TNCore

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.

Copyright:

Bias and sensitivity:

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.

institute for learning

Grade 7

Adjustable to grades 6-8 based on content alignment.

Matter and Energy in Organisms

DL MIDDLE GRADES [MS.LS-MEO]

UNIVERSITY OF PITTSBURGH

Table of Contents

Introduction

Unit Overview 9
Key Terms for Teacher Clarity 10
Why is it important to understand how organisms obtain matter and energy? 10
What do students believe about how organisms obtain matter and energy? 11
How is this unit designed to support all students in understanding how organisms obtain and use matter and energy they need to grow? 13
Matter and Energy in Organisms Conceptual Story 15
Lesson Scheme 17
Active Learning 19
Collaborative Learning 19
Talk and Norms for Discussion 20
Purposeful Questions 21
Purposeful Questions—Talking to Understand: Student Talk 22
Science Notebooks 22
Assessment Strategies 23
How is this unit designed to support me as a teacher? 24
Using Linking Questions 24
Using Driving Questions 24
Implementation Notes 24

Safety 26

Matter and Energy in Organisms Middle School Pacing Guide 27

Master List of Resources 28
Materials (not provided with the unit) 28
Appendix A: Teacher Resources 28
Appendix B: Student Pages 29

Activation Task

Overarching Concept 33
Purpose of Activation Task 33
Preparing for the Task 34
Procedure 35

Concept Development Lesson One: Connected By The Light: Photosynthesis

Key Concept #1 39
Teacher Background 40
Preparing for the Lesson 41
Procedure 42
Linking Question #1 51

Concept Development Lesson Two: How Sweet It Is: Plants Using Sugars

Key Concept #2 55
Teacher Background 56
Preparing for the Lesson 56
Procedure 58
Linking Question #2 65

Concept Development Lesson Three: Energy Plant: Breaking Down Sugar for Energy

Key Concept #3 69
Teacher Background 70
Preparing for the Lesson 71
Procedure 72
Linking Question #3 77

Concept Development Lesson Four: In Need of Food: An Animal's Perspective

Key Concept #4 81
Teacher Background 82
Preparing for the Lesson 82
Procedure 84
Linking Question #4 88

Concept Development Lesson Five: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy

Key Concept #5 91
Teacher Background 92
Preparing for the Lesson 93
Procedure 94
Linking Question #5 97

Application Lesson

Overarching Concept 101
Teacher Background 101
Preparing for the Lesson 102
Procedure 103

Appendix A: Teacher Resources

Implementation Notes 112
Norms for Discussions 113
Talking to Understand: Student Talk 114
Sample Slides: Connected by the Light: Photosynthesis 115
General Rubric for Scientific Arguments 116
Sample Slide: Seed to Tree 117
Sample Slides: Energy Plant: Breaking Down Sugar for Energy Plant Data 118
Sample Slides: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy 119
Sample Slides: Solving a Problem: Designing a Hydroponic Garden 120

Appendix B: Student Resources

Seed to Tree Task Sheet 124
Reading #1: Where Does the Plant Get the Matter to Live and Grow?
Does it come from the SOIL? 125
Reading #2: Where Does the Plant Get the Matter to Live and Grow?
Does it come from the WATER? 128
Reading #3: Where Does the Plant Get the Matter to Live and Grow?
Does it come from the AIR? 131
Scientific Argument Templates 134
Reading: Connected by the Light: Photosynthesis 138
Reading Guide: Connected by the Light: Photosynthesis 140
Corn Plant Diagram 141
How Sweet It Is: Corn Plant Analysis Task Sheet 142
How Sweet It Is: Corn Plant Analysis Data Sets 144
Reading: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants 149
Reading Guide: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants 152
Body Diagram 153
Information Gathering: Video-Watching Guide—In need of food: An animal's perspective 154
Reading: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy:
Cellular Respiration in Animals 155
Reading Guide: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy:
Cellular Respiration in Animals 158
Matter and Energy in Organisms Summative Task Sheet 159
Guidelines for Your Hydroponic Vegetable Garden 160
Sample Information on Vegetables and Hydroponics 162

Grade 7

Adjustable to grades 6-8 based on content alignment.

Introduction

Matter and Energy in Organisms

[MS.LS-ME0]

Unit Overview

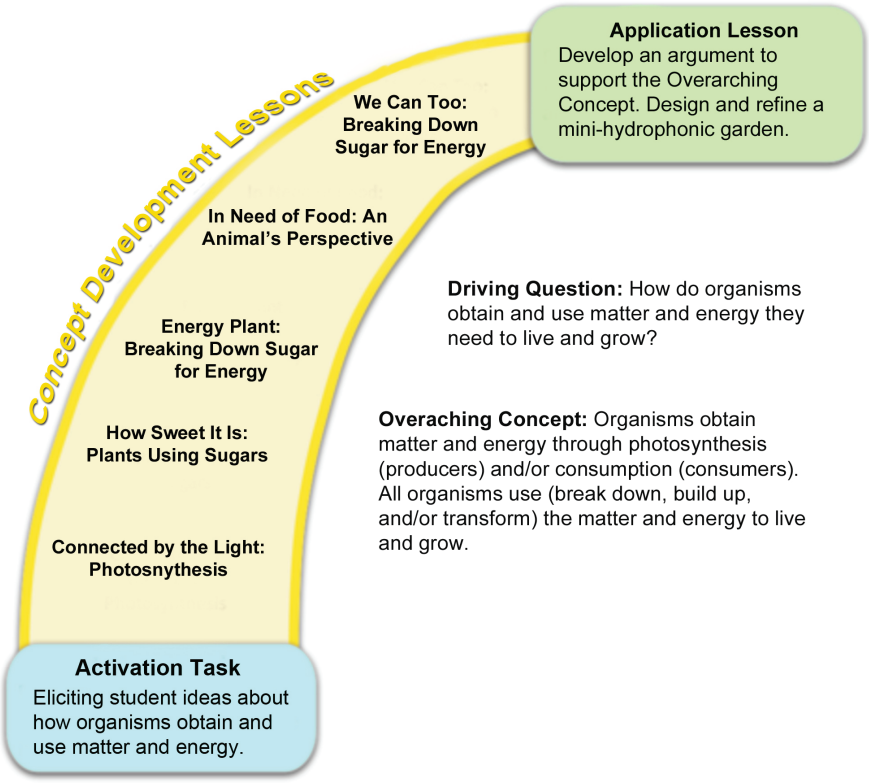
An Institute for Learning (IFL) Disciplinary Literacy (DL) Science unit consists of an arc of lessons designed to promote conceptual understanding of an overarching concept while apprenticing students in the practices of science. The overarching concept is the big idea that encompasses the content learning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

> **Organisms obtain matter and energy through photosynthesis (producers) and/or consumption (consumers). All organisms use (break down, build up, and/or transform) matter and energy to live and grow.**

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 matter and energy they need to live and grow?**

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.

Key Terms for Teacher Clarity

This section outlines some of the key terms that will be used across the unit. They are defined here for you as the teacher and in adult language. The definitions are provided here to mark how they will be used in the readings and activities and to provide insight into how you should use the terms within the scope of these lessons. This section is intended to aid in being explicit, clear, and intentional in the use of vocabulary in the unit.

Food: In this unit, we define *food as molecules that serve as fuel and building material for organisms*. A key aspect of this definition is that food is molecules, not direct energy (i.e., sunlight). Also note that we define food to provide both energy and materials. The definition does not include how the food is obtained (eaten, generated, absorbed). This definition of food will likely be different from students' current understandings. It will be important for you to be consistent in your use of the term across the year. (Benchmarks, p. 120; Driver, p. 27)

Energy: Energy is defined in science as the "ability to do work." Your students may not fully understand this idea, but they should at least get the idea that energy lets you do something.

Matter: Scientifically, matter is defined as anything that takes up space and has mass. It is okay at the level of this lesson for students to think about matter as the stuff things are made of. However, if they use the more specific definition to include mass, be sure they are accurate in differentiating mass from weight.

Eat: To eat means that an organism brings an external food source into its body. Eating provides carbohydrates (i.e., sugars, starches), proteins, lipids, and other necessary nutrients and materials to the organism and ultimately the cells (through digestion and transportation) within the organism.

Digestion: The processes in an organism where food is broken down so that the macromolecules can reach the cells. In more complex animals, such as mammals, the breakdown includes mechanical (i.e., cutting/biting, chewing/crushing, compressing) and chemical (using enzymes, acids, and other chemical processes). There is also a complex series of processes to absorb the broken-down food and then to transport the materials to cells.

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 idea 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.

This foundational idea 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. As students move into understanding ecosystems in later units, the foundational ideas of this unit will provide the scientific reasoning to support understandings of the implications of global warming, drought and other natural disasters, health and medical issues, and other real-world issues they will face.

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: *Organisms obtain matter and energy through photosynthesis (producers) and/or consumption (consumers). All organisms use (break down, build up, and/or transform) matter and energy to live and grow.*

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 (http://www.learner.org/resources/series26.html) 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: *Organisms obtain matter and energy through photosynthesis (producers) and/or consumption (consumers). All organisms use (break down, build up, and/or transform) matter and energy to live and grow.*

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 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 live and grow, but it is not food (does not provide energy). Water does provide some matter for plants, but the majority of the plant matter is from carbon and oxygen obtained from the air as 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 live and grow, 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 CO_2.
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, 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).

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

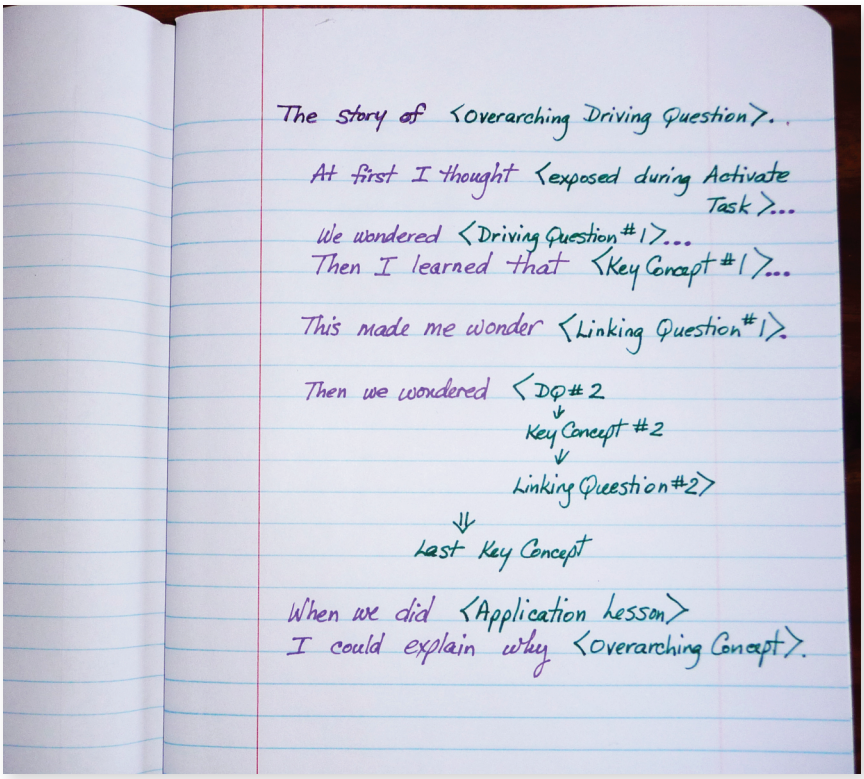
Estimated time to complete the unit: approximately 23 days

- Activation Task: 30 minutes/1 day
- Concept Development Phase: 653-728 minutes/16 days
- Concept Development Lesson (CDL) 1: 255 minutes/6 days
- CDL2: 240-285 minutes/7 days
- CDL3: 173-188 minutes/5 days
- CDL4: 105-120 minutes/3 days
- CDL5: 135 minutes/3 days
- Application Lesson: 260 minutes/6 days

Matter and Energy in Organisms 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. Students are led towards the key concept through the questions, tasks, discussions, and readings. It is not intended that you tell and ask students to memorize the key concepts. 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.



Overarching Concept (OC):
Organisms obtain matter and energy through photosynthesis (producers) and/or consumption (consumers). All organisms use (break down, build up, and/or transform) matter and energy to live and grow.

Overarching Driving Question (DQ):
How do organisms obtain and use matter and energy they need to live and grow?

Activation Task

Exposing student understandings about how organisms obtain and use matter and energy.

Concept Development Lessons

Connected By The Light: Photosynthesis	How Sweet It Is: Plants Using Sugars	Energy Plant: Breaking Down Sugar for Energy	In Need of Food: An Animal's Perspective	If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy
Driving Question #1 How do plants obtain matter and energy they need to live and grow?	**Driving Question #2** What do plants do with the sugars they create through photosynthesis?	**Driving Question #3** How do plants break down the sugar for energy the plants' cells need?	**Driving Question #4** How do animal cells obtain matter and energy they need to live and grow?	**Driving Question #5** How do animals break down the sugars (food) to get the energy the animal cells need?
Key Concept Most plants and some other organisms use the energy from light to make sugars (food) from carbon dioxide (in the air) and water through the process of photosynthesis. Oxygen is released as a waste product through this process.	**Key Concept** Plants use the sugars obtained through photosynthesis either immediately (as food or as building material to grow) or store the sugars for later use.	**Key Concept** Plants break down sugars (food) through a series of chemical reactions (cellular respiration) using oxygen (aerobic) or without oxygen (anaerobic) to provide the energy the plants' cells need to grow, develop, and sustain life.	**Key Concept** Animals obtain food from eating plants or other animals since they cannot produce their own food (cannot perform photosynthesis). This food (plant and animal material) has to be broken down so cells in the animal can use the energy and matter.	**Key Concept** Animals, similar to plants, break down sugars through a series of chemical reactions (cellular respiration) using oxygen or without oxygen to provide the energy the animal's cells need to grow, develop, and sustain life.
Linking Question What do plants do with the sugars they create through photosynthesis?	**Linking Question** How do plants get energy from the sugar they make?	**Linking Question** How do animals get their food?	**Linking Question** How do animal cells get energy from the food they eat?	**Linking Question** What have you learned across this unit?

Application Lesson

Summative Assessment:
Develop argument to support the OC.

Problem-Based Application:
Design and refine a mini-hydroponic garden. Extend by building and testing.

Lesson Scheme

This unit consists of one activation task, five (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 question 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 to 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 actives were excluded because they either distracted from student learning of the concepts or were not appropriate for a middle school setting (i.e., due to safety issues, equipment access, or other access considerations). Laboratory experiences should be used to expand students' skills with scientific practices when the experience also deepens student learning of content. For more information on this thinking, please contact Dr. Spiegel at sspiegel@pitt.edu.

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.

Small group work should be interdependent. To encourage positive interdependence, we suggest that teachers establish roles and expectations for all small group activities; this promotes the engagement of all students. Below you will find roles and expectations that we have found useful. It helps to post the roles with visual cues to clarify the roles. We recommend that the assigned groups stay consistent throughout a lesson and that students rotate roles at the beginning of each new session.

- Equipment Officer: Responsible for gathering materials, ensuring safe and appropriate use of materials, and managing cleanup.
- Communications Officer: Responsible for making sure that the group has a clear understanding of directions and communicates group questions to other groups and/or the teacher.
- Task Officer: Responsible for making sure that the group is on task and on time; also responsible for encouraging participation of everyone in the group.

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…	**You are obligated to…**
• Add ideas. • Ask questions to help you understand. • Be treated like everyone else. • Agree or disagree (and explain why). • Have your ideas discussed.	• 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 (provided through the professional development sessions) provides research-based question stems to promote academic talk and exploration of the topic by the class.

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.

® Accountable Talk is a registered trademark of the University of Pittsburgh.

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.

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 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. 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 teaching is not meant in any way to imply your current teaching is broken or needs to be fixed. 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 understanding), which build to the overarching concept.

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, as well as teacher, lesson, and EL 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

Taking notes as you implement and then reflect on a lesson is helpful. 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

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):
http://www.nsta.org/portals/safety.aspx

Laboratory Safety Training from Flinn Scientific:
http://labsafety.flinnsci.com/CertificateCourseSelection.aspx?CourseCode=MS

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
Middle 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: Gather & Analyze: Steps 1-4 (15-20 minutes)	Lesson 1: Gather & Analyze: Step 5 (45 minutes)	Lesson 1: Gather & Analyze: Step 5 (cont.) (15 minutes) Lesson 1: Gather & Analyze: Step 6 (30 minutes)	Lesson 1: Gather & Analyze: Steps 5-7 (45 minutes)
Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
Lesson 1: Connect (45 minutes)	Lesson 1: Reflect (15 minutes) Lesson 2: Engage (25 minutes)	Lesson 2: Gather & Analyze: Steps 1-3 (45 minutes)	Lesson 2: Gather & Analyze: Step 3 (cont.) (45 minutes)	Lesson 2: Gather & Analyze: Step 3 (cont.) (15 minutes) Lesson 2: Gather & Analyze: Step 4 (30 minutes)
Day 11	**Day 12**	**Day 13**	**Day 14**	**Day 15**
Lesson 2: Gather & Analyze: Step 4 (cont.) (20 minutes) Lesson 2: Gather & Analyze: Step 5 (20 minutes)	Lesson 2: Connect (30 minutes) Lesson 2: Reflect (15 minutes)	Lesson 3: Engage (20 minutes) Lesson 3: Gather & Analyze: Steps 1-3 (25 minutes)	Lesson 3: Gather & Analyze: Steps 4-7 (45 minutes)	Lesson 3: Gather & Analyze: Step 7 (cont.) (10 minutes) Lesson 3: Gather & Analyze: Step 8 (40 minutes)
Day 16	**Day 17**	**Day 18**	**Day 19**	**Day 20**
Lesson 3: Connect (20-35 minutes) Lesson 3: Reflect (15 minutes)	Lesson 4: Engage (30 minutes) Lesson 4: Gather & Analyze: Steps 1-3 (15 minutes)	Lesson 4: Gather & Analyze: Steps 4-5 (15-30 minutes) Lesson 4: Connect (20 minutes)	Lesson 4: Reflect (15 minutes) Lesson 5: Engage (25 minutes)	Lesson 5: Gather & Analyze: Steps 1-4 (45 minutes)
Day 21	**Day 22**	**Day 23**	**Day 24**	**Day 25**
Lesson 5: Gather & Analyze: Step 5 (45 minutes)	Lesson 5: Connect (30 minutes) Lesson 5: Reflect (10 minutes)	Application Lesson: Summative Assessment (45 minutes)	Application Lesson: Problem-Based Application: Steps 1-5 (45 minutes)	Application Lesson: Problem-Based Application: Step 5 (cont.) (45 minutes)
Day 26	**Day 27**	**Day 28**	**Day 29**	
Application Lesson: Problem-Based Application: Step 5 (cont.) (45 minutes)	Application Lesson: Problem-Based Application: Step 6 (45 minutes)	Application Lesson: Problem-Based Application: Steps 7-9 (45 minutes)	Application Lesson: 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 Materials not provided with the unit	Lessons Act	1	2	3	4	5	App
Chart paper, butcher paper, or whiteboard	✓	✓	✓	✓	✓	✓	✓
4 x 6 or 3 x 5 notecards*		✓					
Internet access for students*			✓				
Additional data sets on corn products*			✓				
Corn products (e.g., cornstarch, corn oil, corn meal, popcorn, etc.)*			✓				
Testing supplies such as Lugol's reagent, glucose test strips, Sudan Red, protein test strips, Biuret solution*			✓				
NOVA: *The Universe Within* video or alternate video					✓		
Science textbook*							✓
Colored pen sets (3 colors)* [see note on p. 103]							✓

Appendix A: Teacher Resources	Act	1	2	3	4	5	App
Implementation Notes	✓	✓	✓	✓	✓	✓	✓
Norms for Discussion	✓	✓	✓	✓	✓	✓	✓
Talking to Understand: Student Talk	✓	✓	✓	✓	✓	✓	✓
General Rubric for Scientific Arguments		✓	✓				✓
Sample slides: Connected by the Light: Photosynthesis		✓					
Sample slide: Seed to Tree			✓				
Sample slides: Energy Plant: Breaking Down Sugar for Energy: Plant Data				✓			
Sample slides: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy						✓	
Sample slides: Solving a Problem: Designing a Hydroponic Garden							✓

*These are optional materials.

Appendix B: Student Resources	Act	1	2	3	4	5	App
Seed to Tree Task Sheet	✓						
Readings 1-3: Where Does the Plant Get the Matter? (Soil, Water, Air)		✓					
Scientific Argument Templates		✓	✓				
Reading: Connected By the Light: Photosynthesis		✓					
Reading Guide: Connected By the Light: Photosynthesis		✓					
Corn Plant Diagram		✓					
How Sweet It Is: Corn Plant Analysis Task Sheet			✓				
How Sweet It Is: Corn Plant Analysis Data Sets			✓				
Reading: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants				✓			
Reading Guide: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants				✓			
Body Diagram					✓		
Information Gathering: Video-Watching Guide In need of food: An animal's perspective					✓		
Reading: If Plants Can Do It, Why Can't We? Breaking Down Sugar For Energy: Cellular Respiration in Animals						✓	
Reading Guide: If Plants Can Do It, Why Can't We? Breaking Down Sugar For Energy: Cellular Respiration in Animals						✓	
Matter and Energy in Organisms Summative Task Sheet							✓
Guidelines for Your Hydroponic Vegetable Garden							✓
Sample Information on Vegetables and Hydroponics							✓

Grade 7

Adjustable to grades 6-8 based on content alignment.

Activation Task

Matter and Energy in Organisms

[MS.LS-MEO]

Activation Task

Overarching Concept

Organisms obtain matter and energy through photosynthesis and/or consumption. All organisms use (break down, build up, and/or transform) matter and energy to live and grow.

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. 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.

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. 22) in the Unit Overview for guidance in formatting notebooks to help with the lesson routines.
2. Establish or review Norms for Discussions and begin to set a culture where it is safe to have productive discussions and share thinking before it is solidified.

For Activation Task:

1. Copy or be prepared to display so all students can easily see and read the Seed to Tree Task Sheet (see Appendix B: Student Resources).
2. Post, so that all students can easily see, the Overarching Driving Question: How do organisms obtain and use matter and energy they need to live and grow?

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

Appendix B: Student Resources:

- Seed to Tree Task Sheet

Procedure

Procedure	Teaching Notes	Time[1]
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. For additional information on using productive academic talk in the science classroom, visit the Institute for Learning website (instituteforlearning.org).	Time will vary, depending on how well norms have been established.
1. Ask students to silently and individually reflect for a moment on what they learned in earlier grades or at home about the following questions: Where do plants get the stuff they need to live and grow? What happens inside plants so that they grow?		3 minutes
2. Distribute or display the Seed to Tree Task Sheet and ask students to individually respond to the questions. Students will need to refer back to their responses later in the unit, so their replies should be either secured (e.g., taped, stapled) or written in their notebooks, or collected and saved for later reference.	Encourage students to include what they know from both school and life experiences.	15 minutes

Continued on next page.

1 Time is provided as an approximate estimate for planning purposes.

Procedure	Teaching Notes	Time[1]
3. 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 for Discussion 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 expose student thinking and push a little to get them to be clear in what they are saying. 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
4. Wrap up by directing the students' attention to the overarching driving question (How do organisms obtain and use matter and energy they need to live and grow?). Share that this will be the focus of this unit of study, so we will see how much more we can learn about this topic.	The overarching driving question will be answered by the end of the unit; right now the focus is to uncover student thinking.	2 minutes

Grade 7

Adjustable to grades 6-8 based on content alignment.

Concept Development Lesson One: Connected By The Light: Photosynthesis

Matter and Energy in Organisms

[MS.LS-MEO]

Concept Development Lesson One: Connected by the Light: Photosynthesis

LESSON 1

Key Concept #1

Most plants and some other organisms use the energy from light to make sugars (food) from carbon dioxide (in the air) and water through the processes of photosynthesis. Oxygen is released as a waste product through these processes.

Driving Question #1

How do plants obtain matter and energy they need to live and grow?

Demonstrations of Understanding

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

- develop and revise an argument (Claim, Evidence, & Reasoning) for how plants obtain the matter they need to live and grow. Their argument will include at least one counterargument against an alternate claim. [Their argument will focus on water, carbon dioxide, and light energy being used to produce sugars and release oxygen, not on the chemical equation for photosynthesis];
- accurately analyze claims and evidence addressing the question "From where do plants obtain most of their matter to grow?";
- use a model (diagram) to explain the flow of energy in a plant (from light to sugar) and matter (air and water to sugar—taking carbon and oxygen from air and combining with hydrogen from water, releasing oxygen, to form sugar);
- 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; and
- demonstrate how to safely use tools, instruments, and supplies.

Estimated time to complete Concept Development Lesson One (CDL1): 255 minutes/6 days

- Engage Phase: 25 minutes
- Gather & Analyze Phase: 160 minutes
- Connect Phase: 45 minutes
- Reflect Phase: 25 minutes

LESSON 1

Teacher Background

In plants, as well as algae and cyanobacteria, 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 storable energy source (does not need to be used immediately) and as a source of building materials. Thus the sugar produced through photosynthesis is the organism's food, so the organism produces its own food (eating is not involved in this process).

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_2 into organic compounds). Photosynthetic organisms convert around 100-115 thousand million metric tons of carbon into biomass per year. The role that photosynthesis plays in altering our atmosphere by fixing carbon and releasing oxygen (O_2) will be explored in the *Matter and Energy in Ecosystems [MEE]* unit.

Photosynthesis is a complex and counterintuitive process when one thinks about plants obtaining energy and matter. We learn at an early age that plants need sunlight, soil, and water to grow. We often take the air for granted. It is easy to assume that since we think about soil and water as necessary, that soil and water are the primary things used to grow and live. Once students learn about carbon dioxide, water, minerals (fertilizer), and light as essential, they often then confuse these with "food." The food that plants use is sugar, primarily glucose. We simplify the processes to focus on the general processes and general sugar source (glucose = $C_6H_{12}O_6$). It is important to note that some plants, algae, and cyanobacteria do not undergo photosynthesis. Rather, they use alternate processes to produce food. Also, there are other forms of sugar that can be used as "food" in plants. Further, the sugars are often combined into starches (long sugar chains) that can then be used to store the compounds for later use or as a building block to build plant tissues.

Your students will likely have some understandings about plants using light energy for photosynthesis. This lesson should expand their understanding, as it will push them to think about it in new ways and to be able to explain and argue about the general process. We will not explore the various processes and pathways that occur across photosynthesis in chloroplasts.

End-of-Lesson Takeaway

The goal for this lesson is to lay a strong foundation of the concepts around photosynthesis. Students should get the idea that plants use sunlight to synthesize (build) sugar from CO_2 in the air. This provides carbon building blocks along with storable and useable energy. In other words, **plants get their energy and matter by synthesizing sugar from carbon dioxide and water using light energy. Most of the mass in the plant matter comes from carbon and oxygen from CO_2.** The goal is NOT to memorize the formula for photosynthesis. You should focus and accept student explanations, limiting their description at this level to water, carbon dioxide, and light energy being used to produce sugars and release oxygen. They do not need to move to explaining photosynthesis as a chemical equation.

Within this lesson, we try to avoid the term "food," as the term is often misused in both science and the general public. There are also several widely accepted definitions of food. Sometimes it includes only "a source of energy for life," whereas other times it includes "to sustain growth, repair, and vital processes and to furnish energy." You can allow students to use the term food, but push them for clarity (e.g., "Can you say more about what you mean by 'food'?") and accuracy of how others are using the term (what it includes). In this unit we define food as **molecules that provide matter and energy needed to live and grow**. This is not a point to push for a definition of food. If a definition is exposed (i.e., a student shares his/her definition), be sure to note to the class that they may want to refine the definition later based on what they will learn about energy and matter.

LESSON 1

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. 22) in the Unit Overview for guidance in formatting notebooks to help with the lesson routines.
2. You should also establish or review Norms for Discussions. Please see the section in the overview for more details.

For Engage Phase:

1. Post Driving Question #1 (How do plants obtain matter and energy they need to live and grow?) so that it is visible to the entire class and can remain posted across the lesson.
2. Set up so you can share the three claims below. You will need to be able to show the claims after the students do an initial task. You can cover them with chart paper or other visual blind, or project them as you are ready to show each.
    a. Most of the matter in plants comes from the soil.
    b. Most of the matter in plants from water.
    c. Most of the matter in plants comes from the air.

For Gather & Analyze Phase:

1. You should be prepared to have the questions posted and use the provided sample slides (see Appendix A: Teacher Resources) as a guide to facilitate the discussion.
2. Predetermine how students will be organized (who will be paired with whom) in step #2 based on student replies during the Engage Phase.
3. Copy Readings 1-3 (see Appendix B: Student Resources) such that each student has the reading for their assigned group.
4. Copy Connected by the Light: Photosynthesis reading and guide (see Appendix B: Student Resources).
5. Copy or post the Scientific Argument Templates in a large format so all students can read it (see Appendix B: Student Resources).

For Connect Phase:

1. Copy the Corn Plant Diagram template (see Appendix B: Student Resources) or have a large or projected copy so students can re-create the diagram into their notebooks.
2. Be prepared to post the connection questions listed in step #2.

For Reflect Phase:

1. Be prepared to post the reflection questions and prompts identified in the Procedure section.

LESSON 1

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: 4 x 6 cards (or 3 x 5)—one per student
- Choose a Way: in Engage Phase: chart paper or space to post claims and cover (PowerPoint alternative with all three on one screen)

Appendix A: Teacher Resources:

- Norms for Discussion
- Sample slides: Connected by the Light: Photosynthesis
- General Rubric for Scientific Arguments

Appendix B: Student Resources:

- Reading #1: Where Does the Plant Get the Matter to Live and Grow? Does it come from the SOIL?
- Reading #2: Where Does the Plant Get the Matter to Live and Grow? Does it come from the WATER?
- Reading #3: Where Does the Plant Get the Matter to Live and Grow? Does it come from the AIR?
- Scientific Argument Templates
- Reading: Connected by the Light: Photosynthesis
- Reading Guide: Connected by the Light: Photosynthesis
- Corn Plant Diagram template

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[1]
1. Post Driving Question #1 (How do plants obtain matter and energy they need to live and grow?) on the board, written so it will stay visible to students for the entire lesson. You can do a quick check to have a student share what "matter" means if you think some students might not be clear on this term (see Key Terms for Teacher Clarity in the Unit Overview).	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking. You can support the development of academic vocabulary (matter) with pictures or artifacts to illustrate examples.	

1 Time is provided as an approximate estimate for planning purposes.

Procedure	Teaching Notes	Time[1]
2. If you have not reviewed the norms 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.	Time will vary, depending on how well norms have been established.
3. Ask students to personally (individually and silently) reflect on the question.	Encourage students to include what they know from both school and life experiences.	2 minutes
4. Ask students to write a summation of their thoughts into their notebooks. They should draw a big block to save space to write under this reply later in the lesson.	Scaffold writing as necessary by providing sentence stems for students struggling with where to begin.	3 minutes
5. Now flip the claims posted around the room or project all three (see Preparing for the Lesson, p. 41). Students should choose a claim that they believe best addresses Driving Question #1. It should be the claim that most closely reflects what they think and wrote (step #3). Either you can have students move quickly to stand by one of the claims or you can have them hold up fingers (1 for soil, 2 for water, or 3 for air) or a card (4 x 6 or 3 x 5) where they wrote the claim number and word (1: soil, 2: water, 3: air) they support.		3 minutes

Continued on next page.

LESSON 1

Procedure	Teaching Notes	Time[1]
6. Ask students to share and discuss their reasoning as a whole group. You should begin with the soil claim. Ask an assessing probe along the lines of "Can someone who chose Claim 1: soil help explain why you think that is the most scientifically accurate claim?" The discussion should then be facilitated so the class continues to build on the ideas shared. You can support this by asking a question such as, "Can someone add on to what [name] has said?" Then move the discussion on to the water claim. You might ask, "Can someone who chose Claim 2 explain why you think this claim is stronger than the first?" "Can you take into account what was said about Claim 1?" Continue the discussion to expose student thinking across all three claims. 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. You might end with something like "How might a team of scientists explore this question to be able to explain and predict how plants obtain matter and energy they need to live and grow?"	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 probes 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…	12-17 minutes

LESSON 1

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: 160 minutes/4 class periods (One day is estimated at 45 minutes of instructional time. Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Review the Norms for Discussion (see Appendix A: Teacher Resources).	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.	
2. Begin with a whole group discussion around the following ideas (you may have already addressed some of these in the Engage Phase, if so, omit those ideas): • Energy • Matter • Plants are mostly made of what? • Where does that stuff come from? You can use the sample slides presentation Connected by the Light: Photosynthesis (see Appendix A: Teacher Resources) as a guide to conduct this discussion as an interactive lecture or post the questions and encourage students to engage in a Think-Pair-Share before the discussion. Engage the class to develop a common understanding of how we (students and you) will use these ideas to further refine their current thinking about plants and matter. Use the Key Terms for Teacher Clarity on p. 10 to help focus your use of the terms.	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).	10 minutes

Continued on next page.

LESSON 1

Procedure	Teaching Notes	Time[1]
3. Organize students into one of three groups (soil, water, or air) based on which claim they selected during the Engage Phase. If they chose soil, place them into the water group; if they chose water, place them into the air group; and if they chose air, place them into the soil group. A group can have more students than others, but there should be at least four students in each of the groups. If the groups are too skewed (only one cluster) based on claim selection in the Engage Phase, then place students into pairs and count off by threes to assign groups.	We have them read a text that is different from what they chose to begin to push their thinking. Alternately you can set up the task to scaffold student reading. The readings are written in increasing complexity so you can differentiate the activity by having students with lower reading skills starting with soil. Air is the most complex of the three readings.	5 minutes
4. Subdivide the groups into pairs or triads.	Note students are being grouped by common understandings. You might cluster students within those groups based on skills or language mastery so that each pair or triad has the skills necessary to begin the task.	
5. Each pair or triad will read one of three readings about experimental data exploring a claim (see Appendix B: Student Resources). Students should analyze the argument within their reading and then restate the argument in their own words or present a counterargument to the claim in the reading. Students should consider the evidence presented and how well it supports the claim. Have the triads or pairs discuss their interpretations with the larger group (all students who read the same text in step 3). The larger groups should be prepared to share their interpretation of the argument to the whole class.	Consider reading and writing scaffolds to support your students. Reading scaffolds might include reading in pairs or asking a group member to read small sections aloud to the group and then discussing the passage so that it makes sense to everyone in the group.	60 minutes

LESSON 1

Procedure	Teaching Notes	Time[1]
6. Each of the three groups will share the arguments presented in their readings and their interpretations of those arguments. If reasonable, use chart paper or other means so that writing is large enough to make group thinking visible. As students review each other's arguments, they should provide specific feedback that pushes accuracy, marks interesting or important points, or raises wonderings, and not just states their opinion (e.g., "good"). Ask students to record their thoughts and wonderings into their notebooks as others share.	This step is a public sharing that asks students to listen, read, and respond to some or all of the other groups' work. The purpose is to deepen individual understanding (as individuals read charted work) and to push or advance group thinking (as individuals respond to charted work). If students are new to Claim – Evidence – Reasoning, it might be helpful to ask students to circle the claim, number the evidence, and underline the reasoning as they review another group's chart.	30 minutes

Continued on next page.

LESSON 1

Procedure	Teaching Notes	Time[1]
7. After all groups have shared their ideas, revisit the three claims as a whole group. Students should choose a claim that they now think the evidence best supports. Use the approach you used in the Engage Phase: either have students move quickly to stand by one of the claims or you can have them hold up fingers (1 for soil, 2 for water, or 3 for air) or a card (4 x 6 or 3 x 5) where they wrote the claim number they support (1: soil, 2: water, 3: air). If most or all students select air, have a few students share their thinking behind their decision; then move into the next phase with a brief wrap up marking that carbon dioxide in air is the primary source of matter in plants. If there are a number of students still leaning towards water or soil, ask students to share their thinking; begin with students who don't see the connection to air and develop the conversation through students who see the connection and can help explain why air is where most of the matter comes from in plants. Avoid moving into a lecture at this juncture. There are more activities to help refine the ideas; you just want to use this opportunity for students to help refine each other's thinking. Focus on the thinking, not just selecting the right answer—students explaining why the answer is air.	The goal is to connect with students and create a safe learning environment for all students while leading all students to accurate knowledge. Encourage students who might not have an accurate understanding to share their thinking with the group. Ask students who do have an accurate understanding to share their thinking. Remind students that it is important for everyone to truly understand this idea of air is where most of the matter comes from in plants.	15 minutes
8. Pose the question: "So where does the energy come from to pull all this matter from the air?" Provide time for students to think for a moment, individually and silently, while you distribute the reading on photosynthesis. Students should use the reading guide to record notes into their notebooks as they do the reading. Provide quiet time for students to individually read the text and complete the reading guide.	Scaffold the reading as necessary. This might be a good time for students to work in pairs as they read and fill in the reading guide.	15 minutes

LESSON 1

Procedure	Teaching Notes	Time[1]
9. In pairs, ask students to develop an argument addressing the question: "How do most plants obtain the matter and energy they need to live and grow? [You can note that this process occurs not just in plants, but also algae (including phytoplankton) and many microorganisms.] Their argument should include counterarguments against at least one other idea (e.g., matter coming from soil or water). Each student should have a copy of the argument in his/her notebook. Students should use the General Rubric for Scientific Arguments (see Appendix A: Teacher Resources) and Scientific Argument Templates (see Appendix B: Student Resources) to guide the organization of their writing.	Scaffold student writing by providing a template to support them as they identify the claim, evidence, reasoning, and counterclaims. As you move among groups, use assessing and advancing probes 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. • 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? • Are there alternate claims that we should consider?	20 minutes
10. You should collect, read, and comment on the arguments. Alternatively, you can have pairs swap their arguments and have the other students review and comment. You should review the comments other students noted.	Give specific feedback about their arguments. It may be helpful for you (or the students' peers) to circle the claim, number the evidence, and underline the reasoning. Do students have sufficient evidence? Does the evidence and reasoning support the claim?	5 minutes in class time, plus time for you to review and comment

LESSON 1

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.)

Procedure	Teaching Notes	Time[1]
1. Working in pairs, students should diagram (with labels) the process by which a corn plant obtains matter and energy through photosynthesis. Use the Corn Plant Diagram template (see Appendix B: Student Resources) or have students draw a corn plant outline into their notebooks.		20 minutes
2. Lead a whole group discussion reviewing the diagrams that students labeled in step 1. The goal of the discussion is to have the class (students) articulate a common description of how plants obtain matter and energy through photosynthesis. Your role is to encourage their sharing and pushing of each other's thinking. Ask students to begin by recording their own thinking in their notebooks. As they hear ideas that push their thinking, they can add notes. Students should begin to question each other and mark key ideas shared by others with more than statements such as "good" or "nice."	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). Use assessing and advancing probes 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.	15 minutes
3. Ask students to use either the left side of their notebook page or the back of their notebook and to label the page as "MEO Lesson One." Ask students to write 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 they discussed and learned about?	Students should get the idea that plants use light to synthesize (build) sugar from CO_2 in the air. This provides carbon building blocks along with storable and useable energy. In other words, plants get their energy and matter by synthesizing sugar from carbon dioxide and water using light energy. Most of the mass in the plant matter comes from carbon and oxygen in CO_2. The goal is NOT to memorize the formula for photosynthesis.	10 minutes

LESSON 1

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: 25 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Post and ask students to individually respond in their notebooks to the following: Revisit your initial response to the Driving Question #1 (How do plants obtain matter and energy they need to live and grow?) and mark how your thinking has changed based on your response to the corn diagram and activities so far?	Promote learning in a meaningful context by helping students to realize how their thinking has changed or advanced because of the lesson.	10 minutes
2. Post and ask students to individually respond in their notebooks to the following: How might you explain to a friend or relative how plants obtain matter and energy they need to live and grow?		15 minutes

Linking Question #1

What do plants do with the sugars they create through photosynthesis?

Listen to students talk, and review student notes as you are wrapping up the lesson. You could model for students how to think through what you did and learned in the lesson and what leads you to wonder. The linking question is a simplified version of the types of questions you might hear from students, suggesting they are ready to move on and are engaged in wondering about the topic.

Grade 7

Adjustable to grades 6-8 based on content alignment.

Concept Development Lesson Two: How Sweet It Is: Plants Using Sugars

Matter and Energy in Organisms

[MS.LS-ME0]

Concept Development Lesson Two: How Sweet It Is: Plants Using Sugars

LESSON 2

Key Concept #2

Plants use the sugars obtained through photosynthesis either immediately (as food or as building material to grow) or store the sugars for later use.

Driving Question #2

What do plants do with the sugars they create through photosynthesis?

Demonstrations of Understanding

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

- accurately analyze data addressing the question "What do plants do with the sugars they create through photosynthesis?" to develop a model;
- generate and use a model (diagram) to explain the flow of matter (sugar) in a plant and what happens, in general terms, to the sugar that a plant produces in photosynthesis;
- extrapolate from a model to generalize the overall process of matter flowing in a plant to support the growth from seed to adult plant and then to new seed (describe where all the matter comes from and what is the flow from CO_2 in the air to sugar to the bark of a tree or stem to flower and then into seed);
- use clear and accurate scientific vocabulary to explain what plants do with the sugars they create through photosynthesis;
- 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; and
- demonstrate how to safely use tools, instruments, and supplies.

Estimated time to complete Concept Development Lesson Two (CDL2): 240-285 minutes/7 days

- Engage Phase: 25 minutes
- Gather & Analyze Phase: 170-215 minutes
- Connect Phase: 30 minutes
- Reflect Phase: 15 minutes

LESSON 2

Teacher Background

End-of-Lesson Takeaway

The goal for this lesson is to provide an opportunity for students to think about and understand the buildup and movement of matter in plants. Students will need to see how the buildup and movement of matter in plants supports the cycling of matter in ecosystems when your students explore the *Matter and Energy in Ecosystems (MEE)* unit. Matter builds up and moves through individual organisms; however, the matter that may be captured in an individual one day is cycled through the environment and other organisms creating a continuous cycle of matter. The lesson should also further refine students' understanding of photosynthesis and lay the foundation for later study as they consider food chain, food webs, and ecosystems.

The main buildup and movement that students should be able to clearly articulate at the end of this lesson is that plants take CO_2 from the air and, through the processes of photosynthesis, they synthesize sugar using the carbon and oxygen with some hydrogen from water. The sugar then moves throughout the plant. Some of the sugar is used right away for energy. Some is stored as sugar for later energy use (such as when there is no light to generate sugar for energy). Some of the sugar is combined to create starches and other building materials. These materials are used to build the parts of the plant. As seeds form, they store a large amount of sugar or oils as a source of energy as they begin to sprout so the plant can grow to develop leaves and begin to generate its own food.

Preparing for the Lesson

Advanced Preparation

For Engage Phase:

1. Post Driving Question #2 (What do plants do with the sugars they create through photosynthesis?) 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. 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 Gather & Analyze Phase:

1. Make enough copies of How Sweet It Is: Corn Plant Analysis Task Sheet and How Sweet It Is: Corn Plant Analysis Data Sets (see Appendix B: Student Resources) so that each student has his/her own copy of the task sheet and each pair has access to the data sets.

For Connect Phase:

1. Use the sample slides Seed to Tree (see Appendix A: Teacher Resources) to begin the lesson. You should be prepared to either project the sample slides or have the image represented in another format. Use the slide as a guide to facilitate the discussion.

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
- Optional: Internet access for students or access to additional data sets on corn products
- Optional: Samples of corn products (e.g., cornstarch, corn oil, corn meal, corn flour, corn kernels, popcorn, corn ethanol, etc.)
- Optional: Supplies to run tests as a demonstration on various corn products. These tests include iodine solution (Lugol's reagent) to test for starch, glucose test strips for sugar, butcher paper and Sudan Red to test for oils/fats, and protein test strips and Biuret solution to test for proteins. Be sure to follow safety guidelines and to model the use of appropriate safety gear during the demonstration (e.g., goggles, apron).

Appendix A: Teacher Resources:

- Norms for Discussion
- Sample slides: Seed to Tree
- General Rubric for Scientific Arguments

Appendix B: Student Resources:

- How Sweet It Is: Corn Plant Analysis Task Sheet
- Scientific Argument Templates
- How Sweet It Is: Corn Plant Analysis Data Sets

Additional Thoughts

A timer that is clearly visible to all students (e.g., a projector timer, a large stopwatch display) is helpful in managing the class time. It helps remind us as teachers to keep a structured pace, yet still allows the option to extend time when needed. It also provides a support for students to begin to better manage their own time by being able to monitor how much time they have left to complete a task.

LESSON 2

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 (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. **Think and Write:** Post Driving Question #2 (What do plants do with the sugars they create through photosynthesis?) on the board, written so it will stay visible to students for the entire lesson. Ask students to individually and silently take two minutes to reflect on the driving question. Students should write their thoughts about the answer into their notebooks.	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking.	5 minutes
2. **Pair:** Ask students to quickly form pairs (should be an easy patterned routine by now). Each pair should discuss the driving question, thinking about the sugars that plants make in their leaves. You should present the following scenario to focus their discussion: If sugar is the source of energy and the matter to build the plant tissue, what has to happen to the sugar for the plants to live and grow? What might be done to the sugar in the plant—consider what your body does to food? Where does the sugar go and get used?	Support student understanding by listening to their thinking; look for patterns of thinking across the class and make notes so that you can advance thinking during the next phase of the lesson. During this phase, we are just exposing student thinking, not pressing to advance yet. If students struggle getting starting, you can probe with assessing prompts to clarify and encourage student articulation such as the following: • What does the plant need to do to live and grow? • When does the plant need energy? Does it need energy even when it is dark? • Does the sugar need to move out of the leaves to other parts of the plant? Why? • Where might it need to go? Think of the corn plant diagram from the last lesson. • What might happen to the sugar once it got there? After all, the plant is not just sugar.	10 minutes

1 Time is provided as an approximate estimate for planning purposes.

LESSON 2

Procedure	Teaching Notes	Time[1]
3. **Share:** Using a popcorn strategy, ask pairs to share their initial thinking. This is the time to expose student thinking and to have students pose questions. Probe for clarity and accuracy (e.g., "Say more." and "What do you mean by …?" and "Did anyone else have a similar response?"), but not to advance or correct. Chart student responses onto the board; you might use chart paper or some other format so that the initial responses can be reviewed later in the lesson, allowing students to revisit their thinking and to see how it changes as they learn. One option to keep a record of the initial thinking is to take a picture of the charted notes and print the image for students to place into their notebooks—it saves the manual copying time by students.	The popcorn strategy is an approach to calling on students during a whole class discussion. Randomly call on pairs to share to get coverage of the room (but not necessarily the entire class).	

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: 170-215 minutes/5 class periods (One day is estimated at 45 minutes of instructional time. Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Ask students to individually and silently reflect for a minute about corn plants and corn products (stuff produced from corn plants). As a whole group, ask students to brainstorm a list of corn products (things we get from corn plants). Chart the list so all the students can see the items. Leave a space next to each item or generate a two-column list so you can later add next to each item what types of macromolecules (in general) compose these items (i.e., sugar, starch, oil/fat, protein).	Connect to students and highlight diversity by asking students to share their personal knowledge and experience with various corn products.	10 minutes

Continued on next page.

LESSON 2

Procedure	Teaching Notes	Time[1]
2. Mark that we have learned that corn plants generate sugar through photosynthesis in their leaves. Pose the following questions: • So what are all these products made of? If most of the mass in the plant comes from the formation of sugar from the CO_2 in air, what happens to the sugar to produce these things in the corn plant? • What did it take to make the different parts of the corn plant and the stuff in the corn that make up all these corn products?		3 minutes
3. Organize students into pair or triads. Hand out How Sweet It Is: Corn Plant Analysis Task Sheet. Ask students to follow the directions on the task sheet. Ask them to take two minutes to review the entire sheet and raise any questions they might have about the process. a) We have provided sample data packs for students; you can use these as the data sets for the class or, if your students have reasonable Internet access, you may choose to have them do additional or all of the research on their own. Additionally, you can ask students to bring in labels in advance of this step. b) You may want to bring in examples of some of the corn products depending on the experiences of your students. For instance, your students may not be familiar with corn flour.	Students need to take responsibility for reading complex text. Scaffold reading as necessary by responding to their questions. Only respond to their questions to clarify points; do not orally review the directions (this marks for students that they are expected to read the materials). If the answer to their question is in the printed text, point them to the right location or ask them to review the document again to find their answer. If you have struggling readers who might not be able to comprehend the task sheet, try pairing those students with more capable readers as a support.	90 minutes

LESSON 2

Procedure	Teaching Notes	Time[1]
c) If time allows, and you have access to supplies, and your students are unfamiliar with the test described in the data packs, you could also demonstrate some of the tests described. Your students may be familiar with these tests from previous laboratory experiences in science with "mystery powders," a common elementary grades experience. These tests include iodine solution (Lugol's reagent) to test for starch, glucose test strips for sugar, butcher paper and Sudan Red to test for oils/fats, and protein test strips and Biuret solution to test for proteins. Be sure to follow safety guidelines and to model the use of appropriate safety gear (e.g., goggles, apron) during the demonstration. d) Some students may become very interested in a particular type of product. If so, encourage them to explore this product further. This could be the start of a science fair project.		
4. Ask students to share the products they studied following the task sheet directions. You can organize the sharing through presentations (five minutes to present, three minutes for Q&A), a gallery walk, or by asking each team to partner with two other teams for small group sharing in clusters.	A gallery walk is asking students to visit, read, and respond to some or all of the other groups' work. The purpose is to deepen individual understanding (as individuals read charted work) and to push or advance group thinking (as individuals respond to charted work).	45-90 minutes

Continued on next page.

LESSON 2

Procedure	Teaching Notes	Time[1]
5. Conduct a whole group discussion around the driving question, charting key points around what plants do with the sugars they produce through photosynthesis. Key points should include a close variation of the following: a) The plants use the sugars right away as a source of energy. b) The plants save the sugar for energy when it needs it later (i.e., at night when it can't photosynthesize). c) The plants move the sugar to different parts of the plant for use as energy. d) A lot of sugar goes to the seeds or kernels; the sugar gets used to build other molecules to make plant parts (e.g., starch, cellulose).	Hold students accountable to accurate knowledge and sound reasoning by asking them to connect their key points to data. You should use prompts to clarify and push both individual student and the whole class thinking. You will need to differentiate through the probes you ask. Listen carefully to student replies and push for clarity, to ensure all are on the same page, and to hold everyone to accurate knowledge and rigorous thinking. Some examples of prompts you might use include the following: • Say more about how that happens. • What do you mean when you say…? • Why does that happen? • Add some of the new ideas we've been talking about to your explanation.	20 minutes

LESSON 2

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

Procedure	Teaching Notes	Time[1]
1. Lead a whole class discussion about what happens to carbon in plants. Begin with the initial list of corn products that your class generated. Through a discussion, add to the chart the type of macromolecule that predominately makes up each item (e.g., sugar, starch, oil/lipids, protein).	Support whole group discussions by encouraging several students to engage in the conversation. You might ask the following: • Who can add on to what [student name] said? • Who understands what [student name] said? Please restate it so more of us can understand the idea. Hold students accountable to accurate knowledge and sound reasoning by asking them to connect their key points to data. You should use assessing and advancing prompts to clarify and push both individual students and the whole class thinking. You will need to differentiate through the probes you ask. Listen carefully to student replies and push for clarity.	5 minutes
2. Continue the whole class discussion as you ask students to consider a tree and where the stuff comes from to build the tree and the seeds. You can use the illustration in the Seed to Tree sample slides (see Appendix A: Teacher Resources), or paint a verbal image to focus the discussion.	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). You should also have students refer to their initial responses to the prompt in the activation task.	15 minutes

Continued on next page.

LESSON 2

Procedure	Teaching Notes	Time[1]
3. Ask students to journal into their notebook in their own words about what the big idea of this whole lesson is. You can prompt by asking, "What are some key science ideas you discussed and learned about?"	LISTEN FOR: The main buildup and movement that students should be able to clearly articulate from the information and discussions at the end of this lesson is that plants take CO_2 from the air and, through the processes of photosynthesis, they synthesize sugar using the carbon and oxygen with some hydrogen from water. The sugar then moves throughout the plant. Some of the sugar is used right away for energy. Some is stored as sugar for later energy use (such as when there is no light to generate sugar for energy). Some of the sugar is combined to create starches and other building materials. These materials are used to build the parts of the plant. As seeds form, they store a large amount of sugar or oils as a source of energy as they begin to sprout so the plant can grow to develop leaves and begin to generate its own food.	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[1]
1. Ask students to individually think about and record into their notebooks a response to the following prompt: "Why do seeds have lots of sugar and oils (stored energy sources)?" You may need to help them pull their thinking together by probing with prompts such as "We know a seed begins to grow without leaves, so what will it need to start to grow into the plant? What will the seed need to make the leaves of the initial sprout?"	Check for individual understanding by reading and responding to each student. Provide specific feedback to advance individual understanding.	15 minutes

Linking Question #2

How do plants get energy from the sugar they make?

Listen to students talk, and review student notes as you are wrapping up the lesson. You should hear students wondering about the next logical step in the topic. The linking question is a simplified version of the types of questions you might hear from students, suggesting they are ready to move on and are engaged in wondering about the topic.

Grade 7

Adjustable to grades 6-8 based on content alignment.

Concept Development Lesson Three: Energy Plant: Breaking Down Sugar for Energy

Matter and Energy in Organisms

[MS.LS-ME0]

Concept Development Lesson Three: Energy Plant: Breaking Down Sugar for Energy

LESSON 3

Key Concept #3

Plants break down sugars (food) through a series of chemical reactions (cellular respiration) using oxygen (aerobic) or without oxygen (anaerobic) to provide the energy the plants' cells need to grow, develop, and sustain life.

Driving Question #3

How do plants break down the sugar for energy the plants' cells need?

Demonstrations of Understanding

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

- accurately analyze data addressing the question "How do plants break down the sugar for energy the plants' cells need?" to develop a model;
- extrapolate from data and readings to explain the general pathways of energy transformations that occur in plants going from light energy in photosynthesis to cellular energy and heat;
- use clear and accurate scientific vocabulary to explain what plants do with the sugars they create through photosynthesis;
- 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; and
- demonstrate how to safely use tools, instruments, and supplies.

Estimated time to complete Concept Development Lesson Three (CDL3): 173-188 minutes/5 days

- Engage Phase: 20 minutes
- Gather & Analyze Phase: 108 minutes
- Connect Phase: 30-45 minutes
- Reflect Phase: 15 minutes

LESSON 3

Teacher Background

End-of-Lesson Takeaway

The goal for this lesson is to allow students to understand and explain (not recite from memorization) the overall story of energy flowing in plants. The story begins with light energy being transformed through photosynthesis to chemical energy in sugar. The sugar is broken down through cellular respiration to ATP. Cells use ATP rather than sugar because sugar has huge amounts of energy compared to what a cellular process needs. Whenever energy is transformed, some energy is lost as heat. If sugar were used directly in cells, large amounts of heat would be released, and the heat could damage or kill the cells. It is more efficient to produce ATP and have cells use that as their energy supply.

The lesson addresses the processes and inputs/outputs in general terms using the most common examples. You will want to be careful not to introduce or reinforce the idea that this is the only way it happens; rather this is the general process. There are many variations, but this gives us the gist of what happens to get energy to cells. For instance, we use glucose as the sugar described. Often sucrose or other macromolecules are used as the initial food source. The initial food source can alter the pathway and end products. The goal here is to get the gist of what is happening related to the breakdown of sugar from photosynthesis and getting energy to the cells. Students will delve deeper into this topic and the chemical processes in later grades.

If oxygen is present, the plant can produce a lot of ATP from each sugar molecule through several cyclical pathways. The overall combination of these pathways is called aerobic respiration (aerobic implying that oxygen is required). In cellular respiration sugar ($C_6H_{12}O_6$) is combined with oxygen (O_2) to form water (H_2O) plus carbon dioxide (CO_2) and ATP. The carbon dioxide and water are released as waste products from the process. Approximately 36-38 ATP are produced from each sugar molecule.

If oxygen is not present, the cells use fermentation (a shortened pathway of cellular respiration). In fermentation, the sugar is broken down in plants to form ethanol (C_2H_5OH) plus carbon dioxide and ATP. Only 2 ATP are produced from each sugar molecule. However, some organisms (e.g., yeast) tend to follow fermentation even if oxygen is present as it is a lower energy process. Humans have utilized fermentation by plants for a long time to produce alcohols for consumption and other purposes (e.g., cleaning, fuels). Beer, wine, whiskey, vodka, and ethanol are all examples of fermentation processes that are done by microorganisms.

In both aerobic respiration and fermentation, carbon dioxide is released. The rate of CO_2 released is directly proportional to the rate of respiration (conversion of sugar to ATP) and the energy demand on the organism. In plants, the net change in CO_2 present around a plant in light is a balance of the absorption needed for photosynthesis and the amount being released by respiration. Respiration rates are often measured in plants kept in the dark to reduce the absorption rate (no photosynthesis). Respiration occurs constantly to keep the plant alive and growing. Do not focus on students' memorizing the formula. The goal is to understand that there are multiple processes occurring in plants to break down sugar to use for energy. It will likely be surprising to students that plants use cellular respiration. This lesson challenges that assumption and builds a foundational understanding of the process that students will then apply to animals later in the unit.

LESSON 3

Preparing for the Lesson

Advanced Preparation

For Engage Phase:

1. If you have not introduced K-W-L charts (K = What I think I know; W= What are our learning goals? and L = What I learned), you will want to consider how you will introduce the use of this model and take time to orient students to the task. You might want to make a large (chart paper, projected, or on the board) version as a model.

For Gather & Analyze Phase:

1. Use the data from the sample slides Energy Plant: Breaking Down Sugar for Energy Plant Data (see Appendix A: Teacher Resources) to generate a slide or display for this phase of the lesson (CDL3).
2. Predetermine how students will be organized (who will be paired with whom) in step #7.
3. Copy the Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants reading and reading guide (see Appendix B: Student Resources) such that each student has the reading for their assigned group.

For Connect Phase:

1. Consider in advance how students will share their stories. Depending on the format, you might use a document camera and projector if available. If digital resources are not available, you can always use the old-fashioned "show and tell" approaches (e.g., walking around with an artifact to show, passing around the room, sharing in small groups, etc.).
2. Be prepared to post the connection questions listed in step #2.

For Reflect Phase:

1. Be prepared to post the reflection questions and prompts identified in the Procedure section.

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
- Sample slides to introduce the data of outputs by plants in light and in darkness: Energy Plant: Breaking Down Sugar for Energy Plant Data

Appendix B: Student Resources:

- Reading: Energy Plant: Breaking Down Sugar: for Energy Cellular Respiration in Plants
- Reading Guide: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants

Additional Thoughts

If students are struggling with the idea of size related to the cell, sugars, cell parts, carbon, and so forth, here is a nice resource that they can review quickly at a station, as homework, or you can use as a class demonstration: http://infosthetics.com/archives/2009/10/zoomable_cell_size_and_scale.html.

Addressing the concept of size related to matter and cells helps students make better sense of the idea of matter within cells. Additionally, it helps students get a sense of scale when thinking about matter.

LESSON 3

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: 20 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Conduct a brief whole class discussion to mark, so there is consensus across the class, where the work of a plant occurs. One approach would be to ask students to do thumbs up (yes) or down (no) in response to the question "Does all the work of a plant happen in the cells of plants?" If anyone indicates "no" (thumb down), you can probe by asking him or her to give some examples of what might happen outside of the cells. The point here is to help them come to the conclusion that it does all happen in the cells; for instance, if a student says photosynthesis occurs within the leaves, you can probe by asking, "Where in the leaves does it occur? Is that a cell?"	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking.	7 minutes
2. Once there is relative consensus that the work occurs within the cells of the plant, organize students quickly into pairs.		3 minutes
3. Working in pairs, students should generate a K-W-L chart into each of their own notebooks around the question "What do you know about the energy that a cell uses to do the work?" The learning goal for this lesson (W) is to understand the types of energy used in plants and what happens, in general, to the energy.	A K-W-L chart format we like to use is organized around three columns: K= What I think I know; W = What are our learning goals for this lesson?; and L= What I learned.	10 minutes

1 Time is provided as an approximate estimate for planning purposes.

LESSON 3

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: 108 minutes/3 class periods (One day is estimated at 45 minutes of instructional time. Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Use the information in the provided sample slides presentation (Energy Plant) to introduce the data of outputs by plants in light and in darkness. [4 scenarios: 1. in light (net result = takes in CO_2, gives off O_2); 2. in light without O_2 supply (net result = takes in CO_2, gives off O_2); 3. in darkness (net result = gives off CO_2, takes in O_2); 4. in darkness without O_2 supply (net result is gives off CO_2, but not as much)]		10 minutes
2. Ask students working in pairs to propose what might be happening given the data in each case.		10 minutes
3. Ask pairs to share some of their ideas through a whole group discussion. Keep the discussion mostly around sharing their initial ideas, but you should occasionally probe as to why they think that is what is happening based on the data (exposing not correcting).	You should use assessing and advancing prompts to clarify and push both individual student and whole class thinking. You will need to differentiate through the probes you ask. Listen carefully to student replies and push for clarity to ensure all are on the same page.	10 minutes
4. Now lead the students into the next step by marking to the whole group that the data we saw is related to sugars, energy, and what the plant does with these. Mark that students should look at the CO_2 and O_2 data as well as the physical evidence—plants dying. The physical evidence is what will lead to cellular respiration. Review the inputs and outputs in photosynthesis.	You can help advance the conversation by asking, "Did any of the data support that photosynthesis was occurring?" Follow up with "Which one? How does the data support that?" You can then ask as a transition into the next step, "So what is happening in the other cases?"	5 minutes

Continued on next page.

LESSON 3

Procedure	Teaching Notes	Time[1]
5. Ask students to first review the Energy Plant reading guide. Allow students time to review the sheet and ask questions.		8 minutes
6. Ask students to silently read the Energy Plant reading and to complete the reading guide.	Scaffold the reading as necessary. This might be a good time for students to work in pairs as they read and fill in the reading guide.	20 minutes
7. Working in pairs, students should discuss the reading in light of what they already know about photosynthesis. They should use what they learned from the readings and past lessons to create a description of the story of energy connecting photosynthesis and cellular respiration as pathways for energy transformation for an adult plant.	Story starters can be used to scaffold student writing. You can help students get started by asking them to think about where the story begins (Where does the energy for the plant start?). Then they should describe the general path that it takes to get to be used by the cells in the plant. How does a plant cell keep working when there is no sunlight? As you move among groups, use assessing and advancing probes 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.	15 minutes
8. Ask each pair of students to draft their story into a written story, comic strip, or staged diagram. They should include some notion or description of how the energy changes to different forms along the way, specifically light, chemical, kinetic, and heat.		30 minutes

LESSON 3

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: 30-45 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Ask a pair of students to briefly share their story of energy in plants. Follow up the presentation with questions from other students. Use a round-robin technique to get varying ideas out of the story.	In round-robin you have one group share. Then after clarifying questions are posed and the group responds, you ask if there is another group that has a different story or answer. You continue until all the variations have been shared. After each variation, you should hold a brief discussion to identify the differences among the versions shared and to consider which is best supported by evidence. By the end there should be consensus of the story of energy in plants. The variations should pertain to semantics and formatting, not concepts. Use assessing and advancing probes to differentiate the learning based on where your students are in terms of understanding. Listen carefully to student comments and responses. Continue to push for clarity and to advance their thinking.	20-35 minutes

Continued on next page.

LESSON 3

Procedure	Teaching Notes	Time[1]
2. Ask students to journal into their notebook in their own words what is the big idea of this whole lesson. You can prompt by asking, "What are some key science ideas you discussed and learned about?" If students are unsure where to begin, you can prompt them by directing them to start with the energy from the sun and asking, "What happens to that energy when it gets to a plant? Where does it go? Does it change? How? What does it do in the plant? Where does the energy end up?"	The goal for this lesson is to allow students to understand and explain (not recite from memorization) the overall story of energy flowing in plants. The story begins with light energy being transformed through photosynthesis to chemical energy in sugar. The sugar is broken down through cellular respiration to ATP. Cells use ATP rather than sugar because sugar has huge amounts of energy compared to what a cellular process needs. Whenever energy is transformed, some energy is lost as heat. If sugar were used directly in cells, large amounts of heat would be released and the heat could damage or kill the cells. It is more efficient to produce ATP and have cells use that as their energy supply. If oxygen is present, the plant can produce a lot of ATP from each sugar through several cyclical pathways. If oxygen is not present, the cells use fermentation (a shortened pathway of cellular respiration). In fermentation, the sugar is broken down in plants to form ethanol (C_2H_5OH) plus carbon dioxide and ATP. About 19 times more ATP can be produced through aerobic respiration compared to fermentation. Do not focus on students' memorizing the formula. The goal is to understand that there are multiple processes occurring in plants to break down sugar to use for energy.	10 minutes

LESSON 3

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[1]
1. Ask students to revisit the K-W-L chart they recorded earlier into their notebooks. Ask them to individually fill in the "L" part (What you learned).	Check for individual understanding by reading and responding to each student. Provide specific feedback to advance individual understanding.	10 minutes
2. Ask students to record into the notebooks near the K-W-L chart a reply to "What did you do to help yourself learn that?"	Remind students that they should be aware of strategies that help them to learn and incorporate those strategies as they continue to learn.	5 minutes

Linking Question #3

How do animals get their food?

Listen to students talk, and review student notes as you are wrapping up the lesson. You should hear students wondering about the next logical step in the topic. The linking question is a simplified version of the types of questions you might hear from students, suggesting they are ready to move on and are engaged in wondering about the topic.

Grade 7

Adjustable to grades 6-8 based on content alignment.

Concept Development Lesson Four: In Need of Food: An Animal's Perspective

Matter and Energy in Organisms

[MS.LS-ME0]

Concept Development Lesson Four: In Need of Food: An Animal's Perspective

LESSON 4

Key Concept #4

Animals obtain food from eating plants or other animals since they cannot produce their own food (cannot perform photosynthesis). This food (plant and animal material) has to be broken down so cells in the animal can use the energy and matter.

Driving Question #4

How do animal cells obtain matter and energy they need to live and grow?

Demonstrations of Understanding

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

- accurately interpret information and data from multiple media sources to address the question "How do animal cells obtain matter and energy they need to live and grow?";
- use clear and accurate scientific vocabulary to explain how animals obtain matter and energy to live and grow;
- 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; and
- engage in productive scientific discussion practices during conversations with peers in the context of scientific investigations and model-building.

Estimated time to complete Concept Development Lesson Four (CDL4): 105-120 minutes/3 days

- Engage Phase: 30 minutes
- Gather & Analyze Phase: 30-45 minutes
- Connect Phase: 30 minutes
- Reflect Phase: 15 minutes

LESSON 4

Teacher Background

End-of-Lesson Takeaway

This lesson is intended to deepen student understanding that animals need to eat to get energy and matter. Your students likely have a basic understanding of this idea; we want to push their thinking to a deeper level so they have a strong foundation to learn about respiration in animals and then to apply these ideas to the movement of matter and energy in ecosystems. Students first consider what it means to eat (see Key Terms for Teacher Clarity on p. 10).

After completing the lesson, students should have a rich understanding of Key Concept #4 "Animals obtain food from eating plants or other animals since they cannot produce their own food. This food has to be broken down so cells in the animal can use the energy and matter."

Students should be able to describe food as a source of both energy and matter. Students should be able to articulate the general process of food being eaten by an animal as a series of processes where the food is mechanically and chemically broken down, absorbed, and transported across the body to supply macromolecules (food) to the cells in the animal. Their version of the story may focus on sugars.

We are striving for the big idea of the key concept, with enough detail so that when they move into later studies of body systems and biochemistry, they have the foundational ideas of the processes. If you have extra time and students have grasped the key concept, you can go a little deeper into some of the details. Alternatively, if in the Engage Phase students demonstrate the depth of understanding expected by the end of the lesson, then jump ahead to the next lesson and skip the remainder of this lesson.

Preparing for the Lesson

Advanced Preparation

For Engage Phase:

1. Predetermine how students will be organized (who will be paired with whom) in step #2.
2. You might want to have a picture of a peanut butter and jelly sandwich as an illustration for the discussion.

For Gather & Analyze Phase:

1. Copy or display large enough for all to see the details the Body Diagram template (see Appendix B: Student Resources).
2. Order, rent, or purchase the *NOVA: The Universe Within* video (ASIN: B0002ABU48). See notes under the Resources section below. If you are not able to acquire the video, you will need to gather and organize alternative reference materials. The reference materials should allow students to complete the task of outlining the process of what happens to food as it is eaten and understand how food gets broken down into energy and matter supplies for cells. An alternate video you might consider is a video entitled *Journey of the Digestive System* that can be found at http://www.youtube.com/watch?v=e3O1AdlC8bI&feature=youtube_gdata_player

   [NOTE: As with all videos, you should watch the entire video that you select in advance of showing it to students to ensure the content is appropriate for your students and that it meets any guidelines, policies, or restrictions that your school or district may have regarding video content. You are responsible for complying with your school and district policies pertaining to video use.]

3. Copy the "Information Gathering: Video-Watching Guide—In need of food: An animal's perspective" (see Appendix B: Student Resources) such that each student has a copy for his or her notebook.

LESSON 4

For Connect Phase:

1. Be prepared to post the connection questions listed in step #2.

For Reflect Phase:

1. Be prepared to post the reflection questions and prompts identified in the Procedure section.

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
- *NOVA: The Universe Within* video, the segment on the speed skater eating a sandwich, entitled "A Woman of Speed: Nutrition and Digestion." It is Chapter 5 on the DVD version. The video may be available at your local or school library. You can access the movie through NETFLIX (not currently available as Watch Instantly): http://dvd.netflix.com/Movie/The-Universe-Within-Nova/70002458?strkid=1310780701_0_0&strackid=6cb90b6fe36d5183_0_srl&trkid=222336. The DVD is also available at stores online such as Amazon: http://www.amazon.com/NOVA-Universe-Within-Bonnie-Blair/dp/B0002ABU48 or the Public Broadcasting Station (PBS) site: http://www.shoppbs.org/product/index.jsp?productId=3963799).

Appendix A: Teacher Resources:

- Norms for Discussion

Appendix B: Student Resources:

- Body Diagram
- Information Gathering: Video-Watching Guide—In need of food: An animal's perspective

Additional Thoughts

You will want to assess and monitor student understanding of this concept across the lesson. This is a concept that students might already understand; in other words, they can demonstrate mastery without needing the lesson. In that case, move on to the next lesson. Students might struggle with the difference between food they eat and the notion of food for cells. They might be confused about what happens between the two. Additionally, students may have misconceptions about energy getting to the cells, due to products such as "energy drinks" and other food products. You will need to adjust the time and depth of this lesson based on each group of students.

LESSON 4

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

Procedure	Teaching Notes	Time[1]
1. **Think and Write:** Post Driving Question #4 (How do animal cells obtain matter and energy they need to live and grow?) on the board, written so it will stay visible to students for the entire lesson. Ask students to individually and silently take two minutes to reflect on the driving question. Students should write their thoughts about the question into their notebooks.	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking.	5 minutes
2. **Pair and Write:** Ask students to quickly form pairs (should be an easy patterned routine by now). Each pair should discuss the driving question thinking about how the matter and energy get to animal cells. You should present the following scenario to focus their discussion: "Think about yourself. If we consider a peanut butter and jelly sandwich as food, how does that large piece of food get to the cells in our body?" Each pair should generate a written reply to the scenario question.	Support student understanding by listening to their thinking; look for patterns of thinking across the class and make notes so that you can advance thinking during the next phase of the lesson. If students struggle getting started, you can probe with prompts such as the following: • What does it mean to eat? • Can animals use photosynthesis to make their own food? • What are different types of foods that animals eat?	15 minutes

1 Time is provided as an approximate estimate for planning purposes.

LESSON 4

Procedure	Teaching Notes	Time[1]
3. **Share:** Using a popcorn strategy, ask pairs to share their initial thinking. This is time to expose student thinking and to have students pose questions. Chart student responses on the board; you might use chart paper or some other format so that the initial responses can be reviewed later in the lesson. Recording ideas allows students to revisit their thinking and to see how it changes as they learn. One option to keep a record of the initial thinking is to take a picture of the charted notes and copy the image for students to place into their notebooks—it saves the manual copying time by students.	The popcorn strategy is an approach to calling on students during a whole class discussion. Randomly call on pairs to share to get coverage of the room (but not necessarily the entire class). Probe for clarity and accuracy in this step (e.g., "Say more" and "What do you mean by …?" and "Did anyone else have a similar response?"), but not to advance or correct.	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: 30-45 minutes/1 class period (One day is estimated at 45 minutes of instructional time. Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Ask students to think about the following prompt: "Think about the peanut butter and jelly sandwich we wrote about before. Is cutting the sandwich up into really tiny pieces enough to get it ready for the cells? Why or why not?" If students are struggling with replies, you can further probe by asking, "Does our body do more than cut it into really small pieces?"		3 minutes
2. Distribute the Body Diagram templates. Alternatively, you can ask students to recreate a body template into their notebooks. You can use one of the templates as a model for the students.		2 minutes

Continued on next page.

LESSON 4

Procedure	Teaching Notes	Time[1]
3. Working in pairs, students should use the Body Diagram template to begin to map out what they think happens to a piece of food (to be concrete, they should use a sandwich as the food) from entering the mouth, to some excreted out as waste, with some going into the body as macromolecules (sugar, fat, proteins). Students should use a pencil so they can make changes or different colored ink so they can see changes and additional understandings in the next step. This stage is intended to capture their initial thinking and to get them curious about the process.		10 minutes
4. Ask students to use the Body Diagram template and Information Gathering: Video-Watching Guide—In need of food: An animal's perspective to organize their observations and notes during the movie. After students have reviewed the guide, watch the chapter in the NOVA video (*NOVA: The Universe Within*) on the speed skater eating a PB&J sandwich, entitled, A Woman of Speed: Nutrition and Digestion (see notes in the Advance Preparation section for ordering information and alternate video suggestions). The full chapter is 20 minutes. You can stop the move at 12:39 after the discussion of how the liver stores and then releases glucose (when it cuts back to the skating rink). If you use *Journey of the Digestive System*, the run time is about five minutes. You might consider showing both.	The key aspects students should glean from the video is that food is mechanically and chemically broken down through a series of processes; some of the food is stored for later use and some is used right away; and some of what is eaten is just waste (not used). The food that is broken down is absorbed along the way and delivered to cells in the body. Some of the vocabulary used in the video is advanced for middle grades. Encourage students to focus on the gist of what is happening and to translate that into the notes in the Body Diagram template. You may want to occasionally stop the video to give a minute or two for students to write notes as the food is shown passing through a part of the body.	10-25 minutes
5. Following the viewing of the video, provide time for students to individually and silently organize their notes and thoughts. In addition, ask students to write down questions that need to be clarified during the upcoming discussion.	Support the whole group discussion by asking students to consider what they learned from the video that would be important to share with the whole group.	5 minutes

LESSON 4

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

Procedure	Teaching Notes	Time[1]
1. Conduct a whole class discussion to develop consensus of how animals get the matter and energy they need to live and grow. You can use the round-robin approach to elicit parts of the story from various students. Probe students to get them to describe the story of animals getting matter by eating, that eating means bringing in food and breaking it down physically and chemically so that it becomes food for cells (macromolecules: sugars, proteins, fats). You should chart, or have students chart, an outline of the story.	In round-robin you have one group share. Then after clarifying questions are posed and the group responds, you ask if there is another group that has a different story or answer. You continue until all the variations have been shared. After each variation, you should hold a brief discussion to identify the differences among the versions shared and to consider which version is best supported by evidence. The most accurate version may be a combination of parts of the story from multiple groups. By the end, students should reach a consensus as to how animals get the matter and energy they need to live and grow. The variations should be semantics and formatting, not conceptual. Some questions you might use to probe include the following: • What are some of the foods you eat? • What does it mean to eat? Can someone add to this description of eating? • What does it mean to physically break down food? • What does it mean to chemically break down food? • What is the food being broken down into?	20 minutes

Continued on next page.

LESSON 4

Procedure	Teaching Notes	Time[1]
2. Ask students to journal into their notebook in their own words what the big idea of this whole lesson is. You can prompt by asking, "What are some key science ideas you discussed and learned about?" Review students' notes.		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[1]
1. Ask students to individually think about and record into their notebooks a response to the following prompts: "How did your thinking change across this lesson about the food you eat and what happens to it in your body? What questions do you still have about the food you eat and what your body does with that food?"	Check for individual understanding by reading and responding to each student. Provide specific feedback to advance individual understanding.	15 minutes

Linking Question #4

How do animal cells get energy from the food they eat?

Listen to students talk, and review student notes as you are wrapping up the lesson. You should hear students wondering about the next logical step in the topic. The linking question is a simplified version of the types of questions you might hear from students, suggesting they are ready to move on and are engaged in wondering about the topic.

Grade 7

Adjustable to grades 6-8 based on content alignment.

Concept Development Lesson Five: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy

Matter and Energy in Organisms

[MS.LS-ME0]

Concept Development Lesson Five: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy

LESSON 5

Key Concept #5

Animals, similar to plants, break down sugars (food) through a series of chemical reactions (cellular respiration) using oxygen (aerobic) or without oxygen (anaerobic) to provide the energy the animals' cells need to grow, develop, and sustain life.

Driving Question #5

How do animals break down the sugars (food) to get the energy the animal cells need?

Demonstrations of Understanding

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

- accurately synthesize information to address the question "How do animals break down sugars (food) to get the energy the animal cells need?";
- use clear and accurate scientific vocabulary to explain that animals, similar to plants, break down sugars (food) through a series of chemical reactions (cellular respiration) using oxygen (aerobic) or without oxygen (anaerobic) to provide the energy the animals' cells need to grow, develop, and sustain life;
- 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; and
- engage in productive scientific discussion practices during conversations with peers in the context of scientific investigations and model-building.

Estimated time to complete Concept Development Lesson Five (CDL5): 130 minutes/3 days

- Engage Phase: 25 minutes
- Gather & Analyze Phase: 65 minutes
- Connect Phase: 30 minutes
- Reflect Phase: 10 minutes

LESSON 5

Teacher Background

End-of-Lesson Takeaway

This lesson builds on CDL3, Energy Plant: Breaking Down Sugar for Energy, around cellular respiration in plants. Students will apply their understandings from CDL3 to consider what happens in animals. We focus on what happens to sugar when we consider the general processes of cellular respiration in animals.

Other macromolecules can be food sources (e.g., lipids, proteins), but these follow slightly different pathways during cellular respiration. It is important for students to understand that there are various pathways to handle the other macromolecules, but that we are focusing solely on sugar to keep it simple and to stay focused on the key concept.

If students have a solid understanding of cellular respiration in plants, you may be able to condense or skip this lesson if the students can also make the connection that it is the same process in animals. The variation is the output during fermentation. In most animals, lactic acid is produced rather than alcohol.

The goal for this lesson is to allow students to understand and explain (not recite from memorization) the overall story of energy flowing in animals. The story begins with food being eaten and broken down mechanically and chemically through digestion. The sugar and other macromolecules are then absorbed and transported to cells. The sugar is further broken down through cellular respiration to ATP. Cells use ATP rather than sugar because sugar has huge amounts of energy compared to what a cellular process needs. Whenever energy is transformed, some energy is lost as heat. If sugar were used directly in cells, large amounts of heat would be released, and the heat could damage or kill the cells. It is more efficient to produce ATP and have cells use that as their energy supply.

If oxygen is present, the animal can produce a lot of ATP from each sugar molecule through several cyclical pathways. If oxygen is not present, the cells use fermentation (a shortened pathway of cellular respiration). In fermentation, the sugar is broken down in animals to form lactic acid ($C_3H_6O_3$) plus carbon dioxide and ATP. About 19 times more ATP can be produced through aerobic respiration compared to fermentation.

Do not focus on students' memorizing the formula. The goal is to understand that there are multiple processes occurring in animals to break down sugar to use for energy.

LESSON 5

Preparing for the Lesson

Advanced Preparation

For Engage Phase:

1. Display Driving Question #5 (How do animals break down sugars [food] to get the energy the animal cells need to live and grow?).
2. Predetermine how students will be organized (who will be paired with whom) in step #2.

For Gather & Analyze Phase:

1. Copy If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy: Cellular Respiration in Animals reading and reading guide (see Appendix B: Student Resources) such that each student has a copy for his or her notebook.

For Connect Phase:

1. Prepare probing questions based on the discussions and work students produce in the Gather & Analyze Phase.
2. Be prepared to post the connection questions listed in step #2.
3. Be prepared to display or recreate the sample slides for this phase (see Appendix A: Teacher Resources).

For Reflect Phase:

1. Be prepared to post the reflection questions and prompts identified in the Procedure section.

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
- Sample slides: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy

Appendix B: Student Resources:

- Reading: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy: Cellular Respiration in Animals
- Reading Guide: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy: Cellular Respiration in Animals

Additional Thoughts

This lesson also builds on and further establishes student understanding of the concept that cells are the basic unit of life. Students should be connecting to the idea that animals (including humans) are a collection of working cells.

LESSON 5

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 (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. **Think and Write:** Post Driving Question #5 (How do animals break down the sugars [food] to get the energy the animal cells need?), written so it will stay visible to students for the entire lesson. Post the prompt and ask students to individually and silently take two minutes to reflect on their earlier studies to answer the following questions: "How do animals break down sugars to provide energy to their cells? How does this compare to what plants do?" Students should write their thoughts about the answer into their notebooks.	The driving question will be answered by the end of the lesson; right now the focus is to uncover student thinking.	5 minutes
2. **Pair and Write:** Ask students to quickly form pairs (should be an easy patterned routine by now). Each pair should discuss the general process for how plants break down sugars (food) to provide energy to their cells. Does oxygen matter? Is this the same process in animals?	Support student understanding by listening to their thinking; look for patterns of thinking across the class and make notes so that you can advance thinking during the next phase of the lesson.	10 minutes
3. **Share:** Using a popcorn strategy, ask pairs to share their initial thinking. This is time to expose student thinking and to have students pose questions. Probe for clarity and accuracy, but not to advance or correct. Chart student responses onto the board; you might use chart paper or some other format so that the initial responses can be reviewed later in the lesson, allowing students to revisit their thinking and to see how it changes as they learn.	The popcorn strategy is an approach to calling on students during a whole class discussion. Randomly call on pairs to share to get coverage of the room (but not necessarily the entire class).	10 minutes

1 Time is provided as an approximate estimate for planning purposes.

LESSON 5

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: 65 minutes/2 class periods (One day is estimated at 45 minutes of instructional time. Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Ask students to first review the reading guide on cellular respiration in animals. Allow students time to review the sheet and ask questions.	Students need to take responsibility for reading complex text. Scaffold reading as necessary by responding to their questions. Only respond to their questions to clarify points; do not orally review the directions (this marks for students that they are expected to read the materials). If the answer to their question is in the printed text, point them to the right location or ask them to review the document again to find their answer.	5 minutes
2. Ask students to silently read the text on cellular respiration in animals and to complete the reading guide.		15 minutes
3. Working in pairs, students should discuss the reading in light of what they already know about photosynthesis and respiration in plants. They should use what they learned from the readings and past lessons to create a description of the story of energy for an animal.	As you move among groups, use assessing and advancing probes 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 compare between animals and plants? • Why does that happen? How do you know (what evidence do you have)? • 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? • Can you say that in a different way so it is clearer to others?	15 minutes

Continued on next page.

LESSON 5

Procedure	Teaching Notes	Time[1]
4. Ask each pair of students to draft their story into a written story, comic strip, or staged diagram. They should include some notion or description of how the energy changes to different forms along the way, specifically chemical, kinetic, and heat.	Story starters can be used to scaffold student writing. You can help them get started by asking students to think about where the story begins (Where does the energy for the animal start?). Then they should describe the general path that it takes to get to be used by the cells in the animal.	30 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: 30 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Conduct a whole class discussion to develop consensus of how animals break down sugars to get the energy their cells need so the animal can live and grow. You can use the round-robin approach to elicit parts of the story from various students. Use the sample slide presentation to organize information to review the idea that cellular respiration is very similar in plants and animals. The main variation is that the output from fermentation is lactic acid rather than alcohol.	In round-robin you have one group share. Then after clarifying questions are posed and the group responds, you ask if there is another group that has a different story or answer. You continue until all the variations have been shared. After each variation, you should hold a brief discussion to identify the differences among the versions shared and to consider which is best supported by evidence. By the end there should be consensus of the story of energy in plants and animals. The variations should be semantics and formatting, not conceptual. Probe students to get them to compare the processes in plants and animals. Some questions you might use to probe include the following: • What happens to the sugars so that cells can use the energy? Do you agree or disagree with that idea? Why or why not? • Why don't the cells just use the sugar directly? Can someone add to that? What evidence do you have? • How are the processes similar in plants and animals to break down the sugars? What is used (inputs) and what are the end products (outputs)? Is that always true? What is your evidence? • What happens if oxygen is not available? How do you know? • What evidence supports these ideas? How do we know?	20 minutes

Procedure	Teaching Notes	Time[1]
2. Ask students to journal into their notebook in their own words about the big idea of this whole lesson. You can prompt by asking, "What are some key science ideas you discussed and learned about?"	The goal for this lesson is to allow students to understand and explain (not recite from memorization) the overall story of energy flowing in animals.	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: 10 minutes (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Ask students to individually think about and record into their notebooks a response to the following prompts: "How did your thinking change during this lesson about cellular respiration? What questions do you still have about the food you eat and what your body does with that food?"	Check for individual understanding by reading and responding to each student. Provide specific feedback to advance individual understanding.	10 minutes

Linking Question #5

What have you learned across this unit?

Listen to students talk, and review student notes as you are wrapping up the lesson. You should hear students wondering about the next logical step in the topic. The linking question is a simplified version of the types of questions you might hear from students, suggesting they are ready to move on and are engaged in wondering about the topic.

Grade 7

Adjustable to grades 6-8 based on content alignment.

Application Lesson

Matter and Energy in Organisms

[MS.LS-MEO]

Application Lesson

Overarching Concept

Organisms obtain matter and energy through photosynthesis (producers) and/or consumption (consumers). All organisms use (break down, build up, and/or transform) matter and energy to live and grow.

Overarching Driving Question

How do organisms obtain and use matter and energy they need to live and grow?

Demonstration of Understanding

By the end of this lesson, students will demonstrate their level of mastery of the learning goals identified in the lessons across the unit.

Estimated time to complete application lesson: 260 minutes/6 days

- Summative Assessment: 45 minutes
- Problem-Based Application Phase: 200 minutes
- Reflect Phase: 15 minutes

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. Copy the Matter and Energy in Organisms Summative Task Sheet so that each student has his or her own copy.
2. Optional: colored pen sets (3 colors). See the note in the Procedure section, step #4 on p. 103.

For the Problem-Based Application Phase:

1. Copy the Guidelines for Your Hydroponic Vegetable Garden document so that each student has a copy.
2. Be prepared to provide research access (Internet, media center, or copy sample data packets).
3. Consider how you will want students to share their designs.

For Reflect Phase:

1. Be prepared to post the reflection questions and prompts identified in the Procedure section.

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: science textbook
- Optional: colored pen sets (3 colors). See the note in the Procedure section, step #4 on p. 103

Appendix A: Teacher Resources:

- Norms for Discussion
- Sample slides: Solving a Problem: Designing a Hydroponic Garden

Appendix B: Student Resources:

- Matter and Energy in Organisms Summative Task Sheet
- Guidelines for Your Hydroponic Vegetable Garden
- Sample Information on Vegetables and Hydroponics

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[1]
1. Distribute the Matter and Energy in Organisms Summative Task Sheet or project a copy of the problem stated in the task sheet.		3 minutes
2. Ask students to review the task and to ask any clarifying questions so that they are clear about the task and problem.		5 minutes
3. Ask students to silently and individually complete the task. Allow them to use their notebooks as a resource. You might also consider allowing them to use the textbooks available in your class, depending on the information available in the text.	See the note below about grading—if using the differentiation grading approach, then distribute blue pens and have the other pen sets ready.	35 minutes
4. Collect, review, provide feedback, and grade the tasks.	Differentiation 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 blue pen. After completing as much as they can from memory, students can exchange their blue pen for a green pen. When they have the green pen, they can use their notebooks as a resource. They can then move to a red pen and use their textbook or other reference materials (e.g., Internet) to complete the task. You can then provide a sliding grade scale based on the pen color. For instance, a fully complete response with only blue ink may receive a 100, while a full response in green gets 90, and a full response in red gets 80.	2 minutes, plus time to review, provide feedback, and grade.

1 Time is provided as an approximate estimate for planning purposes.

Continued on next page.

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: 200 minutes. (Times are broken down within the steps of the phase.)

Procedure	Teaching Notes	Time[1]
1. Orient students to the problem using the sample slides as a guide (see Appendix A: Teacher Resources).		5 minutes
2. Ask students to review their notes to consider specifically what a plant needs to live and grow (e.g., carbon dioxide, water, light, oxygen, nutrients).	It is important to provide quiet reflection time to help students organize their thinking.	5 minutes
3. Working in pairs, students should generate a list of what a plant will need to live and grow. Their list should be as specific as possible.		5 minutes
4. From the list of "crops" on the Guidelines for Your Hydroponic Vegetable Garden document, each pair should identify two plants that they will develop a hydroponic garden design to grow. Use the following vegetables for the list: spinach, corn, tomatoes, peas (or some type of legume), and squash. They should also review the Guidelines for Your Hydroponic Vegetable Garden document to understand the parameters they will need to address in their design.		5 minutes

Procedure	Teaching Notes	Time[1]
5. Provide students with time to research their vegetables and hydroponic designs. You can use some of the sample information provided in Appendix B: Student Resources. Students will likely need to adapt an existing design. Help them to consider what their vegetables will need, including space and support. For example, squash need different supports for the heavy fruit compared to spinach that is predominately clustered leaves.	If you can arrange Internet access for students, there are a number of helpful websites. Following are a few you might consider: http://www.soyatech.com/corn_facts.htm http://www.corn.org/ http://www.ncga.com/ http://www.ecoliteracy.org/essays/we-are-what-we-eat http://www.omegagarden.com/ http://www.hydroponics-at-home.com/ http://www.youtube.com/watch?v=FHBhyqowSEc http://www.hydroponics-simplified.com/raft-lettuce.html http://sdhydroponics.com/resources/articles/gardening/hydroponic-lettuce-production-using-nft	90 minutes

Continued on next page.

Procedure	Teaching Notes	Time[1]
6. Provide students with time to draft their design. The design should include the following: • a diagram of the garden that shows design and size • a list of needed materials and parts • a description of how to build and maintain the garden through at least one growth cycle • a justification for the design—how will this design give the plant what it needs to optimize growth? They should relate back to their unit notes and use their understanding of photosynthesis and respiration to support their design • a description of the movement of energy in their system (including what happens in their plants) • a description of the movement of matter in their system (including what happens in their plants) • a description of the estimated expected crop output and a suggested recipe using the two items they grow as a main portion of the meal		45 minutes
7. Conduct a gallery walk or other sharing model (e.g., having groups of four conduct a small group table sharing) 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.		20 minutes

Procedure	Teaching Notes	Time[1]
8. Allow students to revise their drafts into a final version taking into account the feedback and review during the sharing session.		25 minutes
9. Collect and review their final versions. Provide feedback to each student using the rubric in Appendix A: Teacher Resources. The projects may be nice displays of student work in your classroom.	For those students who were excited about their designs, you might want to encourage them to build and test their designs. This could be a nice science fair project or extra credit project.	

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[1]
1. Ask students to review their initial ideas on how organisms obtain and use energy and matter.	Check for individual understanding by reading and responding to each student. Provide specific feedback to advance individual understanding.	5 minutes
2. Each student should write a response in his/her notebook to the following: a) How has your thinking changed across this unit of study? b) What helped you learn about these concepts and enhance your science skills?	Promote learning in a meaningful context by helping students to realize how their thinking has changed or advanced because of the unit.	10 minutes

Grade 7

Adjustable to grades 6-8 based on content alignment.

Appendix A: Teacher Resources

Matter and Energy in Organisms

[MS.LS-ME0]

Appendix A: Teacher Resources

Table of Contents

Page	Title
112	Implementation Notes
113	Norms for Discussion
114	Talking to Understand: Student Talk
115	Sample Slides: Connected by the Light: Photosynthesis
116	General Rubric for Scientific Arguments
117	Sample Slide: Seed to Tree
118	Sample Slides: Energy Plant: Breaking Down Sugar for Energy Plant Data
119	Sample Slides: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy
120	Sample Slides: Solving a Problem: Designing a Hydroponic Garden

Implementation Notes

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

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

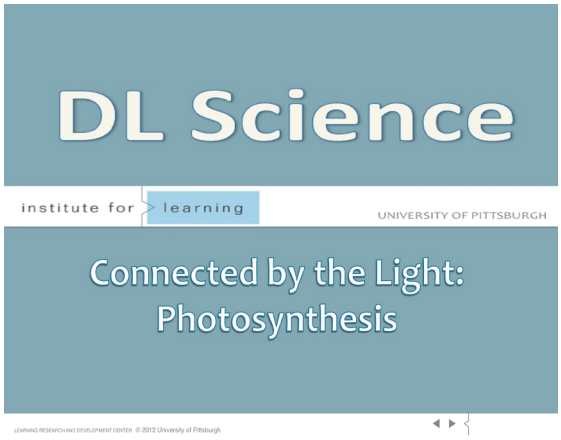
Have you ever noticed how questions help you learn?

Why not ask a few yourself!

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!

Sample Slides: Connected by the Light: Photosynthesis



Connected by the Light: Photosynthesis

We have been starting to talk and think about several things related to photosynthesis:

- Plants
- Energy
- Matter

What do we know about each of these? What are these made of?

Matter

What is matter?

- Matter is anything that takes up space and has mass.
- Mass is a measure of how much and what type of stuff (atoms) makes up something.
- Weight is the measure of gravity on the mass of something. You can use gravity as a measure to calculate mass.

  Weight (N) = mass (kg) x 9.8 m/s^2

Energy

What is energy?

- Energy is a little harder to define, but generally it is the ability to make something happen or to do work.
- The interesting thing about energy is that it can be transformed – changed from light to heat to kinetic to chemical - but the amount going in is always equal to the amount going out (just not all of it still useful).

  In other words, energy is always conserved.

Plants are made of …

So what are plants made of?

- Think about a tree. What is the tree made of?
- Did you think of wood?
  - What is wood mostly made of?
  - What does wood become if it is burned?

Plants are made of …

- Trees and plants are made of mostly carbon and oxygen that are connected in large molecules (macromolecules).
- When the tree burns, you see the evidence of the carbon in the form of the charcoal and carbon dioxide that is released.

How do plants obtain matter and energy they need to live and grow?

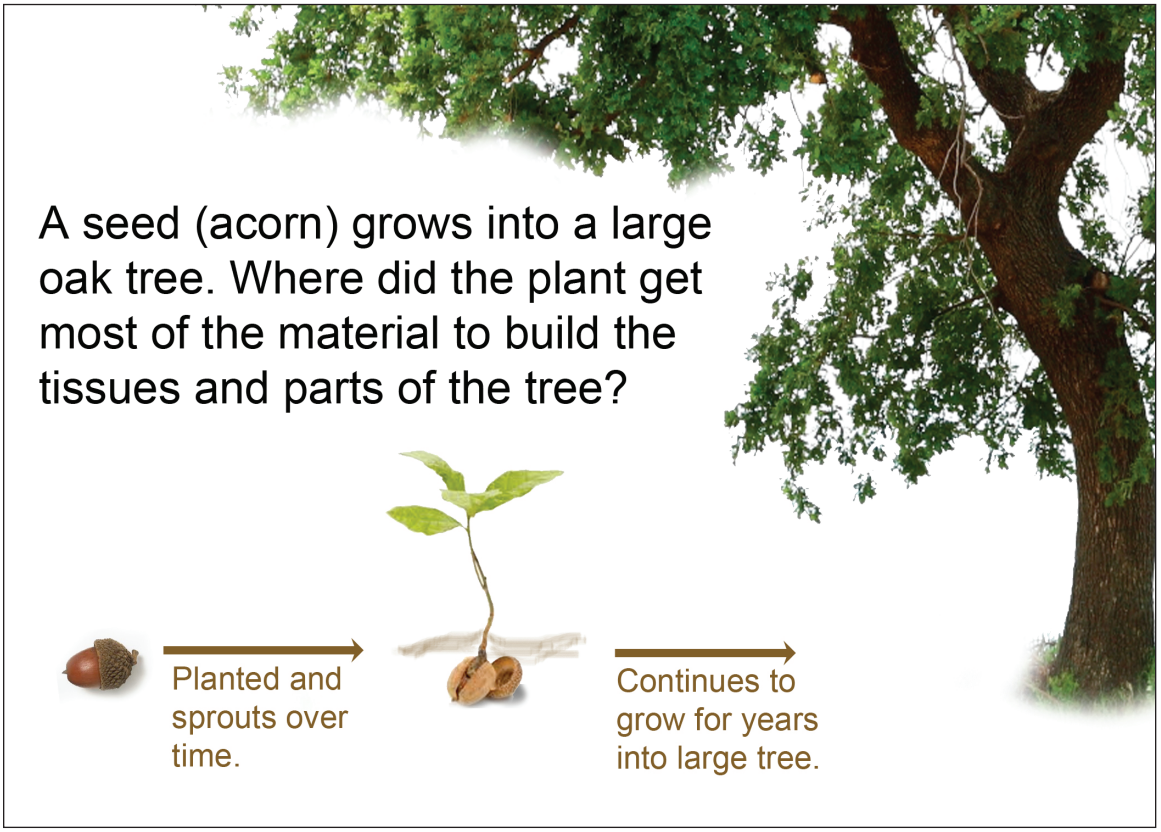
- So where does the carbon come from?
- Where do plants get the carbon and other matter (e.g., oxygen) to build its plant tissues (e.g., wood)?
- What about energy?
- Where can we look for evidence?

General Rubric for Scientific Arguments

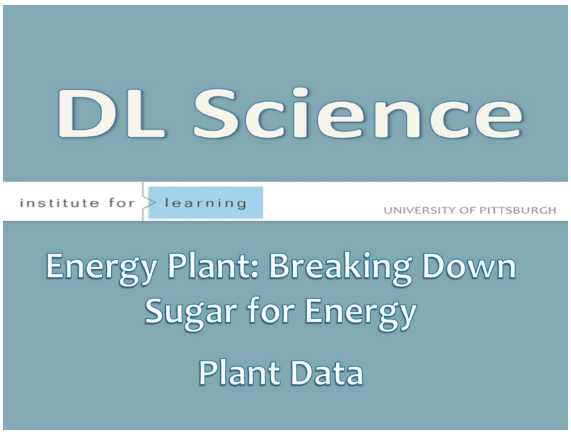
Component	Level 1	Level 2	Level 3
Claim: An assertion that answers the original question.	Makes an inaccurate assertion.	Makes an accurate but incomplete assertion.	Makes an accurate and complete assertion.
Evidence: Analysis of scientific data, explanation, and/or ideas used to support the claim about scientific phenomena. The data needs to be appropriate and sufficient.	Provides inappropriate analysis of scientific data, explanation, and/or ideas to support the claim.	Provides appropriate, but insufficient analysis of scientific data, explanation, and/or ideas to support the claim.	Provides appropriate and sufficient analysis of scientific data, explanation, and/or ideas to support claim.
Reasoning: Justification that links the claim and evidence. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.	Provides reasoning that does not link evidence to claim.	Provides reasoning that links the claim and evidence. Repeats the evidence and/or includes some scientific principles, but is not sufficient.	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.
Counterclaim: Alternate or opposing claims.	Provides inappropriate counterclaim(s).	Provides appropriate counterclaim(s).	Provides appropriate and sufficient counterclaim(s) as well as weakness and limitations in the evidence and reasoning.
Writing style: Clarity of expression.	Argument is not clear.	Argument is written in a clear manner.	Argument is written in a clear, compelling, and authoritative manner.

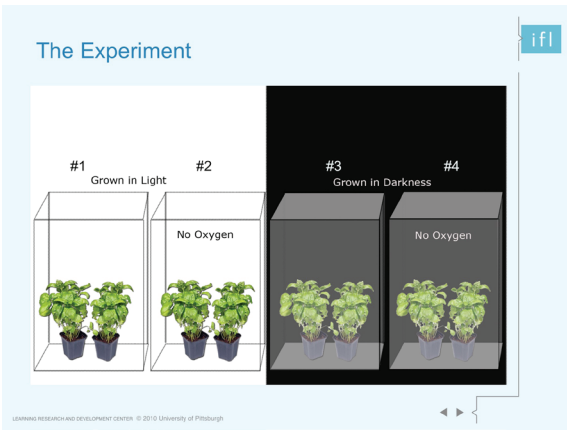
Adapted from: McNeill, K.L. & Krajcik, J. (2008). Inquiry and scientific explanations: Helping students use evidence and reasoning. In Luft, J., Bell, R. & Gess-Newsome, J. (Eds.). Science as inquiry in the secondary setting. (p. 121-134). Arlington, VA: National Science Teachers Association Press.

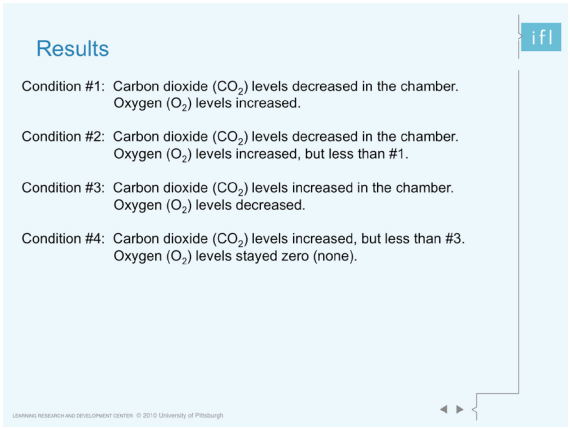
Sample Slide: Seed to Tree

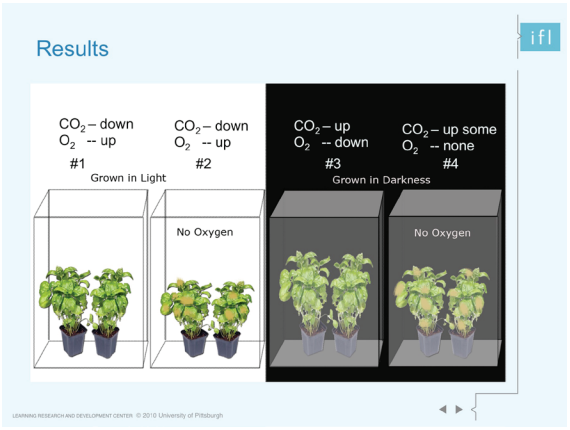


Sample Slides: Energy Plant: Breaking Down Sugar for Energy Plant Data









Sample Slides: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy

DL Science

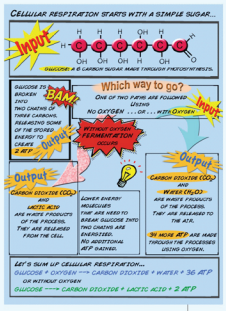
institute for learning — UNIVERSITY OF PITTSBURGH

If Plants Can Do It,
Why Can't We?
Breaking Down Sugar for Energy

How do animals get the matter and energy they need?

ifl

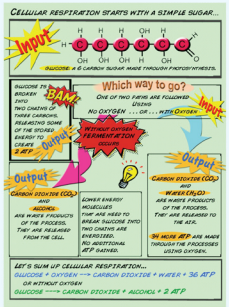
1. What are the main **inputs** into cellular respiration in animals?
2. What are the main **outputs** into cellular respiration in animals?
3. What did you notice about cellular respiration in animals?
4. What do you wonder about cellular respiration in animals?



Recall the processes of cellular respiration in plants.

ifl

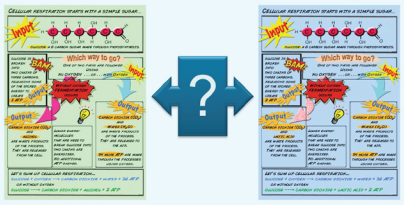
1. Pull out your notes on cellular respiration in plants.
2. What are the main **inputs** into cellular respiration in plants?
3. What are the main **outputs** into cellular respiration in plants?
4. What did you notice about cellular respiration in plants?



Comparing Cellular Respiration in Plants and Animals

ifl

1. What is similar between the processes in plants and animals? Consider the inputs and outputs.
2. What is different between the processes in plants and animals? Consider the inputs and outputs.

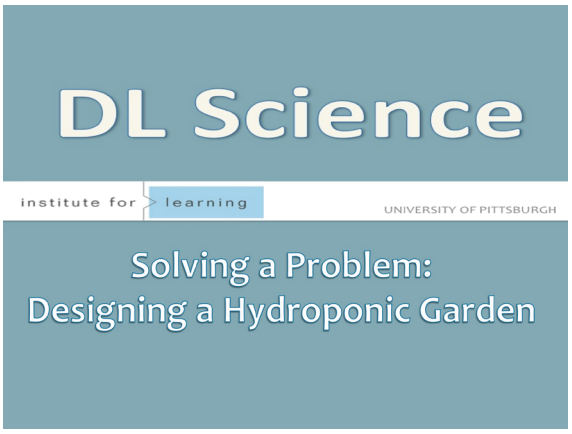


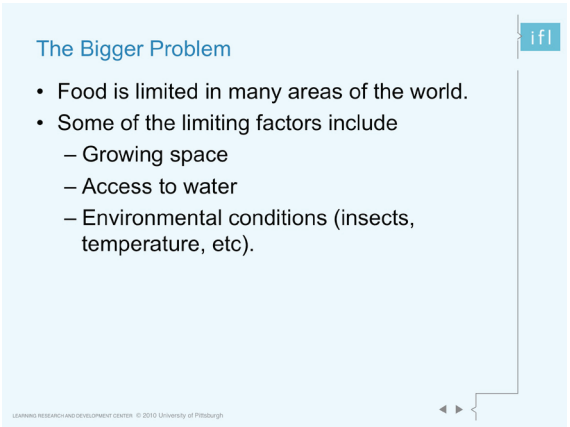
Why is that important?

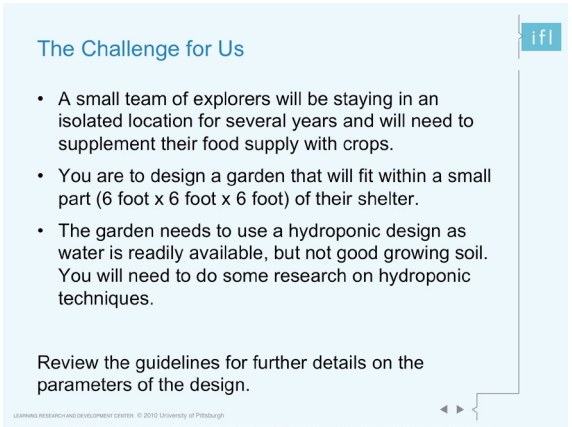
ifl

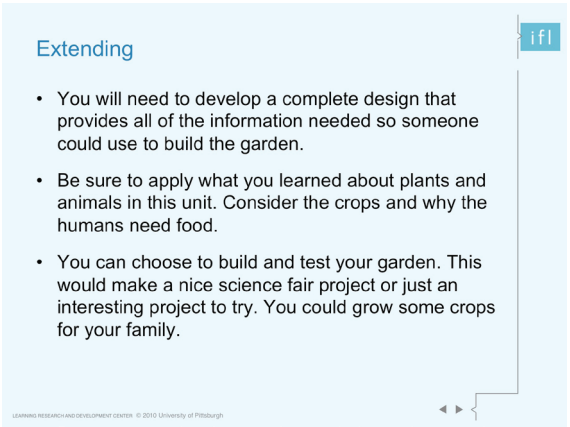
- Why might it be important to know that plants and animals both use cellular respiration?
  - What do both plants and animals need (i.e., inputs)?
  - Are the outputs useful? If so, give some examples of how they are useful.
- What questions do you have about cellular respiration in animals and plants?

Sample Slides: Solving a Problem: Designing a Hydroponic Garden









Grade 7

Adjustable to grades 6-8 based on content alignment.

Appendix B: Student Resources

Matter and Energy in Organisms

[MS.LS-ME0]

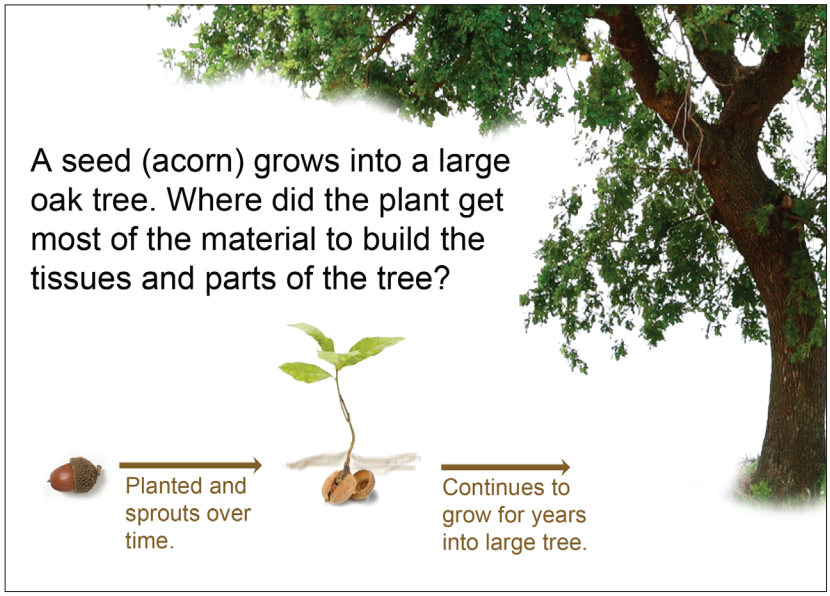
Appendix B: Student Resources

Table of Contents

Page(s)	Title	Lesson
124	Seed to Tree Task Sheet	Activation Task
125 - 127	Reading #1: Where Does the Plant Get the Matter to Live and Grow? Does it come from the SOIL?	CDL1
128 - 130	Reading #2: Where Does the Plant Get the Matter to Live and Grow? Does it come from the WATER?	CDL1
131 - 133	Reading #3: Where Does the Plant Get the Matter to Live and Grow? Does it come from the AIR?	CDL1
134 - 137	Scientific Argument Templates	CDL1, 2
138 - 139	Reading: Connected by the Light: Photosynthesis	CDL1
140	Reading Guide: Connected by the Light: Photosynthesis	CDL1
141	Corn Plant Diagram	CDL1
142 - 143	How Sweet It Is: Corn Plant Analysis Task Sheet	CDL2
144 - 148	How Sweet It Is: Corn Plant Analysis Data Sets	CDL2
149 - 151	Reading: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants	CDL3
152	Reading Guide: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants	CDL3
153	Body Diagram	CDL4
154	Information Gathering: Video-Watching Guide—In need of food: An animal's perspective	CDL4
155 - 157	Reading: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy: Cellular Respiration in Animals	CDL5
158	Reading Guide: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy: Cellular Respiration in Animals	Application
159	Matter and Energy in Organisms Summative Task Sheet	Application
160 - 164	Guidelines for Your Hydroponic Vegetable Garden	Application
29, 5, 102	Sample Information on Vegetables and Hydroponics	Application

Seed to Tree Task Sheet

You are at the park leaning against a tree. As you look up at the large tree and notice some acorns, you begin to wonder: Where did the tree get all the stuff to grow from a tiny seed? Consider the following scenario.

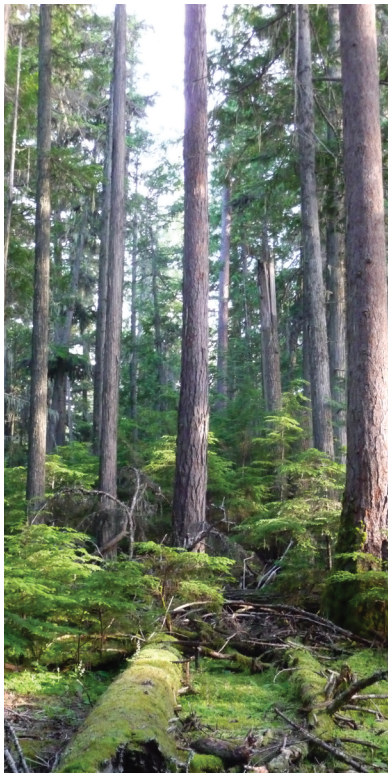


Answer the following questions in your notebook or onto a sheet of paper (check with your teacher for guidance). Label this as "Seed to Tree Task." You can use diagrams (labeled pictures) to help describe your answer. Think about what you know about plants and where they get energy and matter. Leave space after your answers so you can add new information after completing the unit.

1. From where did the tree get the energy to grow? Describe what you know about the processes involved in the tree getting and using energy.

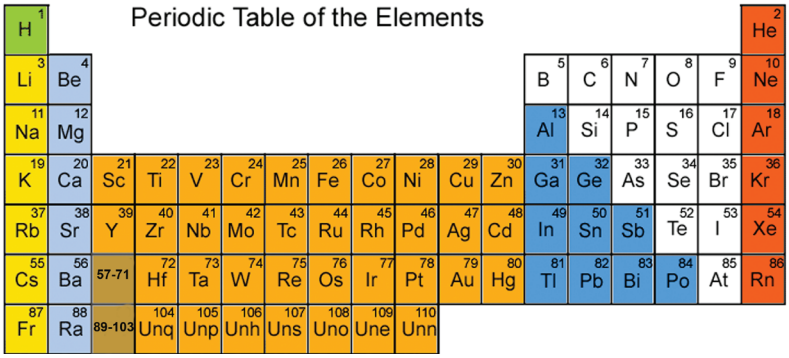
2. Where did all the matter come from to make the tree? Describe what you know about the processes involved in the tree getting and using matter.

Reading #1: Where Does the Plant Get the Matter to Live and Grow? Does it come from the SOIL?



Scientists have been studying plants since the beginning of science. We see plants around us and over time, see them grow from seeds or sprouts to larger plants. Those observations led scientists to wonder, where does the plant get all of the stuff it needs to build new tissue to grow? Early studies began by examining the chemicals that make up plant tissue.

Most of the plant tissue is made of carbon and oxygen. The bulk of the weight of a dead tree is from the carbon and oxygen that are used to form chains of molecules such as glucose and cellulose. We focus on the molecules for several reasons. First, you may recall that cells are the basic unit of life and that cells are made of molecules. Molecules are groups of atoms linked together to form chemical compounds. So molecules are combinations of atoms that make up the stuff of cells. Secondly, molecules are used within cells to do the work of living. And lastly, molecules are formed from atoms (e.g., carbon, oxygen, hydrogen, nitrogen, etc.) and can then be broken down into those atoms. Scientists can track and measure the atoms to see where the stuff comes from and where it goes. The information known about atoms is organized into a table that you may have seen called the Periodic Table.



Since the majority of the plant is made of carbon and oxygen, we will focus our study on these two elements. Plants do need other stuff to live and grow, but carbon and oxygen are the ones that create most of the mass of a plant and are vital to plant growth. These are also the key to thinking about ecosystems, but we will get into that in a later unit of study.

So where does the plant get the carbon and oxygen that it needs to live and grow?

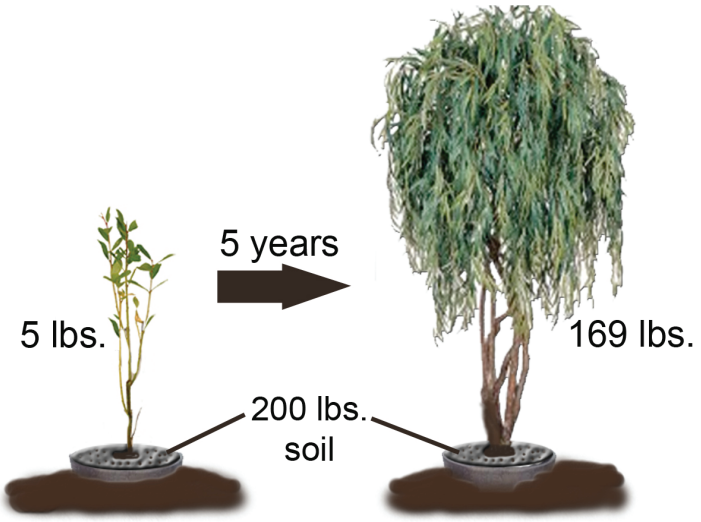
Continued on next page.

Does it come from the soil?

During the 1600s, scientists began to develop quantitative experimental procedures to measure changes in living organisms. Jean Baptista van Helmont was the first known biologist to publish a quantitative experiment. Scientists of his time were trying to understand where plants got their mass (a measure of the stuff of which they are made). In other words, where did the stuff come from that made up the plant parts. The general consensus of most scientists was that the plant obtained their mass from the soil. As scientists, they wanted to test that claim.

Van Helmont developed an experiment with a willow tree based on earlier work by other scientists including a paper presented in 1450 that suggested that plants were not "soil eaters" and got their mass from other sources. Van Helmont summarized his procedure as:

> *I took an earthen pot and in it placed 200 pounds of earth which had been dried out in an oven. This I moistened with rain water, and in it planted a shoot of willow which weighed five pounds. When five years had passed the tree which grew from it weighed 169 pounds and about three ounces. The earthen pot was wetted whenever it was necessary with rain or distilled water only. It was very large, and was sunk in the ground, and had a tin plated iron lid with many holes punched in it, which covered the edge of the pot to keep air-borne dust from mixing with the earth. I did not keep track of the weight of the leaves which fell in each of the four autumns. Finally, I dried out the earth in the pot once more, and found the same 200 pounds, less about 2 ounces.* (van Helmont, 1648)



The tree grew and its weight changed from five pounds to 169 pounds over the five years. Weight is a comparison measure of mass. Weight is the measure of gravity on the mass of something. The gravity stays the same if you make the measurements at the same place, so you can use the change in weight to compare changes in mass. If the tree gained 164 pounds (164 = 169-5), where did the matter come from to add that weight?

You may recall that in biological systems, matter does not get created. Matter may be combined into new molecules or broken down into smaller parts, but living organisms don't create matter. They have to get the matter from somewhere else. If the matter is taken from another source, then we should be able to detect a loss of matter in the source (a change in mass and weight). So what is the source of the matter to make up the 164 pounds? Was it the soil?

What evidence did this experiment generate? What claim does this evidence support? What is the reasoning to support the claim or to reject others?

This experiment supports the claim that **soil is not the main source of matter for plants**. The evidence from this experiment includes:

- the measured change in weight of the tree over the five years;
- the controlling factors to ensure no new soil was added; and
- the measured change in weight of the soil during the same time interval as the tree was measured.

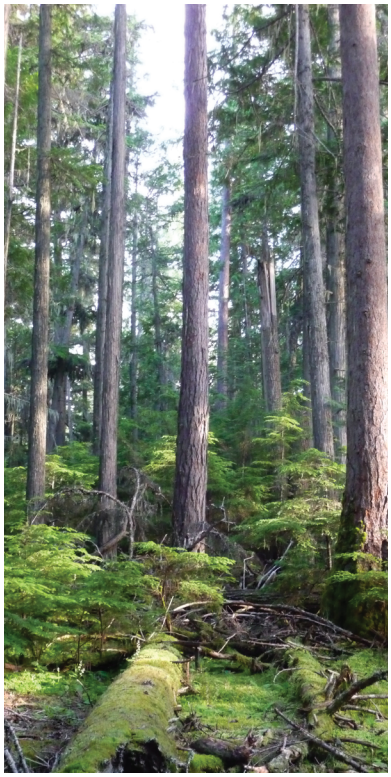
The soil in the pot was relatively sealed so that there was little chance of loss or addition of soil to the pot. The soil only lost 2 ounces of weight, so it could not be the source of the 164 pounds that the plant gained.

The van Helmont experiment led to a strong argument against soil being the source of matter for plants because it provided clear evidence that is measurable and repeatable (others could do the experiment and get similar results). However, it did not provide clear evidence as to where the matter came from other than it is not the soil.

Numerous scientists began to wonder where the matter came from if it is not soil. Some began to investigate water as the potential source. Van Helmont concluded that water must be the source of the matter. "Therefore 164 pounds of Wood, Barks, and Root, arose out of water only" (van Helmont, 1662). He also noted that plants when burned released large amounts of gas (later identified as carbon dioxide). However he did not connect that data with his ideas about water and plants. A few scientists around that time began to wonder if invisible sources within the air itself could be the source of matter for plants.

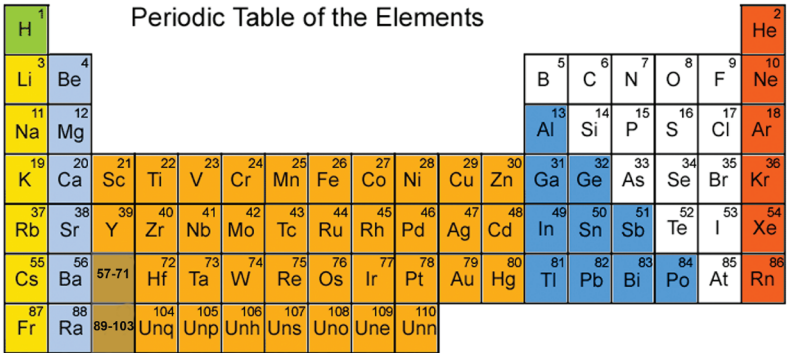
What do you think? What might be the source of matter for plants? What could you do to investigate your claim?

Reading #2: Where Does the Plant Get the Matter to Live and Grow? Does it come from the WATER?



Scientists have been studying plants since the beginning of science. We see plants around us and over time, see them grow from seeds or sprouts to larger plants. Those observations led scientists to wonder, where does the plant get all of the stuff it needs to build new tissue to grow? Early studies began by examining the chemicals that make up plant tissue.

Most of the plant tissue is made of carbon and oxygen. The bulk of the weight of a dead tree is from the carbon and oxygen that are used to form chains of molecules such as glucose and cellulose. We focus on the molecules for several reasons. First, you may recall that cells are the basic unit of life and that cells are made of molecules. Molecules are groups of atoms linked together to form chemical compounds. So molecules are combinations of atoms that make up the stuff of cells. Secondly, molecules are used within cells to do the work of living. And lastly, molecules are formed from atoms (e.g., carbon, oxygen, hydrogen, nitrogen, etc.) and can then be broken down into those atoms. Scientists can track and measure the atoms to see where the stuff comes from and where it goes. The information known about atoms is organized into a table that you may have seen called the Periodic Table.



Since the majority of the plant is made of carbon and oxygen, we will focus our study on these two elements. Plants do need other stuff to live and grow, but carbon and oxygen are the ones that create most of the mass of a plant and are vital to plant growth. These are also the key to thinking about ecosystems, but we will get into that in a later unit of study.

So where does the plant get the carbon and oxygen that it needs to live and grow?

Does it come from the water?

You may recall that in biological systems, matter does not get created. Matter may be combined into new molecules or broken down into smaller parts, but living organisms don't create matter. They have to get the matter from somewhere else. If the matter is taken from another source, then we should be able to detect a loss of matter in the source (a change in mass and weight).

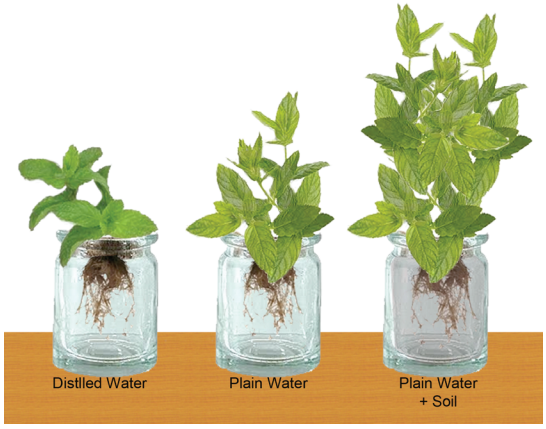
The ancient Greek philosopher Thales proposed that all matter arose from water (540 BCE). In the early 1600s, a few scientists experimented with growing plants in water and found that plants could live without soil, but not without water (Francis Bacon, 1627). In the late 1600s, scientific investigations generated new evidence that plants were not "soil eaters" and got their mass from other sources. The investigations found that the weight of soil stayed relatively the same, while the weight of the tree increased by hundreds of pounds (van Helmont, 1648).
Weight is a comparison measure of mass. Weight is the measure of gravity on the mass of something. The gravity stays the same if you make the measurements at the same place, so you can use the change in weight to compare changes in mass. Is water the source of matter for plants? What evidence might we look for to test the claim that water is the source of matter?
John Woodward conducted experiments with plants grown in water. He was one of the first scientists to collect and report detailed measurements of water loss from a source (sealed jar with plant) and the weight gained by the plant. The ratio, grams of water lost divided by the weight gain of the plant, is what he called transpiration. We now think of transpiration as the amount of water that passes through a plant from its roots through the plant and then into the atmosphere. Woodward did not measure the water leaving the plant to the atmosphere.

In his experiment, Woodward grew plants under controlled conditions. He placed a measured amount of water or a water mixture into a jar. A plant was placed into each jar and the top was sealed so the plant roots and water were inside the sealed jar and the stem and leaves of the plant were outside of the jar. He grew the plants for 56 days under the same conditions (i.e., amount of light, temperature). He grew several plants using each of the variables in water.

The variables in the water were as follows:

- plain water from a well;
- water with a small amount of soil added; or
- distilled water (all minerals removed).

His results are summarized in Table 1 showing the average for each variable. What can you interpret from this data about water being the source of matter for plants? What would you expect to see as the results if water is the source of matter?



Continued on next page.

Table 1. Woodward data on plant growth and water loss

Water Type	% Weight Gain (in live plant)	Transpiration Ratio
Plain	113	105
Plain plus soil	266	59
Distilled	36	215

What evidence did this experiment generate? What claim does this evidence support?

What is the reasoning to support the claim or to reject others?

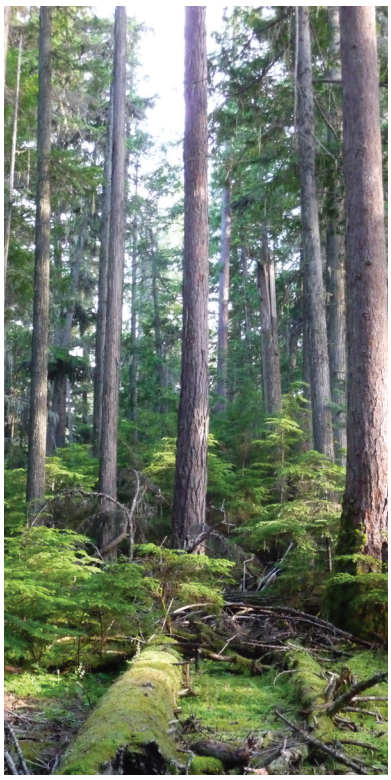
His data showed that plants grown in water with a little soil gained almost three times the mass of those grown in plain water. Those grown in distilled water had little growth. If water were the primary source of matter for plants, we would expect the plants to grow about the same in all three, with the ones in the distilled water (pure water) growing the most. Even if the other factors facilitate growth, such as minerals in the other water types, then we would expect to see the transpiration ratio (weight of water lost divided by weight gained in plant) to be about 1. The weight gained should be about the same lost by the water if it went from the water to the plant.

The claim that water is the source of matter for plants has another issue. Most of the plant matter has carbon. Water is made from two hydrogen atoms and one oxygen atom (H_2O). It might account for oxygen in the plant, but from where is the carbon coming?

What do you think? What might be the source of matter for plants?

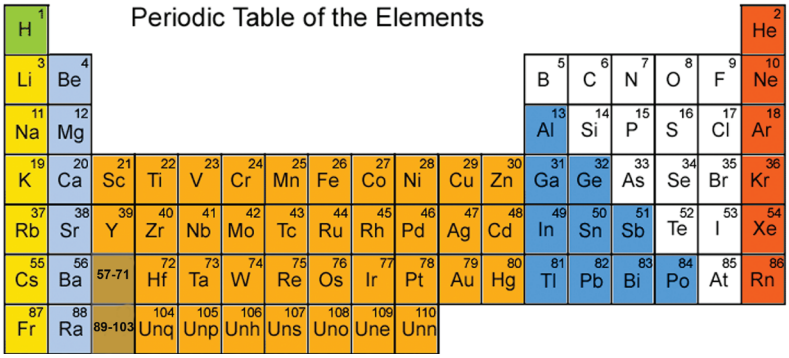
What could you do to investigate your claim?

Reading #3: Where Does the Plant Get the Matter to Live and Grow? Does it come from the AIR?



Scientists have been studying plants since the beginning of science. We see plants around us and over time, see them grow from seeds or sprouts to larger plants. Those observations led scientists to wonder, where does the plant get all of the stuff it needs to build new tissueto grow? Early studies began by examining the chemicals that makeup plant tissue.

Most of the plant tissue is made of carbon and oxygen. The bulk of the weight of a dead tree is from the carbon and oxygen that are used to form chains of molecules such as glucose and cellulose. We focus on the molecules for several reasons. First, you may recall that cells are the basic unit of life and that cells are made of molecules. Molecules are groups of atoms linked together to form chemical compounds. So molecules are combinations of atoms that make up the stuff of cells. Secondly, molecules are used within cells to do the work of living. And lastly, molecules are formed from atoms (e.g., carbon, oxygen, hydrogen, nitrogen, etc.) and can then be broken down into those atoms. Scientists can track and measure the atoms to see where the stuff comes from and where it goes. The information known about atoms is organized into a table that you may have seen called the Periodic Table.



Since the majority of the plant is made of carbon and oxygen, we will focus our study on these two elements. Plants do need other stuff to live and grow, but carbon and oxygen are the ones that create most of the mass of a plant and are vital to plant growth. These are also the key to thinking about ecosystems, but we will get into that in a later unit of study.

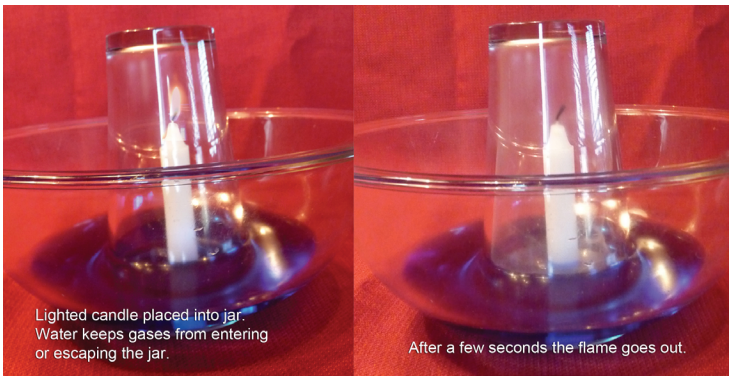
So where does the plant get the carbon and oxygen that it needs to live and grow?

Continued on next page.

Does it come from the air?

Think about a plant. What are plants exposed to as they live? Water, soil, and air. Some scientists explored soil as the primary source of matter, while others explored water as the potential source. It wasn't until the late 1700s that scientists began to understand that air is made of matter. Air takes up space and has weight, so it must be made of something. Recognizing that air has matter created the possibility that air is a source of matter for plants.

Joseph Priestly was a scientist who was curious about air and gases in the late 1700s. There was a general idea that gases existed and affected things, but little was known. For example, oxygen had not yet been discovered. What Priestly observed was that a candle placed in an enclosed jar would burn out very quickly, long before the wax was burned up. He tried to relight the candle using a lens and sunlight, but it would not light in the sealed jar. He then placed a sprig of living mint into the jar with the candle and sealed it after lighting the candle. He again found the candle went out quickly. After 27 days, the candle in the sealed jar with the plant could be relit. He considered the air 'restored' by the plant.



Several years later, another scientist named Jan Ingenhousz repeated Priestly's experiment with a few changes based on some new discoveries by other scientists. Oxygen had been discovered and identified as the gas that allowed things to burn. Ingenhousz repeated the experiment showing that the plants did release oxygen. He also tested plants growing under different conditions, some in constant darkness and others in sunlight. He observed that the plants that were kept in the dark produced less gas than those grown in the light. So what does this mean? Consider both scientists' work. What can you determine from their results?

You may recall that in biological systems, matter does not get created. Matter may be combined into new molecules or broken down into smaller parts, but living organisms don't create matter. They have to get the matter from somewhere else.

Priestly showed that burning depleted something in the air, but that plants could replace that gas. So the plants were releasing a gas that Ingenhousz showed to be oxygen. But giving off oxygen is a loss of matter, not a gain of matter. Where is the source of the oxygen and carbon for the plants and why do they release oxygen if they need it to build plant materials?

Building on the work of Priestly and Ingenhousz, Senebier grew plants under conditions that either exposed them to carbon dioxide or to no carbon dioxide. Senebier collected the gas that was released from the plants and concluded that oxygen was produced by the leaves when carbon dioxide was available. Senebier concluded that it was carbon dioxide that was allowing the plants to release oxygen and that the leaves themselves were not producing any carbon dioxide.

Around the same time, Saussure grew plants in a closed system. He measured the mass of water present initially, the mass gained by the plant, and how much water mass was present at the end of the experiment. If the matter is taken from another source, then we should be able to detect a loss of matter in the source (a change in mass and weight). Weight is a comparison measure of

mass. Weight is the measure of gravity on the mass of something. The gravity stays the same if you make the measurements at the same place, so you can use the change in weight to compare changes in mass.

Saussure concluded that the plant's increase in weight could not be solely due to uptake of carbon but that water was necessary. The uptake of carbon was the main source, but water plays a role in the mass gain in plants (increase in matter).

What evidence did these experiments generate?

What claim does the evidence support?

What is the reasoning to support the claim or to reject others?

Let's outline what the research indicates that plants need to gain mass (increase matter or grow).

- First, plants release oxygen (oxygen = an output) when exposed to light (light is required).
- Second, plants take up carbon dioxide (carbon dioxide = input) in the presence of light (light required).
- Lastly, water is required and taken up by plants (water = input). Let's write this as a chemical equation:

Carbon dioxide + water + light = plant matter + oxygen

Does this look familiar? So what does this mean in terms of where plants get their matter?

What claim about where plants get matter can you support using the evidence from these studies?

Scientific Argument Templates

A scientific argument attempts to analyze, assess, and/or justify a CLAIM. The claim may be an assertion about the analysis of data, an assertion that one explanation is more viable or plausible than another explanation, or support for proposed ideas around phenomena. The scientific argument uses data, scientific principles, and logic to present a persuasive case for the claim — one that is compelling from a scientific perspective (based on evidence, reasonable interpretation of that evidence, and the merits of data collection and analysis).

One model to articulate the core aspects of a scientific argument is the C-E-R model (Claim – Evidence – Reasoning). This model can help scaffold students in writing an argument by helping break down the parts. Students will identify the claim and then the evidence and reasoning to support the claim.

The writing of an argument often works backwards through the process of developing a claim. From a chronological perspective, the process to develop the claim usually begins with a research question or problem to solve. Then the scientist or engineer will focus on generating or gathering of data and information. This generating and gathering may happen quickly or become an iterative process that occurs over an extended period of time. During and following the data and information generating and gathering the researcher will analyze the data. Through the analysis, claims will emerge. Some claims will be considered and set aside (counterclaims that are rejected). A claim will be identified that is the strongest claim given the available evidence and information.

A written claim will begin with the question and claim. Then the evidence and reasoning to support the claim is organized and articulated. Finally, counterclaims are addressed along with the reasoning and evidence to illustrate why they were rejected or not considered the strongest.

The following templates can be used as models to help students organize the writing of their arguments. Use the template that will be most helpful to your students depending on where they are in terms of their skills in writing arguments. Eventually you will want students to write arguments as paragraphs without use of the templates.

Scientific Argument Development Template 1

After reviewing data and information on the question or problem, I assert the following claim (be sure to specifically address the question or problem):

Claim:

I concluded this claim because of the following reasons (include the scientific principles [what scientists have reported about how things work] that guided your decision) that are based on the evidence cited. (Remember, the more lines of reasoning and evidence, the stronger your argument. Write the reasoning to help someone understand why you think this claim is the strongest based on the evidence available. You might use a table such as the one below or write in paragraph form. Be sure to make a clear link between the evidence to the claim through your reasoning.)

	Reasoning	**Evidence (include source or citation)**
Reason 1		
Reason 2		
Reason 3		

I considered the following alternate interpretations of the evidence (something someone else might argue against your claim):

Claim:

Claim:

I did not consider these counterclaims as strong because (reasons and evidence why you rejected the counterclaims):

	Reasoning	**Evidence (include source or citation)**
Reason 1		
Reason 2		

Scientific Argument Development Template 2

What is the question that you want to answer?

List the sources used for the evidence that will be used to support your scientific argument.

Evidence to support your argument

Claim(s) that best answers the question	Evidence that supports your claim(s)

Argument supporting your answer to the question: Claim + Evidence + Reasoning

___(Claim)____ answers the question because ____(Evidence + Reasoning)____.

Scientific Argument Development Template 3

QUESTION:

CLAIM:

EVIDENCE (include source):

REASONING:

Reading: Connected by the Light: Photosynthesis

You have read, discussed, and thought about plants and where they get most of the matter they need to live and grow. Your group should have considered soil, water, and air as potential sources of matter. Given the available evidence and scientific reasoning, you probably came to the conclusion that plants obtain most of their matter from the gases in the air. Scientists today agree that plants pull carbon dioxide from the air and water through the roots. The carbon dioxide and water are then combined through a series of chemical processes in specialized parts of the leaves using energy from light. This series of processes is known as photosynthesis.

Let's examine photosynthesis in a little more detail and consider how we came to understand the process. The name photosynthesis was chosen to represent what happens in the series of processes. Photo means light. Synthesis means to build or combine. Photosynthesis uses energy from light to combine molecules.

In your earlier discussions, you should have considered the research of van Helmont, Woodward, Priestly, Ingenhousz, Senebier, and Saussure. What evidence did the scientists generate? What claims can we make based on that evidence?

Let's summarize what they reported. First, van Helmont found that the weight of a tree increased over time, but the weight of the soil did not decrease. Woodward found that plants in water alone did not grow as well as those with soil in the water. He also reported that the weight gained by the plants was much greater than the amount of mass lost in the water. Priestly found that plants could restore gases to the air. Ingenhousz added to the thinking by identifying oxygen as the gas being replaced by plants and noting that light was required for this to happen. Senebier further clarified that the leaves of a plant released oxygen and that the plant required carbon dioxide along with light for the process to work. Saussure contributed that water was required for the plant to live and added something to the gain of matter. We can further summarize the reported studies as plants release oxygen (oxygen = an output) when exposed to light (light is required). Plants take up carbon dioxide (carbon dioxide = input) in the presence of light (light required). Lastly, water is required and taken up by plants (water = input). Let's write this as a chemical equation:

Carbon dioxide + water + light = plant matter + oxygen

We can further refine the expression based on other studies that have shown the plant matter produced is sugar, usually glucose.

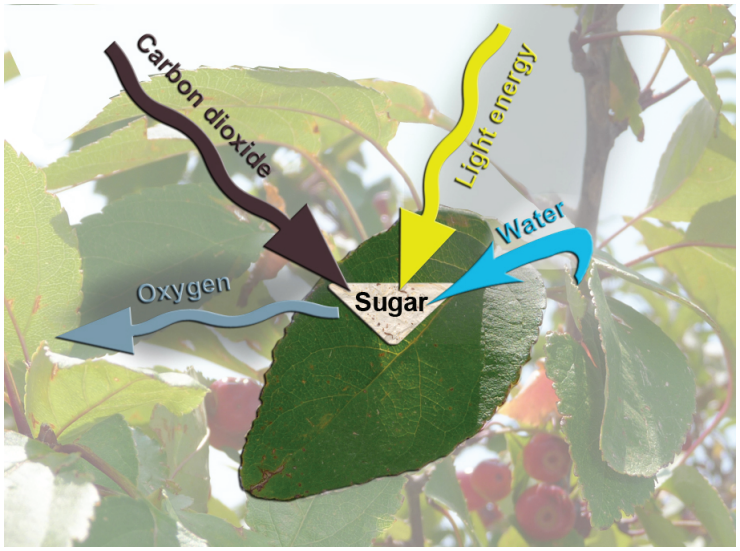


Figure 1. Simplified processes of photosynthesis showing inputs and outputs in a leaf.

Let's rewrite the chemical equation as words and then use the chemical symbols and amount for each.

Carbon dioxide + water + light → glucose (sugar) + oxygen

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

Notice that it takes six molecules of carbon dioxide and six molecules of water for the process to produce one molecule of glucose, and six oxygen molecules are released as waste. In chemistry, like in mathematics, equations must be balanced on both sides. You need to have the same number of carbon on the left as are on the right side of the equation. We use the "yields" symbol (→) rather than an equal sign because the process usually goes in one direction. The formulae are shown here just to familiarize you with them. You will study them in greater detail in later science classes. For now let's stay focused on the general processes, thinking about what goes in and what comes out.

Light energy powers the process to break down the carbon dioxide and water and then recombines the atoms to form sugar, with oxygen as a byproduct. The end result of the processes is that light energy is transformed into some chemical energy in the sugar, plus heat energy that is lost. But if all the light energy is lost or used to make sugar, where does the plant get the energy to live? Sugar is the key. In later lessons we will think about the role sugar (glucose) plays as the key to energy and matter in organisms and ecosystems.

So what does all of this mean in terms of where a plant gets the matter and energy needed to live and grow? Develop a scientific argument to answer the question: **How do most plants obtain the matter and energy they need to live and grow?**

Reading Guide: Connected by the Light: Photosynthesis

As you read the paper entitled Connected by the Light: Photosynthesis consider the questions below and record your notes into your notebook.

Be sure to cite evidence from the paper to support your answer (e.g., page one, second paragraph).

1. What is the process being explained in the paper?

2. Summarize how the process occurs according to the author. What are the inputs and outputs?

3. Why is this process important according to the author?

4. What evidence is presented to support the claim that this process occurs as described by the author? You can use a table like the one below to organize your notes. You will need to create more rows so you have one row for each piece of evidence.

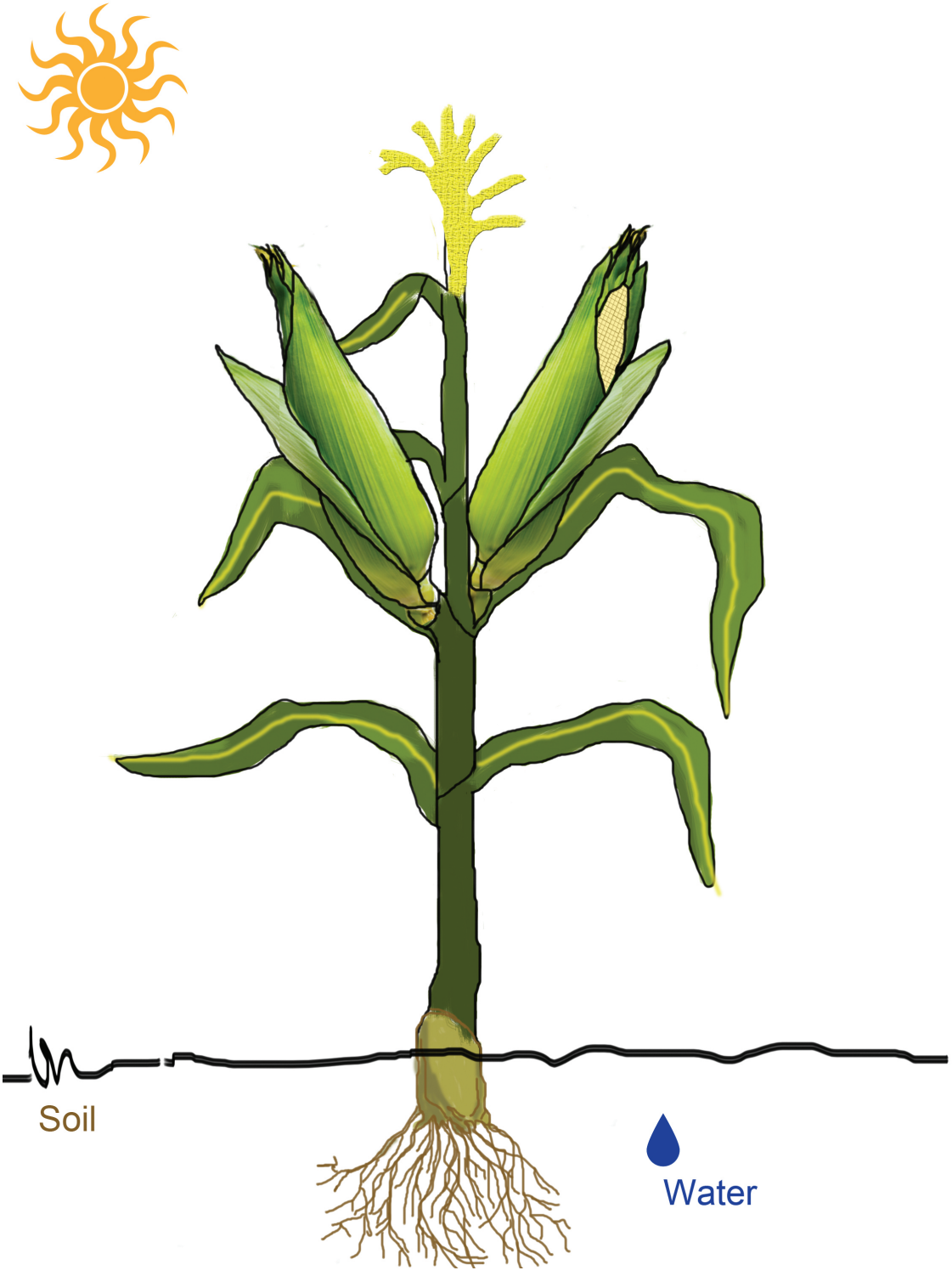
Evidence	Page and Paragraph	What does this evidence support (what does it mean)?

5. What does this reading help you better understand about the question: How do most plants obtain the matter and energy they need to live and grow?

6. What questions do you have about the processes after reading this paper?

Corn Plant Diagram

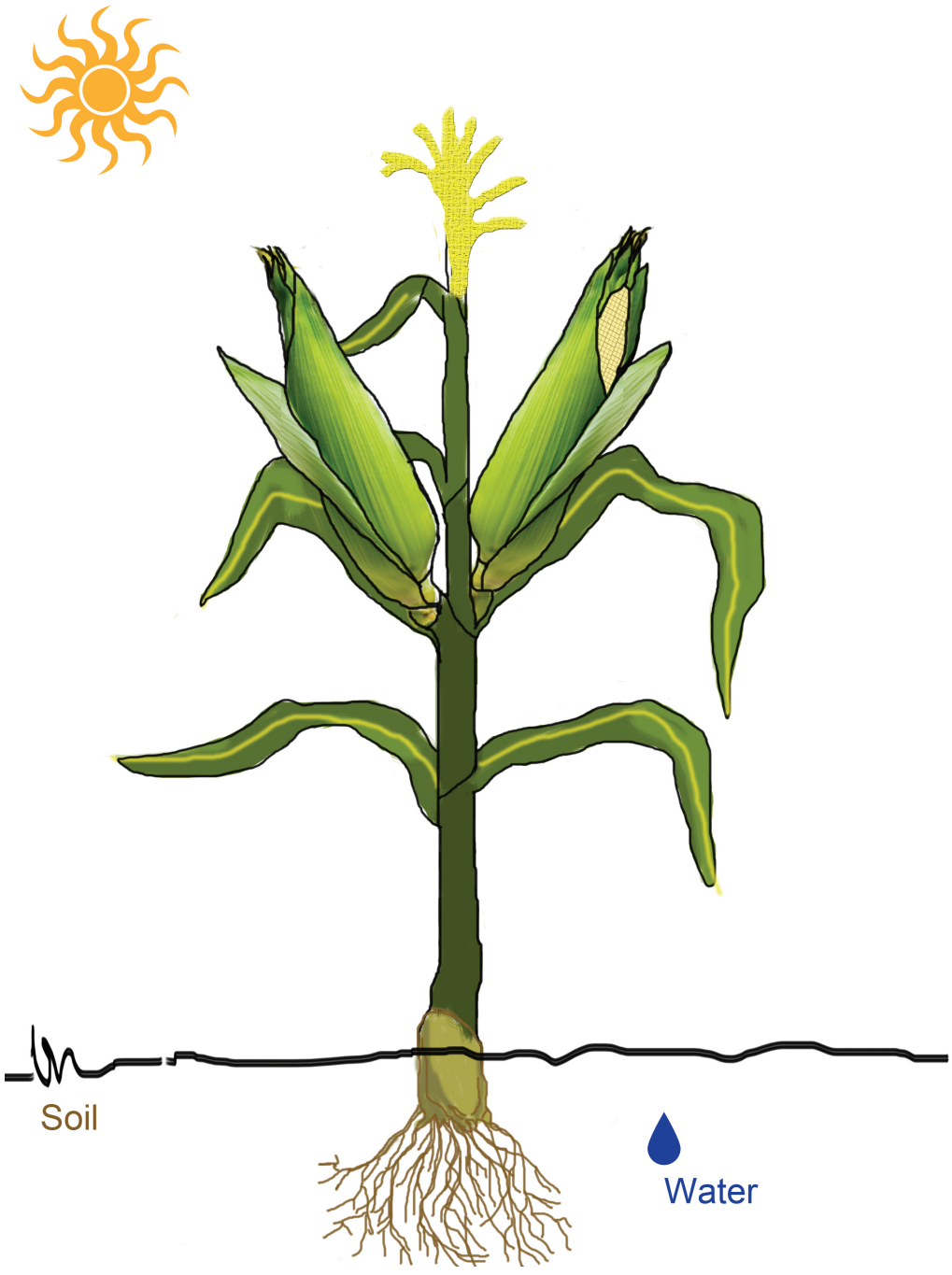
Add to the diagram below to show the process by which a corn plant obtains matter and energy through photosynthesis. Use symbols and words (labels such as air, seeds, etc.) and descriptions (e.g., the light shines on the plant) so that someone else can understand the details of the process from your diagram.



How Sweet It Is: Corn Plant Analysis Task Sheet

In this task you are going to look for evidence to consider what happens to the sugar made through photosynthesis in the leaves of a plant. We are going to use a corn plant as a specific plant to study, but keep in mind how other plants such as an oak tree, sunflower, or lettuce might be similar to or different from the corn plant in their use of sugar. Write your notes into your notebook. You can cut out and paste the corn diagram into your notebook or recreate a version into your notebook.

1. Consider the corn plant diagram and your notes from the earlier discussion about the diagram and corn products. Mark on the diagram where the sugar is produced through photosynthesis.



2. Identify at least six corn plant products and consider what types of macromolecules are found in that product by researching information on each product. Macromolecules are usually large chains of connected molecules and are involved in all of the structures and processes of cells and thus the organism. Macromolecules can be clustered into four categories:

    a. Carbohydrates: chains of carbon atoms with several oxygen and hydrogen atoms attached. These are single or chains of multiple sugar molecules. Examples of carbohydrates include sugars, starches, and cellulose. Cellulose is the primary building block of plant tissue such as stems.

    b. Lipids: long chains of carbon and hydrogen with a polar molecule at the top. The basic building block for lipids is chains of sugars with the oxygen removed. Examples of lipids include fats and oils. Lipids are used for long-term storage of energy.

    c. Proteins: chains of amino acids involved in the function of cells. Proteins require energy in the form of ATP to be formed and used within the cell. ATP transports chemical energy in cells and is formed by breaking down sugars. Proteins facilitate the work of cells and organisms and provide some structural tissue. Examples of proteins include insulin, keratin, collagen, and enzymes.

    d. Nucleic acids: long chains forming DNA or RNA. Sugars form the spine of the structure that forms DNA and RNA, the backbone of the helix. Nucleic acids carry and translate the genetic information for cells.

3. Once you have identified the macromolecules found in the corn plant product, identify which part(s) of the corn plant were used to make the product.

4. Using the corn plant diagram on the first page of this task sheet, mark where the macromolecules can be found in the plant. For instance, if you found that the corn kernels have carbohydrates or sugar in them, then label the kernels as having sugar.

5. With your partner, consider what happens to the sugar after photosynthesis and write responses in your notebook to the following question:

    What happens to the sugar after photosynthesis?

    a. Does it all stay in the leaves? Where does it go?
    b. What does it get used for in the plant?
    c. Does it get used right away or is some of it stored for later?

6. Create a diagram, comic strip, animation, or physical model that illustrates what happens to the sugar. Be prepared to share your project. Your teacher will give you guidance on the sharing process.

How Sweet It Is: Corn Plant Analysis Data Sets

Below are a few samples of information on various corn products. You may need to conduct additional research using the Internet or resources available in your library or media center.

Corn Kernels – Fresh Corn on the Cob

Nutrition Facts

Serving Size 1 cup (154.0 g)

Amount Per Serving	
Calories 132	Calories from Fat 16
	% Daily Value*
Total Fat 1.8g	**3%**
Saturated Fat 0.3g	**1%**
Polyunsaturated Fat 0.9g	
Monounsaturated Fat 0.5g	
Cholesterol 0mg	**0%**
Sodium 23mg	**1%**
Total Carbohydrates 29.3g	**10%**
Dietary Fiber 4.2g	**17%**
Sugars 5.0g	
Protein 5.0g	

Vitamin A 6%	Vitamin C 17%
Calcium 0%	Iron 4%

* Based on a 2000 calorie diet

1 cup of fresh corn on the cob contains the following:

Water	116.98 g		Calcium, Ca	3 mg
Protein	4.96 g		Iron, Fe	0.8 mg
Lipid (fat), total	1.82 g		Magnesium, Mg	57 mg
Fatty acids, total monounsaturated	0.534 g		Phosphorus, P	137 mg
Fatty acids, total polyunsaturated	0.861 g		Potassium, K	416 mg
Carbohydrate, total	29.29 g		Sodium, Na	23 mg
Fiber, total dietary	4.2 g		Zinc, Zn	0.69 mg
Sugars, total	4.96 g		Copper, Cu	0.083 mg
Sucrose	3.17 g		Manganese, Mn	0.248 mg
Glucose (dextrose)	0.77 g		Selenium, Se	0.9 mcg
Fructose	0.74 g		Vitamin C	10.5 mg
Maltose	0.28 g		Niacin	2.618 mg
			Pantothenic acid	1.17 mg

Corn Starch

Nutrition Facts

Serving Size 1 cup (128.0 g)

Amount Per Serving	
Calories 488	Calories from Fat 1
	% Daily Value*
Total Fat 0.1g	**0%**
Saturated Fat 0.0g	**0%**
Polyunsaturated Fat 0.0g	
Monounsaturated Fat 0.0g	
Cholesterol 0mg	**0%**
Sodium 12mg	**0%**
Total Carbohydrates 116.8g	**39%**
Dietary Fiber 1.2g	**5%**
Protein 0.3g	

Vitamin A 0%	Vitamin C 0%
Calcium 0%	Iron 3%

* Based on a 2000 calorie diet

1 cup (128.0 g) of cornstarch contains the following:

Water	10.65 g		Calcium, Ca	3 mg
Protein	0.33 g		Iron, Fe	0.6 mg
Lipid (fat), total	0.06 g		Magnesium, Mg	4 mg
Fatty acids, total saturated	0.012 g		Phosphorus, P	17 mg
Fatty acids, total monounsaturated	0.02 g		Potassium, K	4 mg
Fatty acids, total polyunsaturated	0.032 g		Sodium, Na	12 mg
Carbohydrate, total	116.83 g		Zinc, Zn	0.08 mg
Fiber, total dietary	1.2 g		Copper, Cu	0.064 mg
Sugars, total	~ g		Manganese, Mn	0.068 mg
			Selenium, Se	3.6 mcg

Corn Oil

Nutrition Facts

Serving Size 1 serving (g)

Amount Per Serving	
Calories 120	Calories from Fat 120
	% Daily Value*
Total Fat 14.0g	**22%**
Saturated Fat 2.0g	**10%**
Cholesterol 0mg	**0%**
Sodium 0mg	**0%**
Total Carbohydrates 0.0g	**0%**
Dietary Fiber 1.2g	**5%**
Protein 0.0g	

* Based on a 2000 calorie diet

1 Tablespoon (15 g) of corn oil contains:

Lipid (fat), total	0.06 g
Fatty acids, total saturated	0.012 g
Fatty acids, total monounsaturated	0.02 g
Fatty acids, total polyunsaturated	0.032 g

Corn Syrup

Nutrition Facts

Serving Size 2 tbsp (30.0 g)

Amount Per Serving	
Calories 120	
	% Daily Value*
Sodium 30mg	**1%**
Total Carbohydrates 30.0g	**10%**
Sugars 10.0g	

* Based on a 2000 calorie diet

2 Tablespoons (30.0 g) of light corn syrup contains:

Carbohydrate, total	30 g
Sugars, total	10 g
Sodium, Na	30 mg

Corn Meal

Nutrition Facts

Serving Size 1 cup (122.0 g)

Amount Per Serving	
Calories 442	Calories from Fat 39
	% Daily Value*
Total Fat 4.4g	**7%**
Saturated Fat 0.6g	**3%**
Polyunsaturated Fat 2.0g	
Monounsaturated Fat 1.2g	
Cholesterol 0mg	**0%**
Sodium 43mg	**2%**
Total Carbohydrates 93.8g	**31%**
Dietary Fiber 8.9g	**36%**
Sugars 0.8g	
Protein 9.9g	

Vitamin A 5%	Vitamin C 0%
Calcium 1%	Iron 23%

* Based on a 2000 calorie diet

1 cup (122.0 g) of yellow corn meal contains:

Water	12.52 g		Copper, Cu	0.235 mg
Protein	9.91 g		Manganese, Mn	0.608 mg
Lipid (fat), total	4.38 g		Selenium, Se	18.9 mcg
Fatty acids, total saturated	0.616 g		Thiamin	0.47 mg
Fatty acids, total monounsaturated	1.157 g		Riboflavin	0.245 mg
Fatty acids, total polyunsaturated	1.998 g		Niacin	4.431 mg
Carbohydrate, total	93.81 g		Pantothenic acid	0.519 mg
Fiber, total dietary	8.9 g		Vitamin B-6	0.371 mg
Sugars, total	0.78 g		Choline, total	26.4 mg
Calcium, Ca	7 mg		Betaine	14.2 mg
Iron, Fe	4.21 mg		Vitamin A, IU	261 IU
Magnesium, Mg	155 mg		Vitamin E	0.51 mg
Phosphorus, P	294 mg		Vitamin K	0.4 mcg
Potassium, K	350 mg			
Sodium, Na	43 mg			
Zinc, Zn	2.22 mg			

Corn Flour/Masa

Nutrition Facts

Serving Size 1 cup (114.0 g)

Amount Per Serving	
Calories 416	Calories from Fat 39
	% Daily Value*
Total Fat 4.3g	**7%**
Saturated Fat 0.6g	**3%**
Polyunsaturated Fat 2.0g	
Monounsaturated Fat 1.2g	
Cholesterol 0mg	**0%**
Sodium 6mg	**0%**
Total Carbohydrates 86.9g	**29%**
Dietary Fiber 8.9g	**36%**
Protein 10.6g	

Vitamin A 5% | Vitamin C 0%
Calcium 16% | Iron 46%

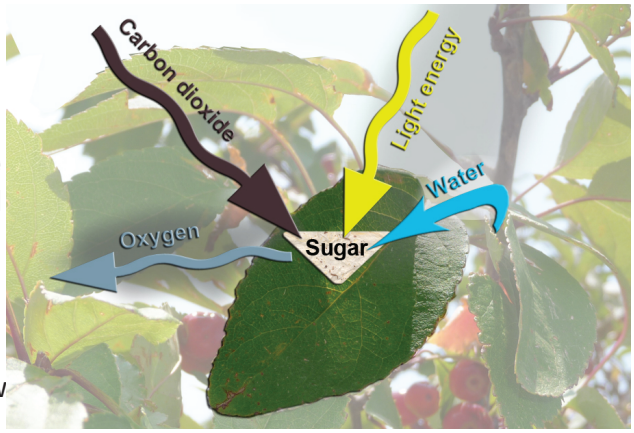
* Based on a 2000 calorie diet

1 cup (122.0 g) of corn flour contains:

Water	10.29 g
Protein	10.65 g
Lipid (fat), total	4.31 g
Fatty acids, total saturated	0.606 g
Fatty acids, total monounsaturated	1.137 g
Fatty acids, total polyunsaturated	1.965 g
Carbohydrate, total	86.95 g
Calcium, Ca	161 mg
Iron, Fe	8.22 mg
Magnesium, Mg	125 mg
Phosphorus, P	254 mg
Potassium, K	340 mg
Sodium, Na	6 mg
Zinc, Zn	2.03 mg
Copper, Cu	0.193 mg
Manganese, Mn	0.552 mg
Thiamin	1.629 mg
Riboflavin	0.858 mg
Niacin	11.221 mg
Pantothenic acid	0.75 mg
Vitamin B-6	0.422 mg
Folate, total	266 mcg
Choline, total	4.9 mg
Betaine	2.3 mg
Vitamin A, IU	244 IU

Reading:
Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants

We have learned that plants manufacture sugar (glucose) from carbon dioxide and water using energy from light. We also learned that the sugar produced through photosynthesis in the leaves moves to all the parts of a plant. Some of the sugar gets used as building blocks to make the parts of the plant such as stems, tissue, and bark. We also have an idea that the sugar is used as food by the plant for energy. But how does the plant get energy it needs to live and grow from the sugar?



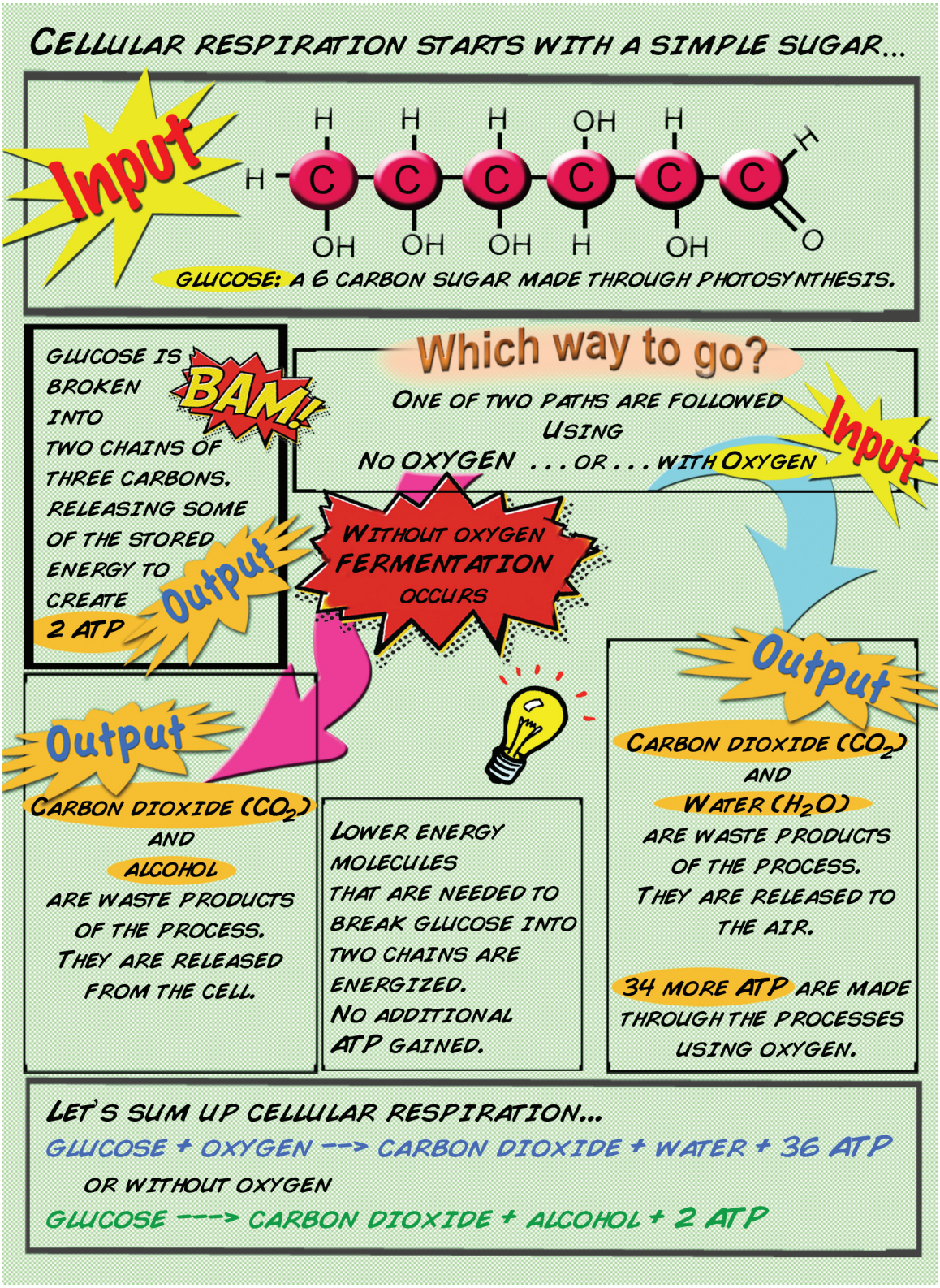
Cells are the basic unit of life. This means that cells are where all the work of an organism occurs. So when we think about the energy needs of an organism, we need to think about cells and how the cells get energy. Sugars and starches store a lot of energy. They store the energy so it does not need to be used quickly. This is beneficial to plants so that they can have some energy stored to continue living when there is no light. Remember, the light energy is transformed into chemical energy in the sugar plus some heat energy. If the plant could not store the sugar for later use, it would not have any during the night. The disadvantage of sugars and starches storing a lot of energy is that cellular processes need small amounts of energy in quick applications. If all the energy in a sugar molecule was used for cellular processes at once, there would be a good amount of energy that was transformed into heat energy. The heat would be enough to kill the cell. So how do cells get the energy without wasting a lot of energy or producing too much heat?

The answer is through a series of processes known as cellular respiration. Through cellular respiration, cells break down sugar in a series of stages to produce smaller energy-rich molecules that have just the right amount of energy to be used by cells. These energy-rich molecules are called Adenosine Tri-Phosphate (ATP). Let's explore the general inputs and outputs of cellular respiration.

The Ins and Outs of Cellular Respiration in Plants

Cellular respiration begins with a macromolecule as its starting energy source. Most of the time it is the sugar produced through photosynthesis, so we will focus on the processes starting with glucose. If the starting product is not glucose, then end products change a little, but you will get the general idea of cellular respiration.

Cellular Respiration Pathways in Plants



Plants use the sugar they manufacture through photosynthesis as their food source. We refer to it as "food" because the plant gets both matter and energy from the sugar. The plant then undergoes cellular respiration to break down sugar molecules to create ATP, the energy source that cells use to do the work necessary to live and grow.

Did you notice the chemical equations for cellular respiration? Does the path with oxygen look familiar?

Glucose (sugar) + oxygen → carbon dioxide + water + 36 ATP (energy)

One way to detect if this process is happening is to measure the carbon dioxide output from plants. Not surprisingly, scientists have large sets of data on different plants measuring their output of carbon dioxide in the light and in the dark. They have similar data measuring the output of oxygen by the plant. Why do you think scientists would want to know both?

Look at the equation again, noticing the inputs (on the left of the arrow) and outputs (to the right of the arrow). What process does it resemble if we reverse the arrow (so the outputs become the inputs and the inputs become the outputs)?

What did you notice as the outputs without oxygen?

Glucose (sugar) → carbon dioxide + alcohol + 2 ATP (energy)

Alcohol and carbon dioxide are the primary outputs. Humans have used the production of alcohol through fermentation for centuries to produce alcohol-based beverages (e.g., wine, beer) and for medicinal purposes (e.g., to clean wounds) and fuels (ethanol-based fuels). Plants use the process to get some energy from sugar to power the work of cells, but need to get rid of the alcohol so the cells don't die.

So what is your answer to the question: **How do plants break down the sugar for the energy the plant cells need to live and grow?**

Reading Guide: Energy Plant: Breaking Down Sugar for Energy: Cellular Respiration in Plants

The cellular respiration reading describes a process that occurs in plant cells. Use the questions below to help focus your reading and organize your notes. Record your notes into your notebook.

1. What information does the author provide about the process in the title of the paper?

2. Which process is illustrated in the figure on page 149 with the leaf in the center? What does it tell you about that process?

3. Why is it important to know how cells get energy if we are concerned about organisms (such as humans)?

4. Summarize the steps of the processes of cellular respiration in plants that are illustrated in the comic strip flow on page 150.

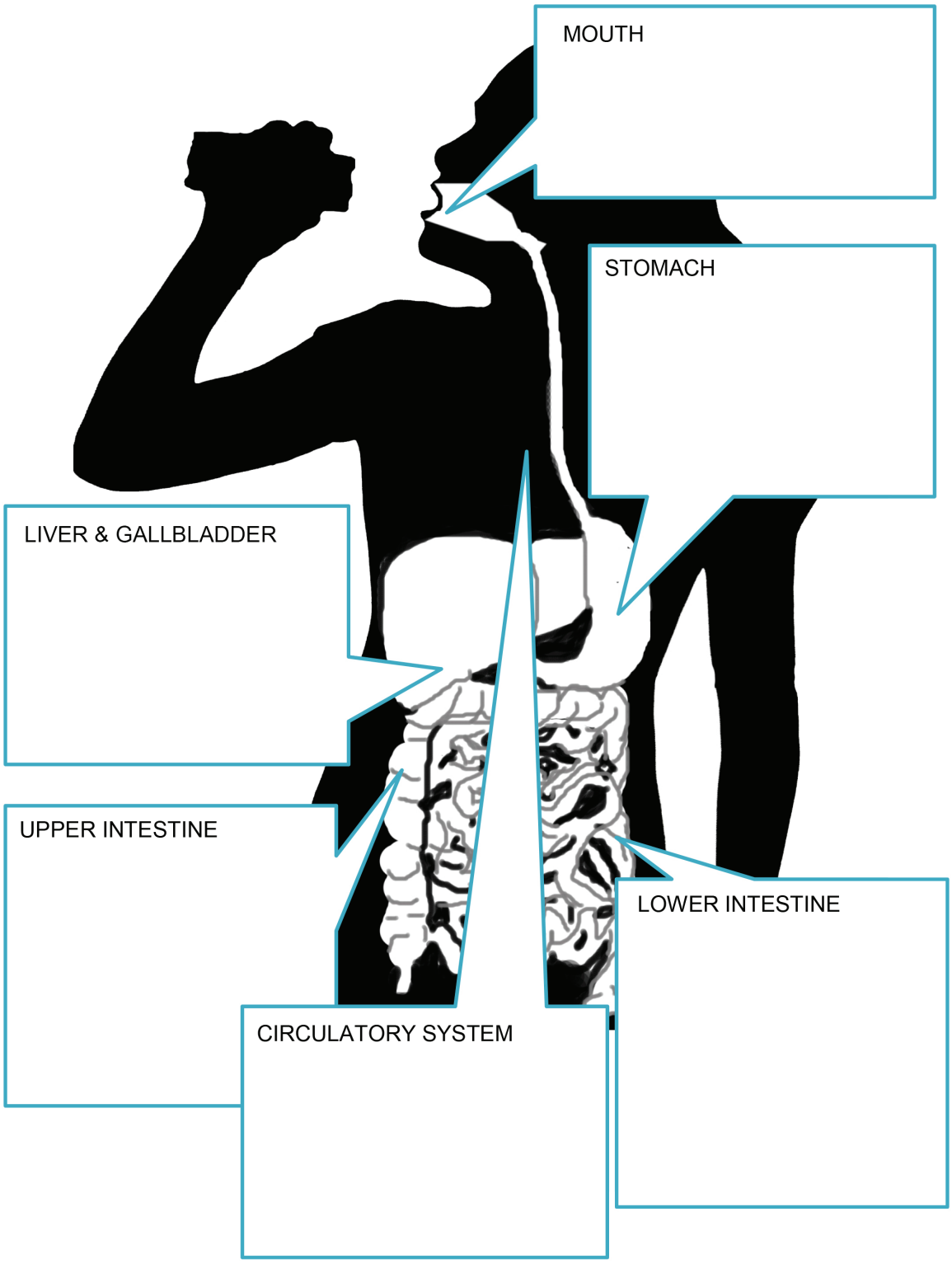
   a. What is the big idea represented in the illustration?

   b. What are the inputs and outputs?

5. What does the path with oxygen, discussed in the second paragraph on page 151, remind you of from earlier studies?

6. Write a response to the question: **How do plants break down the sugar for the energy the plant cells need to live and grow?**

Body Diagram



Information Gathering: Video-Watching Guide
In need of food: An animal's perspective

Focus on what happens to food as it moves through your body. Pay particular attention to the parts highlighted in the Body Diagram and outlined in the table. Use the table below, or one you recreate into your notebook, to help focus your note taking. You may want to do some additional research to learn more about parts of the digestive system. Your teacher may give you additional guidance.

Part of the Digestive System	What happens to the food? Is it mechanically or chemically broken down, used or stored, changed into something else, etc.?	Does this body part do anything else to help with food supplies? Does it store something or do something else?	Where does the food go next?
Mouth			
Stomach			
Liver and Gall Bladder			
Upper Intestine			
Lower Intestine			
Circulatory System			

So what is the story of food being digested to get food to your cells? How does "food" get from a sandwich to the food for your cells (sugar in the cell)?

Reading: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy: Cellular Respiration in Animals

We have learned that plants manufacture sugar (their food) from carbon dioxide and water using energy from light through the processes of photosynthesis. We also learned that most animals are not able to manufacture their own food. Animals must eat or absorb their food. The primary source of food for all animals begins with plants and the sugars they produce.

The sugar from plants is either eaten directly, by eating plants such as lettuce, or indirectly, by eating animals that ate plants, or by eating products made from plants or animals. We will explore the path the sugar takes from plants to animals to other animals in the next unit when we consider ecosystems. For now, let's focus on what happens to the sugar that an animal digests and delivers to the cells in its body. How does the animal get the energy it needs to live and grow from the sugar?

Remember that cells are the basic unit of life. This means that cells are where all the work of an organism occurs. So when we think about the energy needs of an organism, we need to think about cells and how the cells get energy. Sugars and starches store a lot of energy. They store the energy so it does not need to be used quickly. You may also recall that the disadvantage of sugars and starches storing a lot of energy is that cellular processes need small amounts of energy in quick applications. If the energy in a sugar molecule were used for cellular processes, there would be a good amount of energy that was transformed into heat energy. The heat would be enough to kill the cell. So how do cells get the energy without wasting a lot of energy or producing too much heat?

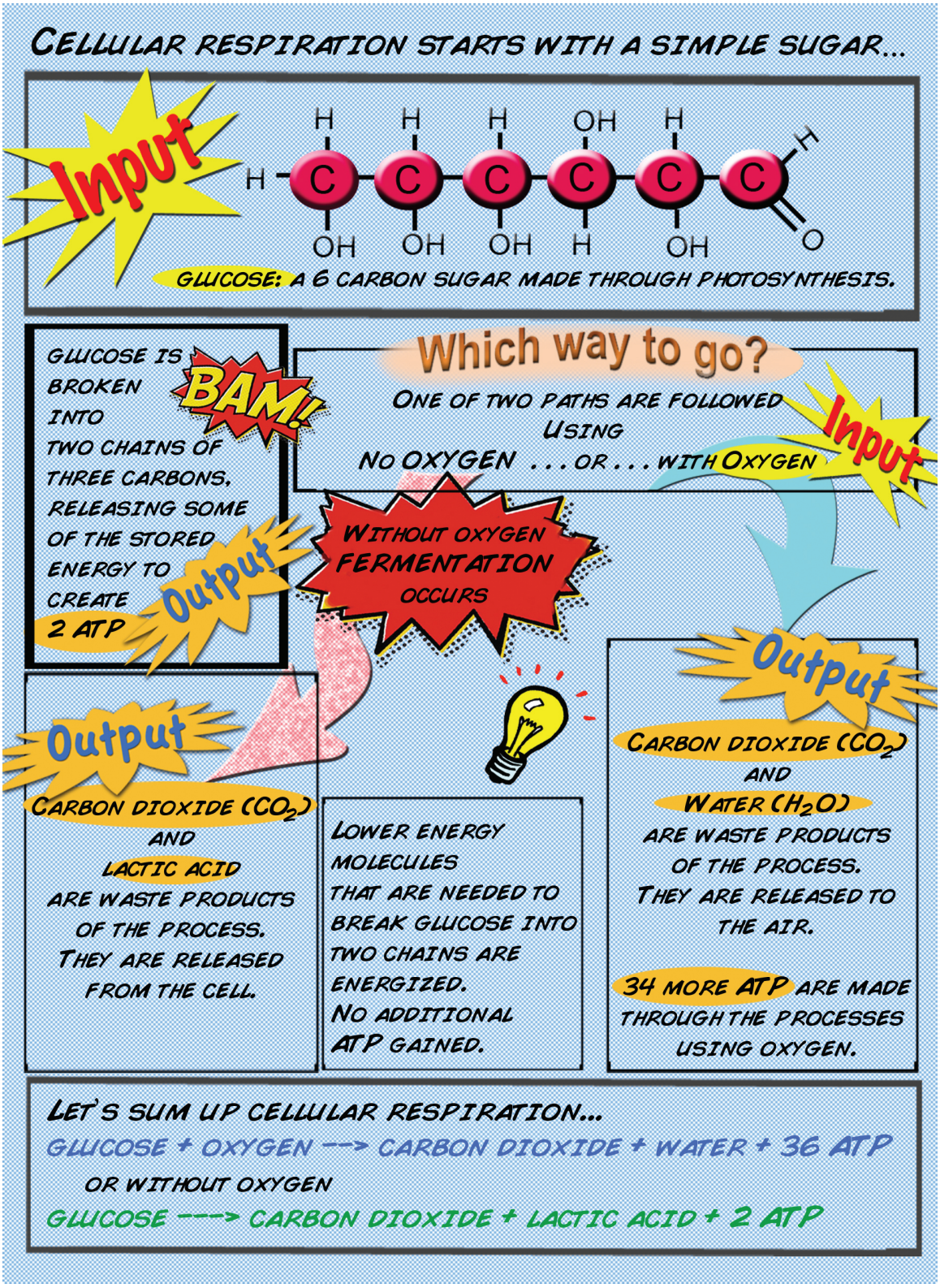
The answer is the same in animals as it was in plants: through a series of processes known as cellular respiration. Through cellular respiration, cells break down sugar in a series of stages to produce smaller energy-rich molecules that have just the right amount of energy to be by cells—ATP. The difference in cellular respiration between plants and animals is in the path without oxygen, fermentation. Let's review the inputs and outputs of cellular respiration in animals.

The Ins and Outs of Cellular Respiration in Animals

Just like in plants, cellular respiration in animals begins with a macromolecule as its starting energy source. Most of the time it is sugar, so we will focus on the processes starting with glucose. If the starting product is not glucose, then end products change a little, but you will get the general idea of cellular respiration.

Animals use the sugar they digest from food sources by breaking it down through cellular respiration, just like plants, to create ATP, the energy source that cells use to do the work necessary to live and grow.

Cellular Respiration in Animals



Did you notice what was different from the inputs and outputs that happen in plants? The pathway with oxygen has the same inputs and outputs in plants and animals. They begin with glucose and then using oxygen produce carbon dioxide, water, and ATP (energy).

Glucose (sugar) + oxygen → carbon dioxide + water + 36 ATP (energy)

When animals do not use oxygen and instead go through fermentation, they produce lactic acid rather than alcohol. Sometimes when we exercise (or when an animal is exerting a lot of energy), we use up the oxygen available to cells in the muscles quickly. In this case, those cells will use fermentation so they still get some ATP and recharge some of the lower energy molecules. When our muscle cells do this, they release lactic acid. The result is that we notice a slight burning feeling in our muscles until the lactic acid has been moved away as a waste product.

So what is your answer to the question: **How do animals break down the sugar for the energy the animal cells need to live and grow?**

Reading Guide: If Plants Can Do It, Why Can't We? Breaking Down Sugar for Energy: Cellular Respiration in Animals

This cellular respiration reading describes processes that occur in animal cells. Use the questions below to help focus your reading and organize your notes. Record your notes into your notebook.

1. What information does the author provide about the processes in the title of the paper?

2. Why can't cells use the energy in sugar without converting it to another form to power cellular activity?

3. Summarize the steps of the processes of cellular respiration in animals that are illustrated on page 156 of reading in the comic strip flow.

   a. What is the big idea represented in the illustration?

   b. What are the inputs and outputs?

4. How do the processes of cellular respiration compare between animals and plants?

   a. What is similar?

   b. What is different?

5. Write a response to the question: **How do animals break down the sugar for the energy the animal cells need to live and grow?**

Matter and Energy in Organisms Summative Task Sheet

A group of students just read the following in their science textbook:

> *Organisms obtain matter and energy through photosynthesis (producers) and/or consumption (consumers). All organisms use (break down, build up, and/or transform) matter and energy to live and grow.*

Develop an essay that argues in support of this idea.

a. What evidence do you have?

b. Why does that evidence support the idea?

You can use a table similar to the one below to organize your argument. We broke out the claim above into smaller ideas to help you organize your evidence and reasoning. You will likely need more cells to add more evidence for each claim. For each line of evidence, you should indicate your reasoning (Why does this evidence support or logically lead to this claim?).

Alternatively, you can write your argument in paragraph form. Be sure to include the claims, evidence, and reasoning to support the idea above.

Claim	**Scientific Evidence** (Data that supports your claim: something that can be seen, measured, tested)	**Why does this evidence support or logically lead to this claim?** (Reasoning)
Organisms obtain matter through photosynthesis.		
Organisms obtain energy through photosynthesis.		
Organisms obtain matter through consumption.		
All organisms use the matter to live and grow.		
All organisms use the energy to live and grow.		

Guidelines for Your Hydroponic Vegetable Garden

You are going to design a vegetable garden using hydroponic techniques. Hydroponic techniques are a method of growing plants without soil, using nutrient-rich water. We learned that plants do not need soil to grow. The primary purpose of soil for plants is to provide some nutrients and support to hold the plant in place.

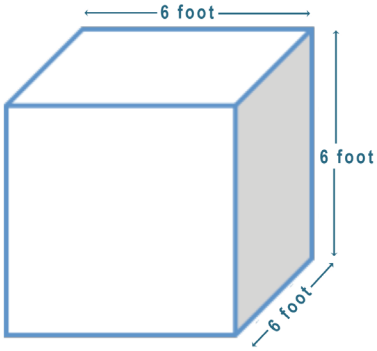
In your hydroponic garden, you will apply what you learned about what plants need to live and grow. You will also need to conduct additional research to learn more about hydroponic techniques and nutrients that your plants will need. You will have to add these nutrients to the water supply for the plants.

Mission Objective

Your mission is to design a hydroponic garden that will grow two food crops for people. The design should allow the growth of enough crops to significantly contribute to at least two meals for four people. Since the crops are intended to be eaten, your design must meet safety guidelines, considering how you will use electricity, what will go into the water, and so forth. You should review and follow safety guidelines from your teacher and have your teacher review your design plans. You can get extra points if you follow organic certification guidelines. You can find information on the guidelines at the following website: http://www.extension.org/pages/18735/an-introduction-to-organic-certification-requirements.

Size

Your garden needs to be small and easy to manage. It should fit within a 6' wide x 6' deep x 6' high space for both crops. Remember, it must grow enough crops to significantly contribute to at least two meals for four people. You can get bonus points for a garden design that is able to be continually in growth/harvest cycle year-round.



Crops

Your crops must include two of the following vegetables:

- spinach,
- corn,
- tomatoes,
- peas (or some other type of legume),
- squash, and/or
- another vegetable approved by your teacher.

Design

The design should include the following:

1. A diagram of the garden that shows how the garden will be built and what it will look like when it is complete. The diagram should indicate the size of parts as well as the whole of the plant.
2. A list of needed materials and parts.
3. A description of how to build and maintain the garden through at least one growth cycle.
4. A justification for the design—how will this design give the plant what it needs, based on your understanding of photosynthesis and respiration.
5. A description of the movement of energy in your system (including what happens in the plants).
6. A description of the movement of matter in your system (including what happens in the plants).
7. A description of the estimated expected crop output.

You may decide to build your garden as a science fair project or to see how the crops develop over time.

Sample Information on Vegetables and Hydroponics

Spinach

Spinach reaches edible maturity quickly (37 to 45 days) and thrives best during the cool, moist seasons of the year.

Varieties

- **Melody F_1:** Plants are large and quick growing with very deep color. This variety is for both spring and fall crops.
- **Vienna F_1:** Large dark green leaves are produced on upright plants. Restrict the variety to fall crops.
- **Skookum F_1:** Round dark green leaves borne on upright plants. Good for spring and fall plantings.
- **Savoy Hybrid 612F:** Large dark green leaves on an upright plant type. It is good for the fall crop and for shipping fresh and freezing.
- **Seven R:** Plants are large and quick growing, good for mechanical harvesting and processing.
- **Tyee:** Plants are large, fast growing, very slow bolting, heat and cold tolerant.

Growing Conditions

- pH should range between 6.4 to 6.8. Low germination, yellowing and browning of the margins and tips of seedling leaves, browning of roots, general slow growth, and even death of plants may indicate that the soil is too acid. If the pH is too high, leaves may have a yellow color referred to as chlorosis.
- Spinach requires relatively high levels of nitrogen (N), potassium (K), phosphorus (P), and boron (B) in its nutrient supply.
- Spinach quickly bolts (produces a flower stalk) and produces seed under long day (short night) and warm weather conditions. The terms "long standing" and "slow to bolt" in the seed catalogs are associated with varieties that have shown a slowness in bolting to seed.
- Best yields are obtained when the days are short and the temperature is moderately cool because the plant will continue to grow without starting to develop a seed stalk. High temperatures are likely to result in leaf yellowing.

Information obtained from Sanders, DC. (2001). Horticulture information leaflets. Spinach. Raleigh, NC: NC State University. Available at: http://www.ces.ncsu.edu/depts/hort/hil/hil-17.html

Corn

Corn reaches edible maturity in 65 to 95 days and thrives best during the warm and wet seasons of the year. It requires full sunlight to grow.

Varieties

- **Early and Medium Early:** Earliking, Spring Gold, Bravo, Sundance, Aztec
- **Mid-season:** Gold Cup, Golden Cross Bantam, Seneca Chief, Victory Golden, NK-199, Jubilee, Merit, Sugar Loaf
- **Late:** Honeycross, Iochief, Silver Queen (white)
- **Mixed White and Yellow Kernels:** Honey and Cream, Butter and Sugar, Gleam and Gold, Sprite, Sweet Sue, Sweet Sal

Growing Conditions

- pH range should be between 5.8 to 6.5.
- Corn grows best when temperatures range from 60 to 80 degrees F.
- Corn requires relatively high levels of Nitrogen (N), Potash (K2O), and Phosphorus (P) in its nutrient supply. This can be obtained using a 12-12-12 and 6-24-24 fertilizer mixture.
- Corn requires large amounts of water, consuming about 0.25 inches of water a day during growth periods.
- The corn stalks can grow quite tall and require adequate support. Some varieties grow shorter stalks.
- Corn plants will develop long roots, some as long as four feet. In hydroponic systems these can be coiled, but there needs to be sufficient room for the roots to grow.

Information obtained from:
http://www.ag.ndsu.edu/procrop/crn/crnftr05.htm
http://www.uri.edu/ce/factsheets/sheets/corn.html

For information on other crops, conduct a search for growing requirements for each crop (vegetable). Be sure to select reliable sites that are based on scientific evidence. University sites are usually trustworthy. Below are a few to get you started.

Tomatoes

For information on tomatoes and hydroponics see the following websites:

http://ag.arizona.edu/hydroponictomatoes/overview.htm
http://www.hydroponics.com/gardens/tomatoes.html

Peas

http://usagardener.com/how_to_grow_vegetables/how_to_grow_peas.php
http://ohioline.osu.edu/hyg-fact/1000/1617.html

Squash

http://www.ces.ncsu.edu/depts/hort/hil/hil-24-a.html
http://www.hort.purdue.edu/ext/ho-8.pdf

Institute for Learning
Learning Research and Development Center

University of Pittsburgh
3939 O'Hara Street
LRDC Suite 310
Pittsburgh, PA 15260
T: 412-624-8319

www.instituteforlearning.org