Session 7: Using Evidence and Reasoning, and Tracking Carbon

Overview

The content focus of this session also reflects the progression of ever-deepening understanding of the Crosscutting Concept of Energy and Matter in both physical and life processes through a deep dive into the carbon reservoirs and flows of the carbon cycle. Participants write their first ideas about 1) how do organisms use carbon? and 2) where does most of the matter in plants come from? Then throughout the session they gather evidence and construct explanations to answer the questions. They use information from a number of various data sources (investigations, simulations, graphs) and a video, and examine different claims that are made. They engage in strategies that encourage discussion of alternative ideas and evaluating claims, and use the strength of evidence and clarity of reasoning to determine the most likely and scientifically accurate explanations for the phenomena as well as how to interpret the data. Participants use their understanding of the science concepts to construct their own model of the carbon cycle.

Session Goals

Theme	Goals
Climate Science Ideas	Understand that: ● Most organisms get energy and materials to build their bodies from molecules that contain carbon. They break down these molecules and release carbon dioxide gas. This is respiration. (OSS 2.2) ● The amount of carbon in all the carbon reservoirs combined is fixed, but the amount of carbon in each individual reservoir can change as carbon moves (flows) from one reservoir to another. (OSS 2.2) ● Most of the matter in plants comes from carbon dioxide (CO_2) from the air, and also from water. (OSS 2.3)

	• CO_2 concentrations in the ocean and atmosphere vary throughout the day and by season, and have increased over the last 50 years (OSS 2.4)
Using Data	Build on skills covered in previous sessions and explore ways to: • Learn about the use and importance of proxies in science. • Observe the overall pattern in the data by looking at a trend line.
Teaching & Learning	Engage in effective strategies designed to explore multiple ideas and encourage discussion
Framework /NGSS	Engage in arguing from evidence as described in the *Framework for K–12 Science Education*

Materials Needed

For the class

- PowerPoint presentation
- Digital/data projector
- Whiteboard or flip chart paper and pens
- Masking tape
- Access to videos:
  - Carbon Tracker online video https://www.youtube.com/watch?v=O4WMdwIwrSw
  - It's All About Carbon video https://www.youtube.com/watch?v=ypbb9Zi5Tao

For each participant:

- Yeast Investigation Worksheets
- Evaluate the Evidence: The Source of Most Matter in Plant Structures handout
- Researching Photosynthesis handout
- Carbon cycle diagram
- Strategies to explore multiple ideas (from Session 2)
- Argumentation Activities
- Following the Water in Photosynthesis (reading)

- Climate Science Ideas chart (from Session 2)
- (optional) Carbon in food (OSS 2.2)
- (optional) Carbon sugar to air (OSS 2.2)
- (optional) Kelp reading (OSS 2.3)
- (optional) PAR and DO handout

For each group of three participants:

- 1 copy of Plant Investigations (B, C, and D in an envelope)
- 1 Concept Cartoon – Mass

For the B. Activity: *Tracking Carbon through Respiration* (OSS 2.2)

- 1 oz active dry yeast (4 packets)
- 16 oz distilled or other water (tested to be sure it doesn't change BTB's color)
- ½ tsp measuring spoon
- ¾ tsp baking soda
- 1 black permanent marker (fine point)
- 1 measuring pitcher, 500 mL
- 3 pipettes
- 2 test tubes
- plastic container with sealable top
- 1 bottle (18.75 g) glucose powder
- 1 plastic drinking straw
- 1 pair scissors
- 1 clear plastic cup (9 oz)
- 1 bottle bromothymol blue (BTB)
- 1 test tube cleaning brush

For each group (2 pairs) of participants:

- 1 cafeteria-style tray
- 2 clear plastic cups (9 oz)
- 4 test tubes with yeast culture
- 1 15 mL bottle of BTB (0.04% solution)
- 2 small plastic cups (1 oz) with 2 pipettes of tested water

- 2 small plastic cups (1 oz) with 2 pipettes of glucose solution
- 1 copy of Carbon Cards in an envelope
- 4 pipettes
- 2 test trays
- 4 stir sticks
- (optional) colored pencils

For C. Activity: *Tracking Carbon through Photosynthesis Part 1* (OSS 2.3)

- Scientific Evidence chart from Session 4 (or 1 sheet of chart paper and a marker)
- 1 tree branch
- (optional) jar with Elodea and BTB solution* (optional activity set up a few days before the start of this session)
- scissors or paper cutter

Preparation of Materials

Before the day of the session:

1. **Set up projection system/review multimedia.** Set up and test the projection system to be sure all participants will be able to see the videos at https://www.youtube.com/watch?v=O4WMdwIwrSw and https://www.youtube.com/watch?v=ypbb9Zi5Tao
2. **Duplicate copies.** Copy the following pages:
   - Make one copy for each participant:
     - Strategies to explore multiple ideas (provided in Session 2)
     - Argumentation activities (provided in Session 2)
     - Carbon cycle diagram
     - Yeast Investigation Worksheets
     - Evaluate the Evidence: The Source of Most Matter in Plant Structures handout
     - Researching Photosynthesis handout
     - Following the Water in Photosynthesis (reading). There are two copies of this reading on one sheet of paper; make the copies then cut the paper in half to provide a copy on ½ sheet of paper for each participant.

- Make one copy for each small group of 3:
    - Concept Cartoon–Mass
    - Plant Investigations
- Have a few copies of *Matrix of K–12 Progressions SEP* handout from Session 5 available for small groups to share in case they have misplaced their copy.
- Optional handouts
    - Optional: Carbon in food
    - Optional: Reflection – Carbon sugar to air
    - Optional: Kelp reading
    - Optional: PAR and DO handout

3. **Label yeast test materials.** Using a permanent marker and Figure 2–1 on page 158 from OSS Unit 2 as a guide, (**a**) mark "S" on half of the test tubes; (**b**) mark "NS" on the other half of the test tubes; (**c**) mark half of the pipettes with "S" and mark "NS" on the other half; (**d**) mark half of the 1 oz cups "Sugar" and the other half "Water;" and (**e**) mark all test trays by writing "S" on the left side and "NS" on the right side.
4. **Prepare trays.** Set the following materials for 2 pairs of participants on each tray:
    - 2 clear cups, each holding 1 "S" test tube and 1 "NS" test tube
    - 4 stir sticks
    - 2 small cups marked "Water"
    - 2 small cups marked "Sugar"
    - 2 "NS" pipettes and 2 "S" pipettes
    - 1 bottle BTB
    - 2 marked test trays
    - (optional) yellow, blue, and green colored pencils
5. **Prepare demonstration straw.** Use scissors to cut a small (~1 cm long) diamond-shaped opening near one end of the straw. This opening will prevent the volunteer from accidentally sucking up liquid through the straw.
6. **Prepare Plant Investigations envelopes (OSS 2.3) for each group.** Copy Plant Investigations (one for each group of three). Cut apart the three descriptions and place them in an envelope (one envelope for each group).
7. **Post Scientific Evidence chart** (from Session 4).
    - Evidence can come from our own investigations.

- Evidence can come from other people's investigations.
- Why the evidence supports a claim needs to be made clear with reasoning.
- Scientific explanations are based on evidence and reasoning. A good scientific explanation puts together evidence in a way that answers a question and provides reasons for the answer.

8. **Obtain a branch (OSS 2.3).** It is strongly recommended that you bring in a real tree branch for the discussion of matter and plants. A small branch is fine, but it should feel heavy enough for participants to notice its weight.
9. **Make copies of the Carbon Cards.** Make one set of 2-sided copies for each small group of 4 participants.

One to two hours before the session:

1. **Prepare yeast culture.** The following makes enough for 1 class of 32 participants:
    a. At least 1 hour before class begins, use the sealable container (in case you're doing this at home and need to transport the culture to school) to mix 1 oz of active dry yeast with 4 oz (125 mL) of body-temperature **(~99ºF)** tested water (see below in notes for success). Let it sit open to the air for at least 1 hour.
    b. After the yeast culture has been sitting for 1 hour, add 3/4 tsp of baking soda, and gently mix. This is to raise the pH slightly so the CO_2 that's produced effects a color change to BTB from blue to yellow.
2. **Make glucose (sugar) solution.** The following quantity is enough for 2 classes of 32 participants: Add 6 oz of tested water (see below in notes for success) to the measuring pitcher. Sprinkle in the contents of 1 bottle of glucose powder while stirring. Keep stirring until all the glucose is dissolved.
3. **Fill test tubes, water and sugar cups on trays.**
    a. Using one of the pipettes, transfer 2 pipettes (see below in notes for success) of yeast culture into all 32 test tubes for participants. (If you go by height, this quantity of yeast should reach ~3.5 cm up from the bottom of the test tubes.)
    b. Using a second clean pipette, place 2 pipettes of tested water into each water cup.
    c. Using a third clean pipette, place 2 pipettes of glucose (sugar) solution into each sugar cup.
4. **Prepare demonstration cup.** Add approximately 5 oz of tested water to a clean 9 oz clear

plastic cup. Add enough drops of BTB to color the water a deep blue. Place the prepared straw near the cup and set this aside until needed in the session.

5. **Prepare BTB demonstration test tubes (controls).** Add 2 pipettes of tested water to one clean test tube marked “NS.” Add 2 pipettes of sugar water to another clean test tube marked “S.” Set both test tubes aside until needed.

Optional: Immediately before the session

Determine if you will use a warm water bath to keep the yeast warm and actively respiring during the investigation. Alternatively, you can ask participants to hold the tubes tightly in their hands to provide warmth to the yeast during the investigation. If your room is warm, these steps are likely not needed.

Notes for success for OSS 2.2:

- Test the water you intend to use—add some drops of BTB to a water sample. The water should be a strong blue. If it turns at all greenish, then use a different water source. Some bottled water and tap water sources cause the BTB to change color, so distilled water is recommended to eliminate variables that will affect the expected color change.
- The pipettes are calibrated. If you pinch the top of the pipette and release, there should be from 2.5 to 3.0 mL of liquid inside pipette. When measuring “2 pipettes,” any quantity from 5 to 6 mL is fine.
- A made-up batch of yeast will be good for about 1½ days.
- If storing overnight, cover the yeast culture, and place it in a refrigerator. Allow an hour or two for the culture to come to room temperature before proceeding.
- Be sure **not** to use “rapid rise” or “highly active yeast.” These have sugar and ascorbic acid added, which interferes with the BTB indicator.
- Important: Keep the yeast warm as it respires during the investigation – use a warm water bath or have participants hold the test tubes tightly in their warm hands as they are reacting.

Session at a Glance

Task	Description	Time (minutes)
A. Introduction: *Session goals*	Session goals are shared.	2
B. Activity: *Tracking Carbon through Respiration* (OSS 2.2)	Participants do a Quick Write to access their prior knowledge about respiration and photosynthesis, and the crosscutting concept of energy and matter. They then engage in an investigation with yeast samples and an acid indicator to answer the question, "what does eating have to do with producing carbon dioxide?"	35
C. Activity: *Tracking Carbon through Photosynthesis Part 1* (OSS 2.3)	The class examines photographs of an investigation with a plant in water and an acid indicator. Groups discuss a concept cartoon to share prior knowledge, then read and discuss evidence cards to gather evidence to make an explanation about where most of the matter in a plant comes from. The activity ends with a reflection on teaching and learning strategies.	55
D. Activity: *Tracking CO_2 Over Time & Professionally-collected Data* (OSS 2.4)	Using graphs of authentic environmental data and a global CO_2 simulation video, students observe and discuss how carbon dioxide levels in the atmosphere change throughout a day, among seasons, throughout the year, and over many years.	45
E. Activity: *Tracking carbon flows*	Participants draw carbon reservoirs and track carbon flows on a diagram. Additional flows are introduced and will be added to the diagram in the next session.	15
F. Reflection	Participants return to the Quick Write prompt from the beginning of the session and add additional ideas to explain the concepts in terms of the crosscutting concepts of energy and matter. The Big Charts of Science & Engineering Practices are updated.	15
G. Homework	1. Answer reflection prompts focused on the carbon cycle,	3

	respiration, and photosynthesis. 2. Watch 1-2 short videos about fossil fuel formation, such as the following: https://www.youtube.com/watch?v=_8VqWKZIPrM or https://www.youtube.com/watch?v=zaXBVYr9Ij0 or https://www.youtube.com/watch?v=jjfs_7kwRks and answer the reflection prompts. 3. Tools of Science videos (http://toolsofscience.org/lessons.html): ● *Practice 1: Asking Testable Questions* ● *Practice 3: Proxies in Scientific Investigations*	
	TOTAL: 2 hrs 50 mins	**170**

Session Details

A. Introduction: *Session Goals*

Display session goals slide. Display the goals and briefly introduce each with a description of how they are connected and flow from one to another.

- **Climate Science Ideas:** Most organisms get energy and matter from molecules that contain carbon, and release CO_2 as the molecules are broken down. Carbon flows from one carbon reservoir to another in the carbon cycle.
- **Using Data:** Use a model as well as professionally-collected and graphed data sources to interpret patterns in atmospheric CO_2 concentrations. Practice orientation, interpretation, and synthesis skills. Explore why we use proxies in science and how to observe the overall pattern in the data through the variability.
- **Teaching & Learning:** Engage in effective strategies designed to explore multiple ideas and encourage discussion.
- **Framework/ NGSS:** Engage in arguing from evidence as described in the *Framework for K–12 Science Education*.

B. Activity: *Tracking Carbon through Respiration* (OSS 2.2)

Introducing Carbon and Reservoirs

1. **Introduce content focus – carbon and the carbon cycle.** Tell participants that the content focus of the course is now shifting towards an emphasis on carbon and the carbon cycle, started during the last session's focus on the Greenhouse Effect. Explain that we will be following carbon as it cycles around the ocean, land and atmosphere.

2. **Turn & Talk - the Carbon Cycle.** Have participants do a turn and talk and discuss the following prompts:
   a. What are other processes involved in atmospheric CO_2 cycling besides fossil fuel combustion?
   b. What does carbon and the carbon cycle have to do with climate change?
   c. How might you relate what we have learned so far about the ocean-atmosphere connection to this new focus on the carbon cycle?

3. **Class discussion and add to class Climate Science Ideas Chart.** Add participant ideas to the Climate Science Ideas Chart started in a previous session to relate the concepts of carbon cycle, climate change and initial climate science ideas presented early in the course.

4. **Quick Write.** Have participants think about and then spend a few minutes writing to the following prompts:
   a. What do you already know about respiration and photosynthesis?
   b. How might you explain these two processes in terms of the crosscutting concept of energy and matter?

   Do not collect the Quick Writes; participants will add to the prompt at the end of the session.

5. **Introduce reservoir.** Explain that a place where something is collected and stored is a reservoir. One familiar type of reservoir stores water, but a reservoir does not have to be pure and contain only one thing. For example, the ocean can be considered to be a reservoir of salt, which is dissolved in seawater with a lot of other things.

6. **Expand definition to carbon.** Point out that anything which is made completely or partially of carbon describes a carbon reservoir, a place where carbon is stored. Ask, **"What's an example of a small carbon reservoir?"** [*The graphite in pencils.*] **"What's an example of a huge carbon reservoir?"** [*All animals and plants on Earth.*] Explain that all living (or once living) organisms are carbon reservoirs.

7. **Distribute carbon cards.** Pass out a set of Carbon Cards to each small group. Explain that these cards provide examples of a diverse array of carbon reservoirs. Encourage participants to explore the back of the cards and talk to the person next to them about what kind of information is provided. Give participants about 5 minutes to explore the cards. [Note to instructor: don't collect the cards yet because they will be used again later in the session.]

8. **Watch video, It's All about Carbon, and Turn & Talk.** Ask participants to jot down questions or ideas as they watch the video – It's All About Carbon (3 minutes, 20 seconds) and then after the video, have them do a Turn & Talk to share their questions and ideas.

9. **Display image and diagram carbon in Sydney Harbor.** Tell participants that this next activity will give them the opportunity to think about and grapple with how carbon might flow in a relatively familiar environment of a coastal city with both natural and human activities taking place. Distribute a blank sheet of paper and tell them that they will have about five minutes to:
   a. make a diagram and label carbon reservoirs they see on the image of Sydney Harbor (or use an approximately equivalent, or locally-relevant image),
   b. show with lines and arrows how carbon might flow (or move) from one carbon reservoir to another, and
   c. generate a list of questions they have about carbon, carbon flows and reservoirs.

   Explain that this diagram is a model of how they are thinking about reservoirs, flows and interactions in the carbon cycle and represents their prior knowledge.

10. **Participants share diagrams and questions with a partner.** After participants have spent about five minutes drawing and writing down questions, give them another couple of minutes to share their drawings, questions and ideas with one another to get additional ideas that may cause them to question their assumptions. IMPORTANT: have participants keep their diagrams to refer and

add to in the next session.

Conducting Yeast Investigations (OSS 2.2)

1. **Introduce yeast activity.** Let participants know that today they'll investigate what happens to carbon when living things (organisms) eat, or consume food. They will collect evidence over multiple investigations today to help answer the overall guiding question: How do organisms use carbon?

2. **Introduce yeast.** Explain that in this first investigation they will be using yeast, a living, single-celled fungus, in an investigation. Yeast is used in making bread and other products, but today they will use yeast to investigate what an organism does with the food it eats. The yeast they will use was dry and dormant (not active), but when water and sugar (a food source) are added, the dry yeast will become active again.

3. **Project slides, Yeast Investigation, Part 1 and Part 2; demonstrate steps.** Each pair will do an investigation and collect observations and evidence to answer the question, "What does eating have to do with producing carbon dioxide?" Describe each of the steps on the slides and answer any questions. Distribute *Yeast Investigation Worksheets* and point out that the handouts have identical information to what is shown on the slides. They will work with a partner to do the investigation, but each of them should complete their own worksheet pages. Remind them to keep the yeast solution in the test tubes warm, either in a warm water bath, or held tightly in warm hands.

4. **Explain doing multiple tests.** Point out that each pair will test both of their yeast samples three times. Doing investigations multiple times helps to get a better sense about the reliability of the results. Knowing that the data are reliable increases your confidence in the data and thus the conclusions you can make from the data. Additionally, the more data that are collected the stronger the evidence can be to support or not support a claim.

5. **Describe BTB's reaction with CO_2.** Explain that BTB stands for bromothymol blue, a chemical that turns green or yellow when it's mixed with an acid. In water, carbon dioxide makes an acid called carbonic acid, so if the BTB turns green or yellow, that is evidence there may be carbon

dioxide present.

6. **Introduce proxies.** It can be difficult to accurately measure the amount of CO_2 in a liquid, but BTB can easily be used as a proxy for indicating the presence or absence of CO_2 in the water. A proxy is: "a measured parameter used to estimate or predict another parameter that cannot be measured or quantified directly." This is helpful in understanding if it is there, but it is important to remember that using proxies does not provide quantitative data about the item we are actually interested in (e.g., we do not know how much CO_2 is present if the BTB turns green). Proxies are an important part of science when it is impossible (e.g., samples from 10,000 years ago), impractical (e.g., doing so would threaten what you are trying to observe), or extremely difficult (e.g., expensive machinery) to get data on the actual variable you are interested in investigating.

Note to instructor: *If you want to explore proxies in science more deeply with your students, consider sharing with them the Tools of Science "Practice 3: Proxies in Scientific Investigations" video from http://toolsofscience.org/lessons.html.*

7. **Introduce controls.** Show participants the two demonstration test tubes, one containing tested water and the other containing sugar water, noting that this is the same as what they'll use in their investigations. Add 8 drops of BTB to each test tube, and tell them that this is how BTB reacts with the water without yeast. Explain that these are controls to help us understand what we observe. In this case, the controls will help us observe the effect of increasing the amount of carbonic acid in the water, due to CO_2 being released by the yeast. By comparing the difference in BTB reactions (color) between the treatment and controls we will be able to observe what happens to the presence of carbonic acid (and thus CO_2) in the water when we add yeast.

Note to instructor: *You may want to introduce and discuss the independent/dependent variables in the investigation. The two variables that are varying in this investigation are the yeast and the amount of CO_2 in the water. Within this investigation the independent variable is the yeast and the dependent variable is the amount of CO_2 in the water. This is because the amount of CO_2 in the water is changing among the treatments (or test tubes) and that difference is being driven by the yeast, aka it is dependent on the yeast. The changes in the yeast are not impacted by, or dependent on, the amount of CO_2 in the test tube. Understanding what the independent and dependent variables are within an investigation as well as why is helpful for having a greater conception of what is being investigated and what conclusions and* *inferences you can or cannot draw from the results.*

8. **Organize groups and tasks.** Have participants divide into two pairs within their table groups and tell them that one person from the table group will get the tray of materials, which contains materials for two pairs of participants. Project the first Yeast Investigation slide again. When most pairs have completed part 1, project the part 2 slide.

9. **Regain attention.** Have participants finish up their Y*east Investigation Worksheets* to prepare for a class discussion about their observations and the evidence they gathered to answer the question, what does eating have to do with producing CO_2?

Making Sense of Yeast Investigations

1. **Share observations.** Ask a few participants to share what they observed. [*Bubbles. Change in color when BTB was added to the yeast.*] Ask, **"What is your evidence that the tube with sugar was producing CO_2?"** [*Bubbles, color change.*] "**Did you find similar results each time you tested the yeast?**" [*most likely yes, unless something was done incorrectly.*]

2. **Question where CO_2 came from.** Confirm that the gas in the test tubes with sugar is carbon dioxide. Ask, **"Where do you think the carbon dioxide came from?"** Listen to a few answers, and for each idea, ask, **"Why do you think that?"** Explain that yeast and most animals, including ourselves, take in solid carbon compounds in the form of sugar when they eat, and give off (release or breathe out) carbon as carbon dioxide gas. Tell them the carbon they ate for dinner last night may be the same carbon they are now breathing out as carbon dioxide.

3. **Volunteer blows into BTB.** Have a volunteer come forward and gently blow (not suck) through the straw into the cup of blue BTB and water you prepared. (Make sure the end of the straw with the small safety hole is the end the volunteer blows into.) As the BTB changes to green and then to yellow, have participants explain to each other what is causing this change. [*Volunteer is exhaling carbon as CO_2 from the solid food they ate, which reacts with the water to form carbonic acid, which reacts with the BTB to change the color.*]

4. **Define respiration.** Tell students that most people think of respiration as simply breathing in and

out. Explain that respiration refers to the whole process of organisms breaking down carbon containing molecules, such as sugar, for energy and for building bodies, and releasing some of the carbon as CO_2 by breathing it out into the atmosphere.

5. **Project and explain the slide, Carbon In/ Carbon Out for Respiration.** Mention that some people find it confusing that solid carbon can be made into a gas, but that's what happens during respiration. Explain that in our bodies, oxygen is absolutely necessary for the process of respiration to occur. During respiration, the atoms in sugar and oxygen get rearranged into atoms of carbon dioxide and water. During this process we get energy from the food.

   *[**Note to instructor:** if your participants are struggling with understanding the process of respiration (or photosynthesis) or just want to know more, you might suggest that they do some outside reading for review. It may be that they have not been exposed to these ideas since high school or their early college years. You might let them know that a deeper understanding of the processes is not required for this course, or for middle school students.]*

6. **(Optional): Point out equal number of atoms on both sides of equation.** Point out the chemical formulas on the slide and explain that the same number of each kind of atom is on either side of the arrow. To illustrate, ask if participants can see how the six carbon atoms in sugar combined with six O_2 atoms to make six CO_2 molecules. Emphasize that atoms aren't destroyed during respiration, but are rearranged to make different chemicals.

7. **Project and explain slide, Releasing Carbon Dioxide and Methane Gas.** In addition to breathing out carbon dioxide, most animals also release carbon in methane gas (CH_4) as flatulence (farts). Ruminant animals, such as cows and sheep, also have methane burps.

8. **Project key concept.** Project the key concept and invite participants to contribute ideas about what they learned in this session that helped to answer the guiding question, how do organisms use carbon?
   - Most organisms get energy and materials to build their bodies from molecules that contain carbon. They break down these molecules and release carbon dioxide gas. This is respiration.

- In water, carbon dioxide makes an acid called carbonic acid, so if the BTB (an acid indicator) turns green or yellow, that is evidence that the water is becoming more acidic and that there may be carbon dioxide present.

9. **Add key concepts to Climate Science Ideas chart and turn and talk.** Add the key concepts to the chart and have participants discuss with a partner what the ideas have to do with climate change. Lead a brief class discussion and record their ideas.
   *[***Note to Instructor:*** having participants discuss what carbonic acid and the ocean becoming more acidic may engage them in a really interesting discussion about whether or not ocean acidification (introduced in session 9) has to do with climate change. Ocean acidification does not lead to climate change, nor does climate change lead to ocean acidification. They are related however in that the cause is the same for both climate change and ocean acidification–increased carbon dioxide in the atmosphere.]*

C. Activity: *Tracking Carbon through Photosynthesis Part 1* (OSS 2.3)

Discussing Photosynthesis

1. **Reflecting on key concept - display leaves slide.** Have participants review the key concept just presented: Most organisms get energy and materials to build their bodies from molecules that contain carbon. Have them briefly discuss the following prompts with a partner: So, where do the molecules of carbon in these leaves comes from. Give them a few minutes to discuss, but don't have a whole group share out yet.

2. **Project slide, BTB Changes.** Using the photographs on the slide, review that BTB in water started out blue **(left)**. Then it turned green **(center)** when gas from yeast was added to the water and carbonic acid was formed. Ask, **"What did the green color indicate?"** [*There was carbon dioxide in the water, because carbon dioxide reacts with water to form carbonic acid, which the BTB reacts with and changes color.*]

3. **Focus on third photo** (show your plant-in-sunlight jar if you set up the optional activity a few days previous). Explain that a water plant was added to the jar of green BTB-CO_2 water. That jar was placed in sunlight for a few days, and this photo shows that the water turned from green to

light blue.

4. **Turn and Talk.** Have participants talk with a partner about the question on the slide. Encourage them to ask each other what they think and to explain their reasoning.
    - Why do you think the BTB changed back to blue after the plant and sunlight were added?

5. **Participants share ideas.** After pairs have discussed the question for a few minutes, regain the attention of the class. Have a few participants share their ideas. Listen to their ideas and maintain neutral responses while encouraging an atmosphere of sharing. Note: If it comes up, wait to reveal where the matter in plant structures comes from.

6. **Project key concept slide.**
    - Plants and other photosynthetic organisms take in CO_2 and give off O_2 during photosynthesis.

Evidence and Explanations

1. **Review Scientific Evidence chart.** Point to the chart that you posted earlier (from Session 4) and encourage participants to provide examples of the different kinds of evidence they have gathered about how organisms use carbon:
    - Evidence can come from our own investigations. [*Yeast investigations. They saw their yeast bubbling, which was evidence of a gas. When the BTB changed from blue to yellow and green, that was evidence that the gas could be CO_2 as that would increase the acidity of the water and thus react with the BTB.*]
    - Evidence can come from other people's investigations. [*Watching a video about carbon is an example of getting evidence from other scientists. Evidence also comes from reading about other people's investigations, talking with others, and looking at raw data.*]
    - Why the evidence supports a claim needs to be made clear with reasoning.
    - Scientific explanations are based on evidence and reasoning. A good scientific explanation puts together evidence in a way that answers a question and provides reasons for the answer.

2. **Review matter.** Show the branch you brought to class and remind participants that it's made of matter. [*Matter is anything that has mass and takes up space. The wood, leaves, and other plant structures of the branch are all made of different kinds of matter.*]

3. **Project slide, Where does most of the matter in plants come from?** Give participants a minute or so to think about the question. Then, as you call on volunteers to share their ideas, hand each of them the branch to hold as they speak. Accept all answers without correcting or confirming them. Remember to do the following to engage participants in the discussion:
   - Listen to their responses
   - Ask them to provide explanations, evidence, or clarifications to elaborate on their thinking. Suggested probing questions:
     - What makes you think that?
     - What evidence do you have to support your ideas?
     - How sure are we? How can we be more sure?
   - Maintain neutral response
   - Invite others to react and respond to the ideas shared. Suggested probing questions:
     - Can anyone add something to that comment?
     - Who would like to share an alternative idea?
     - Does anyone disagree with that comment?
   - Reference and cross-reference their comments as you facilitate the discussion to encourage participants to think about and respond to one another's ideas.

4. **Project slide, Three Common Answers.** Tell participants that in a few minutes they will be considering evidence to help them make scientific explanations about where most of the matter in plants come from. Explain that there are three different answers people often give when asked where most of the matter in plants comes from: (1) the soil, (2) the water, and (3) the air. Tell them that they will work in groups of three to discuss their prior knowledge about the topic and how the evidence they have supports their ideas.

5. **Introduce concept cartoon.** Distribute a *Concept Cartoon – Mass* handout to each small group and explain that each of the concept cartoon characters is putting forth an alternative viewpoint about where most of the matter in plants comes from. Remind participants that they previously

used a concept cartoon for the concept of currents. This strategy sets up a situation to consider a range of claims and respond to them using evidence.

6. **Participants respond to the concept cartoon.** Ask participants to consider which, if any, of the ideas they agree with on the cartoon and to share with their small group their reasons for agreeing or disagreeing with each idea. Give them about 5 minutes to consider and share their ideas about each option. *(Instructor note: be sure participants are discussing the focus question of where most of the mass comes from. Their conversation might wander into a discussion about what plants need to survive, but that is a wholly different concept.)*

Making Explanations with evidence and reasoning

1. **Introduce Plant Evidence and distribute *Evaluate the Evidence* handout.** Tell participants that they will now have the opportunity to gather more evidence upon which to construct an explanation about where the matter in a plant comes from.
    a. Each group of three will receive one envelope containing three descriptions of investigations that involve plants. Groups will go through the descriptions one at a time by having each group member read aloud one description, then the group will discuss how the investigation's results supports or does not support each of the three common answers.
    b. Distribute *Evaluate the Evidence: The Source of Most Matter in Plant Structures* handout to each participant.
    c. The group will decide if the investigation results support any of the answers, but each individual will fill in the table on their own handout, *Evaluate the Evidence: The Source of Most Matter in Plant Structures*. They will write "yes" in the column if the evidence supports that answer, "no" if the evidence does not support the answer, and "maybe" if the group is not sure.
    d. Groups should start with Investigation B and go in order (the class will practice together on Investigation A). The group needs to come to agreement before individuals mark their own sheets. Everyone should be ready to share their reasoning and support their choices.

2. **Review scientific discussion and norms.** Remind participants that the quality of an explanation depends on strong evidence and clear reasoning, emphasize the importance in science of being

ready to change one's mind based on evidence and reasoning, and sharing and asking for evidence, including inviting others to say more about what they are thinking.

3. **Model the process with a first investigation.** Tell participants that you will model what they are to do by discussing one investigation as a class. Read aloud Investigation A:

   > **"In the 1600's, Jan Baptista van Helmont grew a tree in a pot for five years. He measured the weight of the plant and the weight of the dry soil at the beginning and the end of the five-year period. He kept the soil covered so nothing else could get in. He watered the soil regularly. He found that the tree gained 74 kilograms (164 pounds), but the dry soil weighed only .05 kg (2 ounces or** 1/8 **of a pound) less at the end."**

4. **Using reasoning.** Ask participants to consider which of the three answers the evidence from this investigation supports and which it does not support, and why. Give them a moment to think quietly, then discuss with a partner. Explain to the participants that clearly describing how the evidence supports a claim is called reasoning, and that middle school students often have difficulty making their reasoning clear in an argument.

5. **Class discussion followed by individual recording on Evaluate the Evidence sheet using "If, then, because" sentence starter.** For each possible answer, discuss as a class how the evidence supports it or not, prompting the participants to be very clear about why the evidence can support (or not) the answer. (Use a sentence frame, such as 'If….then…' to help with the reasoning). Have each individual fill in the first column on the *Evaluate the Evidence: The Source of Most Matter in Plant Structures* sheet following the discussion. [Soil—no; water—maybe; air—maybe.] *[An example of a complete response follows: If most of the matter came from soil, then the amount of soil should be much reduced. However, soil decreased only slightly, so the evidence doesn't support that most matter comes from soil. Also since water was added throughout the experiment while the plant was exposed to the atmosphere, we can't tell whether the matter came from the water or the atmosphere. Therefore, maybe the matter came from both the water and the atmosphere].*

6. **Distribute Plant Investigations envelopes and start discussion.** Pass an envelope containing

the three other investigation descriptions (B, C, and D) to each group of three. Have them begin discussing and marking their sheets, and thinking about their reasoning process. Tell them they have about 10 minutes to read and discuss the three descriptions and mark their sheets.

Note to instructor*: expected answers are as follows.*

	A	*B*	*C*	*D*
Soil	*No*	*No*	*No*	*No*
Water	*Maybe*	*Yes*	*Yes*	*Maybe*
Air	*Maybe*	*Maybe*	*Yes*	*Yes*

Making Sense of Air, Carbon, and Plants

1. **Discuss Answer 1**. Regain the attention of the class and read aloud the first answer to the question about plant matter, **"Most of the matter in plants comes from the soil."** Ask a few participants to share their evidence and how that evidence supports the claim (reasoning) that most of the matter in plants comes from the soil. If nobody chose that claim, ask for volunteers to cite evidence that led them to believe that soil was not the source of the matter and their reasoning. [*Those who disagree with this statement may mention the 5-Year Experiment or the Hydroponics evidence, using reasoning such as, if most of the matter in plants came from the soil then, the mass of the soil in the 5-Year Experiment would have decreased as the mass of the plant increased.*]

2. **Discuss Answers 2 and 3.** Read the other two answers aloud, and challenge participants to share reasoning that argues why the evidence supports or doesn't support the claim. [*Explanations 2 and 3 are both supported by most of the evidence.*] Tell participants that they should use their reasoning to try to convince others with different ideas about why they think it better represents the most likely source of where the matter comes from.

3. **Project slide, Carbon In/Carbon Out for Photosynthesis; Turn & Talk.** Remind participants that this chemical equation presents additional evidence to explain the source of matter in plant

structures. Have participants discuss the following prompts with those near them:

a. In what ways does this information provide evidence to answer the question about where does most of the matter come from?
b. Would anyone like to change what they believe is the best answer based on additional evidence they have heard? If so, explain your reasoning about why the evidence supports the answer and convinced them.

4. **Gathering more evidence.** Tell participants that there is evidence supporting both water and air as the source of the mass in a plant. Say that it looks like more evidence is needed to sort out which of them provides most of the mass for the plant structures, or if they both contribute to the mass equally. Explain that they will be provided with a reading about scientists searching for answers to this same question in order to gather more evidence.
   Note: *depending on time, you may decide to have participants read the article for homework in order for them to gather the evidence they need to more definitely answer this question.*

5. **Distribute *Researching Photosynthesis* reading.** Have participants use the active reading strategy with the *Researching Photosynthesis* handout and when they have completed the reading, they should pair up with someone to discuss their questions, as well as the following prompts focusing in on the equation for photosynthesis as shown in the reading:
   a. "Where could the oxygen (O) in the sugar have come from?" *[From carbon dioxide or water.]*
   b. "Where could the carbon (C) in the sugar could have come from?" *[From carbon dioxide.]*
   c. Is there enough evidence to support one of the answers (water or air) over another? If yes, explain. If no, what more information would you need in order to have enough evidence to support one of the answers? *[We would need to know where the O in sugar came from – if it came from CO_2, then we would have evidence that most of the mass of the plant structures comes from air since all of the carbon and oxygen atoms needed to build sugar ($C_6H_{12}O_6$) come from air. However, if the O in sugar came from water, then it might be that both air and water contribute equally to the mass of the plant structures.]*

6. **Lead a brief whole group discussion.** Ask for volunteers to share their answers to the prompts and any other questions that arose from the reading. Use the discussion map to encourage

participants to contribute their ideas and probe for evidence and explanations. Tell them that they will read about additional scientific investigations that may provide more evidence to help answer the remaining questions about where does the O in the sugar come from. Without knowing the answer to that question, there may not be enough evidence to support one claim over another.

7. **Gathering even more evidence through an additional reading.** Distribute the short second reading – "Following the Water in Photosynthesis" and have participants sit with a partner to read and discuss.
   [From the reading: Scientist Cornelius van Niel first postulated in the 1930's that the oxygen released from photosynthesis comes from the water molecule. Through experiments with bacteria, he suggested by analogy that the O_2 released in plant photosynthesis is derived from H_2O rather than CO_2. Before that time, it was thought that the O_2 came from splitting the CO_2 molecule. In 1941 Samuel Ruben and Martin Kaman used water labeled with the heavy isotope 18O to try to figure out what role the oxygen in water played in photosynthesis. They labeled the O in H_2O, so they could follow it through the photosynthetic process and determine where it ended up – in sugar or in the O_2 released as a byproduct of photosynthesis. Their investigations confirmed that the O_2 released in photosynthesis does come from the water molecule, as proposed by van Niel. The O in $C_6H_{12}O_6$ (sugar) did not come from the water molecule. Later investigations revealed that only the hydrogen in the sugar comes from water.]

8. **Lead a whole group discussion.** After participants read and discuss with a partner, call on a few volunteers to share any new evidence to support a claim of either air, water or both. Lead a discussion and use the discussion map to encourage alternative ideas. **Note:** *at this point, participants should have enough evidence to support the following claims:*
   - **Most of the matter in plant structures comes from CO_2 and H_2O - both carbon dioxide and water. But all the carbon and oxygen atoms needed to build sugar ($C_6H_{12}O_6$) in a plant are found in air.** Scientists discovered that the oxygen and carbon in the sugar molecule actually come from the CO_2 in air. Only the hydrogen in the sugar comes from the water. Therefore, most of the matter in plant structures comes from the air.

9. **Discuss claim, evidence and reasoning slide.** Show the slide and ask participants to turn and talk to discuss their claim, evidence and reasoning using If___, then___, because___. After about 2 minutes, call on a few volunteers to share their ideas before showing the following example of

an explanation that they might have come up with:

> If most of the mass of a plant comes from CO_2 in the air, then sugar molecules which make up the mass of the plant structures would be made from C and O from CO_2 molecules, because according to the equation for photosynthesis, only CO_2 and H_2O plus sunlight are needed to make sugar molecules. Evidence to support this claim came from reading multiple scientific investigations.

[Note to Instructor: *Most textbooks introduce photosynthesis before respiration and you likely observed that this course introduces respiration first. This was a conscious decision based on a review of misconception research around these two processes. What was discovered was that students have a much easier time understanding and conceptualizing that something containing carbon (like the food we eat) can be broken down into its component parts, including gas like CO_2, much more easily than conceptualizing how something like an invisible gas could provide the carbon that makes up most of the matter in a tree].*

(Optional) Reflecting on Teaching and Learning

1. **Think Pair Share - strategies used to encourage alternate ideas.** Ask participants to do a Think Pair Share about the Concept Cartoon strategy used in the previous activity to encourage sharing and discussion of alternate ideas. Use the following prompt:

   > Did you find the strategy to be effective in helping to make sense of the concepts? If yes, in what ways was it effective? If no, why not?

2. **Refer to "Strategies to explore multiple ideas" handout.** Remind participants that they were provided with the "Strategies to explore multiple ideas" handout in a previous session, which describes this strategy and a few others, and can be used as a resource in their practice.

3. **Refer to the Argumentation Toolkit Resources.** Remind participants that in addition to the "Strategies to explore multiple ideas" handout, they were also directed to another very useful resource – the Argumentation Toolkit Website, http://www.argumentationtoolkit.org/index.html. This website provides additional tools for teachers and videos that show how they might be used in the classroom.

D. Activity: *Tracking carbon levels over time and professionally-collected data* (OSS 2.4)

Note to instructor: For this activity, it is important that participants understand that photosynthesis is fueled by light energy, and that this results in the production of molecular oxygen (O_2). The discussions participants engage in during this section will be referenced again in Session 8.

Note to instructor: *If you would like to have your students actually use professionally-collected data to predict changes in O_2 and CO_2, see the optional Providing More Experience activity "Tracking carbon levels over time using authentic local data" and associated worksheets. This optional activity provides students the opportunity to work with professionally-collected data, make predictions about oxygen production and consumption (i.e. photosynthesis and respiration) in the marine environment, and test their predictions using real-time environmental data recorded at a NERR reserve. This optional activity culminates with students using their oxygen predictions and environmental data to make predictions of CO_2 concentrations in the water. When completed successfully, this final step allows students to further demonstrate an understanding of the relationship between oxygen, carbon dioxide, photosynthesis, respiration, and the variability of these in natural waters - and navigate online data portals.*

Part 1: Predicting changes in O_2 and CO_2 using data

1. **Project slide; Introduce photosynthetic organisms in the ocean.** Tell participants that just as plants on land photosynthesize, there are many organisms in the ocean that photosynthesize — in fact, most of the photosynthesis (and respiration) that happens on Earth occurs in the ocean and is done by tiny ocean organisms called phytoplankton and other microbes. These organisms also build their bodies using carbon from the carbon dioxide they take in.

2. **Project slide, Opposite Processes.** Ask, "What do you notice when you compare what happens in respiration versus photosynthesis?" [*Participants might say that the chemical formulas on either side of the arrow are flip-flopped.*] Matter is conserved because atoms are conserved in physical and chemical processes. Encourage participants to think about their prior knowledge and what they have been doing so far in the session as well.

3. **Have participants reflect on the relationship between light energy, photosynthesis, and respiration.** Referring to the "Opposite Processes" slide, have participants discuss the following

questions:

- What do you think will happen to oxygen concentrations when plants or phytoplankton are exposed to light energy? [*oxygen will be produced by the plant through photosynthesis, and thus the oxygen concentration will increase*]
- Therefore, what do you think will happen to carbon dioxide concentrations when plants or phytoplankton are exposed to light energy? [*carbon dioxide concentrations will decrease because more photosynthesis is happening which requires carbon dioxide*]
- At nighttime and in the absence of light, which of the following is the most dominant process – respiration or photosynthesis? [*respiration*]
- What happens to oxygen and carbon dioxide concentrations if the amount of respiration in a system is greater than the amount of photosynthesis? [*the concentrations of oxygen will decrease because less is being made as a byproduct of photosynthesis, carbon dioxide will increase over time because more is being made as a byproduct of respiration than is being used in photosynthesis*]

4. **Project "Light energy at the Weeks Bay Reserve".** Project a slide of the July photosynthetically active radiation (PAR) figure for the class to see (optional: distribute pg 1 of the "PAR and DO Handout" showing the image). Let them know that light energy in the natural environment is typically measured as photosynthetically active radiation (PAR), which is an areal measurement of amount of light available at the surface of the earth. The unit of measurement for PAR is millimoles per square meter. Explain that this data was collected every 15 minutes over a multi-day period where light intensity was measured by a light sensor installed at the Reserve weather station. Orient participants to the figure by highlighting what the x-axis and y-axis are illustrating and any other components of the figure that they will need to know to be able to interpret the figure. Have participants examine the figure and think of any patterns or observations they see. Discuss the following:
   - How many days do these data cover? What is your evidence for this? [*Seven days, by looking at the time you can see that the data goes through seven cycles of the 24 hour day (12am to 12am). Additional evidence students may point out is that the light intensity goes up and down with the day and night cycle*].
   - What time of day do you see the highest light intensity? The lowest? [*midday. night*]
   - How do you think the weather might have been different on day 1 vs day 3? What is your evidence for this? [*The first day was probably sunny, day three was probably cloudy.*

The evidence is that light intensity was higher and uninterrupted on the first day.].

- What do you notice about the data for Day 6? What do you think happened? [*Missing data. This could result from a failed sensor or maintenance of the monitoring instrument*].

5. **Using oxygen as a proxy.** Instruct participants that they will be making a prediction about how much photosynthesis and respiration is taking place during this period. Explain that for this activity they will be using oxygen as a **proxy** for photosynthesis and respiration. Remind participants that a proxy is: "A measured parameter used to estimate or predict another parameter that cannot be measured or quantified directly." Describe that because it is difficult to measure the cellular processes of respiration and photosynthesis directly – especially in the field – we can more easily measure changes in the concentration of oxygen as a proxy for respiration (i.e. consumption of oxygen and thus a decrease in oxygen concentrations) or photosynthesis (i.e. production of oxygen and thus an increase in oxygen concentrations).

6. **Making predictions about respiration and photosynthesis.** Tell participants that they can use this graph to estimate the changes in dissolved oxygen and carbon dioxide they would expect to find in the water throughout the day as a proxy for photosynthesis and respiration. Have participants work in a small group to discuss the following prompts:
   - Thinking about the relationship between light energy, photosynthesis and phytoplankton in the water, what do you predict would happen to dissolved oxygen concentrations as light intensity increases? [*With more light the rate of photosynthesis would be higher because light energy is needed for photosynthesis; this would lead to higher dissolved oxygen concentrations because oxygen is released during photosynthesis*]
   - Assuming plankton respiration is relatively constant throughout at 24 hour period, what would you predict would happen to dissolved oxygen concentrations at night in the water column? [*The concentration of O_2 will decrease because less is being produced through photosynthesis*].
   - What do you predict will happen to CO_2 concentrations between high light (day) and low light (night) periods? *[The concentration of CO_2 shows an inverse relationship to O_2 with low levels of CO_2 during the day and high levels at night.]*

Optional: Remind participants to think about the following relationships to make predictions:

- when the rate of photosynthesis is greater than the rate of respiration, the dissolved oxygen concentration in the water will increase;
- in the absence of light, the rate of respiration will exceed the rate of photosynthesis and dissolved oxygen concentrations will decrease.

7. **Small then large group discussion.** Discuss the previous two prompts about the level of O_2. Then pose the following questions for reflection and discussion for small groups to consider. After a few minutes of small group discussion, lead a whole group reflection about the questions and encourage participants to explain their reasoning. Don't provide any answers yet as they will be gathering more evidence to support their explanations in the next section.
   a. Given the changes in CO_2 you predicted between high light (day) and low light (night) periods, how would you expect atmospheric CO_2 concentrations to vary throughout the year? What makes you think that?
   b. If only natural processes were involved, what season would you expect to find the highest concentrations of CO_2 in the atmosphere? What is your evidence for that?
   c. What season would you find the lowest concentrations of CO_2 in the atmosphere? Why?

Part 2: Visualizing Global Scale Changes in Atmospheric CO_2

1. **Introduce part 2 focusing on global changes in CO_2.** Tell participants that the previous activity looked at changes in CO_2 at one location. This next activity will look at changes in atmospheric CO_2 on a global scale.

2. **Orienting to and interpreting information from Carbon Tracker.** Project the Carbon Tracker (https://coast.noaa.gov/psc/dataviewer/#view=tracker) and pause it so that it is on January 1st (or as close to that date as possible). Since this is a new type of data visualization, help to orient the participants to the animation using the following questions:
   - What types of data are represented by the scale bars in this figure? [*time (month and year) and carbon dioxide concentrations (parts per million)*]
   - How many years are represented on the scrolling scale at the top of the visualization? *[8 years from 2000-2008]*
   - What is the range of carbon dioxide values on the colored scale bar? [*~360 - 380 ppm*]
   - What color represents the highest values? [*red*] The lowest values? [*purple*]

- What does parts per million of carbon dioxide mean? [*how many molecules or parts of CO_2 there are in the air for every one million parts of air. For example, if the CO_2 is 400 ppm, there are 400 CO_2 molecules per one million parts of air.*]
- How do you think these parameters were measured? [*these data are model outputs that were created using data collected by CO_2 sensors. The samples were taken from the troposphere at about 1.2km above the ground to about 5.5km above ground*]

3. **Focus on northeastern U.S.** Tell participants to focus on northeastern U.S. Explain that they will be asked to interpret the data and describe what they observe to their partners as the visualization plays. Then play it a second time, but this time use the pause feature to pause in each month or season of one year. After going through the year, ask the participants to discuss the following interpretation questions with their partners and to cite evidence from the animation to support their answers:
    - When was there the most CO_2 in the atmosphere in this area? [*Late winter and Spring. For example, in March and April in North America, the CO_2 levels get up to 385 ppm*]
    - When was there the least CO_2 in the atmosphere here? [*Summer and early Fall. For example, in August and September in some parts of North America, the CO_2 levels go down to 365 ppm*]

4. **Evaluating and communicating information from Carbon Tracker.** Have participants synthesize the data by coming up with explanations (based on evidence) for the patterns that they see. Encourage them to use evidence or scientific concepts that they have learned in this session to answer the following questions, accept all responses; participants will revisit this question after gathering more information:
    - Why do you think the amount of CO_2 in the atmosphere might change during a year?
    - What is different about summer and winter that could affect CO_2 in the atmosphere? [*Possible responses are: in the winter in the northern hemisphere there is less sunlight for photosynthesis; in the summer in the northern hemisphere there is more sunlight for photosynthesis*].

NOTE: *Students may also point out differences between the northern and southern hemisphere, such as the greater variability in CO_2 in the northern hemisphere and the opposite timing of peaks in CO_2. A few* *explanations for these differences are listed below.*

- *Summer (i.e. longest days, warmest temperatures) in the southern hemisphere occurs during November thru January.*
- *Most of the annual variability in CO_2 is attributed to natural processes (i.e. photosynthesis and decomposition), with a smaller contribution from seasonal burning of fossil fuels associated with heating and energy use.*
- *Carbon dioxide concentrations increase as a result of decomposition of organic matter (e.g. leaf litter). However, the peak in CO_2 occurs not in the fall, but in late winter/early spring. This is because cold temperatures inhibit microbial processes that drive decomposition. This results in a time lag between trees losing all their leaves in the fall and increases in atmospheric CO_2. It is not until temperatures warm in the spring that rates of decomposition can increase enough to rise atmospheric CO_2.*
- *Similarly, there is a time lag between the beginning of summer and lowest atmospheric concentrations of CO_2 because the lowest atmospheric concentrations generally coincide with accumulation of plant biomass throughout the growing season.*
- *The northern hemisphere generally has more land mass and more human population, contributing to the greater variability in CO_2. There are also more rivers, which deliver nutrients to the ocean and fuel elevated rates of primary productivity in coastal waters.*
- *More of the surface of the planet is ocean in the southern hemisphere, which also contributes to differences in global CO_2 concentrations. Plant communities on land (e.g. deciduous forests) generally grow, accumulate biomass, then lose leaves on an annual cycle and cause large swings in atmospheric CO_2 drawdown and production. Plants in the ocean (e.g. phytoplankton) have much shorter life span (e.g. days to weeks) and cycle much more quickly than land plants. This leads to less variability in ocean waters (and thus the southern hemisphere) throughout the year.*

5. **Share ideas with whole group**. Ask a few participants to share their ideas with the whole class. Encourage them to expand on and use evidence to support their ideas. Ask the other participants for other comments and whether they agree or disagree with the ideas expressed, without correcting or confirming their statements.

6. **Project slides, Spring and Summer/Fall and Winter.** Ask and invite participants to share ideas, using the Carbon Tracker animation to help illustrate their ideas:

- What do you now think about why the amount of CO_2 in the atmosphere changed over the year?
- How does the evidence about sunlight and plants at different times of the year help us answer the question? [Possible responses include: *in the winter in the northern hemisphere there is less carbon dioxide in the atmosphere, because there is less light for photosynthesis and many of the trees have no leaves for photosynthesis. Photosynthesis decreases the amount of carbon dioxide in the atmosphere*].

7. **Project slide of key concept.** Project the key concept and have participants read it.
    - Carbon dioxide concentrations in the ocean and atmosphere vary throughout the day and by season, and have increased over the last 50 years (OSS 2.4).

8. **Replay Carbon Tracker focused on the ocean.** Ask participants to watch the Carbon Tracker one more time, this time focused on the ocean, and discuss with their partner, “Why do you think the amount of CO_2 in the atmosphere above the ocean might change during a year?” [Possible response: *Phytoplankton and algae in the ocean photosynthesize at different rates throughout the year*].

9. **Share ideas with whole group**. Ask a few participants to share their ideas with the whole class. Encourage them to expand on their ideas by providing evidence and/or reasoning for their ideas. Ask the participants for other comments and whether they agree or disagree with the ideas expressed, without correcting or confirming their statements.

10. **Seasonal variability in PAR and photosynthesis**. Project the “Comparison of PAR in July and December” slide. Ask participants to reflect on the figure and discuss the following questions:
    - What do you notice about the difference in PAR? [*PAR in July is almost twice as high as PAR in December*]
    - How do you think the decrease in light availability will affect the rate of photosynthesis? [*With less light the rate of photosynthesis would be lower because light energy is needed for photosynthesis*].
    - If rates of respiration remain relatively constant while the rate of photosynthesis decreases, what do you predict will happen to CO_2 concentrations? [*The concentration of CO_2 will increase because less is being used in photosynthesis*].

- Based on these observations, during what season would you expect to see the highest concentrations of CO_2 in the water or atmosphere? [*winter because less is being used in photosynthesis*]. When would CO_2 be the lowest? [*summer because a lot would be used in photosynthesis as the rate of photosynthesis is high in the light filled summer*].

Part 3: Interpreting data: Carbon levels over many years

1. **Project slide, Keeling Curve: CO_2 Levels in the Atmosphere.** Explain to participants that they will now look at atmospheric CO_2 concentrations over many years. Project the Keeling Curve slide. Explain that this graph is called the Keeling Curve. It is named after the scientist who first made people aware of the relationship between atmospheric CO_2 concentrations over time in Hawaii.

2. **Focus on <u>data orientation</u> skills.** Ask participants the following questions focusing in on data orientation skills, remind the participants that the orientation level of engagement helps to determine "what is there on the page."
   - What type of data are represented by the x- and y-axis of the figure? [*x-axis is time in years, y-axis is amount of CO_2 in the atmosphere (in units of parts per million)*]
   - Where was this data collected? [*Mauna Loa Observatory in Hawaii*]
   - How do you think these parameters were measured? [Possible answers include*: sensors for carbon dioxide, scientists making measurements*]

3. **Focus on <u>data interpretation</u> skills.** Point out that the red line on the graph shows the monthly averages of CO_2 levels in the atmosphere and that the black line reflects the annual values. Ask participants the following questions focusing in on data interpretation skills, remind the participants that the interpretation level of engagement helps to determine "what the data on the page shows."
   - When was the lowest CO_2 concentration? [*1958*].
   - When was the highest CO_2 concentration? [*~2012*]
   - What trend do you notice in the black line? [*Increasing from 1958 to 2010, steeper in more recent years*]
   - What trend do you notice in the red line? [*Increasing like the black line, but with up and down pattern within each year*]

4. **Focus on <u>data synthesis</u> skills.** Ask participants the following questions focusing in on data synthesis skills, remind the participants that the synthesis level of engagement helps to determine "what the data pattern explains regarding what is not on the page."
   - Based upon what you've learned thus far and what you saw in the Carbon Tracker 2004 animation, why is the red line "wiggly"? [*The up and down "wiggly" pattern is due to seasonal changes in the balance between plant growth and photosynthesis, and respiration and decomposition. In the summer when days are longer and there is more sunlight available, carbon dioxide concentrations decrease as plants use up carbon dioxide from the atmosphere. In the winter when light availability decreases, decomposition and respiration is greater than rates of photosynthesis and carbon dioxide concentrations increase*]. See NOTE in Part 2 above for further explanations.
   - Why do you think that the CO_2 concentration is increasing? [*Human activities such as combustion of fossil fuels are causing more* CO_2 *to enter to atmosphere reservoir*]

5. **Discuss increase in atmospheric CO_2.** Ask participants to think to themselves for a moment about where this increase in CO_2 is coming from. Call on a few volunteers to share their ideas. Emphasize that the whole Earth is not receiving more carbon [matter is conserved because atoms are conserved, in this case carbon atoms] but rather the atmosphere reservoir is receiving more carbon. This must mean that carbon is flowing from other reservoirs on Earth into the atmosphere.

E. Activity: *Tracking Carbon Flows with Carbon Cycle Diagrams*

1. **Introduce Carbon Cycle Diagram and explain drawing criteria.** Show the Carbon Cycle Diagram and tell participants that they will start this diagram in this session and continue to add details to these diagrams in the next session to record what they are learning about carbon reservoirs and flows.
   a. This first time with the diagram they only need to add carbon reservoirs, and the two carbon flows (respiration and photosynthesis) that they gathered evidence about. Explain that they can use lines and arrows to model the flow of carbon between reservoirs.

b. They should not spend time making detailed drawings; a label will explain what they mean. Draw an example: a cow with a box for a body, stick legs, and the label "cow." [Note to instructor: Depending on the background of your participants, you might clarify that the atmosphere starts at Earth's surface and extends upwards to about 62 miles (100 kilometers).]

2. **Distribute Carbon Cycle Diagram; participants draw.** Pass out one Carbon Cycle Diagram sheet to each participant. Have them add carbon reservoirs and flows they explored this session and the previous session. After about 5 minutes, regain their attention and ask them to consider other ways carbon might flow from one reservoir to another, and have them also add those flows to the Carbon Cycle Diagram.

3. **Turn and Talk.** Project a slide with the following prompts and ask participants to turn to their partner and discuss:
   - Choose one arrow on your diagram that goes from a plant to an animal. Explain how the carbon (matter) moves between these two reservoirs.
   - Follow arrows on your diagram that show how carbon could move from an animal, to the atmosphere, and then to a plant. Explain how the carbon (matter) moves between these three reservoirs.
   - Show how carbon could flow from the reservoir of a land plant into the reservoir of the ocean. [*Fallen leaves could carry carbon to the ocean.*]

F. Reflection

Reflection Quick Write

1. **Introduce Reflection Quick Write.** Have participants refer back to what they wrote to the initial Quick Write prompts:
   - What are other processes involved in atmospheric CO_2 cycling besides fossil fuel combustion?
   - What do you already know about respiration and photosynthesis?
   - How might you explain these two processes in terms of the crosscutting concept of energy and matter?

2. **Line of Learning.** Have participants draw a line under their original response and add new information and details under the line regarding how they would explain these concepts in terms of the crosscutting concepts of energy and matter. Also include which of their questions were they able to answer about carbon, carbon flows and reservoirs, what questions they still have, and how they might find the answers to their questions.

3. **Revisit Big Chart of SEP.** Return to the Big Chart of science and engineering practices. Have participants add additional ideas to the poster, including strategies or activities used to build understanding of the science and engineering practices. Use the following prompts to add additional ideas as appropriate. Encourage participants to use the *Matrix of K–12 Progressions SEP* handout provided previously (in Session 5) as a reference.
   - Ask participants to share some additional examples of what the instructor did, said, or asked to support their construction of explanations during this session [*asked learners to discuss and write explanations; introduced carbon in/carbon out equation; provided opportunity to do yeast investigation with peers; provided more opportunities to gather evidence with carbon cards and carbon video*]. Record responses on the chart.
   - Ask participants how they engaged as learners with the practice of constructing explanations [*thought about and communicated their own explanations and considered explanations of others (discussed three investigation sheets with peers, and concept cartoon); drew a model of their explanation (carbon cycle diagram); revisited evidence chart*]. Record responses on the chart.
   - Repeat for *Arguing from Evidence* [*Instructor: asked learners to share alternate ideas with peers (concept cartoon), asked learners to share reasoning. Learners: made thinking visible through concept cartoon activity, connected evidence supporting a claim with reasoning during discussions*]. Record responses on the chart.
   - Repeat for *Analyzing and Interpreting Data [Instructor: helped orient participants to new data sources, asked interpretation and synthesis questions, provided opportunities to make predictions before looking at data/models, encouraged students to collect multiple pieces of data to look for a pattern. Learners: collected their own data, looked at professionally-collected and graphed data, reflected on the patterns they observed by themselves, with a partner, as a class.]* Record responses on the chart.

4. **(Optional) Additional reflection prompts.** If you have time, have participants choose (or instructor may want to choose) one of the following prompts to write reflections on what they learned in the session. Possible prompts include:
    - Complete the following: I thought I knew__________, but now I know________. My evidence includes ________________.
    - What is the muddiest point for you? How/where might you find out more about this topic or question?
    - What was most surprising or different from how you previously learned about photosynthesis and respiration? Did you learn the concept more deeply? If so, what helped you?

G. Homework

Show slide of Homework Assignments. Describe Tasks as follows:

1. Write out answers to the following Reflection Prompts:
    - Explain how carbon might move from the atmosphere and eventually end up in you.
    - How might cutting down forests affect CO_2 levels in the atmosphere? Describe the carbon cycle processes that are involved in your prediction.
    - What do you think might happen to a plant grown where there is less CO_2 in the air? Explain your answer.
2. Watch a couple of videos about fossil fuel formation, such as the following: https://www.youtube.com/watch?v=_8VqWKZIPrM or https://www.youtube.com/watch?v=zaXBVYr9Ij0 or https://www.youtube.com/watch?v=jjfs_7kwRks.
   Answer the following prompts:
    - Explain how carbon might move from an organism that dies and eventually ends up in the atmosphere.
    - How does human activity affect the flow of carbon between reservoirs?
    - Considering how fossil fuels form, why are some people worried about running out of fossil fuels? What do you think about this?
3. Watch video from toolsofscience.org:

- *Tools of Science videos (http://toolsofscience.org/lessons.html):*
    - *Practice 1: Asking Testable Questions*
    - *Practice 3: Proxies in Scientific Investigations*