

#### **Science Instructional Units**

#### **Overview of Science units:**

In partnership with the Institute for Learning, the Tennessee Department of Education is offering science units in grades 6-12 as an optional resource for districts as they implement the Common Core State Standards. These units give teachers background knowledge on content and address potential student misconceptions. Students learn about science concepts while strengthening their literacy skills through reading complex texts. Units are composed of multiple texts in which students use claims, evidence, and reasoning to share their thinking in understanding concepts. Students will also write explanatory and/or argumentative papers. Each unit focuses on a specific set of Tennessee science standards. Units support the 2013 summer trainings by incorporating rigorous lessons that lend themselves to using academically productive talk and help students with a deep enough understanding of concepts that they will be successful in completing research simulation tasks. Units are aligned to the Common Core State Standards for literacy and feature detailed guidance for teachers on facilitating all tasks and activities.

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Social, ethnic, racial, religious, and gender bias is best determined at the local level where educators have in-depth knowledge of the culture and values of the community in which students live. The TDOE asks local districts to review these curricular units for social, ethnic, racial, religious, and gender bias before use in local schools.



Adjustable to grades
9-10 based on
content alignment.

# Matter and Energy in Organisms

DL HIGH SCHOOL [HS.LS-MEO]

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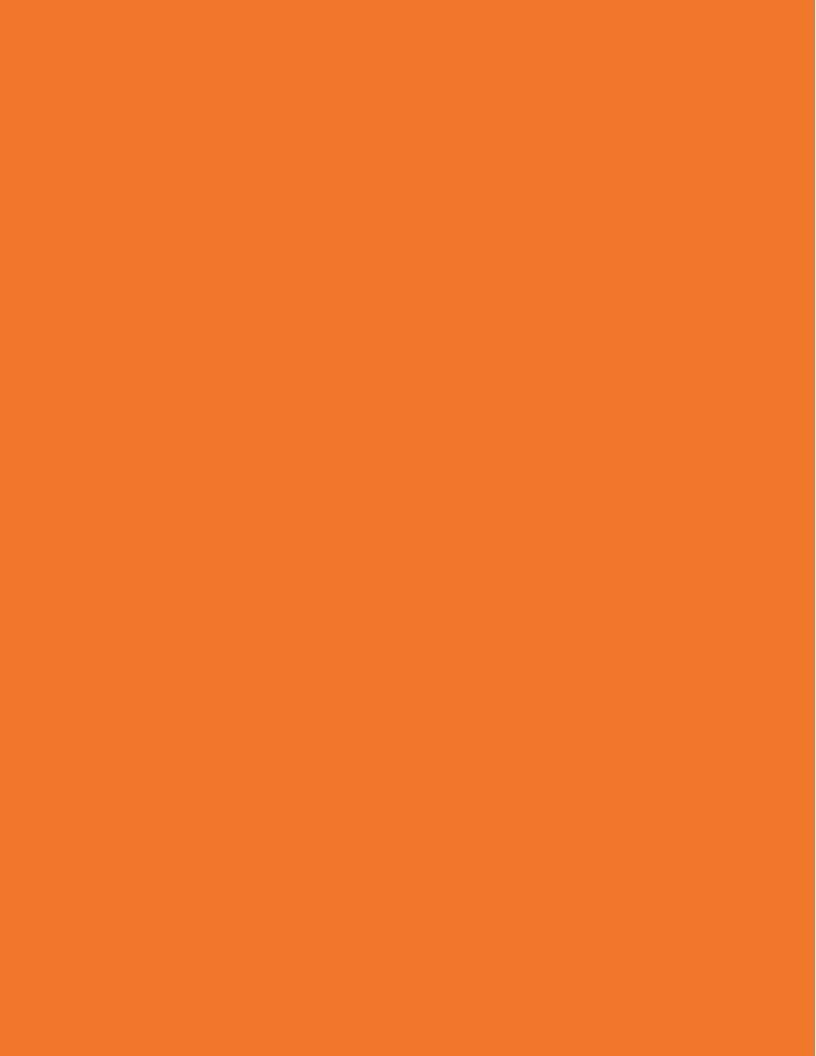


Adjustable to grades
9-10 based on
content alignment.

# Introduction

Matter and Energy in Organisms

[HS.LS-ME0]



## **Unit Overview**

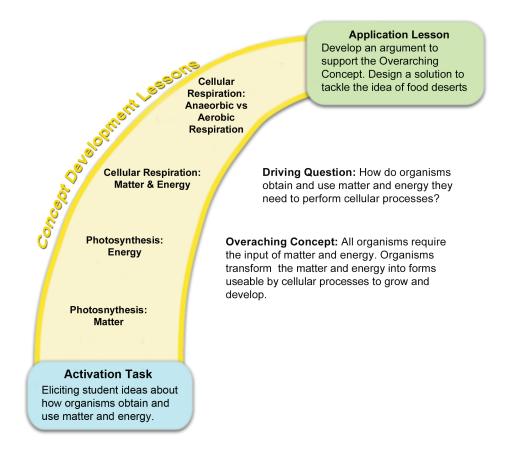
An Institute for Learning (IFL) Disciplinary Literacy (DL) Science unit consists of an arc of lessons designed to promote conceptual understanding of an overarching concept while apprenticing students in the practices of science. The overarching concept is the big idea that encompasses the content learning intended in the unit. The overarching concept for this unit is:

All organisms require the input of matter and energy. Organisms transform the matter and energy into forms usable by cellular processes to grow and develop.

Since science is driven by questions, we use an overarching question to orient students to the focus of the unit. This unit is driven by the overarching question:

How do organisms obtain and use the matter and energy they need to perform cellular processes?

The unit follows the flow illustrated below.



For additional information on the rationale and theory behind the unit design, please visit the IFL website at http://ifl.lrdc.pitt.edu/ifl/ for other resources and support.

# Why is it important to understand how organisms obtain matter and energy?

Understanding how energy and matter are obtained and used within organisms is a foundational concept in science. It is also a core aspect of our lives, and many decisions we make related to diet, environment, and other factors are informed by our understanding of the overarching concept of this unit.

The core concept is a critical link between biology, chemistry, and physics. Students should begin to see connections between energy (which they usually talk about in physical science), molecules (chemistry), and life (biology). It is helpful to use the terms consistently to help students see that energy is energy, regardless of whether we are talking about volcanoes, food, pendulums, solar panels, ecosystems, or energy in other contexts. The same rules of science apply (laws of physics).

Additionally, understanding how organisms obtain and use matter and energy lays the foundation for later study of ecosystems, cells, body systems, and policy issues such as food regulations, dietary considerations, crop and farming management, and food safety.

# What do students believe about how organisms obtain matter and energy?

What do students believe about the overarching concept? Following is the overarching concept for this unit: All organisms require the input of matter and energy. Organisms transform the matter and energy into forms usable by cellular processes to grow and develop.

We confront science phenomena in our everyday lives; we also develop our own explanations about our observations. The ideas that we hold can be in line with current scientific knowledge, partially in-line, or totally inaccurate. Considerable research has been done around students' ideas about science. The chart below provides ideas that are commonly held by students about topics in this unit as well as current scientific explanations related to student ideas. Throughout the unit students will confront commonly held ideas in an effort to move them toward a more scientific understanding.

We highly recommend that you watch the video *Lessons from Thin Air*. This video is the second part of the *Minds of Their Own* series. You can watch the video at the website (<a href="http://www.learner.org/resources/series26.html">http://www.learner.org/resources/series26.html</a>) as a Video on Demand (VoD). It is a free resource (at least at the time this guide was published), but requires you to register. This is a great resource that provides insight into student thinking around the overarching concept and teaching practices.

**CONCEPT:** All organisms require the input of matter and energy. Organisms transform the matter and energy into forms useable by cellular processes to grow and develop.

Related Common Student Ideas	Scientific Explanation
Plants produce oxygen for our benefit. (AAAS, 2001)	Plants release oxygen as a waste product from photosynthesis. They use oxygen during cellular respiration when they break down the sugars to generate ATP. Plants do not consciously produce things for human benefit. They produce things so they can live and grow.
Sunlight is a food for plants. (AAAS, 2001)	Plants use the energy in sunlight to synthesize sugars from ${\rm CO_2}$ and water. The sugar is the food that plants use.
Water is the source of food and matter for plants. (Driver, et al., 1994)	Water is necessary for plants to grow and develop, but it is not food (does not directly provide energy). Water does provide some matter for plants, but the majority of the plant matter (based on % mass) is from carbon and oxygen obtained from the air as $\text{CO}_2$ .
Soil is the source of food and matter for plants. (Driver, et. al., 1994)	Soil is not essential for plants to live and grow. It primarily provides a substrate for support of plants. Some nutrients are obtained through the soils, but soil is not food (does not provide energy nor matter).
Fertilizer is plant food. (Driver, et. al., 1994)	Fertilizer (minerals) is necessary for plants to grow and develop, but it is not food (does not provide energy). Minerals do provide limited matter for plants, but the majority of the plant matter is from carbon and oxygen obtained from the air as $\text{CO}_2$ and water ( $\text{H}_2\text{O}$ ).
Energy gets used up. (Driver, et. al., 1994)	Energy is neither created nor destroyed. It is transformed to different forms of energy (e.g., from light to heat energy, from chemical to mechanical, from mechanical to electrical, and so forth). Usually when energy is transformed to a form that is not viewed as usable by the organism, students interpret this as the energy being used up or gone. In biological systems, energy that is transformed and then dissipated as heat is often viewed as the lost energy.
Air is not made of anything; it does not have any matter. (Driver, et. al, 1994)	Air consists of gases and fine particles of dust and water. It is matter (takes up space and has mass) that can be easily measured and observed. Although students recognize that oxygen and other gases are in air, they often forget about air having matter since air is mostly invisible and always present in our everyday experiences (we often ignore air).
Photosynthesis is a substance. (Driver, et. al, 1994)	Photosynthesis is a process.

Continued on next page.

forms useable by cellular processes to grow and develop.		
Related Common Student Ideas	Scientific Explanation	
Chlorophyll is a food, used for protection or storage; it is a plant's version of blood and/or it makes plants strong. (Driver, et. al, 1994)	Chlorophyll is a pigment found in the chloroplasts of photosynthesizing organisms. There are various types of chlorophyll. In photosynthesis, the primary role of chlorophyll is to capture the energy from light to be used during the process of photosynthesis.	
Photosynthesis is a plant's version of respiration. (Driver, et. al, 1994)	Plants undergo both photosynthesis and cellular respiration.  During photosynthesis, plants and other photosynthesizing organisms transform light energy into stored chemical energy.  During cellular respiration, organisms transfer stored chemical	

energy into an energy source useable by the organism.

**CONCEPT:** All organisms require the input of matter and energy. Organisms transform the matter and energy into

#### How is this unit designed to support all students in understanding how organisms obtain and use matter and energy they need to grow?

The unit has the following elements, which are essential for supporting all students in understanding the content:

- Conceptual Story
- Lesson Scheme
- Active Learning
- Collaborative Learning
- Talk and Norms for Discussion
- Purposeful Questions
- Science Notebooks
- Assessment Strategies

#### Estimated time to complete the unit: approximately 21 days

- Activation Task: 30 minutes/1 day
- Concept Development Lesson (CDL) 1: 235 minutes/~4 days
- CDL2: 232 minutes/~5 days
- CDL3: 172 minutes/~3 days
- CDL4: 184 minutes/~3 days
- Application Lesson: 245 minutes/~5 days

#### **Matter and Energy in Organisms High School Conceptual Story**

Like the picture of a puzzle, the conceptual story provides a "picture" of the unit for teachers, illustrating how the concepts fit together through a student's eyes. Each lesson in this unit was developed around one key concept or idea. Everything in the lesson is explicitly tied to the concept so that students have an opportunity to fully understand it. The linking questions illustrate connections between the concepts. As students progress through each lesson, they (as a class) develop a concept/idea for the lesson and build their own conceptual story that should be similar to the conceptual story below. Each lesson is intended to build to the understanding of the overarching concept. Students demonstrate their level of understanding of the concepts in the application lesson.

You can envision the story as a flow of the parts in the table. By the end of the unit, students should be telling the story in their own words. The story they tell should map closely to the storyline in the table. A generic version of the storyline is provided below to give you a vision of the story telling. One way to do a quick assessment at the end of the unit is to ask students to summarize what they learned through the unit.

The story of Koverarching Driving Question .
At first I thought <exposed activate="" during="" task=""></exposed>
We wondered < Driving Question #1>  Then I learned that < Key Group t #1>
This made me wonder (Linking Question#1)
Then we wondered < DQ#2  Key Concept #2
Key concept #2
Linking Queestion #2>  Last Key Concept
When we did {Application hesson} I could explain why {Overarching Gnoupt}.

#### **Overarching Concept (OC):**

All organisms require the input of matter and energy. Organisms transform the matter and energy into forms useable by cellular processes to grow and develop.

#### Overarching Driving Question (DQ):

How do organisms obtain and use matter and energy they need to perform cellular processes?

	Activati	on Task				
Exposing student	Exposing student understandings about how organisms obtain and use matter and energy.					
	Concept Develo	pment Lessons				
Photosynthesis: Matter	Photosynthesis: Energy	Cellular Respiration: Matter and Energy	Cellular Respiration: Anaerobic vs. Aerobic Respiration			
Driving Question #1 What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?	Driving Question #2 How do plants and other photosynthesizing organisms transform light energy into chemical energy?	Driving Question #3  How do organisms obtain and use the matter and energy they need to perform cellular processes?	Driving Question #4  How do organisms break down matter to get energy if there is no oxygen available?			
Key Concept  Matter makes up all components of organisms and most components of the environment. Plants and other photosynthesizing organisms obtain matter from the environment through the process of photosynthesis.	Key Concept Plants and other photosynthesizing organisms transform light energy into stored chemical energy through the process of photosynthesis.	Key Concept  All organisms require the input of matter and energy. Organisms transform the matter and energy into forms useable by cellular processes to grow and develop.	Key Concept In the absence of oxygen, organisms perform anaerobic respiration to transfer stored chemical energy into a form useable by the organism.			
Linking Question  Do plants and other photosynthesizing organisms obtain anything from photosynthesis besides matter?	Linking Question How do organisms use the stored chemical energy produced during photosynthesis?	Linking Question What happens if all the reactants of cellular respiration are not available?	Linking Question What have you learned across this unit?			

#### **Application Lesson**

#### **Summative Assessment Task:**

Develop an argument to support Overarching Concept.

#### **Problem-Based Application:**

Design a solution to tackle the idea of food deserts in light of humans need for matter and energy.

#### **Lesson Scheme**

This unit consists of one activation task, four (one lesson per key/idea concept) concept development lessons, and one application lesson. A lesson is not limited to one class period and often takes several days to weeks to complete. It is important to provide students with the time they need to make sense of the content. The unit and lessons follow the IFL-DL Science Unit Design Structure outlined below.

#### **Activation Task**

#### Engage

- What questions or problem will be posed to engage students in the overarching concept?
- What questions or activity will be utilized that allows all students to uncover what they already know about the concept, habits of thinking, or skills targeted as the learning goals?

#### **Uncover**

- What activity will allow students to explore what they already know about the posed question or problem?
- What format (whole class, small groups, pairs, or individuals) will help to uncover existing ideas?
- What strategy (Think-Pair-Share, charting, etc.) will help to uncover existing ideas?
- What question(s) will help to uncover prior knowledge?

# Concept Development Lessons

#### **Engage**

 What question or problem will be posed to engage students in this concept?

#### **Gather & Analyze**

- What activity allows students to explore and make sense of ideas, data, and/or explanations around the question or problem?
- What structure or format (whole class, small groups, pairs, individuals) will facilitate learning?
- What questions will help to assess understanding of this key concept?
- What questions will advance student understanding?
- What strategy (Think-Pair-Share, charting, etc.) will help to make all student thinking visible?

#### Connect

- How will students publicly share their current understanding of ideas, data, and/or explanations to further make sense of this key concept?
- What questions will help to promote discussion among students to advance their understanding of the concept?

#### Reflect

- How will students connect this key idea to the overarching concept?
- How will students individually reflect on what they have learned or how they learned it?

#### **Application Lesson**

#### **Summative Assessment**

- What question will be posed to engage students in applying their understanding of key concepts to the overarching concept?
- What activity will allow students to demonstrate their current understanding of the overarching and key concepts?
- What format (whole class, small groups, pairs, or individuals) will facilitate assessment?
- What questions will help assess student understanding of the overarching and key concepts?
- What strategy (Think-Pair-Share charting, etc.) will help make all student thinking visible?

#### **Problem-Based Application**

- What scenario will be posed to engage students in applying their current understanding of the overarching concept to a real-world problem?
- What activity will allow students to extend and connect their current understanding of the overarching and key concepts in light of the posed question or problem?
- What format (whole class, small groups, pairs, or individuals) will facilitate rich engagement by all?
- What probes will assess and advance student understanding of the concepts as they tackle the problem?
- How will students publicly share their current understanding of ideas, data, and/or explanations to further make sense of this key concept?

#### Reflect

- How will students individually reflect on how their ideas have developed or changed through this unit?
- How will students connect their understanding of the overarching concept to other overarching concepts in science?

The activation task is designed to engage students in a purpose for learning and to uncover (assess) student thinking. The task is also designed to uncover student thinking. Your role is to help uncover their thinking and then to consider how adjustments might need to be made to the next lessons, based on their current understandings.

The concept development lessons are designed to develop an understanding of the key concept/idea as well as make connections to the overarching concept. To develop that understanding, students engage in activities that are minds-on, exploring data. Where appropriate, hands-on data generation (laboratories) and exploration are used to further conceptual development and to build laboratory skills. Each Concept Development Lesson is structured around the same four phases: *Engage*, *Gather & Analyze*, *Connect*, and *Reflect*. Each phase and its purpose are described in the table below.

The application lesson is designed to illustrate individual understanding (summative assessment) of the overarching concept as well as the key concepts; this lesson should meet or exceed state or district assessment expectations. The application lesson also includes a problem-based phase where students apply their understandings to a real world context to extend and further refine their understandings beyond the standards. This lesson will provide you with evidence of the level of mastery for the targeted standards by all students.

Phase of Concept Development Lesson	Purpose
Engage	This phase is designed to activate prior knowledge about the key concept or to provide a link that connects this lesson with the previous lesson. It is intended to expose student thinking so you and your students know where they are starting.
Gather & Analyze	This phase is designed to provide students with an opportunity to explore data and information to solve a question or problem. This may be accomplished through a hands-on laboratory to observe and generate data, or the data may be gathered from reliable sources. The data should be focused by a scientific question in order to develop an understanding of the key concept. Students should also begin to analyze and make sense of the data/information to develop an argument or explanation.
Connect	This phase is designed to socialize intelligence for the entire classroom (all students) by connecting the activities during the previous phase to the key concept. This usually involves a teacher-led whole group discussion that explicitly ties the work students have done to the key concept and ensures that a common understanding is achieved at or beyond the level of the targeted standards.
Reflect	This phase is designed to provide time for students to individually reflect on the lesson and to pull their thoughts together to make sense of what they have experienced. They should understand how the activities of the lesson connect to the key concept, as well as how what they have done builds understanding of the overarching concept of the unit. This phase provides evidence of individual learning achieved through the lesson.

Lessons are carefully designed to optimize student cognitive engagement. In other words, student learning of the key concepts is the primary driver of lesson design. In some instances, laboratory activities were excluded because they distracted from student learning. Laboratory experiences should be used to expand students' skills with scientific practices when the experience also deepens student learning of content.

#### **Active Learning**

When we refer to active learning, we mean students should be applying an effort to learn. Lessons should be designed to cognitively engage all students in the classroom such that students are using scientific practices and actively exploring data. All students should be challenged to advance their thinking and skills. Students need opportunities to observe, grapple with data, consider other's thinking, and develop explanations and arguments about the natural world as well as an understanding of how scientific knowledge is generated. To develop a deep understanding of important concepts, students need to reason about data (evidence that addresses the driving question), read and write about their experiences and thinking, talk about their ideas, and listen to the ideas of others. This kind of active learning takes time but is valuable because students are learning rather than memorizing. Further, these practices emulate the practices of science.

Science text can contain technical terms that may increase the reading level one or two years above the intended grade level. The active learning described above is designed to provide students with supports they need to comprehend complex text that they will encounter. Structuring activities for tasks, text, and talk is purposeful to support opportunities for rigor and conceptual understanding.

#### **Collaborative Learning**

Learning is a social endeavor. Many of the activities in this unit are purposely organized in pairs or triads to promote student engagement. As you assign groups, please consider students' command of academic language as well as their levels of conceptual understanding. There are times you will want to group the students heterogeneously, where the group represents a range of thinking and skills (e.g., advanced, average, struggling with the skills or ideas). Other times, you will want to group the students homogenously so that each group can take on a differentiated task and then the class can come together to share and learn across the diversity of tasks. However you group students, it is important to place students who are learning English with students who are effective at encouraging participation of everyone in the group. Regardless of the grouping, the main goal of forming groups is to provide a rich learning opportunity for the students where they can push, support, and learn from each other.

All students are responsible for the following: recording information in science notebooks, presenting information to the class, engaging in discussions, and cleaning up. If students are grouped in pairs, one student can be responsible for two roles. If there are more than three students in a group, students can share roles.

#### **Talk and Norms for Discussion**

Talk is an important part of science learning; academic talk helps students process what they are learning. Scientists share data and results, as well as present and debate findings or conclusions. As apprentices of science, students need to talk about their experiences, their data, and their conclusions. Academic talk promotes cognitive development and conceptual understanding.

Student talk plays a large role in this unit both in small group and whole group discussions. To help establish a community of learners, we encourage teachers to establish norms for classroom discussions that include both rights and responsibilities. Below are some norms that we have used with students.

#### **Norms for Discussion**

#### You have the right to...

- Add ideas.
- Ask questions to help you understand.
- Be treated like everyone else.
- Agree or disagree (and explain why).
- Have your ideas discussed.

#### You are obligated to...

- Speak so that everyone can hear.
- Speak one at a time.
- Listen for understanding.
- Agree or disagree (and explain why).
- Assess ideas, not people.

During whole group discussions it is easy for teachers to fall into the Initiate-Respond-Evaluate (IRE) trap. This is when teachers ask a question (initiate), one student responds (respond), and the teacher evaluates the appropriateness of the student response ("Correct" or "Anyone else?"). Of course, there are times when the IRE talk format is appropriate, but it is overused in classrooms and limits the number of students who are able to engage in sense-making.

To support all students in making sense of science, it is important to facilitate teacher-led, whole-group discussions in which fewer, more important questions guide the discussion and engage more students (most or all the class) to participate in the discussion. Key Accountable Talk® Teacher Moves provides research-based question stems to promote socializing the intelligence of the class around a topic.

In addition, room arrangement is important to the quality of discussions. Sitting in a circle—in chairs, at desks, or on the floor—promotes a community of learners. When the teacher joins the circle, it becomes easier to facilitate rather than dominate the discussion.

Charting or noting key points and then summarizing ideas that emerge from the discussion provide a record of the discussion; this is particularly useful for visual learners and ELs. During each concept development lesson, student ideas about the lesson are shared and summarized into a concept statement about the lesson, which is then added to the student's conceptual story. This helps students to monitor their own learning, understand connections between lesson activities and key concepts as well as understand how lesson key concepts relate to the overarching concept for the unit.

Effective discussions take time, effort, and practice. They are critical to socializing intelligence in science, providing opportunities for students to listen to the ideas of their peers, defend their own ideas, ask questions, develop deeper conceptual understanding, and become more aware of the collaborative nature of science.

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#### **Purposeful Questions**

Teacher questions drive the direction of student thinking. Asking the right question at the right time takes a skilled teacher and leads to more focused reading, reasoning, investigating, speaking, and writing. In this unit, we provide questions to guide teachers; however, the actual line of questioning should be driven by the ideas and understandings of students. Consider the phase of the lesson as well as the purposes for questions in each phase; then ask assessing and advancing questions that realize the intended purpose. In addition, there are Key *Accountable Talk* Teacher Moves that help focus discussions.

Phase of Lesson	Purpose
Engage	To invite students to think about and articulate their own ideas and experiences around the topic. Questions are posed to push for clarity and to expose student thinking.
Gather & Analyze	To invite students to investigate, venture a prediction, collect data, and organize data so that it reveals patterns. (Gathering ideas discussions)  To challenge students to think about what claims can be made and justified by the data. (Drawing conclusions discussions)  To help students clarify their reasoning and reflect on the reasoning of others, always pointing back to the evidence.
Connect	To help students to connect their experience, data, and analysis to key concepts in science. (Synthesizing discussions that clarify confusion and connect with known science.)  To help build a common understanding for all students around the key and overarching concepts.
Reflect	To help students to make sense of their own learning and evaluate each student's understanding and skills aligned to the mastery expected.

Throughout a lesson, the teacher should take every opportunity to probe students with questions or prompts that either *assess* or *advance* a student's current understanding. Purposeful questioning should occur in formal discussions, such as the whole group discussions. However, questioning should be used during interactions with students as they work individually to understand the material and should be utilized to push student thinking while working in pairs and small groups.

It is important to have purpose behind questioning. *Assessing prompts* are formative assessment questions or probing statements designed to learn more about students' prior knowledge, misconceptions, experiences, and ways of making sense. These types of questions help you learn about what students are currently thinking about science ideas and phenomena. Awareness of students' current understandings provides an opportunity to adapt your instruction to challenge student misconceptions and to support them in advancing their ideas toward more scientific, evidence-based understandings.

Advancing prompts push students to think further, to reconsider their thinking, to make a new connection, or to use science terms accurately. These questions push students to think harder rather than simplifying their

thinking. Students are not asked to recall memorized words or phrases; rather they require sense-making and forming mental connections. Advancing prompts require students to think!

You will see assessing and advancing prompts throughout the unit. As you use questioning, think about the purpose of your questions and the effect questions have on student learning. Asking questions is only part of the process. The other part is to **listen to student responses** so that you can make the next move to help students to get from where they are in their understanding to where you want them to be.

#### Purposeful Questions—Talking to Understand: Student Talk

Teacher questions play an important part in the direction and depth of discussion. Students must also play an important role. The ability for students to productively talk and question is valuable to whole group discussion. This ability is also especially valuable in small group and partner talk not directly facilitated by the teacher. The Talking to Understand: Student Talk sheet provides guidance for students in engaging in productive talk and in forming questions.

Purposeful questioning deepens the understanding of both the student asking the question and the student(s) being asked. In order to form a productive question, students must first begin to engage in the content material and/or task. Questioning provides a means to dissect the material for understanding and to push students to make connections with previously learned material and/or forming questions for future learning.

As students learn to question and engage in productive talk, questions must be modeled and practiced. The teacher has the opportunity to model questioning and talk during whole group discussions and as students work individually or in small groups on tasks. The question starters provided on the Talking to Understand: Student Talk sheet offers students the opportunity to form and use questions, in a sense allowing students to practice and model for each other. The question starters guide students in articulating their thoughts and questions. During discussions, encourage students to practice using questioning. As students become more practiced, they may begin to form differently worded questions or to be able to question without the use of the question starters. The Talking to Understand: Student Talk sheet is located in Appendix A: Teacher Resources.

#### **Science Notebooks**

A science notebook is a place where language, data, and experience can come together to form meaning. A notebook is a tool to support student understanding. Notebooks help students create their own references and supports for learning; they are used as learning occurs.

In thinking about helping students organize notebooks, consider asking students to organize their notebooks in three sections:

Section 1: Table of Contents

Section 2: Daily Activity and Notes

Section 3: Reflection

The Table of Contents provides a way for students to organize their notebooks so they can access the information as they move into lessons or other units. It is a good practice to have students often refer back to old notes and information. Students will need to leave enough space to fill in the Table of Contents as they progress through the year. This can be updated daily or as a weekly activity.

The Daily Activity and Notes section provides students with an opportunity to keep track of their daily investigations and reflections on learning. These pages should be numbered and dated so they can be referenced as they build the Table of Contents and also so students can see how their thinking changes across the year. One approach to organizing this section is to use only the right-hand pages. Then the left-hand pages can be used for the Reflection sections. Alternatively, the back of the notebook can be used for Reflections and then the left and right sides can be used for notes. You may want notes to be taped or stapled printed pages (e.g., charts, photos, copied handouts, etc.) as well as have notes written directly onto the pages.

The Reflection section is where students will record their personal thoughts about the content as well as about what supported their learning. This can be thought of as more of a personal learning journal than a science notebook. We suggest your review of this section be focused more on whether students are writing in this section and less on the actual content. Content will be in the Daily Activity and Notes section which provides a more appropriate section for grading or assessment.

Appendix B: Student Resources provides student handouts for their work during lessons. These pages can be copied and inserted in science notebooks. When appropriate, student handouts can be used as a model, and students can generate the work directly in their notebooks rather than on a handout.

#### **Assessment Strategies**

Assessment plays a critical role in this unit beginning with the activation task, which is designed to uncover (assess) student ideas about the topic of study. Teachers are encouraged to use knowledge from this lesson to inform and modify instruction based on student prior knowledge. This may mean moving ahead as planned with the unit, slowing down and adding important knowledge that is a prerequisite to the unit's beginning point, skipping lessons (concepts) that all students have already mastered, or making adaptations based on various groups of students.

Each concept development lesson begins with engaging students with a driving question. The Engage Phase is designed to uncover (assess) student knowledge of the lesson concept. With this knowledge, teachers can focus questions to address student perceptions during the rest of the lesson. Sample questions are incorporated in the teacher notes to trigger possible questions, but for real formative assessment to take place, teachers need to listen and ask questions that will help them to understand what students know and understand about the topic, so that they can push student thinking to a higher, more rigorous level. Assessing and advancing questions and Key *Accountable Talk* Teacher Moves are designed to help formatively assess students. In addition, each concept development lesson provides time for individual students to reflect on and assess their own learning. In time, students will learn to assess what they know and do not know so that they can monitor and make adjustments for their own learning.

The application lesson includes a performance or product-based summative assessment of all of the unit key concepts and the overarching concept. The lesson also includes a problem-based activity that provides rich application assessment of the overarching concept as students connect their learning through a real-world problem.

#### How is this unit designed to support me as a teacher?

This unit is designed to provide you with supports to establish rigorous routines of learning in your classroom along with a clear and coherent storyline to focus student learning at a conceptual level. The level of detail provided is intended to support your development of detailed lesson plans. The details are not intended as a script, but rather as a guide with clear and strong supports to enhance your teaching and advance student mastery of the standards. The notion of enhancing your learning is not meant in any way to imply your current teaching is broken or needs fixing. Rather, by enhance we mean to support you in being more intentional and explicit in your practices. This helps refine your teaching as well as to encourage more consistency in practices across classes so that your 1st period class has as rich an experience as your 3rd and your 7th period classes. All units have an overarching concept. Each lesson includes targets for learning (key concept and demonstrations of learning).

A time estimate for the entire lesson is provided; times are then broken down by phase of the lesson. Teacher Background includes a description to help focus your thinking about the lesson including an End-of-Lesson Takeaway, and important science content.

Preparing for the lesson includes materials and preparations necessary before the lesson. The procedure is organized by lesson phase (Engage, Gather & Analyze, Connect, and Reflect). Teacher notes include recommended instructional procedures on the left and as well as teacher, lesson, and differentiation supports on the right. Teacher resources are available in Appendix A: Teacher Resources. Student handouts are available in Appendix B: Student Resources.

#### **Using Linking Questions**

The linking questions were developed during the creation of the unit. They helped to keep the unit writers focused on making sure that the unit key concepts were linked together in a way that would create a natural progression of understanding for students (a coherent story). The linking questions represent a question that students would likely ask at the end of a lesson. In general, the question provides some evidence of the student's understanding of the concept learned and an indication that he or she is wondering about the next logical progression. The next logical progression should be the next chapter of the story they are learning by engaging in a lesson on the connected key concept.

### **Using Driving Questions**

The driving questions are the focus of the lesson; they drive our thinking towards the overarching concept as we explore the data and information. Teachers and students should seek to answer the driving question throughout the lesson—that is the target of the lesson. While linking questions and driving questions are related, they each serve their own purpose.

## **Implementation Notes**

It is helpful to take notes as you implement a lesson, and to then record reflection notes after instruction. The notes help you stay more evidence-based in your thinking and decisions about the lesson. This can help you work with other teachers, communicate more efficiently with school administrators, and use the notes to help make adaptation or refinement decisions when you teach the unit again in subsequent years. The table on the next page provides an example of a notes page that you might want to use to organize your observations and thinking about each lesson. Copy as many pages as you need for each lesson.

## **Implementation Notes**

D. C.	
Lesson: Dates:	

Common Student Ideas Shared (quotes or close paraphrases)	Outlier Student Ideas Shared (quotes or close paraphrases)	Notes to Think About or Possible Questions to Ask During Next Session Based on Current Student Understanding
What worked well?	Evidence	Reflections/Planning Notes
		for Next Use
What did not work as well as expected?	Evidence	Reflections/Planning Notes for Next Use

## Safety

Safety is always a concern in the science classroom. It is important that you follow and model safe practices with all equipment and chemicals, including the storage, labeling and handling of materials. Safety guidelines are continually updated. Be sure to be aware of local, state, and federal guidelines and practices.

A few resources to consider are the following:

A national perspective and resources from National Science Teachers Association (NSTA): <a href="http://www.nsta.org/portals/safety.aspx">http://www.nsta.org/portals/safety.aspx</a>

Laboratory Safety Training from Flinn Scientific: <a href="http://labsafety.flinnsci.com/CertificateCourseSelection.aspx?CourseCode=MS">http://labsafety.flinnsci.com/CertificateCourseSelection.aspx?CourseCode=MS</a>

You should also be aware of and review your local and state safety requirements from the State Department of Health and the State Department of Education.

# Matter and Energy in Organisms High School Pacing Guide (Approximate times – see Adjusting the Guide)

Day 1	Day 2	Day 3	Day 4	Day 5
Activation Task (30 minutes)	Lesson 1: Engage (25 minutes) Lesson 1:	Lesson 1: Gather & Analyze (55 minutes)	Lesson 1: Gather & Analyze (60 minutes)	Lesson 1: Gather & Analyze (30 minutes)
	Gather & Analyze (20 minutes)			Lesson 1: Connect (30 minutes)
Day 6	Day 7	Day 8	Day 9	Day 10
Lesson 1: Reflect (15 minutes) Lesson 2: Engage (25 minutes) Lesson 2: Gather & Analyze (15 minutes)	Lesson 2: Gather & Analyze (57 minutes)	Lesson 2: Gather & Analyze (57 minutes)	Lesson 2: Gather & Analyze (20 minutes) Lesson 2: Connect (35 minutes)	Lesson 2: Connect (10 minutes) Lesson 2: Reflect (15 minutes) Lesson 3: Engage (25 minutes)
Day 11	Day 12	Day 13	Day 14	Day 15
Lesson 3: Gather & Analyze (60 minutes)	Lesson 3: Gather & Analyze (35 minutes) Lesson 3: Connect (22 minutes)	Lesson 3: Connect (15 minutes) Lesson 3: Reflect (15 minutes) Lesson 4: Engage (25 minutes)	Lesson 4: Gather & Analyze (57 minutes)	Lesson 4: Gather & Analyze (55 minutes)
Day 16	Day 17	Day 18	Day 19	Day 20
Lesson 4: Connect (37 minutes) Lesson 4: Reflect (15 minutes)	Application Task Summative Assessment (45 minutes)	Application Task Problem-Based Application (45 minutes)	Application Task Problem-Based Application (60 minutes)	Application Task Problem-Based Application (60 minutes)
Day 21				
Application Task Problem-Based Application (20 minutes)				
Application - Reflect (15 minutes)				

## **Adjusting the Guide**

Times	Flexibility	Adjusting Lessons		
All daily times are suggestions. Adjust daily times as needed to fit your classroom needs and schedules.  Notice also that lessons are arranged by numbered days, not days of the week. Use the calendar to complement your schedule.	After completing the first lesson, you may notice that your students need more or less time on certain activities. For example: Your students may need more time to read about science but less time for activity setup. Adjust the times of the phases as needed to fit your students and their needs.	You may have noticed, based on the results of the activation task, that your students already understand some of the information contained in the lesson. Adjust lesson times as necessary to fit your students' needs.		

# **Master List of Resources**

Resources	Lessons					
Materials not provided with the unit	Act	1	2	3	4	Арр
Chart paper, butcher paper, or whiteboard	<b>√</b>	<b>√</b>	<b>✓</b>	<b>√</b>	<b>√</b>	<b>√</b>
Internet access for students*						<b>√</b>
Appendix A: Teacher Resources	Act	1	2	3	4	Арр
Norms for Discussion	$\checkmark$	$\checkmark$	<b>✓</b>	<b>✓</b>	$\checkmark$	$\checkmark$
Talking to Understand: Student Talk	<b>√</b>	<b>√</b>	<b>√</b>	<b>√</b>	<b>√</b>	<b>√</b>
Appendix B: Student Resources	Act	1	2	3	4	Арр
Plant Growth in the Absence of Light: Experimental Data	<b>√</b>		<b>√</b>	<b>✓</b>		
Plant Growth in the Absence of Light: Scientific Explanation	<b>√</b>					
Leaf Disk Lab: Photosynthesis and Matter		<b>√</b>				
Reading: Photosynthesis and Matter		<b>√</b>				
General Rubric for Writing Arguments in Science		<b>√</b>				<b>√</b>
Leaf Disk Lab: Photosynthesis and Energy			<b>√</b>			
Reading: Photosynthesis and Energy			<b>√</b>			
Reading: Getting More Specific About Light			<b>✓</b>			
Applying Information: Extension Lab Scenario			<b>√</b>			
Plant Growth in the Absence of Light: Writing Explanatory Text in Science			<b>√</b>	<b>✓</b>		
General Rubric for Writing Informational/ Explanatory Text in Science			<b>√</b>	<b>√</b>	<b>√</b>	
Reading: Cellular Respiration: Matter and Energy				<b>√</b>		
Making Yogurt Lab Procedure					<b>√</b>	
Reading: Anaerobic vs. Aerobic Respiration					<b>√</b>	

<sup>\*</sup>These are optional materials.

Appendix B: Student Resources (continued)	Act	1	2	3	4	Арр
Reading Guide: Anaerobic vs. Aerobic Respiration					<b>√</b>	
Plant Growth in the Absence of Light: Writing an Argument in Science						<b>√</b>
Problem-Based Application: Designing a Plan of Action to Improve Food Deserts						<b>√</b>
Reading: Thinking Deeper About What We Eat						<b>√</b>
Reading: Food Deserts						<b>√</b>
Development Template for Writing Arguments in Science						<b>√</b>

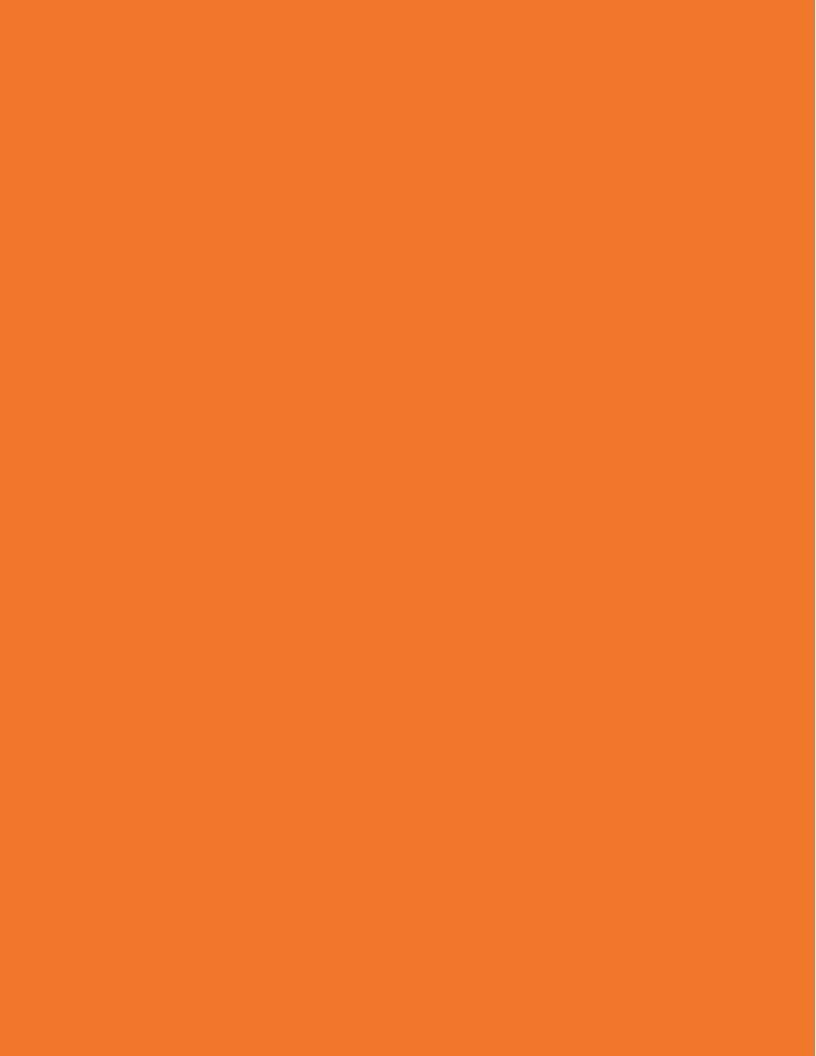


Adjustable to grades
9-10 based on
content alignment.

# **Activation Task**

Matter and Energy in Organisms

[HS.LS-ME0]



# **Activation Task**

#### **Overarching Concept**

All organisms require the input of matter and energy. Organisms transform the matter and energy into forms useable by cellular processes to grow and develop.

#### **Demonstration of Understanding**

• The learner will activate and expose his or her current understandings of scientific principles and concepts related to the unit concepts.

#### **Purpose of Activation Task**

Students enter the classroom with preexisting understandings. These preconceptions are often a mixture of accurate and inaccurate understandings. Regardless of accuracy, students' current understandings influence how students integrate new content. If preexisting understandings are not exposed and addressed, students may not successfully reach an understanding of new material. Or students may engage with new concepts, but return to previous understandings after completing the end assessment. By exposing current thinking, teachers can use preconceptions as the foundation on which to build during the incorporation of new information. Additionally, awareness allows teachers to address, challenge, and when necessary, replace preconceptions (Bransford, Brown and Cocking, 2000).

The activation task provides an opportunity for students to demonstrate their current understanding of how plants obtain energy and matter. It also gives teachers a chance to assess what students already know and understand so that they will be able to make adjustments to the unit lessons. Exposing current understandings activates student thinking about the concepts. It lets students know what they will be studying and allows them to begin to make connections between what they already know and what they will be learning. This helps scaffold the learning by supporting bridges between past lessons and the current learnings.

Being aware of students' current understandings will also aid in forming appropriate groups for collaborative learning. In addition, exposure to students' current understandings gives teachers a heads up regarding when to provide extension activities to students and when to push students to fully explain their thinking to help dispel misconceptions and misunderstandings.

Prior to engaging your students in this unit, take some time to read through the Teacher Background to refresh or check your understanding of the content. Review the Conceptual Story to get a big picture of the unit by studying the overarching concept and the key ideas, making sure it makes sense to you. Examine common student ideas located in the Overview section of this unit; it will give you an idea of what your students may be thinking about this content.

The activation task is designed to engage students in a purpose for learning and to uncover (assess) student thinking. Your role is to help uncover student thinking and then to consider how adjustments might need to be made to the next lessons, based on their current understandings.

Estimated time to complete activation task: 30 minutes

## **Preparing for the Task**

#### **Advanced Preparation**

#### Before Starting the Unit:

- 1. If you have not already done so, before you begin this unit, you should establish a notebook protocol for your students as they work on this unit. Please see the Science Notebooks section (p. 20) in the Unit Overview for guidance in formatting notebooks to help with the lesson routines.
- 2. Establish or review Norms for Discussions and expectations with your students. You might post the Talking to Understand: Student Talk prompts as a reference for students.

#### For Activation Task:

- 1. Copy or print the Plant Growth in the Absence of Light: Experimental Data (see Appendix B: Student Resources).
- 2. Copy or print the Plant Growth in the Absence of Light: Scientific Explanation (see Appendix B: Student Resources).
- 3. Post, so that all students can easily see, the Overarching Driving Question: How do organisms obtain and use the matter and energy they need to perform cellular processes?

#### Resources

#### Materials:

• Chart paper, butcher paper, whiteboard space, or other media for students to be able to illustrate their ideas for the class to be able to see and discuss.

#### Appendix A: Teacher Resources:

- Norms for Discussion
- Talking to Understand: Student Talk

#### Appendix B: Student Resources:

- Plant Growth in the Absence of Light: Experimental Data
- Plant Growth in the Absence of Light: Scientific Explanation

## **Procedure**

Procedure	Teaching Notes	Time <sup>1</sup>
If you have not reviewed the Norms for Discussion or they have not become a well-established routine in your classroom, you should review the norms to ensure that students know what is expected of them in sharing and listening to each other.	The goal is to connect with students and create a safe learning environment for all students.  You might use the Talking to Understand: Student Talk prompt sheet as a visual in the classroom to support productive student talk.	Time will vary, depending on how well norms have been established.
Distribute Plant Growth in the Absence of Light: Experimental Data and Plant Growth in the Absence of Light: Scientific Explanation. Ask students to use the description of the experiment, along with the supplied experimental data, to individually respond to the prompt.		30 minutes
Students will make additions and corrections to their responses in light of the new understandings they acquire during the unit. Therefore, students will need to refer back to their responses later in the unit. Student responses should be either secured (e.g., taped, stapled) or written in their notebooks, or collected and saved for later reference.		

Continued on next page.

<sup>1</sup> Time is provided as an approximate estimate for planning purposes.

	Procedure	Teaching Notes	Time <sup>1</sup>
2.	Conduct a brief class discussion to allow students to share their initial ideas. Some students may want to draw their answer on the board or chart paper to share. This is not a time for correcting, just sharing and building the discussion community.	Monitor the class norms to ensure that students are listening to each other.  Where appropriate, model questioning to push for clarification (ensuring students are clear in what they say and that others understand what they intended). This is not a point where you want to advance thinking, just assess and clarify.  You can prompt students by asking them assessing questions (questions intended to push for clarity—ensuring that others understand what a student is trying to communicate). Some prompts you might use include the following:  • What do you mean when you say?  • Say more about how that happens.  • What examples can you give?	10 minutes
3.	Wrap up by directing the students' attention to overarching driving question (How do organisms obtain and use the matter and energy they need to perform cellular processes?)  Share that this will be the focus of this unit of study.	The overarching driving question will be answered by the end of the unit. During the activation task the focus is to uncover student thinking and promote student curiosity.	2 minutes

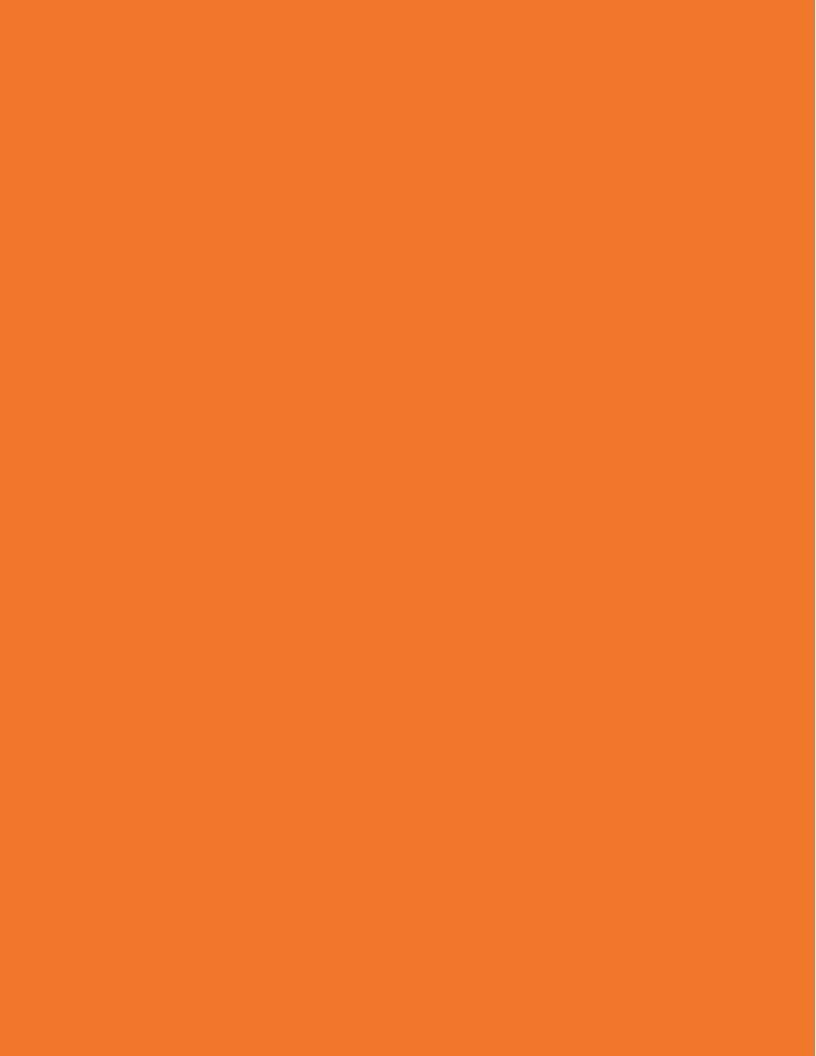


9-10 based on content alignment.

# Concept Development Lesson One: Photosynthesis: Matter

Matter and Energy in Organisms

[HS.LS-ME0]



## **Concept Development Lesson One: Photosynthesis: Matter**



#### **Key Concept #1**

Matter makes up all components of organisms and most components of the environment. Plants and other photosynthesizing organisms obtain matter from the environment through the process of photosynthesis.

#### **Driving Questions #1**

What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?

#### **Demonstrations of Understanding**

By the end of this lesson, students will be able to:

- follow precisely a complex multi-step procedure when carrying out experiments and taking measurements;
- conduct an experiment to identify the inputs/reactants and outputs/products involved in photosynthesis and identify the products of photosynthesis (glucose) as a source of matter for plants and other photosynthesizing organisms;
- monitor their own thinking, as understandings of scientific concepts are refined;
- engage in multiple forms of discussion in order to process, make sense of, and learn from other's ideas, observations, and experiences;
- engage in productive scientific discussion practices during conversations with peers in the context of scientific investigations and model-building;
- write a scientific argument to support a claim using experimental and textual evidence;
- use text to identify that during chemical reactions, the bonds of reactant molecules are broken; the atoms are then rearranged into the product molecules;
- identify the inputs and outputs of photosynthesis in terms of matter (energy will be addressed during Concept Development Lesson Two (CDL2); and
- identify that the bonds of carbon dioxide and water are broken during photosynthesis and the rearrangement of the atoms results in glucose and oxygen. The purpose of photosynthesis is to make glucose to be used for structural or energy purposes (energy will be addressed during CDL2). Oxygen gas is a waste or byproduct.

#### **Estimated time to complete Concept Development Lesson One (CDL1):** 235 minutes

• Engage Phase: 25 min.

• Gather & Analyze Phase: 165 min.

 Connect Phase: 30 min. Reflect Phase: 15 min.



#### **Teacher Background**

Plants and other photosynthesizing organisms undergo the process of photosynthesis. Photosynthesis is a series of chemical reactions that can be summarized as using light energy to synthesize sugar from carbon dioxide and water, releasing oxygen as a waste product. The sugar is used as a stored source of chemical energy (does not need to be used immediately) and as a source of building materials. Plants and other photosynthesizing organisms do not need to consume "food" because they produce the molecules needed to undergo the process of "making" useable energy and packaging matter for use in growth and development during photosynthesis.

Photosynthesis is the source of energy for nearly all life on Earth, the exceptions being chemoautotrophs that live in rocks or around deep-sea hydrothermal vents. In addition to energy, photosynthesis is the source of the carbon in all the organic compounds within organisms' bodies. Photosynthesis accounts for large amounts of carbon fixation (binding of carbon from CO<sub>2</sub> into organic compounds). Photosynthetic organisms convert around 100-115 thousand million metric tons of carbon into biomass per year. CDL1 asks students to view photosynthesis through the lens of matter. Viewing photosynthesis through the energy lens will be covered during CDL2.

Matter is anything that takes up space and has mass. With the exception of light, the reactants and products in the photosynthesis equation are matter. Through a complex series of steps, the process of photosynthesis breaks the bonds of the reactant molecules (carbon dioxide and water). The atoms of the reactant molecules are rearranged, and new bonds are formed, resulting in the formation of different molecules or the product molecules (glucose and oxygen). Glucose is the high-energy sugar most often used in the photosynthesis equation; however, other sugars can also be produced during photosynthesis. The atoms of glucose molecules are the building blocks for the molecules that make up the organism and aid in growth and development.

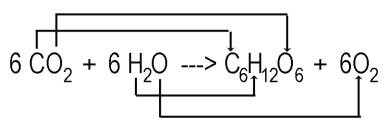
Your students will likely have some understandings about plants and photosynthesis. This lesson asks students to think about the role of matter in the process of photosynthesis. Students need to be able to use the photosynthesis equation to think about the process; however, students are not asked to memorize the complex steps of photosynthesis. The steps (light-dependent reaction and light-independent or Calvin Cycle) are mentioned during CDL2, but do not play a major role in the lesson or the understanding of photosynthesis during this unit.

#### **Teacher Content Knowledge**

High school teachers need a certain amount of background knowledge to teach complex materials. The amount and level of content knowledge varies among teachers. Provided below is a list of science content relevant to the lesson. Educate yourself as necessary to be prepared to engage in discussions and questioning with students. National Science Teachers Association (www.nsta.org) has a variety of resources. Textbooks and Internet searches can also provide valuable resources.

#### Teacher Background: Content Knowledge

- Matter, atoms, and elements
- Chemical reactions, reactants, products, making and breaking of chemical bonds
- The photosynthesis equation—reactants, products, and the movement of atoms through the reaction





The figure above shows the movement of atoms

#### **End-of-Lesson Takeaway**

The goal for this lesson is to look at photosynthesis through the lens of matter. Students should get the idea that photosynthesis is a chemical reaction and can be expressed as a chemical equation. Students should be able to identify that the bonds of the reactant molecules are broken and the atoms of the reactant molecules are rearranged to form the product molecules.

This lesson should lay a foundation of the concepts around photosynthesis, as well as lay a foundation for concepts (such as matter, chemical bonds and chemical equations) used throughout the unit. Students should get the idea that plants use matter from their environment, carbon dioxide and water to synthesize (build) sugar. This provides carbon building blocks that can be used by the organism to grow and develop.

While the purpose of the lesson is not to memorize the photosynthesis equation, students should understand where the reactant and product molecules come from and the role they play in the process. Furthermore, students should be able to use the equation and their understanding of matter to form an argument illustrating the role of photosynthesis in the lab they will perform. The goal of the lesson is to help students think about photosynthesis conceptually with a focus on matter.



#### **Preparing for the Lesson**

#### **Advanced Preparation**

#### Before Starting the Unit:

- 1. If you have not already done so, before you begin this unit, you should establish a notebook protocol for your students as they work on this unit. Please see the Science Notebooks section (p. 20) in the Unit Overview for guidance in formatting notebooks to help with the lesson routines.
- 2. Establish or review Norms for Discussions and expectations with your students. You might post the Talking to Understand: Student Talk prompts as a reference for students.
- 3. Determine how students will be organized into pairs for reading and discussions. This (pairing) should be an established routine in the classroom. You can best decide the most appropriate pairing patterns for your students. For example, you might have them pair with the person sitting next to them, you might have pre-assigned partner names (based on language or reading levels), and of course you may assign or shift partners to avoid disruptive behavior patterns between pairs.

#### For Engage Phase:

- 1. Post Driving Questions #1 (What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?) so that they are visible to the entire class and can remain posted across the lesson.
- 2. Predetermine how students will be organized into pairs for discussion.

#### For Gather & Analyze Phase:

- 1. Prepare materials for Leaf Disk Lab: Photosynthesis and Matter.
  - a. Gather and organize materials (per student group)
    - 1 or 2 syringes (10 ml) without the needles per student group (2 syringes if students are performing the control; 1 syringe if there is a class control)
    - 1 light source and 60 W bulb (be sure not to use high-efficiency bulbs)
    - Single-hole punch
    - Ruler
    - Timer
    - Heat sink source: Place a clear container containing water between the light source and the syringe. The heat given off from the light source is absorbed by the water in the container rather than the solution in the syringe. The light shines through the container with water, allowing the syringe to receive the light.
    - Access to experimental solution
    - Optional: access to control solution
    - Access to leaf material
  - b. Prepare solutions and leaf material.
    - Experimental solution

Mix the following together to yield 1 L of solution (10 ml needed per student group per trial):

- 8.4 g sodium bicarbonate, also known as baking soda (NaHCO<sub>3</sub>)
- 1 L of water
- 1 drop of liquid soap (amount of soap varies, dependent on type of soap used solution should not produce bubbles)
- Control solution

Mix the following together to yield 1 L of solution (10 ml needed per student group per trial):

- 1 L water
- 1 drop of liquid soap

- Spinach or leaf material
  - Place in cool water and under a light source (60 W) at least 1 hour prior to experiment.
  - Be careful not to damage leaves with excessive heat from the light source or water.
- c. Try out your solution and leaves prior to students' performing the experiment.
  - If the leaf disks don't sink, your solution needs more liquid soap.
  - If the leaf disks don't rise, the leaf material may be too old, cold, or damaged.
  - Read over Leaf Disk Lab: Photosynthesis and Matter (located in Appendix B: Student Resources) for the full experimental procedure.
  - Fresher leaves usually yield better results. Be sure not to use high-efficiency light bulbs.
- 2. Predetermine how students will be organized into pairs for pre-lab discussion.
- 3. Copy or print Leaf Disk Lab: Photosynthesis and Matter (see Appendix B: Student Resources).
- 4. Predetermine how students will be organized into pairs or triads for the Leaf Disk Lab.
- 5. Predetermine how students will be organized into pairs or triads for the Reading: Photosynthesis and Matter and small group discussion.
- 6. Be prepared to post the argument writing prompt. (Writing an Argument: Form a claim to answer the following question. Support your claim with evidence and reasoning. Include the photosynthesis equation and matter in your argument. Why do the leaf disks rise to the surface of the solution?)
- 7. Copy or print the General Rubric for Writing Arguments in Science (see Appendix B: Student Resources).

#### For Connect Phase:

1. Make sure Driving Questions #1 (What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?) are posted to guide whole group discussion.

#### For Reflect Phase:

- 1. Make sure Driving Questions #1 (What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?) are posted for student reflection.
- 2. Post the reading reflection questions (How did the format of the reading help you engage as a learner? How did the questions help or change the way you read the information? What did you have to do to support your own thinking as you read?).

#### Resources

#### Materials:

- Chart paper, butcher paper, whiteboard space, or other media for students to be able to illustrate their ideas for the class to be able to see and discuss
- Leaf Disk Lab materials (see Gather & Analyze Phase above)

#### Appendix A: Teacher Resources:

- Norms for Discussion
- Talking to Understand: Student Talk

#### Appendix B: Student Resources:

- Leaf Disk Lab: Photosynthesis and Matter
- Reading: Photosynthesis and Matter
- General Rubric for Writing Arguments in Science





#### **Procedure**



#### **ENGAGE PHASE**

This phase is designed to activate prior knowledge about the key concept or to provide a link that connects this lesson with the previous lesson. It is intended to expose student thinking so you and your students know where they are starting.

Estimated time: 25 minutes; additional time may be necessary to establish norms if they are not already established (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Post Driving Questions #1 (What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?) on the board, written so they will stay visible to students for the entire lesson.	The driving questions will be answered by the end of the lesson; right now the focus is to uncover student thinking.	
2. Ask students to individually and silently reflect on the driving questions. Ask students to record their initial thoughts and understandings in their science notebook. Ask students to be as specific in their answers as possible. Encourage students to share all their thoughts. The purpose of answering the question is not to determine right and wrong answers, but rather to expose ALL current understandings.	Encourage students to include what they know from both school and life experiences.	10 minutes
3. If you have not reviewed the Norms for Discussion or they have not become a well-established routine in your classroom, you should review the norms to ensure that students know what is expected of them in sharing and listening to each other.	The goal is to connect with students and create a safe learning environment for all students.  You might use the Talking to Understand: Student Talk prompt sheet as a visual in the classroom to support productive student talk.	Time will vary, depending on how well norms have been established.
4. Ask students to share and discuss their thoughts with a partner. Ask students to be prepared to share their thoughts with the whole group.		5 minutes

<sup>1</sup> Time is provided as an approximate estimate for planning purposes.

Procedure	Teaching Notes	Time <sup>1</sup>
<ol> <li>Ask students to share and discuss their reasoning as a whole group.</li> <li>The sharing is only to get students talking about their ideas; it is not to correct misconceptions yet or to come to a firm conclusion.</li> <li>During the discussion, try to expose students' understandings about matter, autotrophs, and photosynthesis (in particular how photosynthesis and matter relate to each other).</li> </ol>	Support whole group discussions by providing time for students to individually think about their responses and rehearse their thoughts with a partner before engaging in the whole group discussion (Think-Pair-Share).  Note that your questioning at this point is to assess student understanding and to push for clarity (probe to help students clearly articulate what they mean). You do not want to advance student thinking yet. You can use prompts such as the following:	10 minutes
	<ul> <li>Why do you think that?</li> <li>What do you mean when you say?</li> <li>Say more about how that happens.</li> <li>Who can add on to that?</li> <li>Did anyone have a different idea they would like to share?</li> <li>What examples can you give?</li> <li>Help me to understand what you mean when you say</li> </ul>	





#### **GATHER & ANALYZE PHASE**

This phase is designed to provide students with an opportunity to explore data and information to solve a question or problem. This may be accomplished through a hands-on laboratory to observe and generate data, or the data may be gathered from reliable sources. The data should be focused by a scientific question in order to develop an understanding of the key concept. Students should also begin to analyze and make sense of the data/information to develop an argument or explanation.

Estimated time: 165 minutes (Times are broken down within the steps of the phase.)

	Procedure	Teaching Notes	Time <sup>1</sup>
1.	Ask students to individually read the Photosynthesis and Matter Leaf Disk Lab materials and procedure sections. Encourage students to reread as needed. Ask students to record any questions or wonderings they have in their science notebooks as they read.		5 minutes
2.	Review the Norms for Discussion if they have not become a well-established routine in your classroom. You should review the norms to ensure that students know what is expected of them in sharing and listening to each other.	As students engage in productive talk during this phase, it is important for you and the students to monitor class and individual behavior to ensure that all students feel safe to share their ideas.	
3.	Ask students to turn to a partner and share their questions and wonderings about the lab and the lab procedure.	Support whole group discussions by providing time for students to individually think about their responses and rehearse their thoughts with a partner before engaging in the whole group discussion (Think-Pair-Share).  If you engage in discussions with students during this time, use assessing questions to learn more about students prior knowledge, misconceptions, experiences, and ways of making sense. Some examples of assessing prompts you might use include the following:  Why do you think that?  What do you mean when you say?  How does this relate to that	5 minutes

LESSON

Procedure	Teaching Notes	Time <sup>1</sup>
4. Begin a whole group discussion around the lab and the lab procedure. Ask students to share their understandings and questions. Work together to dissect the parts of the procedure to make sure everyone understands what to do.  It may be helpful to have students diagram the steps of the procedure with pictures. Encourage students to add clarifying points and illustrations to their lab procedure and/or science notebooks.  Facilitate the discussion with guiding questions as needed, but allow students to answer each other's questions and dissect the procedure for understanding.  Record the dissected procedure on the board or a piece of chart paper. Add clarification as students share their understandings and illustrations. Keep the procedure visible as students work on the lab and during the discussion following the lab as a reference.	Make sure students fully understand the procedure. It is important that students learn to read and execute an experiment from a procedure with little to no teacher guidance.  Use assessing questions to guide the discussion. Use prompts to learn more about how students are making sense of the lab procedure. Some examples of assessing prompts you might use include the following:  • Why do you think that? • What do you mean when you say? • How does this relate to that? • What is your evidence?	10 minutes
<ol> <li>Organize students into groups of two or three.</li> <li>Ask students to gather needed materials and perform the lab.         Remind students to take accurate and detailed observations in their science notebooks.</li> <li>As students work, circulate to make sure students are recording detailed lab data in their science notebooks.</li> </ol>	Use assessing prompts as you circulate. See steps 3 and 4 above for examples.  A variation of this lab will be performed in CDL2. Allow students to make mistakes and find solutions during the execution of the lab. This allows students to think more deeply about the lab, develop lab skills, and to be prepared for a more precise execution during CDL2.	45 minutes
6. Provide time for students to clean and return their lab materials, and to clean their lab areas.  Post a class data table on the board. Ask students to fill in their data.		5 minutes



Proc	edure	Teaching Notes	Time <sup>1</sup>
to briefly share Students shoul data in their sc	up. Ask students their findings. d record the class ience notebooks. discussion is make had common,		5 minutes
individually rea and the text. As at the question for guidance as	Ask students to ad the directions sk students to look s in the left column s they read, but d not answer the	The Photosynthesis and Matter reading is divided into two columns. The right-hand column contains the text. The left-hand column contains guiding questions. By placing the questions next to the relevant text, students are exposed to the idea of thinking about questions as they engage in the text.  Throughout the unit students are exposed to different formats of readings and different types of questions. As students engage with the text throughout the unit, they will be scaffolded from questions being next to the text (in a way forcing them to think about guiding questions and purpose as they read), to guiding questions being separate from the text. Students need to develop the habit of considering questions and the purpose of the text as they read.  The directions prior to the text include a description of different types of questions asked throughout the unit readings. In the left-hand column, guiding questions are labeled by type of question. Different types of questions lend to different interactions with the text. A Finding question requires less depth of reading than a Connecting question. Different types of questions also lend themselves to different depths of discussion. A Finding question usually leads to shallow, short dialogue, whereas a Deeper Thinking question might engage students in a discussion of greater depth. It is important that students are aware of different types of questions and the purpose behind questions. You may also want to point out that different types of questions lead to different depths of discussion.	10 minutes

Procedure	Teaching Notes	Time <sup>1</sup>
9. Organize students into groups of two or three. You may choose to have students rejoin their lab groups or choose new groups.  As a group, have students reread Photosynthesis and Matter and answer the questions. Encourage students to discuss their answers with their group members and to support all answers with evidence.		20 minutes
10. Post or display the following writing prompt and directions. Tell students they will be developing an argument to answer the prompt: "Writing an Argument: Form a claim to answer the following question. Support your claim with evidence and reasoning. Include the photosynthesis equation and matter in your argument. Why do the leaf disks rise to the surface of the solution?"  Ask students to record the prompt in their science notebook. In groups of two or three, ask students to form an argument to answer the prompt. Distribute the General Rubric for Writing Arguments in Science. Encourage students to use Leaf Disk Lab: Photosynthesis and Matter, data collected from their lab, and the Photosynthesis and Matter reading to find evidence to support their claim.  Each student should have a copy of the argument in his/her notebook. Encourage students to use the General Rubric for Writing Arguments in Science to guide the organization of their writing.	Scaffold student writing by providing a template to support them as they identify the claim, evidence, and reasoning.  As you move among groups, use assessing and advancing prompts to differentiate the learning based on where your students are in terms of understanding. Listen carefully to student comments and responses. Now is the time to push for clarity and to advance their thinking. Some examples of advancing prompts you might use include the following:  Say more about how that happens.  Why does that happen?  How does this relate to that?  Add some of the new ideas we've been talking about to your explanation.  How can you apply what you have just read to your investigation?  How are the explanations similar?  Are there alternate claims that we should consider?	30 minutes





Procedure	Teaching Notes	Time <sup>1</sup>
11. Ask students to record their arguments (claim, evidence, and reasoning) on chart paper or other means so that writing is large enough to make group thinking visible. Tell students to be ready to share their thinking with the whole group.		5 minutes
12. Quickly review the Norms for Discussion in your classroom.  Make sure students know what is expected of them in sharing and listening to each other.		5 minutes
13. Bring the students back together for a whole group discussion. Ask a group to share their claim, evidence and reasoning. Ask students if they agree or disagree with the argument. If a student agrees, ask him or her to share evidence to support their viewpoint. If a student disagrees, ask him or her to share an alternate claim and the evidence and reasoning that support their viewpoint. Continue this process until all the claims have been shared. Use assessing and advancing prompts to guide the discussion.	Through the discussion the students should get the idea that through the process of photosynthesis, plants are producing oxygen gas. The accumulation of the oxygen gas in the leaf disks causes the leaf disks to rise to the surface of the solution. Students should use the photosynthesis equation in their arguments. Students should be able to identify the reactants and products in the chemical equation. Students should also mention that the chemical bonds of the reactant molecules are broken during photosynthesis and rearranged to form the molecules of the products.	20 minutes



#### **CONNECT PHASE**

LESSON

This phase is designed to socialize intelligence for the entire classroom (all students) by connecting the activities during the previous phase to the key concept. This usually involves a teacher-led whole group discussion that explicitly ties the work students have done to the key concept and ensures that a common understanding is achieved at or beyond the level of the targeted standards.

Estimated time: 30 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Begin a whole group discussion around Driving Questions #1 (What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?).  Encourage students to use evidence gathered during the lab and the reading as they discuss the driving questions. Use assessing and advancing prompts to guide the discussion.	This discussion should focus on photosynthesis from the matter perspective. During this discussion, students should get the idea that plants use the reactants of photosynthesis: water and carbon dioxide (the role of light will be addressed during CDL2) to form the products of photosynthesis. Use guiding questions to help students identify oxygen as a waste product during the process of photosynthesis. Students should identify the production of glucose as the purpose of photosynthesis. Students should also identify ways that glucose is used in the organism, such as structure and matter storage.	20 minutes
2. Ask students to write, in their science notebooks, in their own words what the big idea was of this whole lesson. What is the main thing they learned? What are some key science ideas you discussed and learned about?		10 minutes





#### **REFLECT PHASE**

This phase is designed to provide time for students to individually reflect on the lesson and to pull their thoughts together to make sense of what they have experienced. They should understand how the activities of the lesson connect to the key concept, as well as how what they have done builds understanding of the overarching concept of the unit. This phase provides evidence of individual learning achieved through the lesson.

Estimated time: 15 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
<ol> <li>Direct students' attention to Driving Questions #1 (What is matter? How do plants and other photosynthesizing organisms obtain matter from the environment?) on the board.</li> </ol>		10 minutes
Ask students to revisit their initial thoughts and understandings they recorded in their science notebooks during the Engage Phase. Ask students to individually and silently reflect on the driving questions in light of their learnings during CDL1. Ask students to be as specific in their answers as possible.		
Ask students to individually reflect on the format of the reading during the lesson. Post the following questions on the board:		5 minutes
<ul> <li>How did the format of the reading help you engage as a learner?</li> <li>How did the questions help or change the way you read the information?</li> <li>What did you have to do to support your own thinking as you read?</li> </ul>		
Ask students to respond to the questions in their science notebook.		
Remind students that they recorded thoughts to revisit in their science notebooks when they completed the reading.		

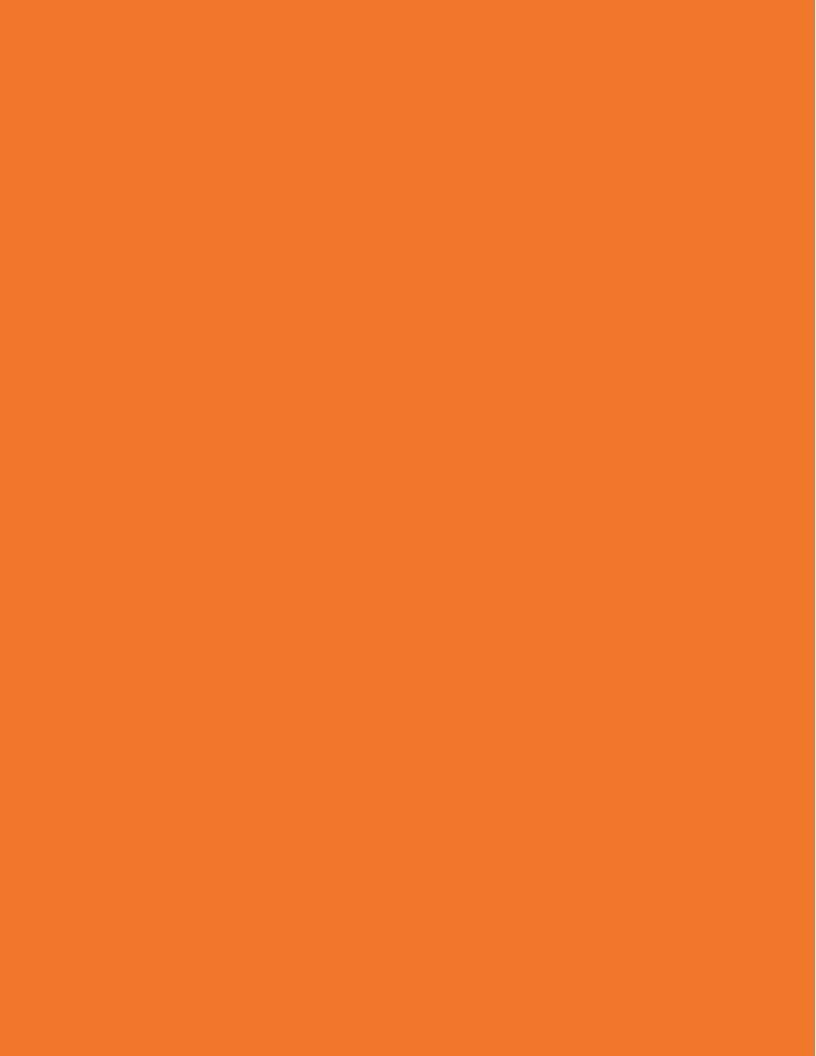


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## Concept Development Lesson Two: Photosynthesis: Energy

Matter and Energy in Organisms

[HS.LS-ME0]



## **Concept Development Lesson Two: Photosynthesis: Energy**



#### **Key Concept #2**

Plants and other photosynthesizing organisms transform light energy into stored chemical energy through the process of photosynthesis.

#### **Driving Question #2**

How do plants and other photosynthesizing organisms transform light energy into chemical energy?

#### **Demonstrations of Understanding**

By the end of this lesson, students will be able to:

- follow precisely a complex multi-step procedure when carrying out experiments and taking measurements;
- monitor their own thinking, as understandings of scientific concepts are refined;
- engage in multiple forms of discussion in order to process, make sense of, and learn from other's ideas, observations, and experiences;
- engage in productive scientific discussion practices during conversations with peers in the context of scientific investigations and model-building;
- write a scientific explanation using experimental and textual evidence;
- conduct an experiment to identify light as an energy source and a necessary input for the process of photosynthesis; and
- identify photosynthesis as the process that transfers and transforms light energy into stored chemical energy.

#### **Estimated time to complete Concept Development Lesson Two (CDL2):** 232 minutes

• Engage Phase: 25 min.

• Gather & Analyze Phase: 147 min.

• Connect Phase: 45 min. Reflect Phase: 15 min.

#### **Teacher Background**

Plants and other photosynthesizing organisms undergo the process of photosynthesis. Photosynthesis is a series of chemical reactions that can be summarized as using light energy to synthesize sugar from carbon dioxide and water, releasing oxygen as a waste product. The sugar is used as a stored source of chemical energy (does not need to be used immediately) and as a source of building materials. Plants and other photosynthesizing organisms do not need to consume "food" because they produce the molecules needed to undergo the process of "making" useable energy and packaging matter for use in growth and development during photosynthesis.

Photosynthesis is the source of energy for nearly all life on Earth, the exceptions being chemoautotrophs that live in rocks or around deep-sea hydrothermal vents. CDL1 asked students to view photosynthesis through the lens of matter. CDL2 asks students to take their knowledge of photosynthesis to the next level by understanding how light energy is transformed into stored chemical energy (in the form of glucose).

Your students will likely have some understandings about light and photosynthesis. This lesson asks students to think about the role of energy transformation in the process of photosynthesis. Students need to be able to use the photosynthesis equation to think about the process; however, students are not asked to memorize the complex steps of photosynthesis. The steps (light-dependent reaction and light-independent or Calvin Cycle) are mentioned during the lesson, but do not play a major role in the understanding of photosynthesis during this unit.

#### **Teacher Content Knowledge**

High school teachers need a certain amount of background knowledge to teach complex materials. The amount and level of content knowledge varies among teachers. Provided below is a list of science content relevant to the lesson. Educate yourself as necessary to be prepared to engage in discussions and questioning with students. NSTA has a variety of resources. Textbooks and Internet searches can also provide valuable resources.

#### Teacher Background: Content Knowledge

- Light energy, visible light spectrum
- Role of chloroplasts and chlorophyll in photosynthesis
- Role of ATP and NADPH in photosynthesis
- Light-dependent reaction and light-independent reaction (Calvin Cycle); students are not learning this in depth, so a deep level of understanding is not needed
- The photosynthesis equation—reactants, products, and the role of light energy

#### **End-of-Lesson Takeaway**

The goal for this lesson is to look at photosynthesis through the lens of energy transformation. Students should get the idea that the energy from light is transformed to stored chemical energy during the process of photosynthesis. Students should also recognize that variables, such as light intensity and light color or wavelength, affect the process of photosynthesis.

Students should make connections from the information learned during CDL1 about photosynthesis and matter, to the learnings of CDL2 about photosynthesis and energy. The discussions about energy and matter will help students during CDL3 as students make connections between photosynthesis and cellular respiration.

While the purpose of the lesson is not to memorize the photosynthesis equation, students should understand where the reactants and products, now including light, come from and the role they play in the process. Furthermore, students should be able to use the equation and their understanding of light energy to form an explanation illustrating the role of photosynthesis in various lab scenarios. The goal of the lesson is to help students think about photosynthesis conceptually with a focus on energy.



#### **Preparing for the Lesson**

#### **Advanced Preparation**

#### For Engage Phase:

- 1. Post Driving Question #2 (How do plants and other photosynthesizing organisms transform light energy into chemical energy?) so that it is visible to the entire class and can remain posted across the lesson.
- 2. Predetermine how students will be organized into pairs for discussion.

#### For Gather & Analyze Phase:

- 1. Prepare materials for Leaf Disk Lab: Photosynthesis and Energy.
  - a. Gather and organize materials (per student group)
    - 1 or 2 syringes (10 ml) without the needles per student group (2 syringes if students are performing the control; 1 syringe if there is a class control)
    - Light source and light bulbs of varying intensities (be sure not to use high-efficiency bulbs);
       assign student groups a light bulb and make sure students record the bulbs' lumens; be sure multiple groups are testing the same light intensity to allow for multiple experimental trials
    - Single-hole punch
    - Ruler
    - Timer
    - Heat sink source: Place a clear container containing water between the light source and the syringe. The heat from the light source is absorbed by the water in the container rather than the solution in the syringe. The light shines through the container with water, allowing the syringe to receive the light.
    - Access to experimental solution
    - Access to leaf material
  - b. Prepare solution and leaf material.
    - Experimental solution

Mix the following together to yield 1 L of solution (10 ml needed per student group per trial):

- 8.4 g sodium bicarbonate, also known as baking soda (NaHCO₃)
- 1 L of water
- 1 drop of liquid soap (amount of soap varies, dependent on type of soap used solution should not produce bubbles)
- Spinach or leaf material
  - Place in cool water and under a light source (60 W) at least 1 hour prior to experiment.
  - Be careful not to damage leaves with excessive heat from the light source or water.
- c. Try out your solution and leaves prior to students' performing the experiment.
  - If the leaf disks don't sink, your solution needs more liquid soap.
  - If the leaf disks don't rise, the leaf material may be too old, cold, or damaged.
  - Read over the Leaf Disk Lab: Photosynthesis and Energy (located in Appendix B: Student Resources) for the full experimental procedure.
  - Fresher leaves usually yield better results. Be sure not to use high-efficiency light bulbs.



- d. Decide whether you will prepare a class control and provide students with results or if you would prefer for each group to set up a control and gather their data.
- e. Prepare a dark location for the control setup in order for students to compare the results of their experiment (variations in light intensity); everything in the control setup will be the same as the experimental setup with the exception of exposure to light.
  - Determine a dark location (e.g., a dark cabinet or shoe box) prior to the start of the lab.
  - Place the control setup syringe with the experimental solution in the dark location.
  - Be sure the dark location is the same temperature as the location the students are using for the light intensity trials.
- 2. Predetermine how students will be organized into pairs for pre-lab discussion.
- 3. Predetermine the light intensity (provide a variety of light bulbs, not energy efficient) student groups will be testing.
- 4. Copy or print the Leaf Disk Lab: Photosynthesis and Energy (see Appendix B: Student Resources).
- 5. Predetermine how students will be organized into pairs or triads for the Leaf Disk Lab: Photosynthesis and Energy.
- 6. Copy or print Reading: Photosynthesis and Energy (see Appendix B: Student Resources).
- 7. Be prepared to post a class data table for data sharing after completion of the lab.
- 8. Make sure Driving Question #2 (How do plants and other photosynthesizing organisms transform light energy into chemical energy?) is posted to guide individual reflection.
- 9. Predetermine how students will be organized into pairs or triads for the Getting More Specific About Light group reading and discussion.
- 10. Copy or print Reading: Getting More Specific About Light (see Appendix B: Student Resources).
- 11. Copy or print the Applying Information: Extension Lab Scenario (see Appendix B: Student Resources).

#### For Connect Phase:

- 1. Make sure Driving Question #2 (How do plants and other photosynthesizing organisms transform light energy into chemical energy?) is posted to guide whole group discussion.
- 2. Copy or print the Plant Growth in the Absence of Light: Experimental Data (see Appendix B: Student Resources).
- 3. Copy or print the Plant Growth in the Absence of Light: Writing Explanatory Text in Science (see Appendix B: Student Resources).

#### For Reflect Phase:

- 1. Make sure Driving Question #2 (How do plants and other photosynthesizing organisms transform light energy into chemical energy?) is posted for student reflection
- 2. Post the reading reflection questions (How did the format of the reading help you engage as a learner? How did the questions help or change the way you read the information? What did you have to do to support your own thinking as you read?).

LESSON 2

#### Resources

#### Materials:

- Chart paper, butcher paper, whiteboard space, or other media for students to be able to illustrate their ideas for the class to be able to see and discuss
- Leaf Disk Lab materials (see Gather & Analyze Phase above)

#### Appendix A: Teacher Resources

- Norms for Discussion
- Talking to Understand: Student Talk

#### Appendix B: Student Resources

- Leaf Disk Lab: Photosynthesis and Energy
- Reading: Photosynthesis and Energy
- Reading: Getting More Specific About Light
- Applying Information: Extension Lab Scenario
- Plant Growth in the Absence of Light: Experimental Data
- Plant Growth in the Absence of Light: Writing Explanatory Text in Science
- General Rubric for Writing Informational/Explanatory Text in Science

#### **Procedure**



#### **ENGAGE PHASE**

This phase is designed to activate prior knowledge about the key concept or to provide a link that connects this lesson with the previous lesson. It is intended to expose student thinking so you and your students know where they are starting.

Estimated time: 25 minutes; additional time may be necessary to establish norms if they are not already established (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Post Driving Question #2 (How do plants and other photosynthesizing organisms transform light energy into chemical energy?) on the board, written so it will stay visible to students for the entire lesson.	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking.	10 minutes

<sup>1</sup> Time is provided as an approximate estimate for planning purposes.

	Procedure	Teaching Notes	Time <sup>1</sup>
2.	Ask students to individually and silently reflect on the driving question. Ask students to record their initial thoughts and understandings in their science notebook. Ask students to be as specific in their answers as possible. Encourage students to share all of their thoughts. The purpose of answering the question is not to determine right and wrong answers, but rather to expose ALL current understandings.	Encourage students to include what they know from both school and life experiences.	10 minutes
3.	If you have not reviewed the Norms for Discussion or they have not become a well-established routine in your classroom, you should review the norms to ensure that students know what is expected of them in sharing and listening to each other.	The goal is to connect with students and create a safe learning environment for all students.  You might use the Talking to Understand: Student Talk prompt sheets as a visual in the classroom to support productive student talk.	Time will vary, depending on how well norms have been established.
4.	Ask students to share and discuss their thoughts with a partner. Ask students to be prepared to share their thoughts with the whole group.		5 minutes
5.	Ask students to share and discuss their reasoning as whole group.  The sharing is only to get students talking about their ideas; it is not to correct misconceptions yet or to come to a firm conclusion.  During the discussion, try to expose students' understandings about energy from the sun, chemical energy, and photosynthesis (in particular how photosynthesis and energy relate to each other). Students may also begin to make connections between the concept of photosynthesis and matter, discussed during CDL1, and energy.	Support whole group discussions by providing time for students to individually think about their responses and rehearse their thoughts with a partner before engaging in the whole group discussion (Think-Pair-Share).  Note that your questioning at this point is to assess student understanding and to push for clarity (probe to help students clearly articulate what they mean). You do not want to advance student thinking yet. You can use prompts such as the following:  Why do you think that?  What do you mean when you say?  Say more about how that happens.  Who can add on to that?  Did anyone have a different idea they would like to share?  What examples can you give?  Help me to understand what you mean when you say	10 minutes

LESSON

2



#### **GATHER & ANALYZE PHASE**

This phase is designed to provide students with an opportunity to explore data and information to solve a question or problem. This may be accomplished through a hands-on laboratory to observe and generate data, or the data may be gathered from reliable sources. The data should be focused by a scientific guestion in order to develop an understanding of the key concept. Students should also

Estimated time: 147 minutes (Times are broken down within the steps of the phase.)

begin to analyze and make sense of the data/information to develop an argument or explanation.

Procedure	Teaching Notes	Time <sup>1</sup>
Ask students to individually read     the Photosynthesis and Energy: Leaf     Disk Lab materials and procedures.     Encourage students to reread as     needed. Ask students to record any     questions or wonderings they have in     their science notebooks as they read.		5 minutes
2. Review the Norms for Discussion (see p. 101).	As students engage in productive talk during this phase, it is important for you and the students to monitor class and individual behavior to ensure that all students feel safe to share their ideas.	5 minutes
Ask students to turn to a partner and share their questions and wonderings about the lab and the lab procedure.	Support whole group discussions by providing time for students to individually think about their responses and rehearse their thoughts with a partner before engaging in the whole group discussion (Think-Pair-Share).	5 minutes

Procedure	Teaching Notes	Time <sup>1</sup>
discussion around the lab and the lab procedure. Ask students to share their understandings and questions.  The discussion should focus on the changes made to the procedure because the variable is now light intensity.  It may be helpful to have students diagram the changed steps of the procedure with pictures. Encourage students to add clarifying points and illustrations to their lab procedure and/ or science notebooks. Facilitate the discussion with guiding questions as needed, but allow students to answer each other's questions and dissect the procedure for understanding.  Record the dissected procedure on the board or a piece of chart paper. To save time, you may want to use the dissected procedure students developed during CDL1. On a separate sheet of chart paper, add the changes to the procedure for CDL2. Add clarification as students share their understandings and illustrations. Keep the procedure visible as students work on the lab and during the discussion following the lab as a reference.	This discussion should be shorter than the discussion about the procedure in CDL1. Students executed the procedure during CDL1. The discussion should focus on the changes made to the procedure because the variable is now light intensity.  Make sure students fully understand the procedure. It is important that students learn to read and execute an experiment from a procedure with little to no teacher guidance.  Use assessing questions to guide the discussion. Use prompts to learn more about how students are making sense of the lab procedure. Some examples of assessing prompts you might use include the following:  • Why do you think that?  • What do you mean when you say?  • How does this relate to that?  • What is your evidence?	5 minutes
5. Distribute the Photosynthesis and Energy reading. Ask students to read the directions, read the text, and answer the questions as they observe the leaf disks during the lab.	The Photosynthesis and Energy reading is divided into two columns. The right-hand column contains the text. The left-hand column contains guiding questions. By placing the questions next to the relevant text, students are exposed to the idea of thinking about questions as they engage in the text.  See CDL1, Gather & Analyze Phase, Teaching Notes, step 8, for additional clarification on reading formats and question types.	2 minutes

	Procedure	Teaching Notes	Time <sup>1</sup>
6.	Organize students into groups of two or three. These may be the same lab groups as during CDL1 or different.  Ask students to gather needed materials and perform the lab.  Remind students to take accurate and detailed observations in their science notebooks.  As students work, circulate to make sure students are recording detailed lab data in their science notebooks.	Use assessing prompts as you circulate. See step 4 above for examples.	45 minutes
7.	Provide time for students to clean and return their lab materials, and to clean their lab areas.		5 minutes
8.	Bring students back together as whole group. Post a data table on the board. Ask students to fill in their data under the appropriate light intensity. Students should record all the class data in their science notebooks.  Ask students to briefly share their thoughts about the data. Students should notice that photosynthesis occurs more quickly at a greater light intensity.		10 minutes
9.	Direct students to the driving question for the lesson (How do plants and other photosynthesizing organisms transform light energy into chemical energy?). Ask students to individually answer the question in their science notebooks. Ask students to organize their answers as it best makes sense to them. This might mean as a paragraph, but it also may mean bullet points or diagrams. Encourage students to revisit the Photosynthesis and Energy reading to find evidence to support their answers.		7 minutes

Procedure	Teaching Notes	Time <sup>1</sup>
10. Bring students back together as whole group. Ask students to share their answers and understandings. It may be helpful to diagram their understandings on the board.		20 minutes
11. Ask students to take five minutes to individually add new understandings and evidence acquired during the discussion to the answers they recorded in their science notebooks. Ask students to leave room to add more to their answer during a future discussion.		5 minutes
<ul> <li>12. Organize students into groups of two or three. You may choose to have students rejoin their lab groups or choose new groups.</li> <li>Distribute the Getting More Specific About Light reading. Ask students to read the text and answer the questions in their science notebooks.</li> </ul>	The Getting More Specific About Light reading is arranged with the questions following the text. Whereas in prior readings, students were given questions throughout, in this reading students are asked to read the questions prior to reading the text and keep the questions in mind as they read. By placing the questions at the end of the text, students are being scaffolded to a format where they must be more aware of the questions, as the questions are no longer next to the relevant parts of the text. As before, students must think about the questions as they engage in the text.  See CDL1, Gather and & Analyze Phase, Teaching Note, step 8, for additional clarification on reading formats and question types.	15 minutes
13. Distribute the Applying Information: Extension Lab Scenario. In their groups ask students to develop a scientific essay that explains the results of the scenario. Distribute the General Rubric for Writing Informational/Explanatory Text in Science. Ask students to use the rubric to help guide their writing.	As you move among groups, use assessing and advancing prompts to differentiate the learning based on where your students are in terms of understanding. Listen carefully to student comments and responses.  Now is the time to push for clarity and to advance their thinking. Some examples of advancing prompts you might use include the following:  Say more about how that happens.  Why does that happen?  How does this relate to that?  Add some of the new ideas we've been talking about to your explanation.	20 minutes



#### **CONNECT PHASE**

This phase is designed to socialize intelligence for the entire classroom (all students) by connecting the activities during the previous phase to the key concept. This usually involves a teacher-led whole group discussion that explicitly ties the work students have done to the key concept and ensures that a common understanding is achieved at or beyond the level of the targeted standards.

Estimated time: 45 minutes (Times are broken down within the steps of the phase.)

LESSON
2

	Procedure	Teaching Notes	Time <sup>1</sup>
1.	Ask students to come back together as a group. Direct students to Driving Question #2 (How do plants and other photosynthesizing organisms transform light energy into chemical energy?). Build off the previous discussion around this question. Ask students to discuss their understandings in light of the new reading and lab scenario.		15 minutes
2.	Ask students to take five minutes to individually add new understandings and evidence acquired during the discussion to the answers they recorded in their science notebooks.		5 minutes
3.	Distribute a clean version of the Plant Growth in the Absence of Light: Experimental Data and Plant Growth in the Absence of Light: Writing Explanatory Text in Science. With a partner, ask students to revisit the task in light of what they have learned during CDL1 and CDL2. Ask students to record evidence they have learned that would help support their answer. Tell students to record their evidence in the form that makes the most sense to them (e.g., bullets, a list, a diagram or a paragraph). Collect the responses or ask students to keep them in a safe place. Students will revisit this task during CDL3 to continue to build a body of evidence.	As you move among groups, use assessing and advancing prompts to differentiate the learning based on where your students are in terms of understanding. Listen carefully to student comments and responses.  Now is the time to push for clarity and to advance their thinking. Some examples of advancing prompts you might use include the following:  Say more about how that happens.  Why does that happen?  How does this relate to that?  What new ideas that we've been talking about can you add?	15 minutes
4.	Ask students to write, in their science notebooks, in their own words what the big idea was of this whole lesson. What is the main thing they learned? What are some key science ideas you discussed and learned about?	Students should get the idea that light plays an important role in the process of photosynthesis. Students should be able to identify that the energy from light is transferred to glucose and transformed into stored chemical energy.	10 minutes





#### **REFLECT PHASE**

This phase is designed to provide time for students to individually reflect on the lesson and to pull their thoughts together to make sense of what they have experienced. They should understand how the activities of the lesson connect to the key concept, as well as how what they have done builds understanding of the overarching concept of the unit. This phase provides evidence of individual learning achieved through the lesson.

Estimated time: 15 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Direct students' attention to Driving Question #2 (How do plants and other photosynthesizing organisms transform light energy into chemical energy?) on the board.		10 minutes
Ask students to revisit their initial thoughts and understandings they recorded in their science notebooks during the Engage Phase and the thoughts they recorded during the Connect Phase. Ask students to individually and silently reflect on the driving question in light of their learnings during CDL2. Ask students to be as specific in their answers as possible.		
Ask students to individually reflect on the format of the reading during the lesson. Post the following questions on the board:		5 minutes
<ul> <li>How did the format of the reading help you engage as a learner?</li> <li>How did the questions help or change the way you read the information?</li> <li>What did you have to do to support your own thinking as you read?</li> </ul>		
Ask students to respond to the questions in their science notebook. Remind students that they recorded thoughts to revisit in their science notebooks when they completed the reading.		

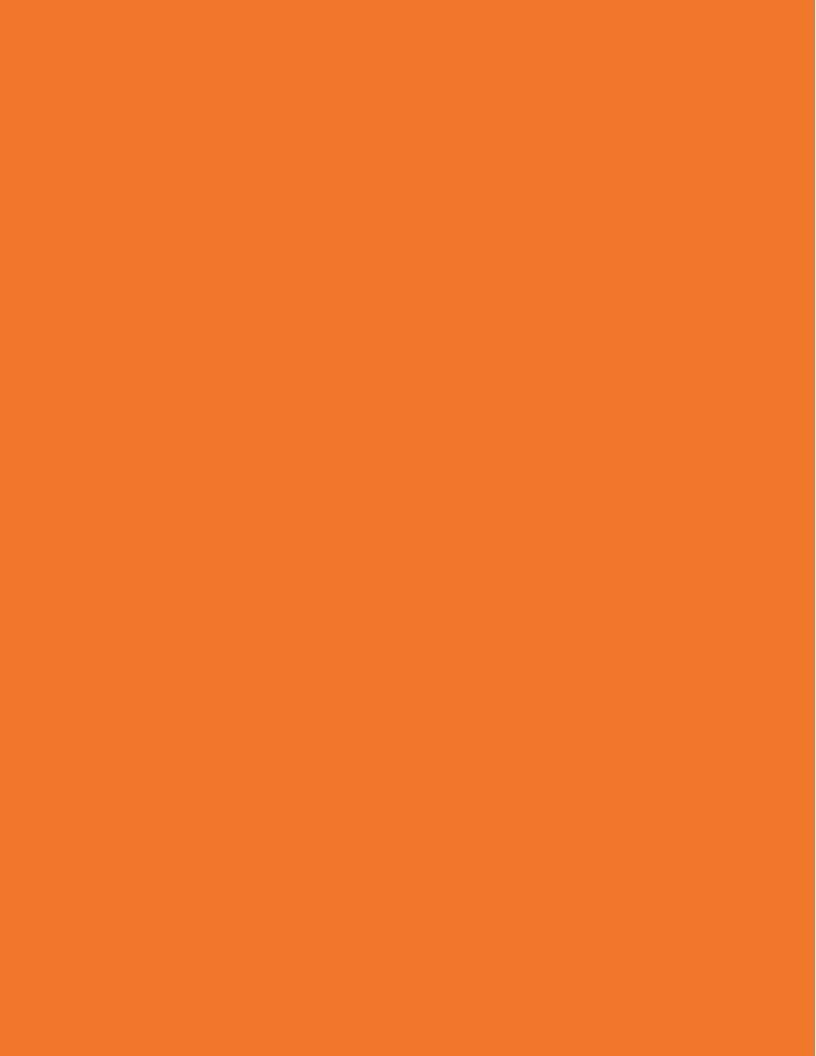


Adjustable to grades
9-10 based on
content alignment.

# Concept Development Lesson Three: Cellular Respiration: Matter and Energy

Matter and Energy in Organisms

[HS.LS-ME0]



# Concept Development Lesson Three: Cellular Respiration: Matter and Energy



#### **Key Concept #3**

All organisms require the input of matter and energy. Organisms transform the matter and energy into forms useable by cellular processes to grow and develop.

#### **Driving Question #3**

How do organisms obtain and use the matter and energy they need to perform cellular processes?

#### **Demonstrations of Understanding**

By the end of this lesson, students will be able to:

- monitor their own thinking, as understandings of scientific concepts are refined;
- engage in multiple forms of discussion in order to process, make sense of, and learn from other's ideas, observations, and experiences;
- engage in productive scientific discussion practices during conversations with peers in the context of scientific investigations and model-building;
- write a scientific explanation using experimental and textual evidence;
- identify the process that transfers stored chemical energy into energy useable by the organism;
- use text to identify that during chemical reactions, the bonds of reactant molecules are broken; the atoms are then rearranged into the product molecules;
- identify the inputs and outputs of cellular respiration; and
- identify that the bonds of oxygen and glucose are broken during cellular respiration and the
  rearrangement of the atoms results in carbon dioxide, water and ATP. Carbon dioxide gas and water are
  waste or byproducts.

## Estimated time to complete Concept Development Lesson Three (CDL3): 172 minutes

Engage Phase: 25 min.

Gather & Analyze Phase: 95 min.

Connect Phase: 37 min.Reflect Phase: 15 min.

#### **Teacher Background**

Organisms, including plants and other photosynthesizing organisms, undergo the process of cellular respiration. Cellular respiration is a series of chemical reactions that can be summarized as transferring stored chemical energy to a form useable by the organism (ATP), using oxygen as a reactant and releasing carbon dioxide gas and water as waste or byproducts. The useable energy provides energy for cellular processes. Plants and other photosynthesizing organisms do not need to consume "food" because they produce the molecules needed to undergo the process of "making" useable energy and packaging matter for use in growth and development during photosynthesis. However, animals must consume "food" in order to "make" useable energy.

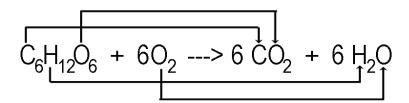
Your students will likely have some understandings about cellular respiration. This lesson asks students to think about the role of matter and energy transformation in the process of cellular respiration. This lesson also asks students to make connections between the processes of cellular respiration and photosynthesis. Students need to be able to use the cellular respiration equation to think about the process; however, students are not asked to memorize the complex steps of cellular respiration. The steps (glycolysis, Krebs or citric acid cycle, and the electron transport chain) are mentioned during the lesson, but do not play a major role in the understanding of cellular respiration during this unit.

#### **Teacher Content Knowledge**

High school teachers need a certain amount of background knowledge to teach complex materials. The amount and level of content knowledge varies among teachers. Provided below is a list of science content relevant to the lesson. Educate yourself as necessary to be prepared to engage in discussions and questioning with students. NSTA has a variety of resources. Textbooks and Internet searches can also provide valuable resources.

#### Teacher Background: Content Knowledge

- Role of mitochondria
- Role of ATP and NADH in cellular respiration
- Glycolysis, Krebs or citric acid cycle, and the electron transport chain—students are not learning this in depth, so a deep, biochemical level of understanding is not needed
- The cellular respiration equation—reactants, products and the role of stored chemical energy and
  useable energy (ATP), including tracking the movement of atoms through the reaction



The figure above shows the movement of atoms during the process of cellular respiration.

How photosynthesis and cellular respiration are interlinked processes

#### **End-of-Lesson Takeaway**

The goal for this lesson is for students to conceptually understand cellular respiration from the viewpoint of matter and energy. Students should get the idea that the stored chemical energy (glucose) is transferred to a form useable by the organisms during the process of cellular respiration. Students should identify that plants and other photosynthesizing organisms go through both photosynthesis and cellular respiration.

LESSON 3

While the purpose of the lesson is not to memorize the cellular respiration equation, students should understand where the reactants and products come from and the role they play in the process. Furthermore, students should make connections between the processes of photosynthesis and cellular respiration, incorporating the information gathered during CDL1, CDL2, and CDL3 to form a scientific explanation.

#### **Preparing for the Lesson**

#### **Advanced Preparation**

#### For Engage Phase:

- 1. Post Driving Question #3 (How do organisms obtain and use the matter and energy they need to perform cellular processes?) so that it is visible to the entire class and can remain posted across the lesson.
- 2. Predetermine how students will be organized into pairs for discussion.

#### For Gather & Analyze Phase:

- 1. Predetermine how students will be organized into pairs for partner reading.
- 2. Copy or print Reading: Cellular Respiration: Matter and Energy (see Appendix B: Student Resources).
- 3. Predetermine how students will be organized into pairs for the Plant Growth in the Absence of Light: Writing Explanatory Text in Science.
- 4. Be prepared to distribute (if collected during CDL2) Plant Growth in the Absence of Light: Experimental Data and Plant Growth in the Absence of Light: Writing Explanatory Text in Science.
- 5. Copy or print the General Rubric for Writing Informational/Explanatory Text in Science (see Appendix B: Student Resources).

#### For Connect Phase:

1. Make sure Driving Question #3 (How do organisms obtain and use the matter and energy they need to perform cellular processes?) is posted to guide whole group discussion.

#### For Reflect Phase:

- 1. Make sure Driving Question #3 (How do organisms obtain and use the matter and energy they need to perform cellular processes?) is posted for student reflection.
- 2. Post the reading reflection questions (How did the format of the reading help you engage as a learner? How did the questions help or change the way you read the information? What did you have to do to support your own thinking as you read?).

#### Resources

#### Materials:

 Chart paper, butcher paper, whiteboard space, or other media for students to be able to illustrate their ideas for the class to be able to see and discuss

#### Appendix A: Teacher Resources:

- Norms for Discussion
- Talking to Understand: Student Talk

#### Appendix B: Student Resources:

- Reading: Cellular Respiration: Matter and Energy
- Plant Growth in the Absence of Light: Experimental Data
- Plant Growth in the Absence of Light: Writing Explanatory Text in Science (distributed during CDL2)
- General Rubric for Writing Informational/Explanatory Text in Science

#### **Procedure**



#### **ENGAGE PHASE**

This phase is designed to activate prior knowledge about the key concept or to provide a link that connects this lesson with the previous lesson. It is intended to expose student thinking so you and your students know where they are starting.

Estimated time: 25 minutes; additional time may be necessary to establish norms if they are not already established (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
Post Driving Question #3 (How do organisms obtain and use the matter and energy they need to perform cellular processes?) on the board, written so it will stay visible to students for the entire lesson.	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking.	10 minutes
2. Ask students to individually and silently reflect on the driving question. Ask students to record their initial thoughts and understandings in their science notebook. Ask students to be as specific in their answers as possible. Encourage students to share all of their thoughts. The purpose of answering the question is not to determine right and wrong answers, but rather to expose ALL current understandings.	Encourage students to include what they know from both school and life experiences.	10 minutes

<sup>1</sup> Time is provided as an approximate estimate for planning purposes.

Procedure	Teaching Notes	Time <sup>1</sup>
3. If you have not reviewed the Norms for Discussion or they have not become a well-established routine in your classroom, you should review the norms to ensure that students know what is expected of them in sharing and listening to each other.	The goal is to connect with students and create a safe learning environment for all students.  You might use the Talking to Understand: Student Talk prompt sheets as a visual in the classroom to support productive student talk.	Time will vary, depending on how well norms have been established.
4. Ask students to share and discuss their thoughts with a partner. Ask students to be prepared to share their thoughts with the whole group.		5 minutes
<ol> <li>Ask students to share and discuss their reasoning as a whole group.</li> <li>The sharing is only to get students talking about their ideas; it is not to correct misconceptions yet or to come to a firm conclusion.</li> <li>During the discussion, try to expose students' understandings about cellular respiration (in particular, how cellular respiration relates to energy and matter).</li> </ol>	Support whole group discussions by providing time for students to individually think about their responses and rehearse their thoughts with a partner before engaging in the whole group discussion (Think-Pair-Share).  Note that your questioning at this point is to assess student understanding and to push for clarity (probe to help students clearly articulate what they mean). You do not want to advance student thinking yet. You can use prompts such as the following:  Why do you think that?  What do you mean when you say?  Say more about how that happens.  Who can add on to that?  Did anyone have a different idea they would like to share?  What examples can you give?  Help me to understand what you mean when you say	10 minutes





#### **GATHER & ANALYZE PHASE**

This phase is designed to provide students with an opportunity to explore data and information to solve a question or problem. This may be accomplished through a hands-on laboratory to observe and generate data, or the data may be gathered from reliable sources. The data should be focused by a scientific question in order to develop an understanding of the key concept. Students should also begin to analyze and make sense of the data/information to develop an argument or explanation.

Estimated time: 95 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Distribute the Cellular Respiration: Matter and Energy reading. Ask students to individually read the directions and text. Ask students to look at the questions for guidance as they read, but that they should not answer the questions at this point.	The Cellular Respiration: Matter and Energy reading is arranged with the questions given to the students before the text. Like the previous reading where the questions were placed at the end of the text, by placing the questions outside of the text, students are being scaffolded to a format where they must be more aware of the questions, as the questions are no longer next to the relevant parts of the text. Moving the questions to different areas of the readings makes students not only flexible, but also forms the habit of looking for guiding questions prior to reading text. By the end of the unit, students will need to guide their own reading in the absence of specific guiding questions. Like prior lessons, students must think about the questions as they engage in the text.  See CDL1, Gather & Analyze Phase, Teaching Notes, step 8, for additional clarification on reading formats and question types.	10 minutes
2. Organize students into pairs.  As a pair have students reread the Cellular Respiration: Matter and Energy reading and answer the questions. Encourage students to discuss their answers with their partner and to support all answers with evidence.	As you circulate, use assessing prompts to learn more about how students are making sense of the reading. Some examples of assessing prompts you might use include the following:  Why do you think that?  What do you mean when you say?  Help me understand what you mean when you say  Say more about how that happens.  What is your evidence?	20 minutes

	Procedure	Teaching Notes	Time <sup>1</sup>
3.	Ask students to come back together as a group.  Quickly review the Norms for Discussion in your classroom. Make sure students know what is expected of them in sharing and listening to each other.		5 minutes
4.	<ul> <li>Begin a whole group discussion around the following guiding questions:</li> <li>What is the purpose of cellular respiration?</li> <li>How does cellular respiration relate to an organism's need for matter and energy?</li> <li>How does the making and breaking of chemical bonds relate to the transfer of energy during cellular respiration?</li> <li>Encourage students to use evidence gathered from the reading as they discuss the guiding questions. Use the questions to guide the discussion but allow student questions and misunderstandings to guide the discussion as well. Encourage students to answer each other's questions when appropriate. Do not let the discussion turn into a lecture.</li> </ul>	This discussion should focus on cellular respiration from the matter and energy perspective. During this discussion, students should get the idea that plants use the product of photosynthesis, glucose, plus oxygen to form the products of cellular respiration. Use guiding questions to help students identify carbon dioxide and water as a waste or byproducts during the process of cellular respiration. Students should identify the transfer of stored chemical energy (glucose) to energy in a form useable by the organism (ATP) as the purpose of cellular respiration. The useable energy is used to run cellular processes in the organism and vital for the organisms survival. The energy is transferred during the breaking and making of chemical bonds.	20 minutes
5.	Distribute or ask students to get out the Plant Growth in the Absence of Light: Experimental Data and Plant Growth in the Absence of Light: Writing Explanatory Text in Science students used during CDL2.  Ask students to individually revisit the task in light of what they have learned during CDL3. Ask students what evidence they have learned that would help support their answer. At this point students should be beginning to make connections between photosynthesis and cellular respiration, as well as between matter and energy.		10 minutes

Continued on next page.

Procedure	Teaching Notes	Time <sup>1</sup>
6. Organize students into pairs.  Ask students to share and compare the evidence they recorded from CDL1 CDL2, and CDL3.  Ask students to use the evidence they have gathered during the three lesson to write an explanation for the prompt in the Plant Growth in the Absence of Light: Writing Explanatory Text in Science. Distribute the General Rubric for Writing Informational/Explanatory Text in Science	to student comments and responses.  Now is the time to push for clarity and to advance their thinking. Some examples of advancing prompts you might use include the following:  Say more about how that happens	30 minutes
<ol> <li>Collect, read, and comment on the explanations. Check for understanding of both photosynthesis and cellular respiration.</li> <li>Alternatively, you can have pairs swap their explanations and have the other students review and comment. You should review the comments other students noted.</li> </ol>	during the application lesson. It is important to recognize misconceptions and confusions at this point so they can be	Time will vary; build in extra time if students are swapping explanations.

#### **CONNECT PHASE**

LESSON 3

This phase is designed to socialize intelligence for the entire classroom (all students) by connecting the activities during the previous phase to the key concept. This usually involves a teacher-led whole group discussion that explicitly ties the work students have done to the key concept and ensures that a common understanding is achieved at or beyond the level of the targeted standards.

Estimated time: 37 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Direct students to Driving Question #3 (How do organisms obtain and use the matter and energy they need to perform cellular processes?). Ask students to individually answer the question in their science notebooks. Ask students to organize their answers as it best makes sense to them. This might mean as a paragraph, but it also may mean bullet points or diagrams. Encourage students to revisit their notes in their science notebooks as well as the Cellular Respiration: Matter and Energy reading to find evidence to support their thoughts and understandings.		7 minutes
2. Ask students to come back together as a group. Begin a whole group discussion around the driving question.  Encourage students to use evidence gathered during the reading, as well as their learnings and experiences from CDL3. Encourage students to connect the understandings they developed during CDL3 with the knowledge they acquired during CDL1 and CDL2.	Use assessing and advancing prompts to differentiate the learning based on where your students are in terms of understanding. Listen carefully to student comments and responses. Now is the time to push for clarity and to advance their thinking. Some examples of advancing prompts you might use are above in step 6, Gather & Analyze Phase.	20 minutes
3. Ask students to write, in their science notebooks, in their own words what the big idea was of this whole lesson. What is the main thing they learned? What are some key science ideas you discussed and learned about?	Students should get the idea that all organisms need matter and energy in order to grow and develop. Students should get the idea that organisms transfer stored chemical energy (they have been learning this is in the form of glucose) to a form of energy useable by the organism (ATP). This provides the organism with energy available for cellular processes.	10 minutes





#### **REFLECT PHASE**

This phase is designed to provide time for students to individually reflect on the lesson and to pull their thoughts together to make sense of what they have experienced. They should understand how the activities of the lesson connect to the key concept, as well as how what they have done builds understanding of the overarching concept of the unit. This phase provides evidence of individual learning achieved through the lesson.

Estimated time: 15 minutes (Times are broken down within the steps of the phase.)

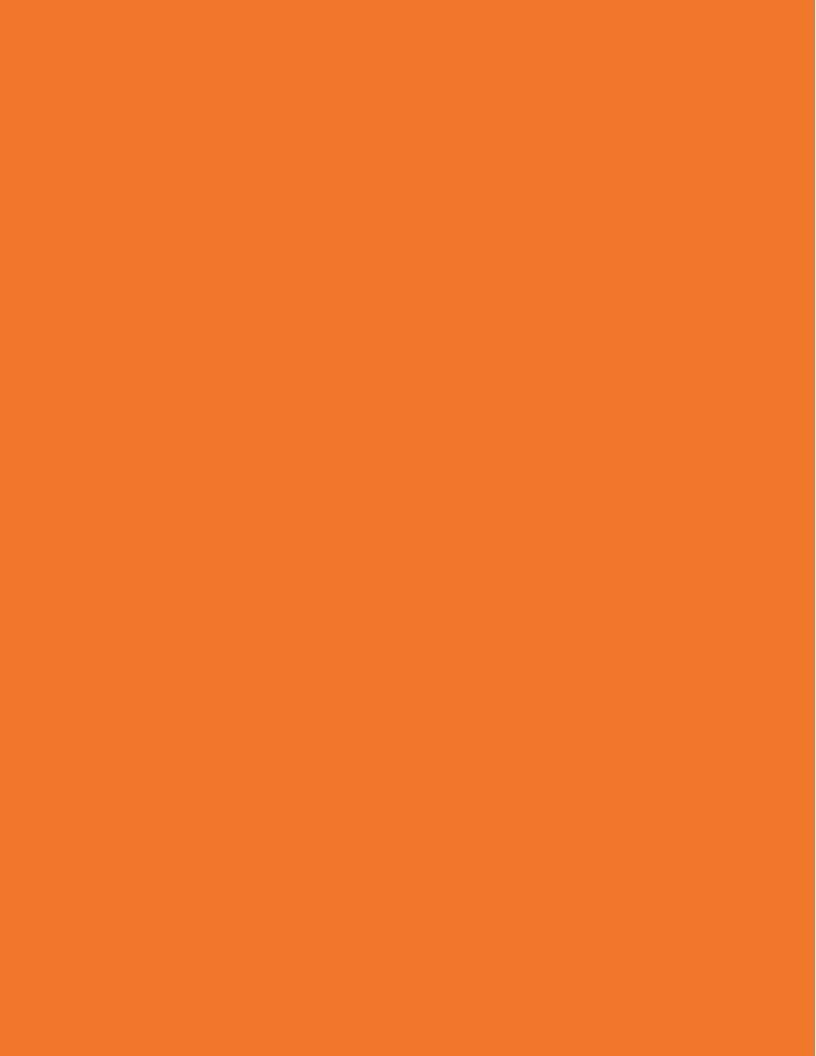
Procedure	Teaching Notes	Time <sup>1</sup>
<ol> <li>Direct students' attention to Driving Question #3 (How do organisms obtain and use the matter and energy they need to perform cellular processes?) on the board.</li> </ol>		10 minutes
Ask students to revisit their initial thoughts and understandings they recorded in their science notebooks during the Engage Phase and the thoughts they recorded during the Connect Phase. Ask students to individually and silently reflect on the driving question in light of their learnings during CDL3. Ask students to be as specific in their answers as possible.		
2. Ask students to individually reflect on the format of the reading during the lesson. Post the following questions on the board:		5 minutes
<ul> <li>How did the format of the reading help you engage as a learner?</li> <li>How did the questions help or change the way you read the information?</li> <li>What did you have to do to support your own thinking as you read?</li> </ul>		
Ask students to respond to the questions in their science notebook. Remind students that they recorded thoughts to revisit in their science notebooks when they completed the reading.		



# Concept Development Lesson Four: Cellular Respiration: Anaerobic vs. Aerobic Respiration

Matter and Energy in Organisms

[HS.LS-ME0]



### **Concept Development Lesson Four: Cellular Respiration: Anaerobic vs. Aerobic Respiration**



#### **Key Concept #4**

In the absence of oxygen, organisms perform anaerobic respiration to transfer stored chemical energy into a form useable by the organism.

#### **Driving Question #4**

How do organisms break down matter to get energy if there is no oxygen available?

#### **Demonstrations of Understanding**

By the end of this lesson, students will be able to:

- monitor their own thinking, as understandings of scientific concepts are refined;
- engage in multiple forms of discussion in order to process, make sense of, and learn from other's ideas, observations, and experiences;
- engage in productive scientific discussion practices during conversations with peers in the context of scientific investigations and model-building;
- write a scientific explanation using experimental and textual evidence;
- identify anaerobic respiration as the process that transfers stored chemical energy into energy useable by the organism in the absence of oxygen; and
- identify the similarities and differences between anaerobic and aerobic respiration, including that a greatly reduced amount of energy is made during anaerobic respiration as compared to aerobic respiration.

#### **Estimated time to complete Concept Development Lesson Four (CDL4):** 184 minutes

Engage Phase: 25 min.

Gather & Analyze Phase: 107 min.

Connect Phase: 37 min. Reflect Phase: 15 min.



#### **Teacher Background**

Organisms, including plants and other photosynthesizing organisms, undergo the process of cellular respiration. In the absence of oxygen, some organisms undergo the process of anaerobic respiration. Anaerobic respiration is a series of chemical reactions that can be summarized as transferring stored chemical energy to a form useable by the organism (ATP). Anaerobic respiration goes through the process of glycolysis, but cannot continue to the Krebs cycle or electron transport chain due to the absence of oxygen. Therefore, organisms undergo fermentation, either lactic acid or alcoholic. Some microorganisms undergo alcoholic fermentation, a process used by humans in food production such as beer, wine, and bread making. Animals and some microorganisms undergo the process of lactic acid fermentation. Like alcoholic fermentation, humans use lactic acid fermentation to make food products like yogurt and cheese.

Like aerobic respiration (described during CDL3), anaerobic respiration transfers stored chemical energy to a form useable by the organism. However, anaerobic respiration occurs in the absence of oxygen and produces a greatly reduced amount of energy per molecule of glucose. Anaerobic respiration results in a net of 2 ATP per glucose molecule, whereas aerobic respiration results in 36-38 ATP per molecule of glucose.

This lesson asks students to think about the process organisms undergo when oxygen is not available. Students need to be able to identify the similarities and differences between the two pathways; however, students are not asked to memorize the complex steps of anaerobic respiration. The steps (glycolysis and fermentation) are mentioned during the lesson, but do not play a major role in the understanding of anaerobic respiration during this unit.

#### **Teacher Content Knowledge**

High school teachers need a certain amount of background knowledge to teach complex materials. The amount and level of content knowledge varies among teachers. Provided below is a list of science content relevant to the lesson. Educate yourself as necessary to be prepared to engage in discussions and questioning with students. NSTA has a variety of resources. Textbooks and Internet searches can also provide valuable resources.

#### Teacher Background: Content Knowledge

- Anaerobic respiration
- Glycolysis, alcoholic fermentation, lactic acid fermentation—students are not learning this in depth, so
  a deep, biochemical level of understanding is not needed.
- Similarities and differences between aerobic and anaerobic respiration, including the understanding that aerobic respiration makes a larger amount of energy than anaerobic respiration.

#### **End-of-Lesson Takeaway**

The goal for this lesson is for students to be able to identify that some organisms undergo anaerobic respiration to transfer stored chemical energy to a form useable by the organism in the absence of oxygen. Students should be able to compare and contrast the processes, purposes, and results of aerobic and anaerobic respiration. Students should recognize that aerobic respiration produces more useable energy than anaerobic respiration and that anaerobic respiration occurs in the absence of oxygen.

#### **Preparing for the Lesson**

#### **Advanced Preparation**

#### For Engage Phase:

- 1. Post Driving Question #4 (How do organisms break down matter to get energy if there is no oxygen available?) so that it is visible to the entire class and can remain posted across the lesson.
- Predetermine how students will be organized into pairs for discussion.

#### For Gather & Analyze Phase:

- 1. Prepare materials for Making Yogurt Lab Procedure.
- 2. Predetermine how students will be organized into pairs for pre-lab discussion.
- 3. Copy or print the Making Yogurt Lab Procedure (see Appendix B: Student Resources).
- 4. Predetermine how students will be organized into pairs for the Making Yogurt Lab.
- 5. Copy or print the Reading: Anaerobic vs. Aerobic Respiration (see Appendix B: Student Resources).
- 6. Copy or print the Reading Guide: Anaerobic vs. Aerobic Respiration (see Appendix B: Student Resources).
- 7. Copy or print the General Rubric for Writing Informational/Explanatory Text in Science (see Appendix B: Student Resources).
- 8. Be prepared to post the guiding questions for the whole group discussion. (How does anaerobic respiration help form yourt? What are the similarities and differences between aerobic and anaerobic respiration?)

#### For Connect Phase:

1. Make sure Driving Question #4 (How do organisms break down matter to get energy if there is no oxygen available?) is posted to guide whole group discussion.

#### For Reflect Phase:

- 1. Make sure Driving Question #4 (How do organisms break down matter to get energy if there is no oxygen available?) is posted for student reflection.
- 2. Post the reading reflection questions (How did the format of the reading help you engage as a learner? How did the guestions help or change the way you read the information? What did you have to do to support your own thinking as you read?).

#### Resources

#### Materials:

- Chart paper, butcher paper, whiteboard space, or other media for students to be able to illustrate their ideas for the class to be able to see and discuss
- Lab Preparation: milk, powdered milk, live culture (from yogurt), sweetener and flavor (optional), containers (heat safe and at least 8 oz.), thermometers, incubator, heat source to boil milk, spoons

#### Appendix A: Teacher Resources:

- Norms for Discussion
- Talking to Understand: Student Talk

#### Appendix B: Student Resources:

- Making Yogurt Lab Procedure
- Reading: Anaerobic vs. Aerobic Respiration
- Reading Guide: Anaerobic vs. Aerobic Respiration
- General Rubric for Writing Informational/Explanatory Text in Science





#### **Procedure**



#### **ENGAGE PHASE**

This phase is designed to activate prior knowledge about the key concept or to provide a link that connects this lesson with the previous lesson. It is intended to expose student thinking so you and your students know where they are starting.

Estimated time: 25 minutes; additional time may be necessary to establish norms if they are not already established (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
<ol> <li>Post Driving Question #4 (How do organisms break down matter to get energy if there is no oxygen available?) on the board, written so it will stay visible to students for the entire lesson.</li> </ol>	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking.	
2. Ask students to individually and silently reflect on the driving question. Ask students to record their initial thoughts and understandings in their science notebook. Ask students to be as specific in their answers as possible. Encourage students to share all of their thoughts. The purpose of answering the question is not to determine right and wrong answers, but rather to expose ALL current understandings.	Encourage students to include what they know from both school and life experiences.	10 minutes
3. Review the Norms for Discussion if they have not become a well-established routine in your classroom to ensure that students know what is expected of them in sharing and listening to each other.	The goal is to connect with students and create a safe learning environment for all students.  You might use the Talking to Understand: Student Talk prompt sheets as a visual in the classroom to support productive student talk.	Time will vary, depending on how well norms have been established.
4. Ask students to share and discuss their thoughts with a partner. Ask students to be prepared to share their thoughts with the whole group.		5 minutes

<sup>1</sup> Time is provided as an approximate estimate for planning purposes.

Procedure	Teaching Notes	Time <sup>1</sup>
<ol> <li>Ask students to share and discuss their reasoning as a whole group.</li> <li>The sharing is only to get students talking about their ideas; it is not to correct misconceptions yet or to come to a firm conclusion.</li> <li>During the discussion, try to expose students' understandings about anaerobic respiration.</li> </ol>	Support whole group discussions by providing time for students to individually think about their responses and rehearse their thoughts with a partner before engaging in the whole group discussion (Think-Pair-Share).  Note that your questioning at this point is to assess student understanding and to push for clarity (probe to help students clearly articulate what they mean). You do not want to advance student thinking yet. You can use prompts such as the following:  Why do you think that?  What do you mean when you say?  Say more about how that happens.  Who can add on to that?  Did anyone have a different idea they would like to share?  What examples can you give?  Help me to understand what you mean when you say	10 minutes



#### **GATHER & ANALYZE PHASE**

This phase is designed to provide students with an opportunity to explore data and information to solve a question or problem. This may be accomplished through a hands-on laboratory to observe and generate data or the data may be gathered from reliable sources. The data should be focused by a scientific guestion in order to develop an understanding of the key concept. Students should also begin to analyze and make sense of the data/information to develop an argument or explanation.

Estimated time: 107 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Ask students to individually read the Making Yogurt Lab Procedure materials and procedures. Encourage students to reread as needed. Ask students to record any questions or wonderings they have in their science notebooks as they read.		5 minutes

Continued on next page.



	Procedure	Teaching Notes	Time <sup>1</sup>
2	If the Norms for Discussion have not become a well-established routine in your classroom, you should review the norms to ensure that students know what is expected of them in sharing and listening to each other.	As students engage in productive talk during this phase, it is important for you and the students to monitor class and individual behavior to ensure that all students feel safe to share their ideas.	Time will vary.
3.	Ask students to turn to a partner and share their questions and wonderings about the lab and the lab procedure.	Support whole group discussions by providing time for students to individually think about their responses and rehearse their thoughts with a partner before engaging in the whole group discussion (Think-Pair-Share).	5 minutes
4.	Begin a whole group discussion around the lab and the lab procedure. Ask students to share their understandings and questions. Work together to dissect the steps of the procedure to make sure everyone understands what to do.  It may be helpful to have students diagram the steps of the procedure with pictures. Encourage students to add clarifying points and illustrations to their lab procedure and/or science notebooks. Facilitate the discussion with guiding questions as needed, but allow students to answer each other's questions and dissect the procedure for understanding.  Record the dissected procedure on the board or a piece of chart paper. Add clarification as students share their understandings and illustrations. Keep the procedure visible as students work on the lab and during the discussion following the lab as a reference.	Make sure students fully understand the procedure. It is important that students learn to read and execute an experiment from a procedure with little to no teacher guidance.  Use assessing questions to guide the discussion. Use prompts to learn more about how students are making sense of the lab procedure. Some examples of assessing prompts you might use include the following:  Why do you think that?  What do you mean when you say?  How does this relate to that?  What is your evidence?	10 minutes
5.	Organize students into pairs.  Ask students to gather needed materials and perform the lab.  Remind students to take accurate and detailed observations in their science notebooks.		2 minutes

	Procedure	Teaching Notes	Time <sup>1</sup>
retur	ide time for students to clean and In their lab materials, and to clean lab areas.		5 minutes
Resp As a direc chart their	ribute the Anaerobic vs. Aerobic pair, have students read the stions, the text and complete the st. Encourage students to discuss answers with their partner and to port all answers with evidence.	The Anaerobic vs. Aerobic Respiration reading guide contains a chart asking students for the similarities and differences between anaerobic and aerobic respiration. Students must guide their own reading to find the similarities and differences. Additionally, students must consider other texts to complete the chart. Students are not guided with specific questions throughout the text, and again the level of self-guiding has increased.  See CDL1, Gather & Analyze Phase, Teaching Notes, step 8 for additional clarification on reading formats and question types.	20 minutes
eat t eat t flavo stude swee flavo bring yogu time One eat t discu to al wher (belo	de when you will have students heir yogurt. Most yogurts that we have some kind of sweetener and ring. You may want to provide ents with sugar, honey, or another etener as well as fruit or another r. You can also ask students to their own flavors to add to their rt. Give students a short amount of to add their flavors before eating.  option is allowing students to heir yogurt during the group ussion (below). Another option is low students to eat their yogurt in they write their explanation ow). After incubation, be sure to the yogurt in the refrigerator until eaten.		5 minutes

Continued on next page.



Procedure	Teaching Notes	Time <sup>1</sup>
<ol> <li>Ask students to come back together as a group.</li> <li>Quickly review the Norms for Discussion in your classroom. Make sure students know what is expected of them in sharing and listening to each other.</li> </ol>		5 minutes
<ul> <li>10. Begin a whole group discussion around the following guiding questions:</li> <li>How does anaerobic respiration help form yogurt?</li> <li>What are the similarities and differences between aerobic and anaerobic respiration?</li> <li>Encourage students to use evidence gathered from the lab, the Anaerobic vs. Aerobic Respiration reading and reading guide, and the CDL3 readings as they discuss the guiding questions. Use the questions to guide the discussion, but allow student questions and misunderstandings to guide the discussion as well. Encourage students to answer each other's questions when appropriate. Do not let the discussion turn into a lecture.</li> <li>Create a chart on the board to record the similarities and differences that students share on the board or on chart paper. Ask students to add anything to their lists that they don't have.</li> </ul>	This discussion should focus on a comparison of aerobic respiration and anaerobic respiration. During this discussion, students should get the idea that some organisms undergo anaerobic respiration to transfer stored chemical energy to energy useable by the organism in the absence of oxygen. Students should recognize that aerobic respiration produces more useable energy than anaerobic respiration.  As you guide the discussion, use assessing and advancing prompts to differentiate the learning based on where your students are in terms of understanding. Listen carefully to student comments and responses. Now is the time to push for clarity and to advance their thinking. Some examples of advancing prompts you might use include the following:  How does this relate to that?  What is your evidence?  How can you apply what you have read to your comparison?  Who understands what [name of student] said? Please restate it so more of us can understand.	20 minutes

Procedure	Teaching Notes	Time <sup>1</sup>
11. Post the following writing prompt and directions on the board. Tell students they will be developing an explanation to answer the prompt. "Why do most human cells perform both aerobic and anaerobic respiration?"  Ask students to record the prompt in their science notebook. In pairs ask students to form an explanation to answer the prompt. Distribute the General Rubric for Writing Informational/Explanatory Text in Science. Encourage students to use evidence gathered from the lab, the Anaerobic vs. Aerobic Respiration reading and reading guide, and CDL3 to find evidence for their explanation.  Each student should have a copy of the explanation in his/her notebook.	As you move among groups, use assessing and advancing prompts to differentiate the learning based on where your students are in terms of understanding. Listen carefully to student comments and responses.  Now is the time to push for clarity and to advance their thinking. Some examples of advancing prompts you might use include the following:  Say more about how that happens.  Why does that happen?  How does this relate to that?  Add some of the new ideas we've been talking about to your explanation.	20 minutes
12. Ask the pairs to swap their explanations and have the other students review and comment. You should review the comments other students noted.		10 minutes





#### **CONNECT PHASE**

This phase is designed to socialize intelligence for the entire classroom (all students) by connecting the activities during the previous phase to the key concept. This usually involves a teacher-led whole group discussion that explicitly ties the work students have done to the key concept and ensures that a common understanding is achieved at or beyond the level of the targeted standards.

Estimated time: 37 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
1. Direct students to Driving Question #4 (How do organisms break down matter to get energy if there is no oxygen available?). Ask students to individually answer the question in their science notebooks. Ask students to organize their answers as it best makes sense to them. This might mean as a paragraph, but it also may mean bullet points or diagrams. Encourage students to revisit their notes in their science notebooks as well as the past readings to find evidence to support their thoughts and understandings.		7 minutes
2. Ask students to come back together as a group. Begin a whole group discussion around the driving question.  Encourage students to use evidence gathered during the reading, as well as their learnings and experiences during CDL4. Encourage students to connect the understandings they developed during CDL4 with the knowledge they acquired during CDL3.	Use assessing and advancing prompts to guide the discussion. See steps 10 and 11 in the Gathering & Analyzing Phase above.	20 minutes
3. Ask students to write, in their science notebooks, in their own words what the big idea was of this whole lesson. What is the main thing they learned? What are some key science ideas you discussed and learned about?	Students should get the idea that some organisms undergo anaerobic respiration to transfer stored chemical energy to energy useable by the organism in the absence of oxygen. Students should recognize that aerobic respiration produces more useable energy than anaerobic respiration.	10 minutes



#### **REFLECT PHASE**



This phase is designed to provide time for students to individually reflect on the lesson and to pull their thoughts together to make sense of what they have experienced. They should understand how the activities of the lesson connect to the key concept, as well as how what they have done builds understanding of the overarching concept of the unit. This phase provides evidence of individual learning achieved through the lesson.

Estimated time: 15 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
<ol> <li>Direct students' attention to Driving Question #4 (How do organisms break down matter to get energy if there is no oxygen available?) on the board.</li> </ol>		10 minutes
Ask students to revisit their initial thoughts and understandings they recorded in their science notebooks during the Engage Phase and the thoughts they recorded during the Connect Phase. Ask students to individually and silently reflect on the driving question in light of their learnings during CDL3. Ask students to be as specific in their answers as possible.		
<ol><li>Ask students to individually reflect on the format of the reading during the lesson. Post the following questions on the board:</li></ol>		5 minutes
<ul> <li>How did the format of the reading help you engage as a learner?</li> <li>How did the questions help or change the way you read the information?</li> <li>What did you have to do to support your own thinking as you read?</li> </ul>		
Ask students to respond to the questions in their science notebook. Remind students that they recorded thoughts to revisit in their science notebooks when they completed the reading.		

90 Concept Development Lesson Four: Cellular Respiration: Anaerobic vs. Aerobic Respiration

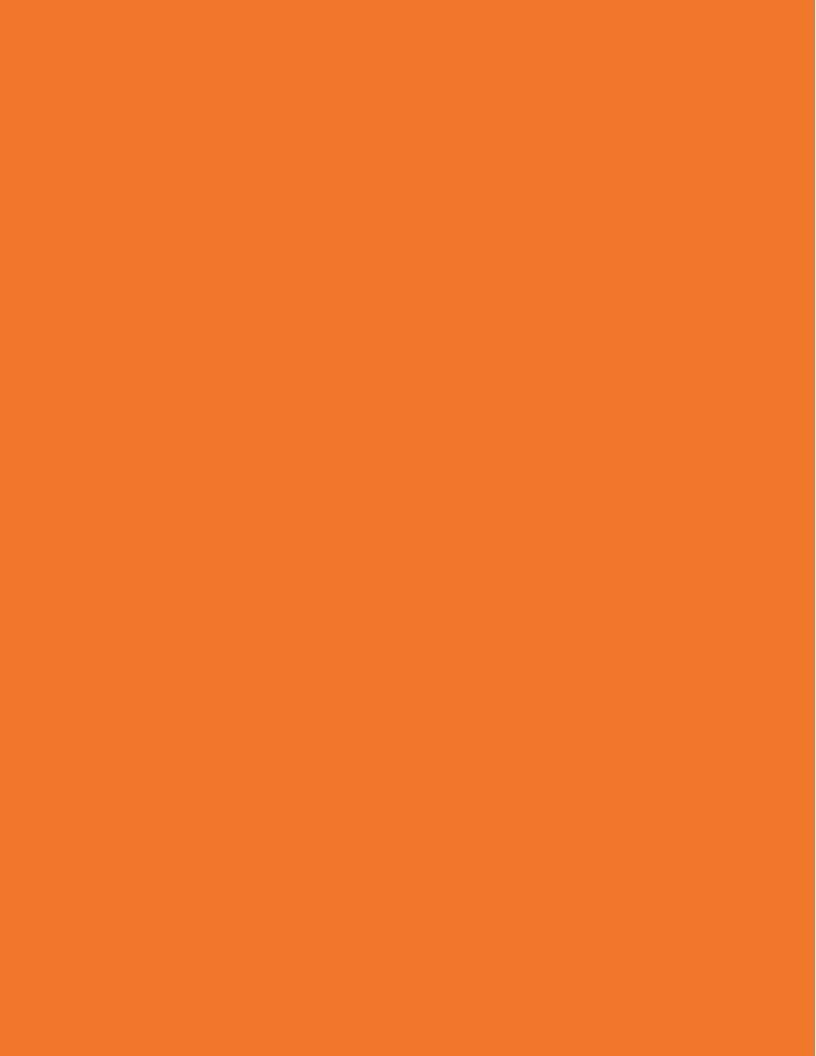


Adjustable to grades 9-10 based on content alignment.

# **Application Lesson**

Matter and Energy in Organisms

[HS.LS-ME0]



### **Application Lesson**

#### **Overarching Concept**

All organisms require the input of matter and energy. Organisms transform the matter and energy into forms useable by cellular processes to grow and develop.

#### **Overarching Driving Question**

How do organisms obtain and use matter and energy they need to perform cellular processes?

#### **Demonstration of Understanding**

By the end of this lesson, students will demonstrate their level of mastery of the standards identified in the unit overview.

#### Estimated time to complete application lesson: 245 minutes

- Summative Assessment: 45 min.
- Problem-Based Application Phase: 185 min.
- Reflect Phase: 15 min.

#### **Teacher Background**

This lesson is intended to assess individual learning and performance of the standards for this unit. It is not the time to teach or add new details. Focus on student assessment and sense-making. As students work through the assessment and application phases, they will likely make connections that will clarify some of the concepts and skills for each student as well as for the whole class.

#### **Preparing for the Lesson**

#### **Advanced Preparation**

#### For the Summative Assessment Phase:

- 1. Print or copy the Plant Growth in the Absence of Light: Writing an Argument in Science so that each student has his/her own copy.
- 2. Optional: colored pen sets (2 colors). See the note in step 4 of the Procedure section.

#### For the Problem-Based Application Phase:

- Copy or print the Problem-Based Application: Designing a Plan of Action to Improve Food Deserts (see Appendix B: Student Resources).
- 2. Copy or print Reading: Thinking Deeper About What We Eat (see Appendix B: Student Resources).
- 3. Copy or print the Reading: Food Deserts (see Appendix B: Student Resources).
- 4. Copy or print the General Rubric for Writing Arguments in Science (see Appendix B: Student Resources).
- 5. Copy or print the Development Template for Writing Arguments in Science (see Appendix B: Student Resources).

#### For the Reflect Phase:

1. Be prepared to distribute the student responses from the Plant Growth in the Absence of Light: Scientific Explanation (from activation task).

#### Resources

#### Materials:

- Chart paper, butcher paper, whiteboard space, or other media for students to be able to illustrate their ideas for the class to be able to see and discuss
- Optional: colored pen sets (2 colors)
- Access to Internet or resources for research during the Problem-Based application

#### Appendix A: Teacher Resources:

- Norms for Discussion
- Talking to Understand: Student Talk

#### Appendix B: Student Resources:

- Plant Growth in the Absence of Light: Writing an Argument in Science
- Problem-Based Application: Designing a Plan of Action to Improve Food Deserts
- Reading: Thinking Deeper About What We Eat
- Reading: Food Deserts
- General Rubric for Writing Arguments in Science
- Development Template for Writing Arguments in Science
- Plant Growth in the Absence of Light: Scientific Explanation (from activation task)

#### **Procedure**



#### **SUMMATIVE ASSESSMENT**

This phase is designed to illustrate individual understanding of the overarching concept as well as the key concepts. Students should show mastery at or beyond (exceed) state or district assessment expectations.

Estimated time: 45 minutes, plus time to review, provide feedback, and grade

Procedure	Teaching Notes	Time <sup>1</sup>
Distribute the Plant Growth in the     Absence of Light: Writing an Argument     in Science sheet or project a copy of     the problem stated in the task sheet		2 minutes
Ask students to review the task and to ask any clarifying questions so that they are clear about the task and problem.		5 minutes
<ol> <li>Ask students to silently and individually complete the task.</li> <li>Optional: Allow them to use their notebooks and texts used during the unit as a resource.</li> </ol>	See the note below about grading—if using the differentiation approach, then distribute black pens and have the other color(s) ready.	35 minutes
4. Collect, review, provide feedback to, and grade the tasks. Use the General Rubric for Writing Arguments in Science (see Appendix B: Student Resources) to guide your feedback and grading.	One approach to noting different levels of proficiency with the information related to the concept is to use a colored grading scheme. In this model, students begin the problem without use of their notebook or other resources. All students should use a black pen. After completing as much as they can from memory, students can exchange their black pen for another color. When they have a different color pen, they can use their notebooks as a resource to complete the task.  You can then provide a sliding grade scale based on the pen color. For instance a response completed in only black pen ink may receive up to a 100, while a full response with a different color may receive up to an 89.	3 minutes, plus time to review, provide feedback, and grade.

<sup>1</sup> Time is provided as an approximate estimate for planning purposes.



#### PROBLEM-BASED APPLICATION PHASE

This phase provides an opportunity for students to apply their understandings to a real-world context as well as the opportunity to extend and further refine their understandings beyond the standards. This phase will provide you with additional evidence of the level of mastery for the targeted standards by all students. Extension suggestions are also provided for the activity to bridge to student-driven projects such as science fair.

Estimated time: 190 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
Organize students into pairs or triads.		3 minutes
2. Ask students to individually read the Problem-Based Application: Designing a Plan of Action to Improve Food Deserts. Ask students to keep the prompt in mind as they read the texts.		5 minutes
Ask students to briefly share their questions and wonderings about the prompt.		5 minutes
Distribute both readings to all students.		2 minutes
<ol> <li>Ask students within the pairs and triads to count off by twos. Ask ones to read Thinking Deeper About What We Eat. Ask twos to read Food Deserts.</li> <li>Remind students to keep the prompt in mind as they read their article.</li> </ol>		10 minutes
6. Ask students to share how the information they learned from their reading is relevant to the prompt.  Ask students to begin to brainstorm and form their plan of action in the form of an argument.  Ask students to form a list of questions and ideas to research.		20 minutes

Procedure	Teaching Notes	Time <sup>1</sup>
7. Provide students with time to research their questions and ideas around their action plan.  As students conduct their research, remind them to revisit the prompt. Also remind students their plan of action in the form of an argument (Claim — Evidence — Reasoning). Provide students with the General Rubric for Writing Arguments in Science and the Development Template for Writing Arguments in Science to guide the formation and writing of their argument.		60 minutes
8. Provide students with time and chart paper to draft their plan of action. Ask students to write large enough for others to easily see the design during the gallery walk. The design should be written in the form of an argument. Remind students to use the General Rubric for Writing Arguments in Science and the Development Template for Writing Arguments in Science to guide their writing.		45 minutes
9. Conduct a gallery walk or other sharing model so that students have an opportunity to see and hear other models that were designed. Students should be encouraged to probe each other for clarity and to push each other's thinking about the designs and what they know about matter and energy in organisms. Focus discussions around how the design takes into account what they know about the movement of energy and matter.		15 minutes

Continued on next page.



#### **REFLECT PHASE**

This phase is designed to provide time for students to individually reflect on the lesson and to pull their thoughts together to make sense of what they have experienced. They should understand how the activities of the lesson connect to the key concept, as well as how what they have done builds understanding of the overarching concept of the unit. This phase provides evidence of individual learning achieved through the lesson.

Estimated time: 15 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time <sup>1</sup>
Distribute the student responses from the Plant Growth in the Absence of Light: Scientific Explanation (from the activation task). Ask students to review their initial ideas on how organisms obtain and use energy and matter.		5 minutes
<ul> <li>Each student should write a response in his/her notebook to the following:</li> <li>How has your thinking changed across this unit of study?</li> <li>What helped you learn about these concepts and enhance your science skills?</li> </ul>	Promote learning in a meaningful context by helping students to realize how their thinking has changed or advanced because of the unit.	10 minutes

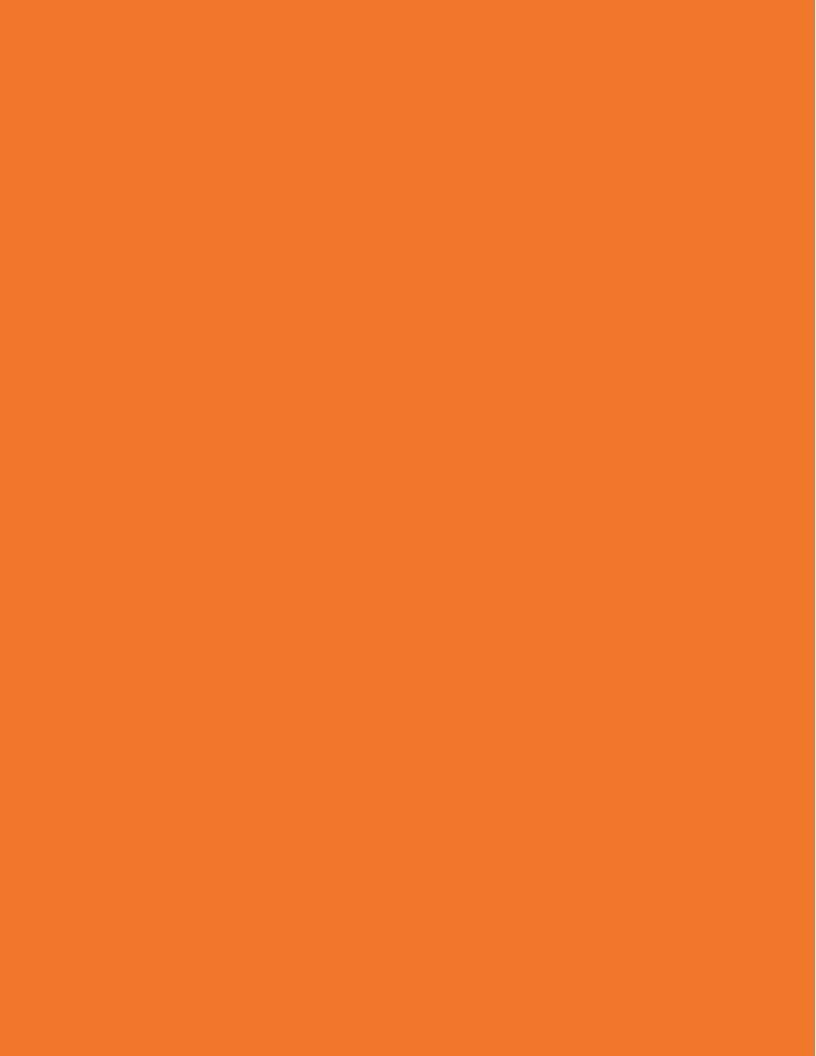


Adjustable to grades
9-10 based on
content alignment.

# **Appendix A: Teacher Resources**

Matter and Energy in Organisms

[HS.LS-ME0]



#### **Norms for Discussion**

Talk is an important part of science learning; academic talk helps us process what we are learning. Scientists share data and results as well as present and debate findings or conclusions. As apprentices of science, we need to talk about our experiences, our data, and our conclusions.

#### **Norms for Discussion**

#### You have the right to...

- Add ideas.
- Ask questions to help you understand.
- Be treated like everyone else.
- Agree or disagree (and explain why).
- Have your ideas discussed.

#### You are obligated to...

- Speak so that everyone can hear.
- Speak one at a time.
- Listen for understanding.
- Agree or disagree (and explain why).
- Assess ideas, not people.

## Talking to Understand: Student Talk

#### Question Starters...

- What do you think about...?
- Why do you think that?
- What do you mean when you say...?
- What examples can you give?
- What is your evidence?
- Where do you see that?
- Why does that happen?
- Can you say that again?
- I'm not sure I understand what you mean. Can you explain it another way?
- Try out your own!

Have you ever noticed how questions help you learn?

Why not ask a few yourself!

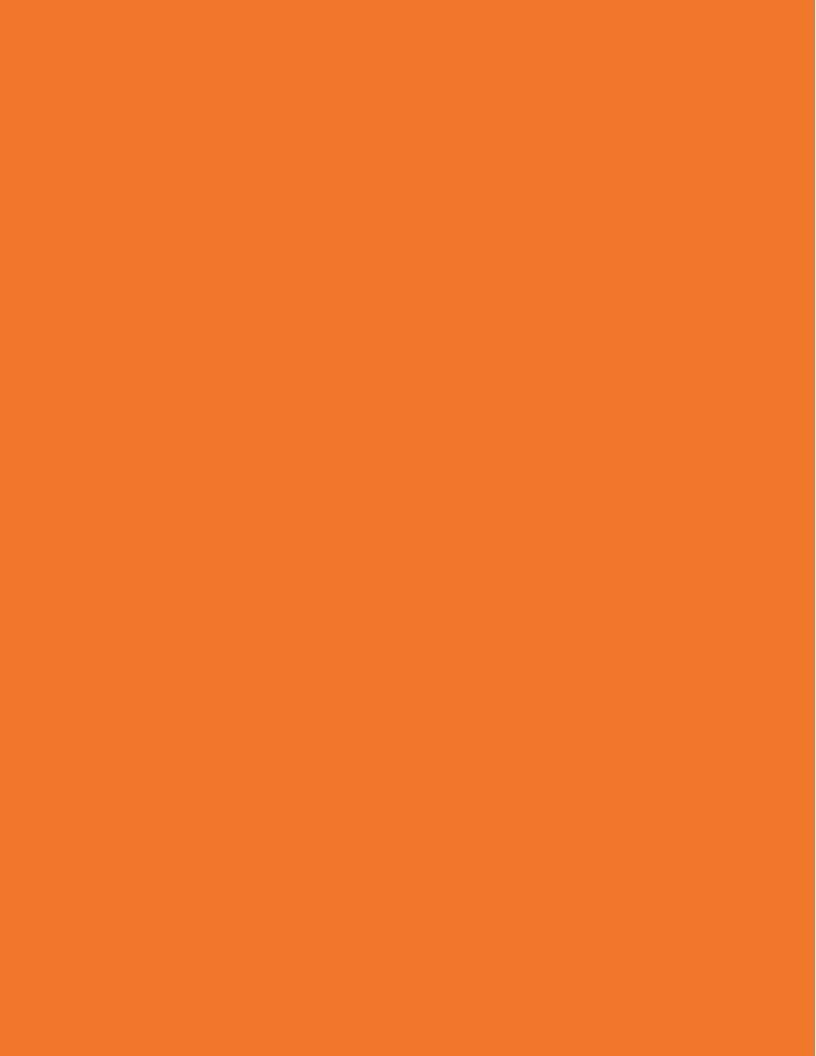


Adjustable to grades
9-10 based on
content alignment.

# **Appendix B: Student Resources**

Matter and Energy in Organisms

[HS.LS-ME0]



#### Plant Growth in the Absence of Light: Experimental Data

#### Purpose:

The purpose of the experiment is to observe the effect of the absence of light on plant growth.

#### **Environmental Conditions:**

Plants were grown in hydroponic conditions to allow for more accurate measurements of mass. Plants grown in hydroponic conditions are grown in water with added nutrients rather than soil.

All plants were exposed to the same environmental conditions except where noted. The conditions are recorded in the table below.

Environmental Conditions	
Air Composition (By Volume)	78% nitrogen (N), 21% oxygen (O), .03% carbon dioxide (CO₂), .00005% hydrogen (H), remaining >1% various other gases
Temperature	21°C = 69.8°F
Light Exposure	Light trial plants (#1, #2, #3) - (12 hours of light + 12 hours of dark per 24-hour period)
	Absence-of-light trial plants (#4, #5, #6) - (0 hours of light + 24 hours of dark per 24-hour period)

#### **Physical Description:**

	Initial						
	Light Trial (12 hours of light + 12 hours of dark per 24-hour period)			(0 hours	sence-of-Light of light + 24 hou er 24-hour perio	ırs of dark	
	Plant #1	Plant #2	Plant #3	Plant #4	Plant #5	Plant #6	
Mass	65.2 g	62.9 g	64.6 g	63.5 g	65.4 g	64.9 g	
Color	Green	Green	Green	Green	Green	Green	
General Notes	All plants (#1, #2, #3, #4, #5, #6) similar in size, color, height, and number of leaves						

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			Midway Throu	ıgh Experiment		
		Light Trial		Absence-of-Light Trail		
	Plant #1	Plant #2	Plant #3	Plant #4	Plant #5	Plant #6
Mass	Increase	Increase	Increase	Slight decrease	Slight decrease	Slight decrease
Color	Green	Green	Green	Greenish/ Yellow	Greenish/ Yellow	Greenish/ Yellow
General Notes	Number of leaves increased as compared to initial data  Slight height increase as compared to initial data—less height increase than absence of light trial plants		Height increased— taller than light trial plants Plant looks spindly, stems thinner	Few leaves have fallen off  Height increased— taller than light trial plants  Plant looks spindly, stems thinner	Height increased- taller than light trial plants Plant looks spindly, stems thinner	

	Final						
	Light Trial			Ab	Absence-of-Light Trail		
	Plant #1	Plant #2	Plant #3	Plant #4	Plant #5	Plant #6	
Mass	Increase	Increase	Increase	Decrease	Decrease	Decrease	
Color	Green	Green	Green	Yellow	Yellow/ Brown	Yellow	
General Notes	Number of leaves increased as compared to midway data		Leaves falling off	Brittle leaves	Leaves falling off		
	Slight height increase as compared to midway data		Some leaves brittle	Stems thinner than light	Some leaves brittle		
	imavay aata			Drooping	trial plants	Drooping	
				Stems thinner than light trial plants		Stems thinner than light trial plants	

#### Plant Growth in the Absence of Light: Scientific Explanation

**Read and study** the Plant Growth in the Absence of Light: Experimental Data sheet. Use the data on the sheet to make sense about what happened to the plants growing in the absence of light.

Answer the prompt and questions below in the form that best helps you understand and express your answer.

- 1. Explain why light is vital for the growth of plants. Include evidence (from the data table) to support your explanation. Include any knowledge you have of cellular processes that might support your explanation.
- 2. What additional information might you seek that could strengthen your explanation?
- 3. What questions do you have about the experiment, cellular processes, or other topics?

# Leaf Disk Lab: Photosynthesis and Matter

#### **Materials**

- Experimental solution: sodium bicarbonate, also known as baking soda (NaHCO<sub>3</sub>); water (H<sub>2</sub>O); and liquid soap solution
- Control solution: water and liquid soap solution
- 1 or 2 syringes (10 ml) without the needles (see Procedure)
- Leaf material
- Single-hole punch (or sturdy straws)
- Ruler
- · Light source
- 60 W<sup>1</sup> light bulb (approximately 860 lumens<sup>2</sup>)
- · Heat sink: clear container filled with water
- Timer

# Read through the procedure. As you read, record questions and wonderings about the lab and the procedure in your science notebook.

Prior to beginning the lab, create a data table in your science notebook to record your observations and experimental data.

#### **Procedure**

- 1. Gather needed materials.
- 2. Remove plungers from syringe(s).
- 3. Ask your teacher which of the following you are setting up:
  - a control setup syringe and an experimental setup syringe. If so label each syringe.
  - only an experimental setup syringe and obtaining data from a class control set-up syringe. If so, you will need only one syringe.
- 4. Create "leaf disks" with single-hole punch. Avoid non-green areas and large veins when cutting the disks. Cut 5 disks per syringe—punch directly into the syringe or onto a paper towel. If cutting onto a paper towel, be careful not to damage leaf material when transferring the leaf disks into the syringe.
- 5. Replace the plunger into the syringe. Be careful not to damage the leaf disks.
- 6. Use the plunger to pull solution into the syringe. Suspend the leaf disks in the solution (either control solution or experimental solution). If needed, push out air and pull additional solution to total 10 ml.
- 7. Make sure all leaf disks are suspended in the solution. Push all air out of the syringe. Cover the opening on the tip of the syringe with finger. Pull down on the plunger (keep finger in place) to create a vacuum. Bubbles should be visible when vacuum is working properly. The vacuum is removing the air from the spaces in the leaf. The solution is drawn into the leaf. As the air is drawn from the leaf disks, the space is replaced with solution.

1 W or watts is the measure of electric power needed to run the light bulb 2 Lumens is the measure of the amount of light emitted by the light bulb

- 8. Hold the vacuum for approximately 5 seconds. This process should cause the leaf disks to sink to the bottom of the syringe (bottom considered the plunger end). If leaf disks remain floating, repeat the vacuum procedure (steps 6 and 7) until all disks have sunk.
- 9. Place the plunger at the 10 ml mark on the syringe. Check to make sure the top of the solution is at 1 ml (top considered to be closest to the tip of the syringe). Add or remove solution as needed. There should be air between the top of the solution and the tip of the syringe.
- 10. Place the syringe upright (plunger end on table), ~20 cm (8 inches) from the light source. If needed, use tape to keep the syringe standing. Place a clear container filled with water between the light source and the syringe. The water in the container will absorb the heat from the light source.
- 11. Turn on light source and start timer at the same time.
- 12. Observe the leaf disks. Watch to see if the leaf disks rise to the surface of the solution. Record your observations in a data table in your science notebook. Provide times corresponding to your written observations.

# As you perform the experiment, record questions and wonderings about the lab and the procedure in your science notebook.

Answer the questions below in your science notebook as you observe the leaf disks.

- 1. What do you think is the purpose of each of the lab materials below?
  - Sodium bicarbonate, also known as baking soda (NaHCO<sub>3</sub>)
  - Water (H<sub>2</sub>O)
  - Liquid soap
  - Leaf disks
  - · Light source
  - Heat sink
- 2. What did you observe when you created the vacuum with your finger and the syringe? Why does creating a vacuum cause the leaf disks to sink?
- 3. Did you observe bubbles during the lab? If so, when and where did you see the bubbles? What do you think the bubbles are made of? Why do you think the bubbles are formed?
- 4. Why do you think the leaf disks rise when they are placed in the light? Be as specific as possible in your answer.
- 5. What are your general findings? Be prepared to share with the whole group.

## **Photosynthesis and Matter**

#### Think while you read.

It is important to think about what you are reading as you read. The text below is set up with the reading in the left-hand column and questions in the right-hand column. This format is designed to help you think about questions that focus your reading (what am I reading to find out) or that might arise as you read. Answer the questions in the right-hand column either directly on this sheet or in your science notebook. When needed, also use the information provided in the procedure of the Leaf Disk Lab: Photosynthesis and Matter or your experimental observations to support and form your answers.



There are many different types of questions. Below are descriptions of some types you may experience as you read. The types of questions are marked in the right-hand column alongside each question. It is important to provide evidence for all types of questions. Evidence includes facts, extended definitions, concrete details, quotations, or other information and examples as appropriate to supporting the answer to the question.

#### Finding

Finding questions are the types of questions that ask you to pull information directly from the text. Finding questions are usually fairly straightforward. The evidence for finding questions can be marked by underlining or highlighting the text, or quoting and citing the text.

#### Applying

Applying questions ask you to take information found in the text and apply it to solving a problem or completing a task. The evidence for the information used to solve the problem or complete the task can be underlined or highlighted, but it is usually quoted or cited. The application is expressed in the solution to the problem or the completing of the task. Applying questions sometimes require you to find additional information from another source to solve the problem or complete the task.

#### Connecting

Connecting questions ask you to find the answer in multiple parts of the text to answer a question. Connecting questions ask you to make connections between different content as well as between different concepts to fully answer the question. Connecting questions can also ask you to make your understandings clear by summarizing the information in your own words. The evidence used to make the connections can be underlined or highlighted, but it is usually quoted or cited.

#### Deeper Thinking

Deeper thinking questions are not plainly answered in the text. Deeper thinking questions ask you to take information from the text and make connections with other texts and/or your own understandings to form an answer. As the name implies, deeper thinking questions require you to engage with the text at a greater depth to decipher what is being said and to seek additional information if needed. Deeper thinking questions require evidence to be written within the answer to illustrate your thinking and support your answer.

As you engage with the text and the questions, think about how the format of the reading helps you engage as a learner. You will be asked to reflect on your experience with the reading during the Reflect Phase. Record your thoughts in your science notebook to revisit during the Reflect Phase of the lesson.

Matter is anything that takes up space and has mass. Matter is found in all living things and makes up most components of the environment. If we use the definition above, which includes space and mass, then light is not defined as matter. However, light is a source of energy. We will discuss light during CDL2.

Matter is made up of elements. If you have seen the periodic table, you probably noticed that it is made up of boxes, each containing a different capital letter (or two). These letters are symbols. Each symbol on the periodic table represents a different element. For example, the symbol for carbon is C, the symbol for hydrogen is H, and the symbol for sodium is Na. The same symbol used for the element is also used for a single atom of the element. Atoms are made up of neutrons, protons, and electrons. Atoms are the smallest unit of matter that still has the properties of the element.

There are 92 elements that occur organically in nature. Of these 92, approximately  $\frac{1}{4}$  are found in plants. Within the organism, elements are often found in the form of molecules. Some molecules are the same type of atoms joined together, while other molecules are a combination of various types of atoms. For example  $O_2$  is a molecule of oxygen, or two atoms of oxygen joined together. Carbon dioxide, or  $CO_2$ , is also a molecule, but it is made up of more than one type of element.  $CO_2$  is made up of one atom of carbon, the C, and two atoms of oxygen. O represents the atom oxygen and the subscript 2 indicates two atoms.

When atoms join together to form molecules, they do so by forming a chemical bond. The strongest type of chemical bond is the covalent bond. Covalent bonds are formed when two atoms share electrons. It is covalent bonds that hold together molecules like water or  $H_2O$ .

+ HH

**Finding:** What is matter?

H₂0

\*\*Applying: What is this molecule? What atoms, and in what amounts, make up this molecule?

**Finding:** What was the purpose of the liquid soap in the Leaf Disk experiment?

Molecules can be put together or broken apart. This occurs during a chemical reaction. A chemical reaction occurred to create the solution we used during the Leaf Disk Lab: Photosynthesis and Matter.

The solution was made of sodium bicarbonate, also known as baking soda (NaHCO $_3$ ); water (H $_2$ O); and a very small amount of liquid soap. Each part of the solution played an important role in the lab. The liquid soap helped to "break down" the natural barriers employed by the plant. This allowed the air to be drawn out of the leaf disks and allowed the solution to be drawn into the leaf. Without the soap, the leaf disks would not have sunk, because the air would have remained inside the leaf and the solution would have remained on the outside.

The water and sodium bicarbonate underwent a short series of chemical reactions to form the solution. Let's use the first reaction to illustrate some important features of chemical reactions.

Chemical Reaction #1  $NaHCO_3 + H_2O \rightarrow NaOH + H_2CO_3$ 

Refer back to the chemical reaction above as you read. The molecules to the left of the arrow (NaHCO $_3$  + H $_2$ O) are called reactants. Reactants are the molecules that go into the reaction, or the input. The addition sign means the molecules are added to each other. The arrow is a symbol for "changes into." The molecules on the right of the arrow (NaOH + H $_2$ CO $_3$ ) are the products. These are the molecules that are formed from the reaction of the molecules on the left and are therefore the output of the reaction. Notice how the number and type of atoms on the left side of the arrow are equal to the number and type of atom on the right side of the arrow. However, the atoms are now arranged differently and form new types of molecules. In order to make the molecules on the right, the bonds of the atoms that form the molecules on the left are broken. The atoms rearrange and form new bonds, forming the molecules on the right.

Now that we can recognize the general features of the chemical reaction, let's look at the two chemical reactions below in more detail.

Chemical Reaction #1  $NaHCO_3 + H_2O \rightarrow NaOH + H_2CO_3$  (sodium bicarbonate) (water) (sodium hydroxide) (carbonic acid)

Chemical Reaction #2  $H_2CO_3 \rightarrow CO_2 + H_2O$  (carbonic acid) (carbon dioxide) (water)

**Applying:** Why did creating a vacuum cause the leaf disks to sink?

**Applying:** Label the reactants and products in Chemical Reaction #1.

**Applying:** Underline the molecules whose bonds are broken during the chemical reaction.

**Applying:** Circle the molecules whose bonds are formed during the chemical reaction.

Refer back to the chemical reactions above as you read. Mixing together sodium bicarbonate (also known as baking soda) with water results in sodium hydroxide and carbonic acid. Carbonic acid is not stable and therefore easily breaks down. When carbonic acid breaks down, it results in carbon dioxide (in a gas form) and water.

But how does all of this fit together? Matter, chemical bonding, and chemical reactions? And why is this important to the leaf disk lab and photosynthesis?

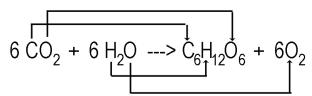
You have probably seen the overall chemical reaction or the equation for photosynthesis before.

$$6CO_2 + 6H_2O + light \rightarrow C_6H_{12}O_6 + 6O_2$$
 (carbon dioxide) (water) (energy) (glucose) (oxygen)

Notice how the atoms on the left of the equation equal the atoms on the right of the equation. Like the sodium bicarbonate and water reaction, some atoms have subscript numbers denoting the particular number of a specific atom in a molecule. Notice how there are also numbers in front of some molecules. For example  $6CO_2$ . The number six indicates that six molecules of carbon dioxide enter the reaction.

Also like the chemical reaction discussed above between sodium bicarbonate and water, photosynthesis is a series of chemical reactions. The chemical equation above shows the overall reaction. All of reactions occur in the chloroplasts, organelles located in the plant cells that perform photosynthesis. Because we are focusing on matter during this lesson, let's forget about light for a moment. We will discuss light's role in photosynthesis during CDL2.

If light is removed from the chemical equation, we are left with the matter coming in (inputs or reactants) on the left side of the arrow and the matter going out (outputs or products) on the right side of the arrow.



The figure above shows the movement of atoms

**Connecting:** Why is sodium bicarbonate used to make the solution in the Leaf Disk experiment?

**Connecting:** Why is water used to make the solution in the Leaf Disk experiment?

**Connecting:** What does the 2 mean in  $CO_2$ .

**Applying:** Label the reactants and products in Chemical Reaction #1.

**Applying:** Underline the molecules whose bonds are broken during the chemical reaction.

**Applying:** Circle the molecules whose bonds are formed during the chemical reaction.

During photosynthesis, the chemical bonds of the reactants (molecules on the left side of the arrow) are broken. The atoms are rearranged to form new molecules, or the products (molecules on the right side of the arrow). The arrows show where the atoms move during the reaction. Notice how the carbon and oxygen atoms from carbon dioxide join with hydrogen atoms from water to form glucose. Plants take in matter from the environment, which they transform into matter used by the plant. It's pretty amazing to think about how plants pull in carbon dioxide and water from their environment and transform a gas and liquid into the matter that helps them continually grow and develop.

Finding: Where do plants get the matter needed to grow and develop?

The production of glucose is the purpose of photosynthesis. Plants use glucose for a variety of purposes. One important use is as a source of energy. We will focus on the energy aspect in future lessons. Plants also use glucose for structural purposes. Plants break the chemical bonds in the atoms of glucose and rearrange them into larger molecules useful for the plants. Carbon is an important building block for larger molecules. One such molecule is cellulose, a molecule that makes up cell walls in plants. Much of the glucose that is produced during photosynthesis is stored, in the form of starch, in structures such as the roots, stems, and leaves. This allows plants to have a reserve of building materials and an energy source when needed.

**Finding:** In terms of matter, why do plants go through photosynthesis?

Plants are not the only organisms that undergo the process of photosynthesis. Plants have the ability to make their own nourishment and are called autotrophs. "Auto" means self, and "troph" means nourishment. So autotrophs are organisms that self-nourish or make their own "food." Plants are an example of an autotroph that uses the energy from the sun to produce complex molecules from simple molecules in the environment. In nature, certain types of algae and bacteria can also be autotrophic.

# General Rubric for Writing Arguments in Science

		Level 1	Level 2	Level 3	Level 4
	Introduction	The writing • lacks introduction or introduction is irrelevant.	The writing  contains a limited introduction.	The writing  contains a relevant introduction.	The writing  contains a logical and relevant introduction.
Focus and Organization	Organization	The writing  I lacks a claim or contains inappropriate claim(s); and  I lacks a clear organizational structure connecting claim(s), evidence <sup>2</sup> , reasoning, and (if applicable) counterclaim(s) <sup>1</sup> .	The writing  contains claim(s); and  is organized, but the relationship among the claim(s), evidence², reasoning, and (if applicable) counterclaim(s)¹ is difficult to follow.	The writing  contains precise claim(s);  contains (if applicable) appropriate counterclaim(s)¹;  is organized adequately, creating a mostly unified whole that aids in comprehension; and  organization communicates the relationships among the claim(s), evidence², reasoning, and (if applicable) counterclaim(s)¹.	The writing  contains precise claim(s);  contains (if applicable) appropriate counterclaim(s)¹;  is organized effectively, creating a unified whole that aids in comprehension; and  organization communicates clear and effective relationships among the claim(s), evidence², reasoning, and (if applicable) counterclaim(s)¹.
	Cohesion	The writing  Iacks a concluding statement or section or conclusion is irrelevant; and does not follow and/or support the argument presented.	The writing  contains a limited concluding statement or section; and  weakly follows and/or supports the argument presented.	The writing  contains a relevant concluding statement or section; and follows and supports the argument presented.	The writing  contains a logical and relevant concluding statement or section; and explicitly follows, supports, and strengthens the argument presented.

<sup>1</sup> Counterclaims are claims that are alternate or oppose the main claim. Counterclaims are included when applicable and must be appropriate to the argument.

<sup>2</sup> Evidence includes facts, extended definitions, concrete details, quotations, or other information and examples as appropriate to the task and the stimuli.

		Level 1	Level 2	Level 3	Level 4
	Evidence <sup>2</sup>	The writing  contains mostly irrelevant or no data or evidence <sup>2</sup> , or mostly/ only personal knowledge, that inadequately supports claim(s) and (if applicable) counterclaim(s) <sup>1</sup> ; evidence <sup>2</sup> is inaccurate or repetitive.	The writing  contains mostly relevant but insufficient data and evidence² that partially supports claim(s) and (if applicable) counterclaim(s)¹; some evidence² may be inaccurate or repetitive.	The writing  contains relevant and sufficient data and evidence <sup>2</sup> that adequately supports claim(s) and  contains (if applicable) relevant and sufficient data and evidence <sup>2</sup> to adequately support counterclaim(s) <sup>1</sup> .	The writing  contains well- chosen, relevant, and sufficient data and evidence <sup>2</sup> that thoroughly and insightfully supports claim(s) and  contains (if applicable) well- chosen, relevant, and sufficient data and evidence <sup>2</sup> to thoroughly and insightfully support counterclaim(s) <sup>1</sup> .
Development	Reasoning	The writing  inadequately or inaccurately explains the evidence² provided; evidence², claim(s), and (if applicable), counterclaim(s)¹ are disconnected; and  does not contain or has inaccurate scientific principles in the analysis and reasoning.	The writing  contains reasoning that explains some of the evidence² or connects some of the evidence² to claim(s) and (if applicable) counterclaim(s)¹; and  inconsistently includes scientific principles in the analysis and reasoning; may include some level of inaccuracy.	The writing  contains logical, scientific reasoning that clearly and accurately explains and connects the evidence² to claim(s) and (if applicable) counterclaim(s)¹;  contains accurate strengths and limitations of claim(s) and (if applicable) counterclaim(s)¹; and  contains accurate and appropriate scientific principles in the analysis and reasoning.	The writing  contains logical, scientific reasoning that clearly, accurately, and thoroughly explains and connects the evidence² to claim(s) and (if applicable) counterclaim(s)¹;  contains accurate and thorough strengths and limitations of claim(s) and (if applicable) counterclaim(s)¹; and  contains accurate and thorough counterclaim(s)¹; and  contains accurate and thorough connection to scientific principles in the analysis and reasoning.
	Attention to Audience	The writing  • does not emphasize the strengths and limitations of both claim(s) and (if applicable) counterclaim(s) <sup>1</sup> in a manner that anticipates the audience's knowledge level and concerns.	The writing  inconsistently emphasizes the strengths and limitations of both claim(s) and (if applicable) counterclaim(s) in a manner that anticipates the audience's knowledge level and concerns.	The writing  adequately emphasizes the strengths and limitations of both claim(s) and (if applicable) counterclaim(s) <sup>1</sup> in a manner that anticipates the audience's knowledge level and concerns.	The writing • effectively emphasizes the strengths and limitations of both claim(s) and (if applicable) counterclaim(s) <sup>1</sup> in a manner that anticipates the audience's knowledge level and concerns.  Continued on next page

		Level 1	Level 2	Level 3	Level 4
	Vocabulary	The writing  illustrates little to no use of precise language and/or domain-specific vocabulary.	The writing  illustrates inconsistent command of precise language and/or domain-specific vocabulary.	The writing  illustrates consistent command of precise language and domain- specific vocabulary appropriate to the task.	The writing  Illustrates consistent and sophisticated command of precise language and domain- specific vocabulary appropriate to the task.
Language	Style	The writing  contains few or no links between major sections of the text;  does not clarify the relationships between claim(s) and reasoning, between reasoning and evidence², and (if applicable) between claim(s) and counterclaim(s)¹; and does not establish or maintain a formal style and an objective tone appropriate to the science discipline and context.	The writing  contains basic or repetitive words, phrases, and clauses that link major sections of the text;  inconsistently clarifies the relationships between claim(s) and reasoning, between reasoning and evidence², and (if applicable) between claim(s) and counterclaim(s)¹; and  inconsistently maintains formal style and an objective tone appropriate to the science discipline and context.	The writing  contains appropriate words, phrases, and clauses that link major sections of the text and create cohesion; clarify the relationships between claim(s) and reasoning, between reasoning and evidence², and (if applicable) between claim(s) and counterclaim(s)¹; and establishes and maintains a formal style and an objective tone appropriate to the science discipline and context	The writing  contains sophisticated words, phrases, and clauses that link major sections of the text and create cohesion;  clarify the relationships between claim(s) and reasoning, between reasoning and evidence², and (if applicable) between claim(s) and counterclaim(s)¹; and  establishes and maintains an effective, formal style and an objective tone appropriate to the science discipline and context.

Name	

# Leaf Disk Lab: Photosynthesis and Energy

#### **Materials**

- Experimental solution: sodium bicarbonate, also known as baking soda (NaHCO $_3$ ); water (H $_2$ O); and liquid soap solution
- Control\*: dark location to place control set-up syringe
- 2 syringes (10 ml) without the needles
- Leaf material
- Single-hole punch (or sturdy straws)
- Ruler
- Light source
- Light bulbs (variety of light intensities)
- Timer

# Read through the procedure. As you read, record questions and wonderings about the lab and the procedure in your science notebook.

Prior to beginning the lab, create a data table in your science notebook to record your observations and experimental data.

#### **Procedure**

- 1. Ask your teacher which light intensity your group will be testing.
- 2. Gather needed materials.
- 3. Remove plungers from syringe(s).
- 4. Create "leaf disks" with single-hole punch. Avoid non-green areas and large veins when cutting the disks. Cut 5 disks per syringe—punch directly into the syringe or onto a paper towel. If cutting onto a paper towel, be careful to not damage leaf material when transferring the leaf disks into the syringe.
- 5. Replace the plunger into the syringe. Be careful not to damage the leaf disks.
- 6. Use the plunger to pull solution into the syringe. Suspend the leaf disks in the solution. Push out air and pull additional solution to total 10 ml.
- 7. Make sure all leaf disks are suspended in the solution. Push all air out of the syringe. Cover the opening on the tip of the syringe with finger. Pull down on the plunger (keep finger in place) to create a vacuum. Bubbles should be visible when vacuum is working properly. The vacuum is removing the air from the spaces in the leaf. The solution is drawn into the leaf. As the air is drawn from the leaf disks, the space is replaced with solution.
- 8. Hold the vacuum for approximately 5 seconds. This process should cause the leaf disks to sink to the bottom of the syringe (bottom considered the plunger end). If leaf disks remain floating, repeat the vacuum procedure (steps 6 and 7) until all disks have sunk.
- 9. Place the plunger at the 10 ml mark on the syringe. Check to make sure the top of the solution is at 1 ml (top considered to be closest to the tip of the syringe). Add or remove solution as needed. There should be air between the top of the solution and the tip of the syringe.
- 10. Place the syringe upright (plunger end on table), ~20 cm (or 8 inches) from light source. If needed, use

- tape to keep the plunger standing. Place a clear container filled with water between the light source and the syringe. The water in the container will absorb the heat from the light source.
- 11. Turn on light source and start timer at the same time.
- 12. Observe the leaf disks. Record your observations in a data table in your science notebook. Provide times corresponding to your written observations. Record the amount of time it takes for the leaf disks to rise to the surface of the solution.
- 13. \*Optional: Check with your teacher to see if you are setting up a control or if your teacher will be setting up the control. If you are setting up the control, repeat steps 2-9. Place the syringe in the dark location identified by your teacher. Start your timer. Observe the leaf disks. Record your observations in a data table in your science notebook. Provide times corresponding to your written observations. Record the amount of time it takes for the leaf disks to rise to the surface of the solution.

# As you perform the experiment, record questions and wonderings about the lab and the procedure in your science notebook.

Answer the questions below in your lab notebook as you observe the leaf disks.

- 1. What do you think is the purpose of using various light sources?
- 2. Why does step 4, in the procedure, warn to avoid areas of the leaf material that have large veins or are not green when making the leaf disks?
- 3. What are your general findings? Be prepared to share with the whole group.

# **Photosynthesis and Energy**

#### Think while you read.

It is important to think about what you are reading as you read. The text below is set up with the reading in the left-hand column and questions in the right-hand column. This format is designed to help you think about questions that might arise as you read. Answer the questions in the right-hand column either directly on this sheet or in your science notebook. When needed, also use the information provided in the procedure of the Leaf Disk Lab: Photosynthesis and Matter, Leaf Disk Lab: Photosynthesis and Energy, or your experimental observations to support and form your answers.



There are many different types of questions. Below are descriptions of some types you may experience as you read. The types of questions are marked in the right-hand column alongside each question. It is important to provide evidence for all types of questions. Evidence includes facts, extended definitions, concrete details, quotations, or other information and examples as appropriate to supporting the answer to the question.

#### Finding

Finding questions are the types of questions that ask you to pull information directly from the text. Finding questions are usually fairly straightforward. The evidence for finding questions can be marked by underlining or highlighting the text, or quoting and citing the text.

#### Applying

Applying questions ask you to take information found in the text and apply it to solving a problem or completing a task. The evidence for the information used to solve the problem or complete the task can be underlined or highlighted, but it is usually quoted or cited. The application is expressed in the solution to the problem or the completing of the task. Applying questions sometimes require you to find additional information from another source to solve the problem or complete the task.

#### Connecting

Connecting questions ask you to find the answer in multiple parts of the text to answer a question. Connecting questions ask you to make connections between content as well as between concepts to fully answer the question. Connecting questions can also ask you to make your understandings clear by summarizing the information in your own words. The evidence used to make the connections can be underlined or highlighted, but it is usually quoted or cited.

#### • Deeper Thinking

Deeper thinking questions are not plainly answered in the text. Deeper Thinking questions ask you to take information from the text and make connections with other texts and/or your own understandings to form an answer. As the name implies, deeper thinking questions require you to engage with the text at a greater depth to decipher what is being said and to seek additional information if needed. Deeper thinking questions require evidence to be written within the answer to illustrate your thinking and support your answer.

As you engage with the text and the questions, think about how the format of the reading helps you engage as a learner. You will be asked to reflect on your experience with the reading during the Reflect Phase. Record your thoughts in your science notebook to revisit during the Reflect Phase of the lesson.

Remember from CDL1 that matter is anything that takes up space and has mass. Matter is found in all living things and makes up most components of the environment. If we use the definition above, which includes space and mass, then light is not defined as matter. However, light is a source of energy.

Light is not alone in being an example of an energy source. Heat and chemical compounds like glucose are also examples. All three of these examples are important to organisms. We will revisit heat and chemical compounds in CDL3. For now, let's focus on light.

During CDL1, we removed light from the chemical equation for photosynthesis so that we could focus on matter. Let's add the light back in.

$$6CO_2$$
 +  $6H_2O$  + light  $\rightarrow$   $C_6H_{12}O_6$  +  $6O_2$  (carbon dioxide) (water) (energy) (glucose) (oxygen)

Without light photosynthesis cannot occur. But why is light so important? What role does light play in photosynthesis?

Light is made up of really tiny particles called photons. Each photon carries a fixed quantity of energy. So photons traveling at a certain wavelength¹ have a certain amount of fixed energy. If we were to compare photons at a specific wavelength at a low light intensity against photons at the same wavelength but at a high light intensity, the energy of the photons would be the same. However, the lower light intensity has fewer photons than the greater light intensity. The greater the light intensity, the greater the number of photons.

Plants and other photosynthesizing organisms have the ability to capture the energy from light.

Plants have specialized organelles called chloroplasts. Chloroplasts are found within plant cells that perform photosynthesis. When light hits matter, it can be absorbed or reflected. Molecules that absorb the light are called pigments. Chloroplasts contain multiple types of pigments that are able to capture the energy from light to use during photosynthesis. One of these pigments is called chlorophyll. There are two main forms of chlorophyll that greatly aid the process of photosynthesis: chlorophyll a and chlorophyll b. The chlorophyll molecules absorb the light, but they also, importantly, absorb the energy from light.

1 Wavelength is a measurement of light.

**Applying:** Underline the matter in the photosynthesis equation.

**Applying:** Circle the energy in the photosynthesis equation.

**Connecting:** What is the relationship between chloroplasts and chlorophyll?

**Deeper thinking:** Why is chlorophyll important for photosynthesis?

Photosynthesis is a series of complex chemical reactions. The chemical reactions make up two overall processes. The first is the light-dependent reaction. The second is the light-independent reaction, or the Calvin cycle. For our purposes, we don't need to know the minute details of these processes. Rather, let's focus on the overall understanding of how the energy from light is captured during photosynthesis when making a high-energy sugar, like glucose.

#### **Light-Dependent Reaction**

As its name suggests, the light-dependent reaction needs light in order to occur. The other reactant needed in the light-dependent reaction is water.

During the light-dependent reaction, the chemical bonds holding the water molecules together are broken. Remember that the chemical formula for a water molecule is  $H_2O$ . As the chemical bonds in the water molecule are broken apart, hydrogen (H) atoms and the oxygen (O) atom are released. The oxygen atom joins with other oxygen atoms (from other "broken" water molecules) to form molecules of oxygen gas  $(O_2)$ .

Light is captured by the chloroplasts. The energy harvested from the light is used to make two special molecules. The first molecule is an electron and hydrogen atom carrier². This molecule transports hydrogen atoms to the light-independent reaction (Calvin cycle) to be used in the making of glucose ( $C_6H_{12}O_6$ ). The rest of the energy from the light is harvested to make ATP. ATP or adenosine triphosphate provides chemical energy for the making and breaking of chemical bonds in the light-independent reaction.

#### **Light-Independent Reaction**

The light-independent reaction, as its name denotes, does not require direct light to occur. This is because the energy from the light was captured and packaged during the light-dependent reaction. During the light-independent reaction, the chemical bonds of carbon dioxide are broken and the atoms are rearranged into new molecules. Carbon atoms, hydrogen atoms, and oxygen atoms are rearranged into glucose ( $C_6H_{12}O_6$ ). The breaking and reforming of the chemical bonds into a new molecule could not occur without ATP. And the ATP could not be formed without the energy from the light.

**Connecting:** In your own words, what happens to water during the light-dependent reaction?

#### Deeper thinking:

What happens to the oxygen gas  $(O_2)$  that is formed during the light-dependent reaction? \*Hint: Think about the photosynthesis equation.

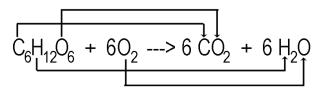
**Applying:** What are the reactants and products of the light-dependent reaction?

Applying: Carbon, hydrogen, and oxygen are needed to make glucose. Where does each of these atoms come from?

**Connecting:** Why are the products of the light-dependent reaction important?

<sup>2</sup> The electron and hydrogen carrier is called NADP+. Each NADP+ has the capacity to "carry" 2e and 1H+. The molecule is known as NADPH or Nicotinamide adenine dinucleotide phosphate.

Look at the chemical equation below. Notice how the reactant molecules on the left side of the arrow are rearranged to form the product molecules on the right side of the arrow.



The figure above shows the movement of atoms during the process of cellular respiration.

We know that sunlight is a source of energy. However, light is not a source of energy that organisms can use directly for cellular processes. During photosynthesis, the energy from light is converted into stored chemical energy. This is done by converting carbon dioxide and water, the reactants of photosynthesis, into glucose (high-energy sugars) and oxygen, the products of photosynthesis. In terms of energy, the energy captured from sunlight is transferred and transformed into the energy stored in glucose.

The process of photosynthesis makes high-energy sugars for plants and other photosynthesizing organisms to use, but it is also the main way that the sun's energy is captured and stored in Earth's organisms. This ability to capture solar energy is why plants are called producers. Throughout the process of photosynthesis plants produce food both for themselves and for other organisms or consumers.

**Connecting:** Why is light important in photosynthesis?

Finding: Why is photosynthesis important?

**Deeper thinking:** In the Leaf Disk Lab, why do the leaf disks rise when they are placed in the light? Include both energy and matter in your answer.

# **Getting More Specific About Light**

#### Think while you read.

It is important to think about what you are reading as you read. The text below is set up with questions following the text. Read the questions prior to reading the text. Read for understanding, but also think about the questions as you read.

As you engage with the text and the questions, think about how the format of the reading helps you engage as a learner. What do you have to do to support your own thinking as you read? You will be asked to reflect on your experience with the reading during the Reflect Phase. Record your thoughts in your science notebook to revisit during the Reflect Phase of the lesson.

To better understand photosynthesis, let's look more closely at how the energy from light is captured and helps to drive the process.

Imagine the waves in water. We see water waves in oceans, ponds, puddles, even bathtubs. Light travels in waves. However, unlike water, light waves do not cause disturbances in matter, but rather cause disturbances in electric and magnetic fields. Because of this, light is part of the electromagnetic spectrum.

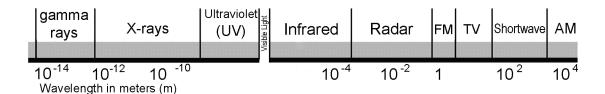


Figure 1: Electromagnetic Spectrum

Electromagnetic waves are measured in wavelengths. The unit for a wavelength is nanometers or nm. Rays of light from the sun are the full electromagnetic spectrum. The Earth's atmosphere blocks most of the electromagnetic waves on the spectrum, but the atmosphere does not block the waves of visible light. Therefore, visible light, in the form of white light, strikes the objects on Earth. Unlike the other electromagnetic waves, the human eye can see visible light.

Visible light is a small slice of the electromagnetic spectrum, ranging from 380 nm to 750 nm, but it is extremely important for life on Earth. Its importance lies in visible light's ability to drive photosynthesis.

Light is made up of really tiny particles called photons. Each photon carries a fixed quantity of energy, dependent on the wavelength of light. Different colors of light, and therefore the corresponding photons, travel at different wavelengths. The shorter the wavelength of light, the greater the energy of the photon.

Plants and other photosynthesizing organisms have the ability to capture the energy from visible light.

White light is a combination of all of the colors. The color of light seen is determined by the wavelength of the light.

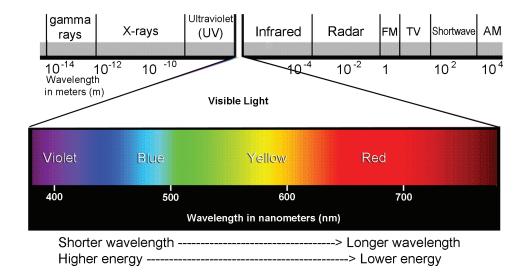
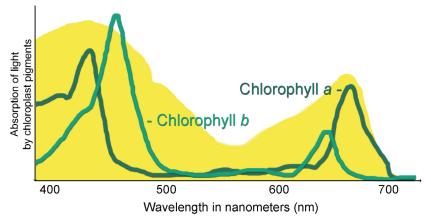


Figure 2: Electromagnetic Spectrum with Visible Light Spectrum

When light hits matter, it can be absorbed or reflected. The human eye can see light that is reflected, but it cannot see the colors that are absorbed. For example, if your eyes detect a red shirt, it is because the pigments in the shirt are reflecting the red wavelengths and absorbing the other color wavelengths of light.

Remember that plants have specialized organelles called chloroplasts. Chloroplasts contain chlorophyll a and b, light-absorbing molecules called pigments. The chlorophyll molecules absorb the light, but they also, importantly, absorb the energy from light. However, the chlorophyll molecules can absorb light only at certain wavelengths.



The shaded area illustrates the rate of photosynthesis mapped to light wavelength.

Use the text above and Reading: Photosynthesis and Energy to answer the questions below. Support all answers with evidence from the text(s).

- 1. **Applying:** What wavelengths of light are best absorbed by chlorophyll a?
- 2. Applying: What wavelengths of light are best absorbed by chlorophyll b?
- 3. **Connecting:** How does the absorption of light relate to the rate of photosynthesis?
- 4. Applying: What colors of light would you say produce the highest rate of photosynthesis?
- 5. Connecting: Why are many plants green?

# **Applying Information: Extension Lab Scenario**

Use what you have learned so far to explain the following lab results.

After learning about chloroplasts and the visible light spectrum, a biology class decided to design an extension of the Leaf Disk Lab. The students set up four syringes. Each syringe had the same concentration of sodium bicarbonate solution and five leaf disks from the same plant. All syringes were placed 21cm (~8 inches) from the light source.

To test the effects of colored light, the students made covers for each syringe out of cellophane baggies. Syringe #1 was covered with a clear cellophane bag. Syringe #2 was covered with a blue cellophane bag. Syringe #3 was covered with a green cellophane bag. Syringe #4 was covered with a red cellophane bag.

Explain the results. Use evidence to support your answer.

Summary of Results: The students calculated the average time it took for the leaf disks in each syringe to rise to the surface of the solution. Here is the ranking from fastest average rise time to slowest average rise time: 1) Clear, 2) Blue, 3) Red, 4) Green (only two of the green disks rose to the surface after 60 minutes).

# Plant Growth in the Absence of Light: Writing Explanatory Text in Science

**Reread and study** the Plant Growth in the Absence of Light: Experimental Data sheet. Use the data on the sheet and the information gathered during CDL1and CDL2 to make sense about what happened to the plants growing in the absence of light.

Answer the prompt below in an essay that explains. Your answer should be written in multiple-paragraph form. Include evidence from the data sheet and the CDL1 and CDL2 labs and readings in your essay. Use the General Rubric for Writing Informational/Explanatory Text in Science to help guide your writing. You will revisit and revise your essay during CDL3.

1. Explain why light is vital for the growth of plants. Include evidence (from the data table) to support your explanation. Include any knowledge you have of cellular processes that might support your explanation.

Reflect on the questions below.

- 1. What additional information might you seek that could strengthen your explanation?
- 2. What questions do you have about the experiment, cellular processes, or other topics?

# General Rubric for Writing Informational/Explanatory Text in Science

		Level 1	Level 2	Level 3	Level 4
	Introduction	The writing • lacks introduction or introduction is irrelevant.	The writing  contains a limited introduction.	The writing • contains a relevant introduction.	The writing • contains a logical and relevant introduction.
Focus and Organization	Organization	The writing • lacks organizational structure.	The writing  • is organized, but ideas may be hard to follow at times.	The writing  is organized adequately, creating a mostly unified whole that aids in comprehension; and  organization adequately communicates ideas, concepts, and information, making important connections and distinctions.	The writing  is organized effectively, creating a unified whole that aids in comprehension; and  organization effectively communicates ideas, concepts, and information, making important connections and distinctions
Focus and (	Cohesion	The writing • fails to clarify relationships among ideas and concepts; concepts are unclear and/ or there is a lack of focus.	The writing  clarifies some relationships among ideas and concepts, but there are lapses in focus.	The writing  clarifies most relationships among ideas and concepts, but there may be some gaps in cohesion.	The writing  • effectively clarifies relationships among ideas and concepts to create cohesion.
	Conclusion	The writing  contains no or an irrelevant concluding statement or section; and  does not follow and/or support the information or explanation presented.	The writing  contains a limited concluding statement or section; and  weakly follows and/or supports the information or explanation presented.	The writing  contains a relevant concluding statement or section; and  follows and supports the information or explanation presented.	The writing  contains a logical and relevant concluding statement or section; and explicitly follows, supports, and strengthens the information or explanation presented.

		Level 1	Level 2	Level 3	Level 4
Development	Evidence <sup>1</sup>	The writing  contains mostly irrelevant or no evidence¹, or mostly/ only personal knowledge, to inadequately develop the topic; evidence is inaccurate or repetitive; and  lacks data and evidence and fails to explain the science content.	The writing  contains mostly relevant but insufficient evidence¹ to partially develop the topic; some evidence may be inaccurate or repetitive; and  contains mostly relevant but insufficient data and evidence that partially explains the science content.	The writing  contains relevant and sufficient evidence¹ to adequately develop the topic; and  contains well-chosen, relevant, and sufficient data and evidence that adequately explains the science content.	The writing  contains well- chosen, relevant, and sufficient evidence¹ to thoroughly and insightfully develop the topic; and contains well- chosen, relevant, and sufficient data and evidence that thoroughly and insightfully explains the science content.
Deve	Attention to Audience	The writing  I acks attention to the audience's knowledge of the topic.	The writing  contains some information and examples appropriate to the audience's knowledge of the topic.	The writing  contains vocabulary, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.	The writing  contains vocabulary, extended, definitions, concrete details, quotations, or other information and examples that appropriately and effectively attend to the audience's knowledge of the topic.

<sup>1</sup> Evidence includes facts, extended definitions, concrete details, quotations, or other information and examples as appropriate to the task and the stimuli.

		Level 1	Level 2	Level 3	Level 4
Language	Vocabulary	The writing  illustrates little to no use of precise language and/or domain-specific vocabulary; and  contains incorrect use of domain-specific vocabulary and conveys a style inappropriate to the science discipline and context.	The writing  Illustrates inconsistent command of precise language and/or domain- specific vocabulary and contains inconsistent use of domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the science discipline and context.	The writing  illustrates consistent command of precise language and domain- specific vocabulary appropriate to the task; and  contains domain- specific vocabulary to manage the complexity of the topic and convey a style appropriate to the science discipline and context.	The writing  Illustrates consistent and sophisticated command of precise language and domain- specific vocabulary appropriate to the task; and  contains domain- specific vocabulary to manage the complexity of the topic and convey a style appropriate to the science discipline and context.
	Transitions and Style	The writing  I acks structure; and  I acks formal style and an objective tone appropriate to the science discipline and context.	The writing  contains basic or repetitive sentence structure and transitional words and/or phrases; and  establishes but inconsistently maintains a formal style and/or an objective tone appropriate to the science discipline and context.	The writing  contains appropriate and varied sentence structure and transitional words and phrases; and  establishes and maintains a formal style and an objective tone appropriate to the science discipline and context.	The writing  contains sophisticated and varied sentence structure and transitional words and phrases; and  establishes and maintains an effective formal style and an objective tone appropriate to the science discipline and context.

# Cellular Respiration: Matter and Energy

#### Think while you read.

It is important to think about what you are reading as you read. The text below is set up with questions before the text. Read the questions prior to reading the text. Read for understanding, but also think about the questions as you read.

As you engage with the text and the questions, think about how the format of the reading helps you engage as a learner. What do you have to do to support your own thinking as you read? You will be asked to reflect on your experience with the reading during the Reflect Phase. Record your thoughts in your science notebook to revisit during the Reflect Phase of the lesson.

Use the questions below to guide your reading. Write your answers in your science notebook. Be sure to include evidence from the text to support your answers.

- 1. **Applying:** Write the cellular respiration equation. Label the reactants and products in the cellular respiration reaction. Label the matter. Label the energy.
- **2. Connecting:** What similarities and differences do you notice between the cellular respiration and photosynthesis chemical equations?
- 3. Finding: What is the purpose of cellular respiration?
- 4. **Deeper thinking:** How does cellular respiration relate to an organism's need for matter and energy?
- 5. Connecting: Why do plants go through both photosynthesis and cellular respiration?
- **6. Connecting:** How does the making and breaking of chemical bonds relate to the transfer of energy during cellular respiration?

In many ways the processes of photosynthesis and cellular respiration are similar. Both plants and animals go through the process of cellular respiration. During photosynthesis, plants produce glucose, a high-energy carbohydrate. Sugars are a type of carbohydrate. This high-energy sugar becomes a reactant in the process of cellular respiration. Animals, however, do not go through the process of photosynthesis; therefore, they do not produce the high-energy carbohydrates needed to begin the process of cellular respiration. In order to begin the process, animals must consume a source of glucose or other source of "food" molecules. This source is another organism, be it plants or other organisms. Plants' ability to create their own "food" is the reason that they do not need to eat.

Cellular respiration, like photosynthesis, can be represented with a chemical equation.

$$C_6H_{12}O_6$$
 +  $6O_2$   $\rightarrow$   $6CO_2$  +  $6H_2O$  + Energy (glucose) (oxygen) (carbon dioxide) (water) (ATP)

Each of the molecules in the reaction above is held together by chemical bonds. During the process of cellular respiration, the bonds of the reactants are broken and rearranged to form the product molecules.

Notice how the products of photosynthesis are the reactants in cellular respiration. Notice also how the products of cellular respiration are very similar to the reactants in photosynthesis. Upon first glance, it would appear that plants go through the entire process of photosynthesis simply to reverse the process during cellular respiration, but there is an important difference.

You may have noticed how in the reactants of photosynthesis, the input of energy is light; whereas in cellular respiration, the energy output is ATP¹ and heat. ATP is the source of energy that is used by organisms to run the cellular processes in their bodies. This is true of plants, animals, and even some types of bacteria.

Energy cannot be created or destroyed; instead it can only move between one place and other, or be transferred. In the case of photosynthesis, the energy from the sun—light energy—is transferred to the stored chemical energy in glucose or other carbohydrates. Some of those carbohydrates, with their stored chemical energy, become the reactants in the process of cellular respiration. The stored chemical energy is transferred into the molecules of ATP during cellular respiration.

But how does the process of cellular respiration transfer the stored chemical energy from glucose to the energy useable by the body in ATP? The answer lies in the breaking and making of chemical bonds.

Chemical bonds "contain" energy. Even though chemical bonds "contain" energy, in many cases, in order to break chemical bonds, there must be an input of energy. Bonds do not release energy as they break. Rather, energy is released when stable bonds are formed.

Cellular respiration is an example of this. Glucose has fairly weak bonds. Water and carbon dioxide have stronger bonds than the glucose molecule. When the weak bonds are broken and stronger bonds are formed, there is a release of energy. The energy output or release from the bonds in glucose breaking is used as the energy input for the forming of ATP. The energy released from one reaction is used to drive another reaction.

The exchange of energy to drive reactions is used all over your body. In fact, when ATP reacts with water, its bonds are broken and the energy "contained" in its bonds is used to form bonds in other reactions.

When the chemical bonds in ATP are broken, heat is released. Heat is also a form of energy. The heat that is released heats the surrounding area. In most cases, the surrounding area is the organism's body. The heat released during the reaction is what allows humans to maintain a high body temperature of 98.6°F. However, the release of heat has the potential to be dangerous, because if cells get too hot, the cellular processes that keep cells running could stop, in turn killing the organism. One of the places where ATP is greatly used is in muscle cells, because it takes a good amount of energy to move the muscles of the body.

The purpose of cellular respiration is to transfer the energy found in molecules of glucose and other "foods" into a form useable by the organism. If glucose is unavailable for the reaction, the body will use other molecules, such as other carbohydrates, fats or proteins. Without ATP, most cellular processes could not occur.

<sup>1</sup> ATP is the abbreviation for the molecule Adenosine triphosphate.

But how does cellular respiration produce ATP? What's the process?

The process of cellular respiration occurs in three steps. Chemical reactions occur during each step. Let's start at the beginning.

$$C_6H_{12}O_6$$
 +  $6O_2$   $\rightarrow$   $6CO_2$  +  $6H_2O$  + Energy (glucose) (oxygen) (carbon dioxide) (water) (ATP)

Glycolysis is the first step in cellular respiration. It occurs in the cytoplasm of the cell. During glycolysis, the chemical bonds in glucose molecules are broken. The atoms in glucose are rearranged to make a molecule called pyruvate. The energy released when the bonds of the pyruvate are formed fuel the ATP formation reaction. During glycolysis, a net<sup>2</sup> of two molecules of ATP are formed. In addition, like in photosynthesis, a molecule used to carry hydrogen atoms and electrons is formed.<sup>3</sup>

The pyruvate molecule made during glycolysis is transported to the next step of cellular respiration, the citric acid cycle. The citric acid cycle<sup>4</sup> occurs in the mitochondria. The mitochondria is organelle found in the cells of the organism. During the citric acid cycle, the chemical bonds of the pyruvate molecules are broken. As the atoms in the molecules are rearranged, carbon dioxide molecules are formed. Carbon dioxide is a product of the citric acid cycle. Two molecules of ATP are also formed. In addition, like in glycolysis, a molecule used to carry hydrogen atoms and electrons is formed. The hydrogen atoms and electrons originated from the glucose molecule, now in the form of pyruvate, the reactant for the citric acid cycle.

The molecule carries hydrogen atoms and electrons to the next step in cellular respiration, the electron transport chain. Oxygen molecules, or  $O_2$ , also enter the electron transport chain. The hydrogen atoms and electrons join with the oxygen to form water or  $H_2O$ . As the chemical reactions occur, 32 to 34 molecules of ATP are formed.

Looking at all of the steps together allows us to observe the reactants and products of cellular respiration as well as the total amount of ATP made during the entire process.

<sup>2</sup> In order to break the bonds of glucose, an input of 2 ATP molecules is needed to start the reaction. The energy that is released when the pyruvate molecule is formed fuels the ATP reaction. Enough energy is released to form 4 ATP molecules. Because 2 molecules of ATP are needed to start the reaction, but 4 molecules are made during cellular respiration, we say the net output of ATP molecules for cellular respiration is 2 ATP (4 ATP molecules made minus 2 ATP molecules used).

<sup>3</sup> The electron and hydrogen carrier is called NAD+. Each NAD+ has the capacity to "carry" 2e- and 1H+. The molecule is known as NADH or Nicotinamide adenine dinucleotide.

<sup>4</sup> The citric acid cycle is also known as the Krebs cycle. Named for Hans Krebs, the German biochemist who fully realized the process.

#### **Making Yogurt Lab Procedure**

\*\*Important: Make sure all materials and laboratory areas are food safe.\*\*

#### **Materials**

- Container large enough to hold all ingredients and withstand heat
- Source to heat milk
- Thermometer (food safe)
- 110-115°F environment (incubator, hot water bath, or oven)

#### Ingredients (food materials)

- 6 oz. of milk
- Powdered milk (2 heaping tsps.)
- Bacteria culture (1 heaping tsp. from yogurt containing "live culture" in ingredients)

#### **Procedure**

- 1. Add 6 oz. of milk to a temperature-safe container. Milk contains the sugar lactose.
- 2. Add 2 heaping tsps. of powdered milk. Powdered milk helps to make the yogurt thicker.
- 3. Bring the milk and powdered milk to a boil. Stir the mixture occasionally. Be careful. Hot milk has the potential to boil over quickly. It can also boil over when stirred. Stir with caution.
  - It is important to boil the milk for a few reasons. Boiling the milk sterilizes the milk and helps to
    ensure that you are growing the bacteria used to make yogurt, rather than unintended, foreign
    bacteria. This process is called pasteurization. Boiling the milk also helps make a smoother,
    thicker yogurt with less separation of whey. Whey is the liquid that sometimes gathers at the top
    of yogurt.
- 4. Let the milk cool to approximately 116°F. It is important that the milk is not too hot as it might kill the bacteria you are adding, which is necessary to make the yogurt.
- 5. Add 1 heaping tsp. of plain yogurt that contains "live culture."
- 6. Stir your mixture to make sure the bacteria is evenly distributed in your heated milk mixture.
- 7. Incubate your milk for 6-10 hours at 100°F-115°F. The milk can be incubated a little longer if needed, such as overnight (~12 hours). However, if milk is incubated for too long, the yogurt will begin to taste sour.

#### Questions

Use the procedure and the Anaerobic vs. Aerobic Respiration reading to answer the questions below.

- Write the procedure above as a chemical reaction. Label the reactants and products.
- Explain the process of the formation of yogurt from a scientific standpoint.

## Anaerobic vs. Aerobic Respiration

Glucose and oxygen are the reactants for the process of cellular respiration. When both molecules are present, the resulting products are carbon dioxide, water, and 36-38 molecules of ATP. Without both reactants, the products cannot be formed because the needed atoms are not available.

The chemical reaction below shows cellular respiration in the presence of oxygen. Because oxygen is used, the reaction is referred to as aerobic respiration.

$$C_6H_{12}O_6$$
 +  $6O_2$   $\rightarrow$   $6CO_2$  +  $6H_2O$  + Energy (glucose) (oxygen) (carbon dioxide) (water) (ATP)

All organisms need a source of energy in order to perform the necessary cellular process needed for life. However, organisms find themselves in situations and environments where oxygen is unavailable. In order to survive, organisms must have a process to produce energy in the absence of oxygen. This process is called anaerobic respiration.

Different organisms undergo this process in different ways. However, the end goal is the same, to transfer energy from "food" molecules into a form useable by the organism.

#### **Alcoholic Fermentation**

Like aerobic respiration, anaerobic respiration begins with glucose or other "food" molecules. Oxygen is not needed for the process of glycolysis to occur. Therefore, regardless of the presence of oxygen, glycolysis will occur.

During glycolysis, 2 molecules of ATP are formed, as well as pyruvate and the molecule used to carry hydrogen atoms and electrons.

In the absence of oxygen, neither the citric acid cycle nor the electron transport chain can occur. In order for glycolysis to continue, the hydrogen atoms and electrons must be removed from the carrier molecules. During alcoholic fermentation, the chemical bonds in the pyruvate molecules are broken. The atoms from pyruvate are rearranged to produce alcohol¹ and carbon dioxide. As the atoms are rearranged, the hydrogen atom and electrons are removed from the carrier molecule and used to make the products (alcohol and carbon dioxide). This allows glycolysis to continue to occur because the carrier molecules are "empty" and able to carry the hydrogen atoms and electrons "produced" as glucose molecules are broken during glycolysis.

This type of anaerobic respiration occurs in microorganisms such as bacteria and yeast<sup>2</sup>. Humans have used the products of this reaction to produce alcoholic beverages, such as beer and wine. Different ingredients and different microorganisms result in different tastes. Alcoholic fermentation is also used to make food products such as bread and pizza dough. If you have ever made dough, you probably added yeast and sugar. The sugar supplies the needed reactant for glycolysis to occur. As the yeast performs alcoholic fermentation, the dough "rises." The expanding of the dough is due to the production of carbon dioxide. During the production of beer, wine, and bread, the microorganisms are placed in environments that lack oxygen.

- 1 The alcohol produced during alcohol fermentation is ethanol.
- 2 Yeast is a type of fungus.

#### **Lactic Acid Fermentation**

Not all organisms perform alcoholic fermentation. Many instead go through an alternate type of anaerobic respiration, lactic acid fermentation. This process serves the same purpose as alcoholic fermentation. In order for glycolysis to continue, the hydrogen atoms and electrons must be removed from the carrier molecules. During lactic acid fermentation, the chemical bonds in the pyruvate molecules are broken. The atoms from pyruvate are rearranged to produce lactic acid. As the atoms are rearranged, the hydrogen atom and electrons are removed from the carrier molecule and used to make the lactic acid. Glycolysis can continue to occur because the carrier molecules are available to carry the hydrogen atoms and electrons "produced" during glycolysis.

Like alcoholic fermentation, lactic acid fermentation occurs in bacteria and fungi. Humans use the products of this process to make foods such as cheese and yogurt. Again, the microorganisms are placed in anaerobic environments. The lactic acid formed during fermentation reacts with the proteins in the milk to give the yogurt its characteristic texture and slightly sour taste.

This type of anaerobic respiration also occurs in humans and other animals. With every breath, you bring in the oxygen needed to perform aerobic respiration. Your blood gathers the oxygen from your lungs and takes it to the cells in your body. For the most part, your blood is very efficient at delivering the needed oxygen. However, when your muscles need energy quick, as when you run, your blood can't deliver the oxygen fast enough to keep the process of aerobic respiration going. In cases like this, anaerobic respiration jumps in to continue to produce ATP in the absence of oxygen, just until the body is able to catch up and supply the needed cells with oxygen.

The body can sustain itself in anaerobic respiration for only a brief period of time. While for humans anaerobic respiration might occur during exercise, anaerobic respiration is often used in survival situations. For example, anaerobic respiration occurs in the leg muscles of both prey and predator during a hunt.

For many years, lactic acid was thought to be the cause of muscle soreness. However, lactic acid is no longer believed to be the cause. This is an example of how scientific understandings can change as more information is gathered and our knowledge increases.

#### **Performing the Process**

Not all organisms alternate between aerobic and anaerobic respiration. For example, obligate anaerobic organisms are microorganisms that live in environments without oxygen. There are even some microorganisms that are poisoned in the presence of oxygen.

Other organisms can produce enough energy to survive, performing either aerobic or anaerobic respiration. However, to survive in anaerobic conditions, the organism would need greater amounts of sugar to transform the needed amount of energy. There are also a few types of cells that can perform only aerobic respiration. One example of this type of cell are vertebrate brain cells. In the absence of oxygen, vertebrate brain cells have a limited amount of time until damage or death occurs.

Notice that both aerobic and anaerobic respiration begin with glycolysis. Unlike the other steps of cellular respiration and photosynthesis<sup>3</sup>, glycolysis does not occur within a specific cell organelle. Rather, glycolysis takes place in the cytoplasm of the cell.

Ancient cells probably didn't have cell organelles. Many scientists believe the ancient atmosphere probably lacked high levels of oxygen. Therefore, ancient one-celled organisms may have used glycolysis and anaerobic respiration to make ATP in the absence of oxygen. The process of anaerobic respiration was passed on and continues to occur in modern cells today.

3 The citric acid cycle and the electron transport chain both occur in the mitochondria of cells. Photosynthesis occurs in the chloroplast.

#### Think while you read.

It is important to think about what you are reading as you read. Read the chart below prior to beginning the reading to help guide your reading.

Record the similarities and differences between anaerobic and aerobic respiration in the chart or in your science notebook. Refer back to previous readings as needed to guide your understanding. Read the text for understanding, but remember to consider the similarities and differences between anaerobic and aerobic respiration as you read.

As you engage with the text and the chart, think about how the format helps you engage as a learner. What do you have to do to support your own thinking as you read? You will be asked to reflect on your experience with the reading during the Reflect Phase. Record your thoughts in your science notebook to revisit during the Reflect Phase of the lesson.

Anaerobic Respiration Only (Differences)	Anaerobic and Aerobic Respiration (Similarities)	Aerobic Respiration Only (Differences)

# **Plant Growth in the Absence of Light: Writing an Argument in Science**

Over time, plants not exposed to light cannot grow and develop. Choose the claim that best explains why plants cannot grow and develop in the absence of light. Develop an argument to support the claim you choose. Include evidence from the unit to support the claim. Provide reasoning to illustrate how the evidence you provide supports or logically leads to the claim.

#### Claims:

- 1. The plants could not grow and develop in the absence of light because they could not perform photosynthesis.
- 2. The plants could not grow and develop in the absence of light because they could not perform cellular respiration.
- 3. The plants could not grow and develop in the absence of light because they could not perform photosynthesis and cellular respiration.

# Problem-Based Application: Designing a Plan of Action to Improve Food Deserts

Food deserts are places that have low access or completely lack access to fresh, healthy foods, like fruits and vegetables. The low access to fresh foods can be attributed to a variety of reasons.

The two provided readings will give you background information on access to healthy foods and healthy lifestyles; they are also intended to help generate questions and ideas for research. Use the texts and additional resources to support your plan of action.

Design a possible plan of action to improve access to fresh food and healthy lifestyles in an area designated as a food desert.

Set up your plan of action like an argument. The steps you are taking to increase access to healthy foods and healthy lifestyles will be your claim. Support your steps with evidence. Link the evidence to the steps with your reasoning. Your reasoning should include why it is important for people to have access to fresh, healthy foods and healthy lifestyles in terms of cellular processes.

For more information on areas' access to food, visit the United States Department of Agriculture—Food Access Research Atlas.

http://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas.aspx#.UbpKLxbvxhA

# Thinking Deeper About What We Eat

#### "Food" for Cellular Respiration

Glucose is not always available for use in cellular respiration. In fact, most human diets include very little glucose. Because of this, organisms must be able to break down other foods, such as carbohydrates, fats, and proteins, in order to transfer stored chemical energy into energy useable by the body, or ATP.

Carbohydrates come in many different forms.
Sugars, such as sucrose, can be broken down through chemical reactions to glucose (and other molecules) to be used during the glycolysis step of cellular respiration. Larger carbohydrate molecules, like starch and glycogen (molecules stored in liver and muscle cells), can also be broken down into glucose to be used. When there is an excess of glucose molecules, it is packaged into starch and glycogen to be stored for later use.

Excess proteins in the organism can also be broken down. However, proteins cannot be broken down into glucose; therefore, the molecules enter later in the process of cellular respiration. The chemical reactions are slightly different, but the end product of ATP is the same. Cellular respiration can also utilize fat molecules. Fats, like proteins, cannot be broken down into glucose and so also enter the process of cellular respiration a bit later. They can also be used for the production of ATP.





#### **Calories**

Food is often described in terms of calories. But what are calories and how do they relate to cellular respiration?

Calories are a measurement of energy. Specifically, a calorie is the amount of energy needed to raise the temperature of one gram of water exactly one degree Celsius. Cellular respiration transforms the energy in food into energy useable by the body (ATP). The amount of calories needed to "run" an organism depends on many factors, such as size of the organism and amount of activity the organism is performing. In the case of an animal, if too few calories are consumed to "run" the cellular processes of the animal, it will begin to use its reserves. In other words, it will break down molecules storing energy, such as fat, to be used for cellular respiration. If an animal were to consume more calories than needed to run the cellular processes, the animal's body would turn the excess calories into stored chemical energy for later use, like fat.

#### Why vegetables?

A cup of vegetables has fewer calories than a cup of a food high in fat. In fact, vegetables are naturally low in fat and calories. Vegetables contain carbohydrates, proteins, and fats. The amount of each depends on the vegetable.

In humans, the "full" feeling is triggered by the stomach, as well as the amount of food, rather than the amount of calories. Eating vegetables allows for lower calorie intake while still feeling full.

Vegetables are also an important source of nutrients. They may also provide health benefits such as reducing the risk for heart disease, developing kidney stones, and bone density loss. In addition, vegetables may help protect the body from certain types of cancers and lower blood pressure.

However, vegetables can be costly, often costing more than processed foods, and fresh produce can be hard to find.

#### Why physical activity?

Your muscle cells have more mitochondria, the cell organelle where cellular respiration occurs, than any other type of cell in the body. Our bodies need increased amounts of useable energy in order to do physical activity. To transfer the chemical energy from "food" into energy useable by the body, we must undergo increased amounts of cellular respiration. Increased activity leads to increased cellular respiration, which in turn leads to burning calories.





While physical activity can lead to weight loss, it may also help to reduce the risk for certain diseases and health conditions, such as type 2 diabetes, depression, and arthritis, as well as help to prevent stokes and falls. Exercise is also believed to help improve mood, increase energy and endurance, and foster better sleep.

#### **Other Atoms and Nutrients**

Glucose is often used as the starting molecule in the cellular respiration equation. Glucose contains carbon, hydrogen and oxygen atoms. All of these atoms are vital for organisms. However, in order to run cellular processes and build body matter, organisms need other atoms and nutrients as well.

Oxygen (65%), carbon (18.5%), hydrogen (9.5%), and nitrogen (3.3%) make up 96% of human body weight. Calcium (1.5%), phosphorous (1.0%), potassium (0.4%), sulfur (0.3%), sodium (0.2%), chlorine (0.2%), and magnesium (0.1%) make up nearly 4% of human body weight. The remaining body weight is composed of fourteen other elements called trace elements. Trace elements include iodine, iron, fluorine, and zinc, among others, and can be toxic in large amounts.

The percentages can vary between organisms, but for the most part organisms are composed of mainly the same elements. This is also true of plants. The composition of plant matter is similar to humans. However, different elements are utilized in different percentages and put to different uses.

Organisms obtain the necessary elements needed for cellular processes, growth and development predominately through consumption (if you are an animal) or absorption.

As a human, the food we eat determines how well our bodies work. In order to function properly our bodies need specific minerals. Calcium is a mineral found in dairy products and in vegetables like collard greens and garlic. Calcium is found in bones and teeth, but it also aids in the regulation of muscle and blood vessel contraction. Plants need minerals as well. Magnesium is important to both plants and animals. Plants use magnesium to build chlorophyll molecules. Chlorophyll allows plants to absorb light and gives green plants their color. Animals use magnesium to contract and relax muscles, and in the making of proteins. Dark, leafy green vegetables, like spinach, are a good source of magnesium. Nuts, seeds, fish, avocados, and even dark chocolate are also sources of magnesium.

Animals also need vitamins. Vitamins are molecules. Many are mainly composed of carbon, hydrogen, oxygen and nitrogen. Vitamins play an important role in proper cell function. Scientists are still researching the role of vitamins in plants. Vitamin C or ascorbic acid is found in fresh fruits and vegetables. Oranges are a good source of vitamin C, but so are hot chili peppers, dark, leafy greens, kiwis and strawberries. Vitamin C supports a healthy immune system, including aiding in the healing of wounds and burns. Vitamin B3, or niacin, is necessary for the process of cellular respiration. Vitamin B3 can be found in fish, rice, wheat, and peanuts.





# **Food Deserts**

Have you noticed that different grocery stores have different products available? Maybe you have noticed that different neighborhoods have different types of food available in grocery stores, restaurants, or other places where you can buy food. Have you noticed different foods in other people's houses? The types of food you have access to are important in determining your diet.

The foods you eat make up your diet and can affect your health. Having access to fresh fruits and vegetables is an important part of a nutritious diet. So why doesn't everyone have access to fresh fruits and vegetables or other nutritious foods?



#### What limits food access, creating food deserts?

There are several factors that influence access to food. When nutritious food access is limited. we refer to this as a "food desert." Notice we say "desert" not "dessert"; although desserts are not usually the healthiest of foods, we are referring to a region with limited resources. What limits the food resources includes physical access, financial access, and mental (perceived or desired) access.

#### **Physical Access**

Physical access to food considers what is available for sale or use in a local community or neighborhood. Distance, transportation, safety of the location, and/or a diversity of store or purchase

options can impact a person's physical access to nutritious foods. For instance, an elderly person who does not drive a car and only walks to the store may be limited in which stores he/she can shop based on the location of the store to his/her home. A family that uses public transportation can carry only a limited number of bags when they buy groceries. If a store is in a part of the neighborhood that is not perceived to be "safe," that will limit access to the store.

Diversity of purchase options may limit choices if there is only one grocery store or no grocery stores nearby, requiring consumers to purchase foods that are from restaurants and convenience stores, or by requiring long trips to the store. Some neighborhoods have access to local farmer's markets, providing greater diversity of locally grown foods. Farmer's markets are usually held outdoors in public places, and allow farmers to sell fresh produce (fruits and vegetables) directly to consumers. However, farmer's markets are not always available in all areas and are usually only available on certain days.

If a person travels longer distances to the store, they are more likely to shop less often, and it is harder to keep fresh fruits and vegetables in the home. Also if a person feels that the store with the fresh fruit is far or feels their means of getting to the store is difficult, their perception of the distance will limit their access.

#### **Financial Access**

Financial access to food considers how much different types of foods cost. If fresh fruits and vegetables are expensive compared to prepared or processed foods, the cost may influence what someone buys or can afford to buy. Often foods high in processed sugars or fast foods appear to be cheaper than fresh fruits and vegetables. Other financial considerations include the ability to store and prepare foods. Lower income or people in

temporary locations may not be able to keep fresh foods (e.g., limited refrigerator space, limited clean and dry pantry/cabinet space) or to prepare fresh foods (e.g., no stove or oven).

#### **Mental Access**

Mental access to food is based on a person's perceptions or understanding of foods and diet. Sometimes we limit our foods based on what we like or what we think is healthy. Someone who doesn't know about the health benefits of eating a variety of fresh fruits and vegetables may not buy fresh produce (fruits and vegetables). Also, if someone has never been exposed to new and different types of food, they may not be willing or even know to try new foods. Education is an important part of eliminating food deserts. The more we know, the more we can make better choices and influence industry decisions, such as locations of grocery stores and types of products carried by local stores.

# What are the impacts of food deserts?

Food deserts limit access to nutritious foods. The impacts of eating poorly (i.e., not eating a nutritious diet including a variety of fresh produce) include poor health, obesity, and other risk factors. Persons with limited access to fresh produce often rely on processed or fast foods as the main part of their diet. The processed and fast foods often reduce the nutrients in the foods and increase fats and sugars. The increase in fats and sugars in our diets has led to an increase in heart disease, obesity, cancer, and mental illnesses (e.g., Alzheimer's disease, depression). On the other hand, fresh produce provides many beneficial nutrients and dietary requirements; so if you do not have access to these, you are eliminating the benefits gained from these foods.



#### Why should I care?

Numerous studies have shown that some form of food deserts exist in every state in the United States. Lower socio-economic neighborhoods tend to be more frequently and significantly impacted by food deserts, but notable impacts have been reported in urban and rural communities. So it is possible that you live in a food desert. Here are some questions to consider: What foods are you limited from (what don't you have access to) and why? Are the limiting factors physical, financial, or mental? What could you do to increase your access to foods? What are some things other areas have done to tackle food deserts?

The Centers for Disease Control (CDC) and Rand Corporation have developed maps and statistical information to highlight some of the trends related to food deserts. Other statistical information is available from a variety of sources. Do some research on your own and learn what you can do to reduce food deserts.

# Development Template for Writing Arguments in Science<sup>1</sup>

#### Claim - Evidence - Reasoning (C-E-R)

Question, Prompt or Problem to Solve

Claim(s)

An assertion (statement), based on scientific evidence that answers the original question, prompt, or problem.

Evidence	Reasoning
Data and evidence used to support the claim. Evidence includes facts, extended definitions, concrete details, quotations, or other information and examples. Evidence must include source(s) and/or citation(s).	The justification that links the claim and evidence. Includes appropriate and accurate scientific principles to make clear connections between the claim and evidence. Reasoning explains why the provided evidence supports the claim.

Counterclaim(s)

Alternate or opposing claim(s). Be sure to point out strengths and limitations of both claim(s) and counterclaim(s). Include sources and/or citations.

<sup>1</sup> This page serves only as a guide and has limited space. Use additional pages and/or modify the layout as needed to fit your needs and understandings.

146 Appendix B: Student Resources

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