individually process your thinking on the Making Sense questions on your Making Sense of Burning Fat Investigation Results. We will share out next class.

**On your own**

17. Open your science notebooks to the Making Sense questions on your Making Sense of Burning Fat Investigation Results.
Consensus Discussion: What happens to matter when burned? (Talking Sticks Protocol)

We want to see what we can agree upon regarding what happens to matter and energy when fat is burned in a closed system.

18. Small Group Talking Stick Round 1:
   a. Pass around a pencil as a talking stick to take turns having each person share their response to question 1.
   b. As each person shares, think about how this connects to your response in the next question.

19. Small Group Talking Stick Round 2:
   a. Pass around a pencil as a talking stick to take turns having each person share their response to question 2.
   b. As each person shares, think about how this connects to your response to the next question.

20. Small Group Open Discussion:
   a. Each person shares a connection that they noticed about matter and energy in regard to something that was said by another group member.

Consensus Discussion: What happens to matter when burned?

21. Talk with your class about the following questions:
   a. What connections about matter and energy did you make to other students’ ideas during the talking stick protocol?
   b. How do we know energy is provided to the system?
   c. How do we know energy was produced in this reaction?
   d. Where did that energy come from, and what evidence do we have that there was energy there to start?

Analyze Nutrition Labels

22. Look closely at the nutrition labels with your partner:
   a. Do these foods contain other food molecules besides carbohydrates and protein?
   b. Do they both have calories?
   c. Do you think that, if we burn these foods, the same thing would happen as when we burned the oil?
   d. Do you think we could burn other non-food things and get energy from them? Explain why or why not for each of your examples.
   e. The examples you mentioned are likely all types of fuel. A fuel is any material/matter that can react with other substances so that it releases energy.
   f. If you burned these others foods as fuel, what do you predict would be the products?
Compare Carbon Dioxide and Water to Food Molecules

Let’s revisit the molecular representations of food to look for evidence for the source of matter in the products of carbon dioxide and water.

**With your class**

23. Look closely at Air Molecule Reference:
   a. Where do you think the atoms that make up the carbon dioxide and water molecules that started appearing in the container came from as we burned the food?
   b. What happened to the amount of each substance during our investigations?
   c. Why is what happened during the investigations considered a chemical reaction?
   d. What could we identify as our reactants and products as we burn fat as fuel in this chemical reaction?

**Adding to Our Progress Trackers**

We have just spent a lot of time building understanding and then coming to a consensus on what we think is happening to food molecules when fat is burned. Now, we are going to individually construct an explanation in the form of a model (or some other representation) for showing how what we have figured out helps explain what happens to food molecules when they are burned.

**In your notebook**

24. Someone will give a 30-second speech summarizing everything we have figured out about burning fat today. The rest of the class will listen to make sure we have evidence to support those ideas and be ready to agree or disagree.

25. Add to what we figured out to your Progress Tracker along with the lesson question and source of evidence that led to these findings.

**Navigation**

New Ideas and Next Steps: Let’s take what we have figured out and problematize where to go next.

**Turn and talk**

26. Brainstorm our next steps with a partner:
   a. Do you think a similar kind of chemical reaction is happening in our bodies to provide us with energy from food to do things?
   b. Do we have little fires to burn things like fat, protein, and glucose, for energy inside our bodies?
   c. What additional evidence could we collect to help us investigate this?
# What Happens to Fat When It Burns?

<table>
<thead>
<tr>
<th>Sample</th>
<th>1. Wick only</th>
<th>2. Vegetable fat and wick</th>
<th>3. Animal fat and wick</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Observations of the substances in the container before the burn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Mass of the substances in the container before the burn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Observations of the substances in the container after the burn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Mass of the substances in the container after the burn</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 3: Make Sense of Your Results

Complete the making sense questions in your science notebook.

1. How does the color, odor, and hardness of the substances that you ended up with compare to what you started with?

2. Based on the property changes you observed, what claim can you now make about what happened to the original substances in these containers beyond just saying “they burned”?

3. Compare the masses of the substances in each container before and after they burned. If matter can't disappear, how can you explain the patterns in your data?

4. What clues does this give you about what might be happening to food inside our bodies and M’Kenna’s body when it is used for energy? Or what new questions does this raise for you?
# Burning Fat in Open and Closed Systems

## Part 1: Burning Fat in Open and Closed Systems

<table>
<thead>
<tr>
<th>System</th>
<th>Mass of the entire system before the burn</th>
<th>Mass of the entire system after the burn</th>
<th>Additional Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System 2:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Part 2: Measuring the Products of Burning Fat in a Closed System

<table>
<thead>
<tr>
<th>Substance</th>
<th>A. What do we predict will happen to the amount of this substance in the system?</th>
<th>B. Amount of Substance measured (before the burn)</th>
<th>C. Amount of substance measured (after the burn)</th>
<th>D. What happened to the amount of this substance in the system?</th>
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</tbody>
</table>
Making Sense of Burning Fat Investigation Results

Part 3: Making sense of your results

1. Record the states of matter of the air, oil, water vapor, and carbon dioxide in the table below. Then answer the question in the last column.

<table>
<thead>
<tr>
<th>Substance</th>
<th>What is the state of matter of each of these substances?</th>
<th>Describe what happened to the amount of the substance during the investigation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Something from the air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable Oil (Fat)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Vapor (H2O)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide (CO2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Think about when we burned the vegetable oil. Where do you think the matter from this fat is going?

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
3. What do you think is causing these changes to occur when a food item is burned? Explain your reasoning.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

4. What clues does the claim give you about what might be happening to food inside our bodies and M’Kenna’s body when it is used for energy? Or, what new questions does this raise for you?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Air Molecule Reference

If carbon dioxide and water molecules are being produced when foods are transferring energy through burning, then the atoms that make them up must be coming from somewhere. Where are they coming from?
<table>
<thead>
<tr>
<th>Question</th>
<th>Source of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What we figured out in words/pictures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
LESSON 12: Does this chemical reaction to burn food happen inside our bodies?

PREVIOUS LESSON
We conducted two investigations to trap the gases produced by burning food. We used the results of these investigations to figure out that food needs to undergo a chemical reaction with oxygen to release energy and that carbon dioxide gas and water vapor are products of that process. We wondered if this reaction could happen inside our bodies.

THIS LESSON
INVESTIGATION
2 days

We gather multiple sources of evidence, such as observing a chemical reaction after blowing into BTB solution, to prove that a reaction between food and oxygen happens in the cells of the body to provide them with energy and releases carbon dioxide and water. This reaction helps us explain why certain materials that we take into our bodies, like oxygen and food, are different from the materials that leave our bodies, like carbon dioxide and water. We consider the purpose of the reaction and analyze activity data to see if when the activity level changes, whether this chemical reaction happens at a different speed.

NEXT LESSON
We will build small-group models, drawing primarily on what we figured out in Lessons 8-12, to explain how food is rearranged in the body to create energy, store matter for later use, and use matter for growth. We will compare our models and then develop a consensus model to explain how a healthy body obtains energy and how M’Kenna’s body could be functioning differently.

BUILDING TOWARD NGSS
MS-LS1-3, MS-LS1-5, MS-LS1-7

WHAT STUDENTS WILL DO
Analyze and interpret data to identify spatial and temporal relationships in order to determine causes for changes to blood glucose, oxygen, and carbon dioxide levels in the body.

Obtain, evaluate, and communicate information to clarify a claim that a chemical reaction that produces energy in the body is occurring in different parts of the body and that the body uses more glucose and oxygen to provide energy to cells (effect) during exercise (cause) than while resting.

WHAT STUDENTS WILL FIGURE OUT
- Oxygen is taken in (inhaled) through the lungs, and carbon dioxide is exhaled through them. These gases enter and exit the blood by passing through the lung membrane wall and are transported to and from the cells of the body.
- Chemical reactions that happen within cells in the body rearrange glucose and oxygen into carbon dioxide, water, and energy that the cells can use.
- This reaction, called cellular respiration, happens when we’re resting, but even more when we exercise.
# Lesson 12 • Learning Plan Snapshot

<table>
<thead>
<tr>
<th>Part</th>
<th>Duration</th>
<th>Summary</th>
<th>Slide</th>
<th>Materials</th>
</tr>
</thead>
</table>
| 1    | 5 min    | **NAVIGATION**  
Review that chemical reactions can be used to release energy from food. Pose the question, “Does this chemical reaction between food and oxygen really happen in our bodies?” | A-B |  |
| 2    | 15 min   | **BTB INVESTIGATION: DEMONSTRATION**  
Gather evidence that a similar type of chemical reaction is happening in the body by having each student blow into bromothymol blue (BTB). | C | BTB Investigation |
| 3    |  min     | **BUILDING UNDERSTANDINGS DISCUSSION**  
In a Building Understandings Discussion, help students make sense of the evidence they collected in the BTB investigation, which demonstrates that we are breathing out carbon dioxide. | D |  |
| 4    | 8 min    | **FOLLOW THE PATH OF AIR IN OUR LUNGS**  
Gather evidence from an image of alveoli in the lungs and from comparing the size of glucose, carbon dioxide, and the molecules in the air we breathe. Map the parts of the respiratory system to what we generally know about body systems. Help students figure out that the molecules in the air we breathe and carbon dioxide are small enough to pass through lung membranes and in and out of the blood. | E-H | systems mapping chart from Lesson 8 |
| 5    | 17 min   | **ANALYZE OXYGEN AND CARBON DIOXIDE LEVELS IN THE BLOOD**  
Students analyze oxygen and carbon dioxide levels in the blood. Help students figure out that the chemical reaction is happening in cells in the body. | I-J | Oxygen and Carbon Dioxide in the Blood - Part 1, tape, blank loose leaf paper |
| 6    | 7 min    | **NAVIGATION: MAKING SENSE**  
Facilitate an Initial Ideas Discussion to make predictions about how the chemical reaction that provides cells with energy would vary across different tissues and between periods of rest and activity. | K-L |  |
| 7    | 20 min   | **INTERPRETING ACTIVITY DATA**  
Interpret oxygen consumption data to see which cells in which parts of the body use the most oxygen while at rest. Analyze and interpret glucose data in the blood over 24 hours to figure out that the chemical reaction is always happening and that it happens more when we are exercising. | M-O | Interpreting Activity Data - Part 2, tape |
| 8    | 15 min   | **FACILITATE CONSENSUS DISCUSSION AND UPDATE THE 3-COLUMN PROGRESS TRACKER**  
In a Scientists Circle, facilitate a Consensus Discussion, then update the 3-column Progress Tracker to represent the ideas that (1) chemical reactions between food and oxygen are happening in cells inside the body; (2) reactants are transported from the lungs (oxygen) and small intestine (glucose) to the cells, and products (carbon dioxide and water) are transported from the cells through the blood; and (3) reactions happen all the time in the body, while at rest and even more while active. | P-Q | Progress Tracker, chart paper, markers |
| 9    | 3 min    | **NAVIGATION: TAKING STOCK**  
Consider how what we've figured out can help us explain M'Kenna’s non-digestive symptoms. | R | Revisiting Symptoms and Systems |

End of day 1

End of day 2
Lesson 12 • Materials List

<table>
<thead>
<tr>
<th>BTB Investigation materials</th>
<th>per student</th>
<th>per group</th>
<th>per class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 straw</td>
<td>2 cups with 10 mL of diluted BTB in each cup</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 plastic cup with 10 mL diluted BTB</td>
<td>1 plastic cup with 10 mL of carbonated water with eyedropper</td>
</tr>
<tr>
<td></td>
<td></td>
<td>safety goggles</td>
<td>1 plastic cup of with 10 mL plain water</td>
</tr>
<tr>
<td>Lesson materials</td>
<td>science notebook</td>
<td>systems mapping chart from Lesson 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oxygen and Carbon Dioxide in the Blood - Part 1</td>
<td>chart paper</td>
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<tr>
<td></td>
<td>tape</td>
<td>markers</td>
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<td></td>
<td>blank loose leaf paper</td>
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<tr>
<td></td>
<td>Interpreting Activity Data - Part 2</td>
<td></td>
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<td></td>
<td>Progress Tracker</td>
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<tr>
<td></td>
<td>Revisiting Symptoms and Systems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Materials preparation (25 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If your class does not have access to bromothymol blue (BTB) or sufficient BTB to conduct the investigation, you can play this video https://youtu.be/4Cyald4etic.

Day 1: BTB Investigation

- **Group size:** Three students per group
- **Setup:**
  - To make the diluted BTB solution, add 25 mL of BTB (straight from the container) to a 1000 mL beaker. Add water to the beaker until it reaches the 1000 mL line. The BTB solution should appear light blue in color. If it does not, it is possibly over-contaminated with carbon dioxide so pour it into a container and leave it open to the air so that the carbon dioxide can dissipate.
  - ***Be sure to test a small sample of your tap water to make sure that no color change occurs. Some tap and bottled water have additional minerals in them that will change the color of the BTB. If this is the case, try changing your water source to using a different filtered or deionized water. Fill 1 clear plastic cup with 10 mL of bromothymol blue solution (BTB) for every 3 students. Prepare enough for all classes ahead of time.
  - Fill one clear plastic cup with about 10 mL of BTB (for the class demonstration) for each class.
  - Fill one plastic cup with 10 mL carbonated water for each class. Do not throw away the bottle.
  - Fill one plastic cup with the 10 mL of plain water for each class.
  - **Notes for during the lab:** Some sources of water for dilution might make the BTB solution take longer to change color because of the added minerals. Be sure to test by blowing into the BTB with a straw to make sure you can see the color change with a small sample before diluting the full amount.
  - **Safety:** Students should wear safety goggles while breathing into the BTB. The solution is not hazardous but if it comes into contact with the skin or eyes, rinse thoroughly with water for 15–20 minutes. If swallowed, get medical attention.
  - **Disposal:** Disposal should be in accordance with applicable regional, national, and local laws and regulations. Local regulations may be more stringent than regional or national requirements.
  - **Storage:** Keep in a tightly closed container. BTB can be stored at room temperature with a shelf life of approximately 36 months.
Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

This lesson addresses a key Disciplinary Core idea that, in animals, oxygen reacts with carbon-containing molecules to provide energy and produce carbon dioxide (LS1.C). Specifically, students are introduced to the idea that this chemical reaction happens in cells and energy is released. Students figure out that the respiratory and circulatory systems work together to move reactants to the cells and products out of the body. Students do not need to know the specific chemical reaction for cellular respiration.

This lesson also addresses the idea that sugars are used immediately (LS1.C). Students figure out that cells immediately use the energy produced by this reaction for organs to function while at rest and use more glucose and energy when the body is active.

This lesson also builds upon the idea that was developed in previous lessons that substances can move across the surface of an organ. In this lesson, students figure out that oxygen and carbon dioxide can also pass through membranes because they are small like glucose.

Where We Are NOT Going

Students do not need to know how cellular respiration happens in cells or how cells use the energy.
LEARNING PLAN for LESSON 12

1 · NAVIGATION

MATERIALS: None

Present slide A to the class and have students turn and talk to review what we figured out in the last class and what new questions we have now.

ADDITIONAL GUIDANCE

Encourage students to look back in their science notebooks to review some of the ideas the class came up with in the previous class.

Listen in on the discussions, prompting students to use their science notebooks to support their thinking. After a couple of minutes, ask students to share these with the whole group.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did we figure out last class?</td>
<td>Food goes through a chemical reaction when it is burned. In this chemical reaction, something in the air is used up, and carbon dioxide and water are products, as well as energy, which we saw in the forms of heat and light.</td>
</tr>
<tr>
<td>What questions did this raise for us?</td>
<td>Can this really happen in our bodies? Where does it happen?</td>
</tr>
</tbody>
</table>

Say, *Let's start by figuring out if this chemical reaction might be happening in our bodies.*

Present slide B. Introduce the first half of the lesson question by posing: “Does this chemical reaction to burn food happen inside our bodies?”

ADDITIONAL GUIDANCE

Students need to come to an agreement that the chemical reaction they figured out in the last class is happening in our bodies before they address the second half of the Lesson 12 question, “And if so, how do our energy needs affect the reaction?” Students investigate the second half on day 2 of this lesson.

Discuss evidence we would see if this chemical reaction were happening in the body. Have the class think through how we could gather evidence. Encourage students to consider what would be different about the evidence we would collect if we exercised.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>If this chemical reaction were happening in our bodies, what evidence would we see of substances going into or coming out of our bodies?</td>
<td>We would see something from the air, maybe oxygen, and food going in, and carbon dioxide and water coming out.</td>
</tr>
</tbody>
</table>

Tell students that we'll look for some of this evidence, specifically focusing on one reactant (something from the air, possibly oxygen) and one product (carbon dioxide) in this lesson.*

*ATTENDING TO EQUITY

Students will have encountered the terms, “chemical reaction,” “reactant,” and “product,” in previous units. To support all learners and to ensure that all students feel comfortable with these terms, consider pausing the learning to add these words to the word wall if you have not already done so. Co-construct definitions with students based on their understanding and experience from previous units.

openscied.org
Introduce bromothymol blue (BTB), a carbon dioxide indicator.

Say, I have another indicator we can use, called bromothymol blue, or BTB for short, that indicates the presence of carbon dioxide. Let's see how we might use this indicator to gather evidence to see whether this reaction is happening in our bodies. I also have a known source of carbon dioxide we can use to test how the indicator works.

**ADDITIONAL GUIDANCE**

Be sure to test a small sample of your tap water to make sure that no color change occurs. Some tap and bottled waters have additional minerals in them that will change the color of the BTB. If this is the case, try changing your water source to a different filtered or deionized water. Also, some water might make the BTB solution take longer to change color because of the added minerals. Be sure to also test blowing into the BTB with a straw to make sure you can see the color change with a small sample.

Project slide C, which shows the label for carbonated water. Ask students to notice what is in the ingredients of this liquid.

Share with students that carbonated water is water with added carbon dioxide. After establishing that it has both water and carbon dioxide in it, suggest that we make some observations about what happens when we mix BTB with this carbonated water, which has a lot of carbon dioxide in it, and compare the results to what happens when we mix BTB with water that doesn't have carbon dioxide in it.

**ALTERNATE ACTIVITY**

If students are unsatisfied by your explanation that carbonated water is water with added carbon dioxide simply based on the food label, consider showing a video or providing an additional short reading that explains how carbonated water is made. You could share information, for example, about how the SodaStream machine makes carbonated water out of tap water.

Demonstrate the color of BTB when mixed with two known sources.

Have students create the table on slide C in their science notebooks and record the results for the first row of the table. Pour about 10 mL of BTB into a glass beaker and walk around showing students what color it is with no water added. Have them record the color of the BTB in the entire column for “Color before mixing.”

Next, show students what happens when you add plain water to the BTB in the beaker. Take an eyedropper full of distilled water and squirt it into the BTB. Swirl the beaker. Show students the color of the liquid after adding water. The color should remain blue. Have students add the results to the data tables in their notebooks.

Say, OK, next I am going to add a small amount of carbonated water to the liquid, which is a combination of water and carbon dioxide. We'll examine the color, and then I will add some more. Let's see how it affects the BTB.

Take a new eyedropper, fill it with carbonated water, and squirt the water into the BTB. Swirl the beaker. Walk around and show the results. Fill the eyedropper again with the carbonated water and squirt it into the BTB. Swirl the beaker again and walk around to show the results. Have students record their observations.
<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What do you notice?</td>
<td>The carbonated water made the BTB change to a green/yellow color.</td>
</tr>
<tr>
<td>What does the color change tell us?</td>
<td>The BTB changes color when it comes in contact with carbon dioxide, so this tells us that the carbonated water really does have carbon dioxide in it.</td>
</tr>
</tbody>
</table>

Make some predictions about what we will see if we mix BTB with the air we exhale.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What should we see happen to the color of the BTB if we mix it with the air we exhale from our lungs and that air has more carbon dioxide in it than the surrounding air does?</td>
<td>It should turn colors (green or yellow), depending on how much carbon dioxide is in it.</td>
</tr>
<tr>
<td>How could we mix air that we exhale from our lungs into this liquid?</td>
<td>We could blow into it.</td>
</tr>
</tbody>
</table>

**ADDITIONAL GUIDANCE**

If students don't suggest blowing into it, say, “If we were to use a straw to blow into the BTB, do you think we would see a color change? Should we try that?”

Ensure student safety. Ask student volunteers to wear goggles while handling BTB solution.

- Have students pick one volunteer per group of three to four students to get a straw and a clear plastic cup with 8–10 mL of BTB solution already in it.
- Remind students not to share the straw and to keep one end of it in the BTB liquid the whole time.
- Remind students to breathe in between blowing bubbles into the BTB and to be careful to not accidentally suck the BTB into their mouths.
1. Set up one beaker with 10 mL of BTB solution and an eyedropper. Set up another beaker with 10 mL of plain water and an eyedropper. Have students record the color of the BTB in their data tables in their science notebooks.

2. Add one eyedropper full of plain water to the BTB. Swirl the water and the BTB in the beaker and show students the color of the BTB. Have students record the color of the BTB and water in their data tables in their science notebooks.
3. Add one eyedropper full of carbonated water to the BTB. Swirl the carbonated water and the BTB in the beaker and show students the color of the BTB. Have students record the color of the BTB and water in their data tables in their science notebooks.

**ALTERNATE ACTIVITY**
If you prefer, you can have every student in the group perform the BTB experiment so that each student gets a chance to blow into the solution.

Tell students that they may need to keep blowing bubbles into the solution for a little over a minute to notice any effects and that holding the beaker against a piece of white paper will allow them to see any color changes more easily.

**Conduct the investigation.** Give students four minutes to send one person up to get a cup and a straw, conduct the test at their tables, record their results, dump the liquid in the sink, and throw away the straw and cup.
3 · BUILDING UNDERSTANDINGS DISCUSSION

MATERIALS: science notebook

Make claims based on this evidence. Project slide D. Give students a couple minutes to add their responses to the questions on this slide to their science notebooks.

Facilitate a Building Understandings Discussion.

<table>
<thead>
<tr>
<th>KEY IDEAS</th>
<th>Purpose of this discussion: The purpose of this discussion is for students to start making the claim that we have a growing body of evidence that a chemical reaction of burning food could be happening in the body.</th>
</tr>
</thead>
</table>
| Listen for these ideas: | The air we exhale contains carbon dioxide.  
Carbon dioxide is a product of a chemical reaction when food is burned.  
We breathe in air through our nose and mouth and it travels to our lungs. |

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What does the color change from blowing into the BTB tell you about the air coming out of our lungs?</td>
<td>We breathe out carbon dioxide.</td>
</tr>
<tr>
<td>How does this support the claim that a chemical reaction, like the one we figured out last class when we burned the oil, is happening inside our bodies?</td>
<td>The burning reaction produces carbon dioxide. And that is also what is coming out of us!</td>
</tr>
<tr>
<td>Where does that carbon dioxide in our breath come from inside our bodies?</td>
<td>Our lungs.</td>
</tr>
<tr>
<td>When you breathe in air, where does that air go inside your body?</td>
<td></td>
</tr>
<tr>
<td>Why do you think you have air going in and carbon dioxide coming out of your lungs?</td>
<td>I'm not totally sure! Maybe there is a chemical reaction in our lungs?</td>
</tr>
</tbody>
</table>

Say, If we think this chemical reaction might be happening in the body and air is going in and carbon dioxide is coming out, where is this air going to and where is this carbon dioxide coming from in our bodies? Earlier in this unit, we followed the path of food to help us figure out what happens to food. Let's follow the path of air to help us figure out where these gases are going to and coming from in our lungs.
4 · FOLLOW THE PATH OF AIR IN OUR LUNGS

MATERIALS: science notebook, systems mapping chart from Lesson 8

Compare the organization of the respiratory system to the digestive system and general body systems. Project slide E. Use the image on the slide to have students trace the path of the air that is inhaled, which travels to the bottom of the lungs (the red circle). As students come to the projector to do this, map the respiratory system to the general organizational structure of body systems, like you did in Lesson 8.

On the same chart paper that you used in Lesson 8, add a third column in which you will track the respiratory system.

Begin by adding “respiratory system” next to “subsystem.”

Say, Air that enters through our noses or mouths travels down our windpipes, or tracheas, into our lungs through a branching network of smaller and smaller air tubes. These are called bronchial tubes.

Add the term “lungs” next to “small intestine” on the chart.

Say, Tiny air sacs (alveoli) line the sides of the ends of these air tubes, like the red circle shows.

Add the term “alveoli” next to “villi” on the chart.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Do you notice a pattern between the digestive and respiratory systems?</strong></td>
<td>Yeah, both of these body systems seem to be organized in the same way, with systems, subsystems, organs, and tissues.</td>
</tr>
<tr>
<td>I see that pattern, too. In fact, all of our body systems have this same general structure. If this is true, what other structure do you predict you would see in this part of the lung tissue?</td>
<td>We should see that the alveoli are made up of cells.</td>
</tr>
</tbody>
</table>

Say, What other structure do you predict you would see in this part of the lung tissue?

Give students a minute to turn and talk about their predictions with a partner.

Say, Let’s take a closer look at that spot where those air sacs are located.

Project slide F with an image of alveoli and another image of the cells that line the alveoli and have students share their observations and ideas with the whole class. Let students know that the blue, red, and yellow areas in the image are dye so that the parts of the cells are more visible.
<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What do you notice about the structures in this part of the lungs?</td>
<td>They are made up of a lot of tiny circles or sacs, and those are made up of cells. They are covered with what looks like blood vessels.</td>
</tr>
<tr>
<td>If these red branching vessels contain blood, what might happen to gas particles when they reach the edge of these air sacs and run up against the surface of the blood?</td>
<td>Maybe they go in and out of the blood. It could be similar to how glucose crosses into the bloodstream through the villi. Maybe gases go through the lung membrane wall and into the blood?</td>
</tr>
<tr>
<td>What determines whether a molecule can pass through a membrane?</td>
<td>How big it is. Small molecules like glucose can pass through, but big molecules like starch (a special type of complex carbohydrate) can't.</td>
</tr>
<tr>
<td>How would we know whether gas molecules like carbon dioxide are small enough to pass through the lung membrane into blood?</td>
<td>We need to see how big the molecules are and if they're small enough to pass through.</td>
</tr>
</tbody>
</table>

**ADDITIONAL GUIDANCE**

If students aren't remembering, project slide L from Lesson 3, which compares the starch and glucose molecules. This will help remind students that really big molecules cannot pass through membranes.

Examining the size of molecules in the air and glucose. Project slide G and have students turn and talk to discuss what they know about glucose, how it gets into the blood, and what parallels they can draw to gas molecules like carbon dioxide.

**ADDITIONAL GUIDANCE**

Prompt students to use the idea of small food molecules crossing a membrane in the small intestine to get to the blood as a way of making sense of how other small molecules get in and out of cells and move between systems. Students first explored this concept in Lesson 8.

**Share ideas in a whole-class discussion.** Project slide H and discuss how gas molecules would get in and out of the body if a chemical reaction is happening in the body.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could the molecules in the air get into the blood from the lungs? Why or why not?</td>
<td>The gas molecules in air are really small, even smaller than glucose. So they can probably pass through the lung membrane into the blood like glucose did with the small intestine.</td>
</tr>
<tr>
<td>Could carbon dioxide move through the lungs? Why?</td>
<td>We're pretty sure it's oxygen.</td>
</tr>
<tr>
<td>We know that for food to burn, it needs something in the air because the fire went out when we didn't allow more air to go into the closed system. Looking again at the different molecules in air—which gas molecule do you think is most likely the one that is needed in the chemical reaction to burn food?</td>
<td></td>
</tr>
</tbody>
</table>
### Suggested prompt

(Refer to the closed-system container you used in Lesson 11.) So, if the chemical reaction with food needs oxygen to keep burning, what would happen to the oxygen levels inside the closed container as food is burning?

So, if a chemical reaction to burn food is happening inside our bodies and it's the oxygen that is needed to burn food, what would you predict would happen to the oxygen levels inside our bodies?

If a chemical reaction to burn food is happening inside our bodies and if carbon dioxide is produced when you burn food, what would you predict would happen to the carbon dioxide levels inside our bodies?

Should we check out those levels of gases inside our bodies and see what we find?

### Sample student response

The oxygen levels should go down over time because the chemical reaction would be using up the oxygen to burn the food.

I guess the oxygen levels inside our bodies should go down, too, if they are using the oxygen in a chemical reaction to burn food.

The carbon dioxide levels inside our bodies should go up if it is being produced in a chemical reaction to burn food.

Yeah!

---

### 5 · ANALYZE OXYGEN AND CARBON DIOXIDE LEVELS IN THE BLOOD

**MATERIALS:** science notebook, *Oxygen and Carbon Dioxide in the Blood - Part 1*, tape, blank loose leaf paper

**Introduce blood data.** Project slide I and have students look at *Oxygen and Carbon Dioxide in the Blood - Part 1*, which shows the same data.

Say, *This is some blood work from a healthy person that shows the person’s oxygen and carbon dioxide levels in different places around the lungs inside the person’s body. Let’s see if this can help us figure out whether a chemical reaction is happening, and if so, where it’s happening.*

**Divide into pairs to analyze the graphic.** Give students five minutes to work in pairs to complete the questions in part 1 of *Oxygen and Carbon Dioxide in the Blood - Part 1*, analyzing and interpreting the blood data and answering the questions. Have students tape the handout into their science notebooks and answer questions.

**Facilitate a Building Understandings Discussion.** Bring the whole class together to make sense of the blood data. Consider presenting slide I as the class looks at the oxygen and carbon dioxide levels in the blood, so they can point to specific evidence. During this discussion, be sure to make a public record of the key ideas that emerge.

---

**ATTENDING TO EQUITY**

If students struggle to interpret the data laid out in the data table in *Oxygen and Carbon Dioxide in the Blood - Part 1*, ask them to first verbalize what a change in levels would indicate. Ask, *“If you see the oxygen levels go down, what would that mean? What about the carbon dioxide levels?”*

Have students highlight or add arrows to their data tables to indicate where they see a change in levels. This will assist students with sensemaking as they look at the data.

It may also be beneficial to draw a connection to the work students did in Lesson 8 when they analyzed food molecule data to determine which organ in the digestive system is responsible for breaking molecules down and absorbing them across the cell membrane.

**ATTENDING TO EQUITY**

One strategy for differentiation might be to call up the image of body systems from Lesson 1.
### Purpose of this discussion

Make sense of the blood data to understand that, when oxygen levels drop, it indicates that the oxygen is being used in different parts of the body to cause chemical reactions.

### Listen for these ideas:

- Oxygen levels change the most between the point at which oxygen enters the blood and when it returns to the heart.
- Oxygen levels decrease and carbon dioxide levels increase when blood is returning from other parts of the body.
- The decrease in oxygen and increase in carbon dioxide indicate that a chemical reaction is occurring in the parts of the body between the location where oxygen enters the blood and when blood returns to the heart from other parts of the body.
- Oxygen and carbon dioxide pass through the lung membrane into the blood because the molecules are small enough, smaller even than glucose, which passes through the membrane of the small intestine into the blood.
- When we burned things in Lesson 11, a chemical reaction occurred when a reactant and fuel were combined, which produced carbon dioxide and water and released energy in the form of heat and light. This burning is occurring in the body, but we don't see a “fire.” In our bodies, energy is transferred as heat and a usable form of energy for our cells.

### Suggested prompt

<table>
<thead>
<tr>
<th>Question</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where do the oxygen levels change the most?</td>
<td>They change the most between when oxygen travels to other parts of the body and when it returns from them.</td>
</tr>
<tr>
<td>How do the oxygen levels change in these other parts of the body? Do they increase or decrease when they are there?</td>
<td>They decrease.</td>
</tr>
<tr>
<td>Where do the carbon dioxide levels change the most?</td>
<td>They change the most between when carbon dioxide travels to other parts of the body and when it returns from them.</td>
</tr>
<tr>
<td>How do the carbon dioxide levels change in these other parts of the body? Do they increase or decrease when they are there?</td>
<td>They increase.</td>
</tr>
<tr>
<td>What clues does this give us about where the chemical reaction is happening that is using food and oxygen to provide the body with energy and produce carbon dioxide in the process?</td>
<td>The chemical reaction must be happening in other parts of the body.</td>
</tr>
<tr>
<td>How does this relate to the burning we did in Lesson 11? Are there little fires inside our bodies?</td>
<td>Kind of. The chemical reaction is really similar because nutrients from food are reacting with oxygen to produce energy. Instead of the energy being released as light like the flame we saw, it’s releasing energy that the body is using to power the heart, brain, muscles, etc. Carbon dioxide is a product in both scenarios.</td>
</tr>
<tr>
<td>What do we know about all the tissues that make up the parts of our bodies? What smaller structures are they made of?</td>
<td>Cells.</td>
</tr>
<tr>
<td>Suggested prompt</td>
<td>Sample student response</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td><em>Could glucose and oxygen molecules in the blood go into cells across their cell membranes? Could carbon dioxide come out of cells and go into the blood? Why?</em></td>
<td>Yes, they are all small enough molecules.</td>
</tr>
</tbody>
</table>

**ADDITIONAL GUIDANCE**

If students use language, such as “carbon dioxide gets created,” probe further by asking, “Do you mean created out of nothing or created out of or produced out of something else? Can the atoms that make it up appear out of nowhere? Where is the matter that makes up the carbon dioxide coming from?” This will push students to remember that this carbon dioxide is a product of a chemical reaction between food and oxygen.

**ADDITIONAL GUIDANCE**

If students need help remembering that each organ is made of tissues, which are made of tightly packed cells, you can use a virtual microscope to gather evidence of this: [http://bit.ly/virtual-microscope](http://bit.ly/virtual-microscope). Have students explore the heart muscle sample by focusing on the repeating patterns in tissues. Prompt students to notice that each tissue is composed of smaller subunits (cells) that look almost identical to each other. Thus, cells make up tissues, which make up organs, and cells in different tissues work together to perform different functions in different organs.

Summarize our findings that chemical reactions to burn food happen inside our bodies. Suggest that we seem to have found a lot of evidence for the idea that the chemical reaction that releases energy from food molecules is happening in the cells throughout our bodies. Keep track of students’ ideas on a public record. Here is one suggested representation:

**WHAT WE FIGURED OUT**

- O₂ levels change most between leaving and returning to the heart
- When blood returns from other parts of the body, O₂ decreases and CO₂ increase
- 1 CO₂ + 1 O₂ = chemical reaction is occurring
- O₂ and CO₂ pass through lung cells in alveoli. Molecules are smaller than glucose! O₂ + CO₂ move in and out of bloodstream.
- “Burning” reaction is happening inside our bodies, but we don’t see “fire.” Energy is transferred as heat and energy cells can use.

Project slide J. Refer to the class artifact and summarize the main points of what the class has figured out.

Have students complete an exit ticket on a loose leaf sheet of paper. Do you think we have a chemical reaction to burn food happening inside our bodies? Why or why not?

Then ask students to turn and talk with a partner to start brainstorming some predictions for the three questions at the bottom of this slide.
End of day 1

6 · NAVIGATION: MAKING SENSE

MATERIALS: science notebook

Conduct an Initial Ideas Discussion to share predictions. Project slide K. Read through the prompts and questions. Ask students to share their predictions from last class.

KEY IDEAS

Purpose of this discussion: Students will revisit their predictions about how different levels of physical activity would impact the chemical reactions occurring in the cells of the body that provide the body with energy.

Listen for these ideas:
- Cells in the heart, lungs, and brain require the most energy.
- Increased physical activity, such as running, causes the muscles to need more energy than when the body is at rest.
- Increased mental activity, such as studying, causes the brain to need more energy than when the brain is at rest.

ADDITIONAL GUIDANCE

It is important that at least one student brings forward the idea that increased physical activity may cause certain parts of the body to require more energy and, therefore, more oxygen and glucose. If students do not come up with these ideas right away, prompt them to think about the times during which they used up a lot of energy. Ask students to think about what they were doing in those moments. They will likely say that they were exercising or working hard on a project that required a lot of mental energy. Capitalize on these ideas and help move students toward the connection to the body parts (muscles, brain) that needed more energy.

Suggested prompt

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which cells in which parts of the body do you think would need to use the most energy during a typical day?</td>
<td>Maybe your heart or lungs.</td>
</tr>
<tr>
<td></td>
<td>Maybe your brain.</td>
</tr>
<tr>
<td>What if you were running or jogging? Why?</td>
<td>Your muscles. Because they are moving more.</td>
</tr>
</tbody>
</table>

SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Students have gathered some evidence to make the claim that the body uses more energy during times of activity than at times of rest. They identify data that they need to analyze and clarify this claim. In the next activity, students will examine the effects of exercise on oxygen and glucose levels in the body. Students will be able to assume that, if more of the reactants (glucose and oxygen) are used and more energy and carbon dioxide (products) are produced, the cells in some parts of the body are requiring more energy when active than when they are at rest. Students are then able to clarify their claims to reflect this new information.
### Suggested prompt vs. Sample student response

| What you were studying? Why? | Your brain because that part of you is doing a lot, but the rest of your body isn’t. |

Say, What claim can we make about our predictions for how an increase in physical or brain activity might impact which cells in the body would need to use the most energy? Write a claim in your science notebook.

Brainstorm ideas for data that we would need to find this out. Project Slide L. Have students turn and talk with a partner for a minute to brainstorm ideas.

<table>
<thead>
<tr>
<th>Suggested prompt</th>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What kind of data might be helpful for us to figure out which cells in which parts of the body use the most energy during a typical day?</strong></td>
<td>Maybe glucose data or energy-use data for cells in different tissues. Maybe oxygen or carbon dioxide in the blood of different tissues.</td>
</tr>
<tr>
<td><strong>What kind of data would we need to see if exercise or studying changed how much energy cells need?</strong></td>
<td>We need to measure the energy use of different tissues, like the muscles or brain, during different activities. The amount of oxygen or glucose used by the cells should be related to the amount of energy they need. Oxygen and glucose are both needed for the chemical reaction that produces energy in the body.</td>
</tr>
<tr>
<td><strong>How would knowing the amount of oxygen or glucose used by the cells in different tissues in the body help us check our predictions?</strong></td>
<td>We would want to see where and when oxygen and glucose are being used in the body.</td>
</tr>
<tr>
<td><strong>What other data could we use to determine which cells in different tissues are using glucose to make energy?</strong></td>
<td></td>
</tr>
</tbody>
</table>

### 7 · INTERPRETING ACTIVITY DATA

**MATERIALS:** science notebook, Interpreting Activity Data - Part 2, tape

**Introduce the oxygen data.** Tell students that we’re going to look at data that show the amount of oxygen that the cells in different organs use for the chemical reaction that releases energy from food when the body is at rest.

**Make observations about the use of oxygen in different organs at rest.** Present slide M. Ask students to first share patterns they notice and then share what these patterns tell them about the energy needs of cells in those organs.
### Suggested prompt

<table>
<thead>
<tr>
<th><strong>What patterns do you notice?</strong></th>
<th><strong>Muscles use the most oxygen and the brain the second most.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How does this data support the claim that food is being used for fuel in all the cells inside our bodies?</strong></td>
<td>We know from Lesson 11 that oxygen and fuel are needed for the “burning” chemical reaction and that a product of that reaction is carbon dioxide. That’s how our cells get energy, and we know from a previous unit that every part of our bodies is made up of cells. The graph shows that all different parts of our bodies are using oxygen, so we can assume that a chemical reaction is happening in all of the cells inside our bodies.</td>
</tr>
<tr>
<td><strong>Why would cells in some of these organs be consuming more oxygen than cells in other organs?</strong></td>
<td>They need more energy. These organs are used more, so they are more active.</td>
</tr>
<tr>
<td><strong>Why would heart cells need energy? To do what?</strong></td>
<td>To help the heart beat and to pump blood.</td>
</tr>
<tr>
<td><strong>Why would brain cells need energy? To do what?</strong></td>
<td>To help us think and figure things out.</td>
</tr>
<tr>
<td><strong>Why would cells in the digestive system need energy? To do what?</strong></td>
<td>To help us break down food.</td>
</tr>
<tr>
<td><strong>Why would cells in our muscles need energy? To do what?</strong></td>
<td>To help us move.</td>
</tr>
</tbody>
</table>

### Make predictions about the energy needs of cells during increased activity.

**Project slide N.** Help students make predictions about glucose and oxygen levels in the blood during periods of increased activity and connect this to the needs of cells.

<table>
<thead>
<tr>
<th><strong>Suggested prompt</strong></th>
<th><strong>Sample student response</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Do you think these percentages would stay the same when you exercise?</strong></td>
<td>No. When our muscles are active, they may need more oxygen to produce more energy.</td>
</tr>
<tr>
<td><strong>What do you predict would be the effect of exercising on the amount of glucose in our blood?</strong></td>
<td>The amount of glucose should start decreasing because glucose is the fuel for the chemical reaction that produces energy in the cells.</td>
</tr>
<tr>
<td><strong>What effect do you predict eating would have on glucose levels in our blood?</strong></td>
<td>Glucose levels would probably increase after eating because glucose gets absorbed into the bloodstream during digestion.</td>
</tr>
</tbody>
</table>

### Introduce students to the glucose data.

Remind students that we decided the cells inside our bodies are using glucose and oxygen to provide us with energy. Tell students were going to look at blood glucose levels throughout the day and decide how changes in glucose levels give us information about the energy needs of different body parts.

### Divide students into groups to analyze the graph.

**Present slide O.** Pass out copies of Interpreting Activity Data - Part 2. Have students analyze the graph using the I² sensemaking strategy and answer the questions below it. Have students tape this handout into their science notebooks.
---

**ADDITIONAL GUIDANCE**

The Identify and Interpret (I²) strategy was introduced in Lesson 2 and revisited in Lesson 4.

---

**Lead a whole-class Building Understandings Discussion to make sense of the graph together.**

**KEY IDEAS**

Purpose of this discussion: Students will draw connections between what they have gleaned from the oxygen and glucose data to explain that increased activity, either physical or mental, increases the need for energy in certain parts of the body. Therefore, oxygen and glucose are needed more in those parts of the body so that a chemical reaction can occur.

Listen for these ideas:
- Glucose levels go up after eating.
- Exercise causes glucose levels to decrease more rapidly because the glucose is being used to provide energy.
- Certain cells in the body, such as those in the heart, lungs, and muscles, need more energy when exercising, so more glucose is burned.

**Suggested prompt**

<table>
<thead>
<tr>
<th>Sample student response</th>
</tr>
</thead>
<tbody>
<tr>
<td>We predicted that the blood glucose levels would increase after eating and decrease after exercising. We were correct!</td>
</tr>
<tr>
<td>Glucose levels increase after each meal.</td>
</tr>
<tr>
<td>Glucose levels increase after meals, but not as much as when you don't exercise. The glucose level decreases more quickly between meals when you exercise versus when you don't.</td>
</tr>
<tr>
<td>Glucose must be getting used up more quickly when you exercise versus when you don't.</td>
</tr>
<tr>
<td>We need more energy when we exercise, so we would have to burn more glucose to provide that.</td>
</tr>
<tr>
<td>Your muscles to move, heart to beat faster, and lungs to breathe faster.</td>
</tr>
</tbody>
</table>

Say, *Revisit the claim you wrote down in your science notebook about the impact of an increased activity level in the body or brain on the parts of the body that need the most energy. Take into account what you've figured out from the data you analyzed and clarify your claim.*

---
Facilitate a Consensus Discussion in a Scientists Circle. Have students bring their science notebooks with them.

Project slide P and ask students to contribute their ideas to the questions below with the whole class to determine what they’ve figured out and what they want to represent in their 3-column Progress Trackers. If time is short, you may want to record the ideas that students share directly on chart paper in a public space (e.g., poster), showing what the class agrees needs to go into their 3-column Progress Trackers.

### Suggested prompt

| What chemical reaction is happening in the cells of our bodies that uses food as fuel? | Our cells are burning food as fuel. |
| What does this reaction provide to the cells of our bodies? | It provides energy to the cells of our bodies. |
| How do reactants (oxygen and small food molecules like glucose) get into the body and to cells? | Cells have doors in their cell membranes that small molecules can pass through. |
| How do products (carbon dioxide and water) leave the cells and the body? | Cells have doors in their cell membranes that small molecules can pass through. |
| How do our energy needs affect the reaction? Do our cells always need the same amount of energy? | When we exercise, certain parts of our body need more energy, so the reaction happens more and uses up more glucose. When we’re resting, the reaction happens less, so we use less glucose. |
| How are our circulatory and respiratory systems involved in providing the reactants to the cells and in removing the products from them produced by this chemical reaction? | Oxygen enters the body through the lungs and then is pumped around to all the cells through the blood. Carbon dioxide is released in the reaction. It leaves the body through the blood, and then we breathe it out through our lungs. |
| How does this help explain how the digestive, circulatory, and respiratory systems might be connected? | The digestive system processes the food we eat and breaks it down so that small food molecules like glucose can pass into the blood to be fuel for cells to burn. The respiratory system brings oxygen into our bloodstream. The circulatory system delivers the glucose and oxygen to different parts of the body so that a chemical reaction can occur where the body needs energy. The circulatory system returns the products to the respiratory system so that they can be breathed out through the lungs. |

Name the chemical reaction that occurs in cells and provides them with energy as “cellular respiration.”

Say, It seems that we are in agreement that there is a chemical reaction occurring in cells that provides the cells with energy. Scientists call this type of chemical reaction “cellular respiration.” Let’s add this to our word wall.※

※ ATTENDING TO EQUITY

When new scientific words, like “cellular respiration,” are introduced, it can be helpful for Emergent Multilingual students to see a reference to those words added to a word wall.

Here is one possible representation:

- Cellular respiration
- a chemical reaction that occurs in cells and provides them with energy

$$\text{O}_2 + \text{Glucose} \rightarrow \text{Energy}$$

$$\text{CO}_2 + \text{H}_2\text{O}$$
If students aren’t able to make connections between the circulatory and respiratory systems, ask them, “How do oxygen and glucose get to the cells? How does the carbon dioxide get out of the cells and our bodies?”

Remain in a Scientists Circle to update the 3-column Progress Tracker. Project slide Q.

Ask students to argue from evidence for how what we figured out helps explain (1) whether a chemical reaction between food and oxygen happens in our bodies and, if so, (2) how our energy needs affect the reaction.

Ask students to share ideas for how to represent the chemical reaction happening in the cells, how the reactants get to the cells, and how the products leave the cells and body.

As a class, come to a consensus for how to update the 3-column Progress Tracker to represent these ideas and record what you agree upon on a class 3-column Progress Tracker/chart paper in a public space (e.g., on a poster).

Have students add these ideas to their individual 3-column Progress Tracker along with the lesson question and sources of evidence that have led to these findings.

Here is one suggested representation:

<table>
<thead>
<tr>
<th>Question</th>
<th>Source of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Does this chemical reaction between food and oxygen happen in our bodies (and if so, how do our energy needs affect the reaction)?</td>
<td>• BTB indicator and color changes from the air we exhale&lt;br&gt;• Images of respiratory system and alveoli&lt;br&gt;• O₂ and CO₂ data in the bloodstream&lt;br&gt;• Glucose levels in the bloodstream&lt;br&gt;• Graphs of oxygen used by different parts of the body</td>
</tr>
</tbody>
</table>

**What I figured out in words/pictures**

There is a chemical reaction happening in our cells that rearranges food (glucose) in our blood and oxygen into carbon dioxide and water. In that process, called cellular respiration, energy that the cells can use while at rest or when active is released. Cells use more glucose and more energy when we’re active. Oxygen gets to cells when it is inhaled through the lungs and goes from the blood to the cells. Carbon dioxide leaves the cells, is transported through the blood, and is exhaled through the lungs.
Say, We need to celebrate! We’ve figured out some really important science ideas about the way that our body systems work together. Now I think we’re ready to connect our understanding to some of M’Kenna’s other symptoms.

Present slide R. Assign home learning to be completed before the next lesson: Students should revisit Symptoms and Systems, which they should have taped into their science notebook. Pass out Revisiting Symptoms and Systems to students and have them copy some of the non-digestive symptoms they listed in part 2 of the table in Symptoms and Systems into the blank table at the top of Revisiting Symptoms and Systems. Instruct students to choose some of the symptoms and try to connect them to some of what they’ve figured out about the way the body systems are interconnected.

Tell students that, in the next class, we will use the ideas that they identify as important criteria in an explanation that will help us build models to explain what is happening inside M’Kenna.

**HOME LEARNING OPPORTUNITY**

In this home learning assignment, students begin to take stock of how what they’ve figured out in Lessons 9–12 could help explain what’s going on with M’Kenna’s non-digestive symptoms. This prepares them for putting all the pieces together in Lesson 13. Remind students to use evidence they’ve gathered in Lessons 9–12 to support their ideas.
Discuss with a partner:

- What did we figure out last class?
- What questions did this raise for us?

Does this chemical reaction between food and air happen inside our bodies?

Turn and Talk

- How could we investigate this question?
- If this chemical reaction was happening in our bodies, what evidence would we see of substances going in or coming out of our bodies?

Bromothymol blue (or BTB) is an indicator that turns a different color when it mixes with carbon dioxide.

Let’s observe the color changes that occur with a known source of carbon dioxide (carbonated water) and with a control (water alone).

<table>
<thead>
<tr>
<th>INDIVIDUAL</th>
<th>WHOLE GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make this table in your notebook to record your observations.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BTB mixed with</th>
<th>Color before mixing</th>
<th>Color after mixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water and carbon dioxide (carbonated water)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air from our lungs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Jot the answers to the following questions in your science notebook to prepare for the whole class discussion.

- What does the color change from blowing into the BTB tell you about the air coming out of our lungs?
- How does this color change provide evidence about a chemical reaction that might be occurring in our bodies?
- Where does the air go when we breathe it in, and where is carbon dioxide coming from when we breathe out?

Be ready to share these ideas in the discussion.
Follow the Path of Air in Our Lungs

Slide E

Which path does the air we breathe in and out follow?

Tiny air sacs (alveoli) line the sides of these air passages. What other structure do you predict you would see in this part of the lung tissue?

Follow the Path of Air in Our Lungs

Slide F

Share your observations and ideas:
- What do you notice about the structures in this part of the lungs?
- How might these structures help explain where the gases that reach here go to next or come from?

This image shows some of the structures found along these air sacs, or alveoli, within lung tissue.

This image zooms in on one of the air sacs, or alveoli, to reveal structures along the lining.

Follow the Path of Air in Our Lungs

Slide G

Turn and Talk

How does glucose get from the small intestine into the blood? Why?

Compare the molecular models below.

Could the molecules in the air get into the blood from the lungs? Could carbon dioxide move through the lungs? Why or why not?

Glucose

C₆H₁₂O₆

Molecules in the air we breathe

Follow the Path of Air in Our Lungs: Making Sense

Slide H

Discuss as a class

- Could the molecules in the air get into the blood from the lungs? Could carbon dioxide move through the lungs? Why or why not?
- Which gas molecule is most likely the one that is needed in the chemical reaction that burns food?
Analyze Oxygen and Carbon Dioxide Levels in the Blood

<table>
<thead>
<tr>
<th>Location</th>
<th>Oxygen (PO$_2$)</th>
<th>Carbon dioxide (PCO$_2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Air inhaled</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>2: Gases entering into the blood from the lungs</td>
<td>98</td>
<td>40</td>
</tr>
<tr>
<td>3: Blood going to other parts of the body</td>
<td>95</td>
<td>40</td>
</tr>
<tr>
<td>4: Blood returning from other parts of the body</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>5: Gases entering into the lungs from the blood</td>
<td>40</td>
<td>46</td>
</tr>
<tr>
<td>6: Air exhaled</td>
<td>40</td>
<td>46</td>
</tr>
</tbody>
</table>

Tape Oxygen and Carbon Dioxide in the Blood - Part 1 into your science notebook.

Discuss with a partner:
- Which cells from which parts of the body would likely need to use the most energy in a typical day?
- How would energy needs change if you were running or jogging? Why?
- How would energy needs change if you were studying? Why?

Complete the exit ticket:
- Do you think we have a chemical reaction to burn food happening inside our bodies? Why or why not?

Discuss with a partner:
- Which cells from which parts of the body would likely need to use the most energy in a typical day?
- How would energy needs change if you were running or jogging? Why?
- How would energy needs change if you were studying? Why?

Navigation: Making Sense

In the last class, you and a partner started making some predictions based on the claim that the chemical reaction that releases energy from food molecules is happening throughout our bodies.

Share your predictions as a whole class:
- Which cells from which parts of the body would likely need to use the most energy in a typical day?
- How would energy needs change if you were running or jogging? Why?
- How would energy needs change if you were studying? Why?

Navigation: Interpreting Data

Discuss with a partner:
- What kind of data might be helpful for us to figure out which cells in which parts of the body use the most energy during a typical day?
- What kind of data would we need to see if exercise or studying changed how much energy cells need?
- How would knowing the amount of oxygen or glucose used by the cells in different tissues in the body help us check our predictions?
- What other data could we use to determine which cells in different tissues are using glucose to make energy?
Interpreting Activity Data

In which kind of cells is this reaction occurring the most?

Total proportion of oxygen consumption by cells in these organs while at rest (%)

- Heart: 17%
- Muscles: 39%
- Brain: 26%
- Other Organs: 14%
- Digestive Organs: 29%

What patterns do you notice?

Why would cells in some organs be consuming more oxygen than cells in other organs?

Tape Lesson 12 - Student Handout 2 into your science notebook.

Interpreting Activity Data: Making Sense

Share your ideas with the class about the following:

- Do you think these percentages would stay the same when you exercise?
- What do you predict would be the effect of exercising on the amount of glucose in our blood?
- What effect do you predict eating would have on glucose levels in our blood?

Glucose levels in the blood over a 24-hour period

- What chemical reaction is happening in our bodies that uses food as fuel, and where does it happen?
- What does that provide to cells in our bodies?
- How do reactants get into the body and to the cells?
- How do products leave the cells and the body?
- How do our energy needs affect the reaction?
- How are our circulatory and respiratory systems involved in providing the reactants to the cells and in removing the products from them produced by this chemical reaction?
- How does this help explain how the digestive, circulatory, and respiratory systems might be connected?
Update the 3-column Progress Tracker

Together as a class, determine how you want to represent the following in your 3-column Progress Tracker:
- The chemical reaction occurring in cells in different parts of the body
- How reactants for the chemical reaction get to cells
- How products of the chemical reaction leave the cells and the body

Navigation: Taking Stock

Home Learning:
Tape Lesson 12 - Student Handout 3 into your science notebook.

Revisit Lesson 9 - Symptoms and Systems to fill in the symptoms you haven't yet been able to connect to what we've figured out. Use what we've figured out in Lessons 10-12 to complete Lesson 12 - Revisiting Symptoms and Systems
Lesson 12: Does this chemical reaction to burn food happen inside our bodies?

Navigation

With a partner

1. Work with a partner about the following questions:
   - What did we figure out last class?
   - What questions did this raise for us?

Navigation: Predictions

Turn and talk

2. Turn and talk to a partner about the following questions:
   - How could we investigate this question?
   - If this chemical reaction was happening in our bodies, what evidence would we see of substances going into or coming out of our bodies?

BTB Investigation: Demonstration

We will use an indicator called bromothymol blue, or BTB for short, that indicates the presence of carbon dioxide.

In your notebook

3. Create the table in your notebook to record your observations.
4. Examine the ingredients label on slide C.
5. Create the table found on slide C.
   - Record your observations for the first row of the table.
6. Observe the color changes that occur with a known source of carbon dioxide (carbonated water) and with a control (water alone).
7. Make predictions about what we will see if we mix BTB with the air we exhale.
8. Conduct the investigation.

Building Understandings Discussion

In your notebook

9. Jot down the answers to the following questions in your science notebook to prepare for the whole class discussion.
   - What does the color change from blowing into the BTB tell you about the air coming out of our lungs?
   - How does this color change provide evidence about a chemical reaction that might be occurring in our bodies?
   - Where does the air go when we breathe it in, and where is carbon dioxide coming from when we breathe out?
   - Be ready to share these ideas in the discussion.
Follow the Path of Air in Our Lungs

With your class 10. Work with your class to answer the following questions.
   - Which path does the air we breathe in and out follow?
   - Tiny air sacs (alveoli) line the sides of these air passages. What other structure do you predict to see in this part of the lung tissue?

Follow the Path of Air in Our Lungs

With your class 11. Share your observations and ideas about the following questions with your class.
   - What do you notice about the structures in this part of the lungs?
   - How might these structures help explain where the gases that reach here go to next or come from?

Follow the Path of Air in Our Lungs

With a partner 12. Turn and talk to a partner about the following questions.
   - How does glucose get from the small intestine into the blood? Why?
   - How does this help you predict how the air we breathe in and the carbon dioxide we breathe out might pass between the lungs and the blood?

Follow the Path of Air in Our Lungs: Making Sense

With your class 13. Work with your class to answer the following questions.
   - Could the molecules in the air get into the blood from the lungs? Could carbon dioxide move through the lungs? Why or why not?
   - Which gas molecule is most likely the one that is needed in the chemical reaction that burns food?

Analyze Oxygen and Carbon Dioxide Levels in the Blood

With your group 14. Obtain a copy of Oxygen and Carbon Dioxide in the Blood - Part 1 and tape it into your science notebook.
15. Work with your group to analyze and interpret the blood data.
16. Use the evidence from the blood data to answer the questions on Oxygen and Carbon Dioxide in the Blood - Part 1.
Navigation: Analyze Oxygen and Carbon Dioxide Levels in the Blood

**With a partner**

17. Work on your own to answer the following question on your exit ticket.
   - Do you think we have a chemical reaction to burn food happening inside our bodies? Why or why not?

18. Discuss the following questions with a partner.
   - Which cells from which parts of the body would likely need to use the most energy in a typical day?
   - How would energy needs change if you were running or jogging? Why?
   - How would energy needs change if you were studying? Why?

**Check your learning**

**Navigation: Making Sense**

In the last class, you and a partner started making some predictions based on the claim that the chemical reaction that releases energy from food molecules is happening throughout our bodies.

**With your group**

19. Share your predictions with the whole class.
   - Which cells from which parts of the body would likely need to use the most energy in a typical day?
   - How would energy needs change if you were running or jogging? Why?
   - How would energy needs change if you were studying? Why?

**Navigation: Interpreting Data**

**With a partner**

20. Turn and discuss the following questions with a partner.
   - What kind of data might be helpful for us to figure out which cells in which parts of the body use the most energy during a typical day?
   - What kind of data would we need to see if exercise or studying changed how much energy cells need?
   - How would knowing the amount of oxygen or glucose used by the cells in different tissues in the body help us check our predictions?
   - What other data could we use to determine which cells in different tissues are using glucose to make energy?

**Interpreting Activity Data**

**With your class**

21. Work with your class towards answering the question on slide M.
   - In which kind of cells is this reaction occurring the most?

22. Analyze the data in the graph and answer the following questions.
   - What patterns do you notice?
   - Why would cells in some organs be consuming more oxygen than cells in other organs?
Interpreting Activity Data: Making Sense

With your class

23. Share your ideas with the class about these questions.
   - Do you think these percentages would stay the same when you exercise?
   - What do you predict would be the effect of exercising on the amount of glucose in our blood?
   - What effect do you predict eating would have on glucose levels in our blood?

Interpreting Activity Data

With your group

24. Obtain a copy of Interpreting Activity Data - Part 2 and tape it into your science notebook.
   - Analyze the graph using the $I^2$ sensemaking strategy.
   - Answer the question on Unknown material with identifier: mr.l12.jo2.

Interpreting Activity Data: Making Sense

With your class

25. Bring your science notebook and join the Scientists Circle.
26. Share your ideas with the class about the following:
   - What chemical reaction is happening in our bodies that uses food as fuel, and where does it happen?
   - What does that provide to cells in our bodies?
   - How do reactants get into the body and to the cells?
   - How do products leave the cells and the body?
   - How do our energy needs affect the reaction?
   - How are our circulatory and respiratory systems involved in providing the reactants to the cells and in removing the products from them produced by this chemical reaction?
   - How does this help explain how the digestive, circulatory, and respiratory systems might be connected?
27. Argue from evidence for how what we figured out helps explain:
   - Whether a chemical reaction between food and oxygen happens in our bodies, and if so, how our energy needs affect the reaction.
28. Add these ideas to your 3-column Progress Tracker in Progress Tracker.

Check your learning

Navigation: Taking Stock

Home learning

29. Complete the following assignment as home learning.
   - Tape Lesson 12 - Student Handout 3 into your science notebook.
   - Use Lesson 9 - Student Handout 1 to fill in the symptoms you haven’t yet been able to connect to what we’ve figured out. Use what we’ve figured out in Lessons 10-12 to complete Lesson 12 - Student Handout 3.
Oxygen levels
1. Where are oxygen levels the highest?

2. Where are they the lowest?

3. Where do they change the most?

Carbon dioxide levels
4. Where are carbon dioxide levels the highest?

5. Where are they the lowest?

6. Where do they change the most?
7. What clues does this give us about where the chemical reaction might be happening that uses food and oxygen to provide energy?
Interpreting Activity Data - Part 2

Draw arrows to parts of the data and write “What I see” (WIS) and “What it means” (WIM) comments.

Glucose levels in the blood over 24 hours

1. What happens to the glucose levels in the blood right after a meal? Why does this happen?

2. What is different about how glucose levels change when you exercise after meals versus when you don’t?
3. What does this tell us happens to the rate at which the chemical reaction between food and oxygen occurs when we exercise?

4. Why would more of that reaction need to occur when we exercise?
## Progress Tracker

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<th>Question</th>
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Revisiting Symptoms and Systems

Which of M’Kenna’s symptoms could be connected to what we’ve figured out now?

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