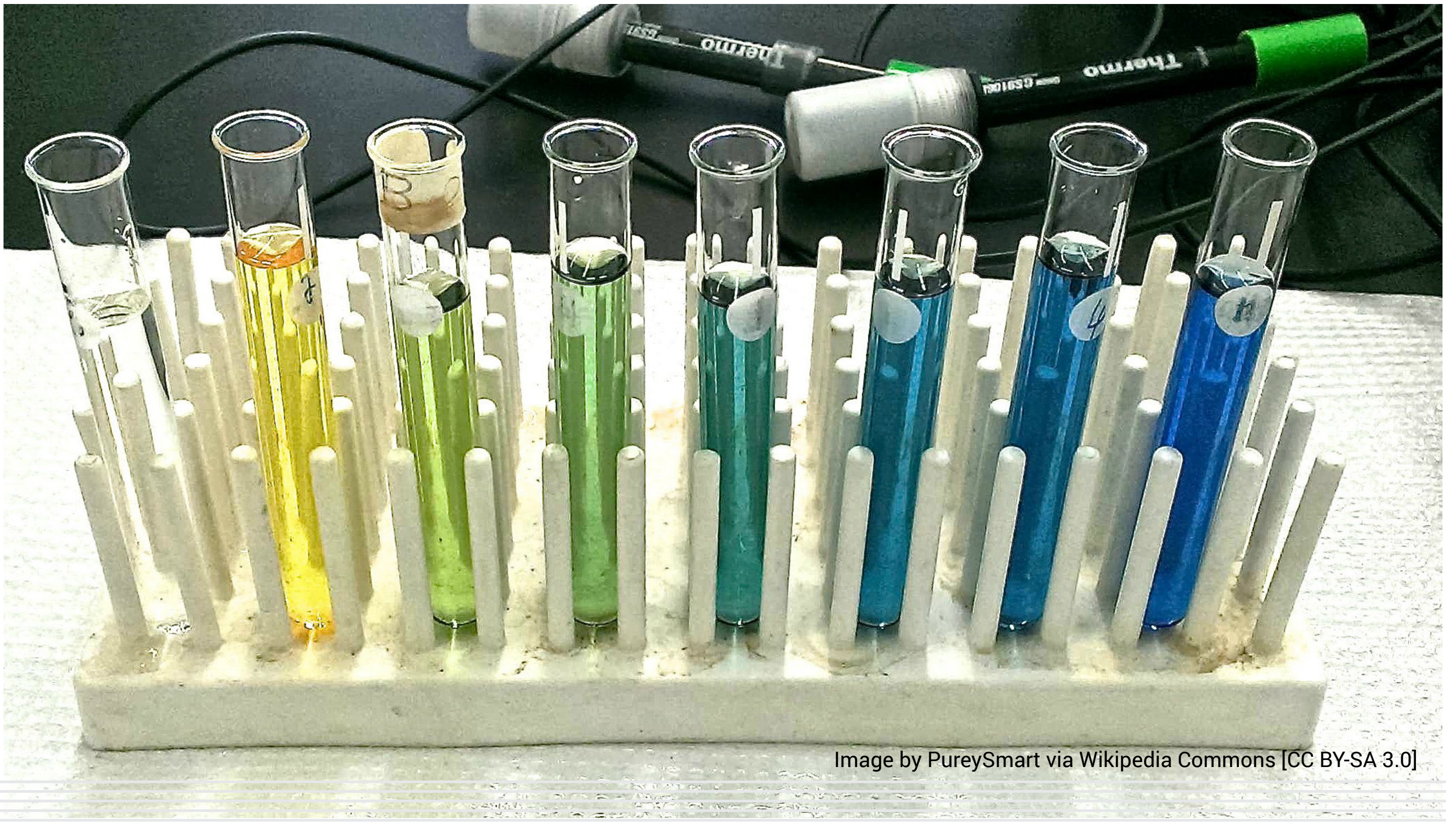
Investigating Gases

7.4



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Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Lesson Concept

Conduct an investigation to produce data to explain that carbon dioxide gas is involved when plants matter (live and grow).

Investigative Phenomenon

The amount of carbon dioxide in the water surrounding aquatic plants increases and decreases depending on the amount of light.

Standards

Refer to Appendix 7.4 for NGSS, CCSS (ELA), and California ELD Standards.

7.4 Investigating Gases

Storyline Link

In this lesson, students will build on the learnings from the previous lesson that plants need sunlight to add mass, but soil and water are not part of the additional mass. In this lesson, students investigate the gases that are exchanged within the plant. They will continue to use models to explain their thinking about the phenomenon, extending their models to include components too small to be seen (invisible). Students will plan and conduct another investigation by building on their understanding of variables and tools from the previous lesson to plan and conduct the investigation. Students will apply the concept of stability and change to think about how changing the inputs in one part of the system (amount of light, amount of CO_2), affect other parts of the system as they analyze evidence collected from their investigations.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

120 minutes

Part I	60 minutes	Explore
Part II	60 minutes	Explain

Materials

Group

- ❑ 2–4 Elodea sprigs (found at pet stores)
- ❑ 2–4 125 ml Flasks
- ❑ 2–4 Rubber stoppers (#5) or other sealant such as wax
- ❑ Diluted 0.1 solution of bromothymol blue (BTB) by adding seven drops to 30 ml of water
- ❑ Water
- ❑ 1 Light source (full spectrum if possible—can be purchased at home improvement or pets stores)
- ❑ 1–2 Drinking straws
- ❑ Chart paper and markers

Individual

- ❑ Science notebook
- ❑ Safety goggles
- ❑ 7.4.H1: Storyboard Template (optional)

Advance Preparation

1. Create enough BTB 0.1 percent solution for each team to have enough solution to fill two flasks, plus extra solution in case students need to set up their investigation a second time.
2. Practice with blowing into the BTB solution (while blue) to create a color change.
3. Review safety procedures for working with chemicals and glassware in your state safety handbook such as chapter 7 of https://www.cde.ca.gov/pd/ca/sc/documents/scisafebook2014.pdf.
4. Print one copy per student of **7.4.H1: Storyboard Template** (optional).

Procedure

Part I

Explore (60 minutes)

Conduct an investigation to collect data on observable and unobservable variables to explain how trees rearrange carbon dioxide and water into complex molecules to support growth.

1. Ask students to review their notes from Lesson 7.3: Historical Investigations. Ask them to think about what they know so far about where plants get the matter to grow from a seedling into a tree. Review the student questions collected at the end of Lesson 7.3: Historical Investigations. Explain that students will have an opportunity to plan another investigation to answer some of their questions in this lesson.
    - Ask students to think about the models they created. Students should review the entries of their models in their science notebook from Lesson 7.3: Historical Investigations (step 11). How do the models describe how the tree is getting energy to gather more mass? With which parts of their model are they satisfied? For which parts do they think need more information? What did they include in their models about energy?
    - Tell students that all models are revised with new evidence. In the next part of the lesson, they will have an opportunity to evaluate the limitations of their model and design an investigation to collect evidence that may improve their model.

TEACHER NOTE

▶ This is another opportunity to assess what students understand about the crosscutting concept of Energy and Matter, similar to the assessment in Lesson 7.3: Historical Investigations. New aspects to consider in this lesson include: Does the model include a representation that matter is made of particles? Are students thinking about the amount of matter before, during, and after the process? Do they include energy in different forms? If they do not, you may want to consider pausing the sequence here and returning to previous lessons on matter taught prior to this sequence. Students may need an opportunity to reconnect with these concepts via a brief review of their science notebook, additional reading or video, or brief small group discussion.

2. Chart student responses as they share. Summarize their thoughts once all have had a chance to discuss what we know so far on the chart. Explain to students that they have developed their models and will continue to consider the limitations of their models to decide what additional evidence they need to revise and improve their models. Tell students that they are also deepening their use of the crosscutting concept Energy and Matter to help think about ways in which the plant is transferring energy to gain matter for growth. Direct students to their previous questions (in the class chart and their science notebook) and ask them to consider what questions they have developed that relate to how the plant is getting energy or how the plant is using energy to get more matter.

3. Use the ideas that students shared to facilitate a discussion about gases and how to find out more about them (in the next investigation). Ask students to consider which part of the system gases might exist. Direct students to write out their ideas in their science notebook before continuing with a class discussion. If the issue of gas exchange has not come up yet, ask students to think about the historical investigations. What did they tell us about gases? (Gases are exchanged, but the historical studies did not provide evidence about what gases were involved.) Students may bring up oxygen or carbon dioxide from personal experience. If students bring up these gases, acknowledge the idea, and suggest that we need additional data to understand this better. Acknowledge that while we know a great deal about how trees rearrange matter to gain mass, we need additional information about how gases are moving through the system to improve our models and explanations. Provide a few minutes for students to record any new ideas into their science notebook from the class discussion.

Demonstration of Technique

TEACHER NOTE

You will want to review safety procedures with the class prior to starting the investigation. Important safety issues to reinforce basic safety rules include do not put any materials in your mouth, wear goggles when working with liquids, and use care when using glassware. You should have a special container to collect any broken glass so it is not placed in the classroom trash can. Bromothymol blue is a relatively safe chemical, but you should review the material safety data sheet prior to using it: http://www.labchem.com/tools/msds/msds/75033.pdf.

4. Explain to the class that they will plan and conduct their own investigation to collect more evidence in their table groups (2–4 students). During this investigation, students will be able to use a special chemical called bromothymol blue or BTB for short. Demonstrate with the BTB:
   - Fill a beaker half-full with the diluted BTB.
   - Tell the class that you are going to blow into the liquid with a straw. Ask the class to think about what you will probably add to the liquid when you blow into it. (What gas is in our breath when we breathe out?)
   - Insert a straw into the liquid and gently blow until the color changes from blue to green to yellow. It is useful to stop when the liquid begins to change color and ask the class what they think is happening. What do they think will happen when you continue to blow into the liquid? WEAR GOGGLES WHEN DEMONSTRATING.
   - Ask the class to discuss with a partner what they think is happening. Solicit a few suggestions from the groups. Students should connect the blowing breath into the liquid with the color change. Ask students what they know about the gases in their breath. What is in your breath? Confirm that you are adding CO_2 to the liquid when you blow through the straw.

TEACHER NOTE

BTB is an indirect indicator that CO_2 is present. BTB is normally blue (as the name indicates), but when CO_2 is added, it will cause the BTB to change to green, and with increasing amounts of CO_2, to yellow. When CO_2 is taken out of a BTB solution, the color change reverses back toward blue. For English Learners, it is useful to have a visual reminder of terms such as CO_2 on a yellow card, some CO_2 on a green card, and no CO_2 on a blue card.

- Ask students to think about how they might investigate their question using the BTB. This is a good place to introduce roles for discussion. If you already have an established protocol for roles during group work, this is a good point to use them. Otherwise, introduce the following roles to be used as groups plan their investigation:
  - **Facilitator:** This person makes sure that the group is on task and the discussion is moving. The facilitator can remind the group about the purpose of your tasks or ask questions to keep the discussion going. He or she also makes sure that everyone is contributing to the discussion and all ideas are included.
  - **Timekeeper:** This person's job is to watch the time and make sure the group is moving along in the task at an appropriate pace. The timekeeper can alert the group of certain points in time with comments such as half our time has passed or there's *5 minutes left*.
  - **Summarizer:** This person will record the important ideas from the group discussion and provide a summary of the discussion for the group. The summarizer may summarize ideas in words, symbols or pictures. Other students then suggest edits and additions or simply approve the summary.
  - **Presenter:** This person will share the group's ideas with the class. The presenter should discuss with the group how much of the discussion/information will be shared.

  You can assign roles randomly or allow students to select. It is useful to provide descriptions of these roles on a student handout or as a table placemat.
- Allow students to discuss in their groups, and listen to their discussions as they work. As students consider using the BTB to investigate their questions, ask the groups to consider how the BTB might provide evidence about how gases are consumed over time and how they might use the color changes. Have students identify in which part of the system to use BTB to develop a deeper understanding. How might the color change (effect) help us to understand the phenomenon (what cause)? Direct students to record their ideas in their science notebook. For struggling students, you can provide a template or a table with these three headings: Part of the System to Investigate, Changes in Gases to Investigate, and What a BTB Color Change Tells Us About Gases. This is a good time to remind students that they created a plan for an investigation in Lesson 7.2: Planning Plant Investigations and evaluated plans in Lesson 7.3: Historical Investigations. Ask students to refer back to these plans and the ways in which they identified independent and dependent variables in those plans. Students should also consider what they learned about selecting which data measurements to collect and the tools needed to do so.

- After a few minutes of discussion, ask the groups to review their science notebook, and provide time for the summarizer and presenter to get ready to share their ideas with the class. Record possible ideas shared by the students on the board or chart paper. This will provide an opportunity to check if students have any questions about what BTB is, what the colors indicate, and how to use BTB to further their investigation. Allow student teams to revise their plan based on any ideas from the whole group discussion. Look for evidence that students are considering the inputs and outputs of the phenomenon in their design. Students should be able to justify the use of BTB to revise weak parts of their model (by adding additional evidence).

Planning Their Investigation

5. Tell students that they will be given 20 minutes to discuss/plan and write their procedure. Remind students that their investigation should gather evidence to help explain what gases are exchanged within a plant/tree system as it lives and grows. Advise students to consider whether the transfer of energy is affecting the motion of gases in and out of the plant (system) when they select a question to investigate. Remind them that they are using the crosscutting concept of Energy and Matter to think about their investigations.
6. Tell students that they will need to draw or storyboard their plans and have them approved by you before gathering materials. (If needed, a template for storyboard is provided in **7.4.H1: Storyboard Template**). Teams can continue using the roles from the prior group or switch roles. Clarify that the "summarizer" for the group takes responsibility for writing the storyboard. Provide feedback during the planning time as students work. Explain to students that they will be able to leave their experiments set up overnight. Explain that they will collect data on the next day. Remind students that they have planned investigations in Lesson 7.2: Planning Plant Investigations and Lesson 7.3: Historical Investigations) If necessary, you can clarify elements they have considered in the development of their previous plans:

    - identify the scientific question that you will be testing in your experiment
    - choose the independent and dependent variable(s)
    - select variable controls
    - decide what tools are needed to do the gathering
    - determine how measurements will be recorded

    Possible student investigations might include changing the number of plants in each tube, the amount of light exposure, the amount of carbon dioxide placed in the water (students can add CO_2 into the liquid using the method modeled earlier). Students may want to put a flask in a cabinet or cover it with paper to reduce its access to light. Others may decide to change the initial color of the liquid in which the plants are placed. As students begin to develop their plans, monitor that they are using the crosscutting concept of Energy and Matter as they select variables and tools for measuring. Ask students to explain how their design will gather evidence about the motion of gases in and out of a plant. Did students consider the transfer of energy (such as availability of light) in their design? These questions are to ensure that students have considered these concepts thoughtfully in their plans, but do not direct students on how to conduct their investigations. You will want to make sure that at least one group's investigation has a plant in yellow BTB in the light and one plant in yellow BTB in the dark. However, running two plants in blue BTB (one in the dark and one in the light) is also useful to the class discussion.

TEACHER NOTE

This is an opportunity to differentiate for students progressing more rapidly or slowly with the SEP through the complexity of the investigation design. Since students will conduct this investigation, the sophistication of data collected and the complexity of the design can be adjusted. For example, some groups may want to collect data of multiple variables (multiple set-ups) or run part of the investigation outside of the classroom.

7. As students work collaboratively to develop their investigation plans, encourage teams to think about how to create a "fair test" and how to take accurate measurements. Remind students that they have considered these elements before, and if they are struggling, students can review their previous plans from Lesson 7.2: Planning Plant Investigations and Lesson 7.3: Historical Investigations. These details should be included in their plans or storyboards. Students may need help limiting their investigation to one variable or including some type of control for comparisons. This activity works best when there is a control set-up (no change) and an experimental set-up (change based on variable selected) in order for a color change to be interpreted accurately. If teams have not thought about what or how they will record their data, ask them to think about how they might do this. Move teams along to get their plans completed within the 20-minute time window.

8. Once students have completed their plan, direct table groups to swap their plan with another group. Tell students to provide feedback to the other group on their investigation plan. Student teams should record their questions and suggestions on sticky notes on the other team's plan. Students may need support on how to give feedback. Tell students that feedback has to be detailed and suggest some action. You may choose to provide feedback sentence stems, such as:

   Need Clarification

   - What do you mean by _____?
   - Can you elaborate on _____?

   Suggestions for Improvement

   - It seems like you are measuring _____. We agree/disagree because _____.
   - You are controlling _____. We think you should ALSO _____.
   - Your plan says _____. We disagree because _____ and think you should change_____.
   - We agree/disagree with the plan to _____ and think you should add _____ because _____.
   - We do not think _____ in the plan matches _____.

Select which groups will share and provide feedback by common design elements or complementary areas of strengths and weaknesses.

9. After 10 minutes, direct the class to return the plans to the original team and give students a few minutes to consider the feedback and revise their plans before bringing it to you for approval. Remind students that it is useful to get ideas from our peers about ways we might improve our designs. Tell students that they should read the feedback carefully as a group. If the feedback is unclear, they can ask the other group for clarification. Discuss whether or not you agree or disagree with the feedback and revise your work accordingly.

10. Once teams have completed their plans and they have been approved, direct them to get their supplies and set up their experiments before the end of the class period. Remind students to record the initial conditions of their experiments in their science notebook before leaving for the day.

Conducting the Investigation

11. Provide another 10–15 minutes for students to set up the experiment according to their design. The experiments will need to be left overnight (24 hours). For those that include light, the lights should remain on for the entire 24 hours.

Part II

Explain (60 minutes)

Analyze and interpret data to provide evidence for how trees rearrange carbon dioxide and water into complex molecules to support growth.

12. The next day, quickly review the purpose of the investigations (to find out additional information about how trees rearrange matter to improve our models). Students should review their plans in their science notebook and then move on to collect data from their experiments. Students should be recording data in the data table in their science notebook. Rotate to each group and ask the teams to tell you what they observe in their data. Students may respond by talking about the color change observed in one but not both conditions (control and experimental). If this happens, ask students to tell you about both conditions. Ask students, "What was similar? What was different?" Depending on the variables selected, there may not be any noticeable difference in the results. Assure students that "no change" may still be an important finding.

13. Allow time to consider what they will share with the class. In the grade 3–5 band, students make observations and/or measurements to produce data to serve as the basis for an explanation. In this lesson, students are extending that previous learning to use data to serve as the basis for evidence to answer a scientific question. Students may need facilitation in their small teams to support the connection between the question they were attempting to answer and the data they are selecting as evidence.

14. Once teams have collected data from their experiments, ask each team presenter to report the team's findings. Tell teams to report on the variables they tested and the results after 24 hours. Students should be encouraged to ask questions as teams report their findings. However, instruct students to ask clarifying questions, rather than evaluating the experimental design. Critiquing the design of an investigation is an important skill, but the focus at this point of the lesson is to provide students with enough data to make a claim. Remind students to use the discussion prompts from Lesson 7.2: Planning Plant Investigations.

15. As teams report, chart the results on a class chart. For teams who chose to test the same variable, ask the teams to discuss whether their data are consistent with that of the other team. If not, what might be the cause? Providing a set of sentence frames around discussing ideas will support English Learners in the classroom discussion. Examples can be found at https://www.fossweb.com/delegate/ssi-wdf-ucm-webContent?dDocName=D567151.

16. After each team has presented their results, students will have all the data from the class, not just their own data. They can use all the data to revise their previous models about what is happening with matter in the growth of the sequoia tree or plants at their home/school. Tell students that they will now work on summarizing the class results and generating questions that still remain.

17. Distribute chart paper and markers to each team. Provide 10 minutes for teams to review and think about their previous models. On the chart paper, teams should represent their new understanding of how trees gain mass, integrating their new data into their model.

    - Encourage students to include information about the variables selected by their team and other teams into their revised model.
    - Ask students to consider how the movement and rearrangement of gas particles explain what was observed over time as the seedling grew into a large tree. How does the behavior of particles on a very small scale explain the observations of things at a large scale?
    - Ask students if their models explain how changes in the variables would lead to growth over time. How might changes in one part of a plant cause large changes in another part?
    - Ask students to consider where energy is entering the system. How is that shown in the model? How do you see that energy transferring into the system?
    - Ask students to consider if changing the inputs in one part of the system (amount of light, amount of CO_2), would affect other parts of the system. For example, how does changing the amount of light change the amount of CO_2 produced?

    Students should include ideas about how matter moves into and out of the plant in different conditions. (The plant absorbed CO_2 when placed in sunlight but not when placed in the dark. Plants only absorb CO_2; they do not produce it. Without sunlight or CO_2, the plants die and start to decompose). Their models may include ideas about how access to light energy affects how plants cycle matter into and out of the plant. At this point, students should have a conceptual idea that some matter (CO_2) moves into a plant in the presence of light energy (Energy and Matter) and that the energy transfer is a driver for more CO_2. However, this is the first time that students have been asked to use the crosscutting concept Energy and Matter with matter that they cannot see or touch (CO_2). In Lesson 7.5: Matter Models, students will investigate the particles involved in the phenomenon. Students' ability to connect this crosscutting concept to the molecular nature of the phenomenon may not develop fully until the end of the next lesson. They may start to include the reference to particles in their models and arrows to show how specific particles are moving into the plant with arrows or other drawings (Modeling) to explain how plants use energy to grow (LS1.C & PS3.D).

18. Tell students to record their new ideas about plants, matter, and their models in their science notebook. Ask students to consider what questions they now have about how plants get and use energy and matter, the relationship between energy and matter, their models, or any other thoughts about the phenomenon. Explain that in the Lesson 7.5: Matter Models they will continue to investigate the phenomenon.

19. ▶ Assessing student progress: Multiple student artifacts were developed during this lesson including group investigation plans and models and individual science notebook entries including revised models. This would be a good opportunity to review individual student models in their science notebook. You could also ask students to record their model on a separate piece of paper in step 20. Reviewing these individual models will give you an opportunity to assess class progress and in particular, students above or below the learning target. This is also an opportunity to provide individual student feedback. As you review the student models, provide specific feedback about where the model is effective and points that need clarification or addition. Some suggested areas to review include:

    - Are the variables selected by the team included in the model?
    - Does the model indicate the movement and rearrangement of gas particles? Is this connected to tree growth?
    - Does the model show energy is entering the system? Does it clearly show how energy transfers within the system?
    - Does the model show how changing the inputs in one part of the system affect other parts of the system? Does it show how modifying the amount of light changes the amount of CO_2 produced?

TEACHER NOTE

The intent is not to "correct" students' models but to provide guidance that will help students reflect on their model and provide suggestions for things they may have not considered. When you return the feedback to students, tell them to read the feedback and consider what they could use to improve their models. Tell them if something in the feedback is unclear, they should ask you for clarification. Remind students that the feedback is intended to be useful and is not an indication of a good or bad model.

References

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Toolbox Table of Contents

7.4.H1 Storyboard Template 7.4.14

Storyboard Template

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [*Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.*]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Planning and Carrying Out Investigations
• Plan an investigation collaboratively and in the design identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded and how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. • Collect data to produce data to serve as the basis for evidence to answer scientific questions.
Engaging in Argument from Evidence
• Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
Developing and Using Models
• Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution (from Grade 3–5).

Appendix 7.4

DISCIPLINARY CORE IDEAS (DCI)
LS1.C Organization for Matter and Energy Flow in Organisms
• Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.
PS3.D Energy in Chemical Processes and Everyday Life
• The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.

CROSSCUTTING CONCEPTS (CCC)
Energy and Matter
• Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within a system.
• Models are limited in that they only represent certain aspects of the system under study.

Common Core State Standards (CCSS)

CCSS SPEAKING AND LISTENING
ELA-LITERACY.SL.7.1.B
Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.

Appendix 7.4

California English Language Development (ELD) Standards

CA ELD		
Part I 7.3 Supporting opinions and persuading others		
EMERGING	EXPANDING	BRIDGING
P1.7.3 Negotiate with or persuade others in conversations (e.g., to gain and hold the floor or ask for clarification) using learned phrases (e.g., *I think … , Would you please repeat that?*) and open responses.	**P1.7.3** Negotiate with or persuade others in conversations (e.g., to provide counter-arguments) using learned phrases (*I agree with X, but …*), and open responses.	**P1.7.3** Negotiate with or persuade others in conversations using appropriate register (e.g., to acknowledge new information) using a variety of learned phrases, indirect reported speech (e.g., *I heard you say X, and I haven't thought about that before*), and open responses.