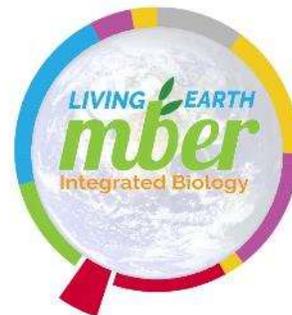


# Photosynthesis Learning Segment Table

(approximately 7-10 traditional class days)

Note this unit is the last of 4 total units in the MBER Curriculum that explore how living things get and use the matter and energy they need to survive. Broadly these first 3 units are asking the question, “Why do organisms need to eat food?” Below is a summary of the model ideas that have already been developed in the previous 2 units (Chemical Reactions and Cellular Respiration) and those that will be developed during this unit. This is summarized so you can track the model development over time. The step-by-step learning segment table begins on p. 2



Matter from Food	Energy from Food
<p><u>Ideas from Chemical Reactions (previous unit)</u></p> <ul style="list-style-type: none"> <li>Matter is conserved, neither created nor destroyed. Matter is rearranged in chemical reactions.</li> <li>Food has matter in the form of protein, carbs and fats—the same things we find our bodies are made of. We also take in matter as oxygen and water.</li> <li>Some of this matter is used in our body, but we take in much more matter than we need to use to grow or maintain body structures.</li> <li>Some of this matter (especially much of the water but also some indigestible material) basically passes through us.</li> </ul> <p><u>Ideas from Cellular Respiration (previous unit)</u></p> <ul style="list-style-type: none"> <li>Some of this matter is really taken in for energy. It is rearranged to obtain energy in a reaction called cellular respiration. The products are expelled from the body as carbon dioxide and water.</li> </ul> <p><u>Ideas from Biosynthesis (previous unit)</u></p> <ul style="list-style-type: none"> <li>Some of our digested food is broken down and rearranged to build new macromolecules we use to both repair tissue and build new body tissue.</li> <li>Food consumed in excess of what we need for energy and growth/repair is converted to fat and stored.</li> </ul> <p><u>Ideas from Photosynthesis (this unit)</u></p> <ul style="list-style-type: none"> <li><b>Plants take in low energy molecules (<math>\text{CO}_2 + \text{H}_2\text{O}</math>) and use energy from the sun to rearrange them into high energy molecules, glucose (<math>\text{C}_6\text{H}_{12}\text{O}_6 = \text{food!}</math>) and <math>\text{O}_2</math>. The reactions involved are collectively called photosynthesis.</b></li> <li><b>Over a 24-hour period, the rate of photosynthesis in a plant is greater than the rate of respiration. As a result:</b> <ul style="list-style-type: none"> <li>Plants use more <math>\text{CO}_2</math> than they give off.</li> <li>Plants produce more <math>\text{O}_2</math> than they use.</li> </ul> </li> <li><b>This means that a plant produces more glucose than it uses for energy.</b></li> <li><b>Glucose not used for energy is used to build biomass.</b></li> </ul>	<p><u>Ideas from Chemical Reactions (previous unit)</u></p> <ul style="list-style-type: none"> <li>Energy is conserved, neither created nor destroyed. Energy is transformed in chemical reactions.</li> <li>When the reactants have more potential energy than the products, energy is released in the reaction (“downhill” reaction).</li> <li>Food has energy in the form of calories.</li> <li>Living things get energy by rearranging food and oxygen molecules.</li> </ul> <p><u>Ideas from Cellular Respiration (previous unit)</u></p> <ul style="list-style-type: none"> <li>Living things rearrange food (specifically glucose - <math>\text{C}_6\text{H}_{12}\text{O}_6</math>) and <math>\text{O}_2</math> into <math>\text{CO}_2</math> and <math>\text{H}_2\text{O}</math></li> <li><math>(\text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2)</math> have higher energy than <math>(\text{CO}_2 + \text{H}_2\text{O})</math> so this rearrangement releases energy. <ul style="list-style-type: none"> <li>The rearrangements occur in a series of steps rather than all at once.</li> <li>Collectively the reactions are called cellular respiration.</li> <li>Usable energy is released in the form of ATP.</li> </ul> </li> </ul> <p><u>Ideas from Biosynthesis (previous unit)</u></p> <ul style="list-style-type: none"> <li>Building new biomolecules (proteins, fats and carbs) from the products of digestion requires energy (which is provided by cellular respiration).</li> <li>More generally, in chemical reactions where the products have more potential energy than the reactants, energy must be added to the reaction (“uphill” reaction).</li> <li>If you run out of glucose, your body can pull from fat stores—and then as a last resort, amino acids—to provide fuel for cellular respiration.</li> </ul> <p><u>Ideas from Photosynthesis (this unit)</u></p> <ul style="list-style-type: none"> <li><b>Plants take in low energy molecules (<math>\text{CO}_2 + \text{H}_2\text{O}</math>) and use energy from the sun to rearrange them into high energy molecules, glucose (<math>\text{C}_6\text{H}_{12}\text{O}_6 = \text{food!}</math>) and <math>\text{O}_2</math>. The reactions involved are collectively called photosynthesis. (See “uphill reaction” above.)</b></li> <li><b>Plants respire using the same cellular respiration reaction as other organisms to acquire the energy they need.</b></li> </ul>

Seg	Model Move	Est Time (min)	Overview	What did we figure out?	Model Ideas Generated
1	M→P	55	In finally moving our attention to matter and energy in plants, we consider a new Challenge Question: Seed to Tree. How does a tiny acorn grow into few-ton oak tree? We reference our models for Matter from Food and Energy from Food in order to generate a list of key points and questions that will motivate our investigations in the coming learning segments.	We've established some ideas around matter and energy in plants, but we have a number of questions, especially regarding the role of CO <sub>2</sub> .	N/A
2	Q→P	110	We set aside some of our questions in favor of addressing a central idea, "What is the role of CO <sub>2</sub> with plants?" The Students design, set-up and execute an investigation to look at CO <sub>2</sub> output and uptake in an aquatic plant in both light and dark conditions.	We've decided on an experimental design that will help us answer our questions about CO <sub>2</sub> and light. We await the results.	N/A
3	P→M	55	We examine the results of our experiment and construct posters that communicate our findings and analysis. We review other groups' results and discuss as a class.	We come away with some key ideas about photosynthesis: we recognize that plants use CO <sub>2</sub> in the light because they are doing photosynthesis. In the dark, plants give off CO <sub>2</sub> because they are doing cell respiration. But we still wonder about whether plants may be respiring in the light too.	Plants respire using the same cellular respiration reaction as other organisms to acquire the energy they need.

Seg	Model Move	Est Time (min)	Overview	What did we figure out?	Model Ideas Generated
4	P→M	55	Here we examine the phenomenon of the lab more deeply to refine our model ideas. Students do the “Light and Dark” 4 Corners activity which reveals their thinking on the still-unanswered questions about plants. In discussion we go deeper to establish that plants do photosynthesis only in the light, but cell respiration all the time. We also reason about why our results do not reveal that CO <sub>2</sub> is released in the light.	Plants only do photosynthesis in the light, but they do cell respiration all of the time. Thus, in the light plants are both releasing and taking in CO <sub>2</sub> . However, we reasoned that photosynthesis happens at a much faster rate than cell respiration, so CO <sub>2</sub> taken in greatly exceeds CO <sub>2</sub> produced. In fact, the rate of photosynthesis is so much faster that the net effect of a plant on the environment over time is to reduce the amount of CO <sub>2</sub> in the atmosphere.	On the whole, plants take in more CO <sub>2</sub> than they give off. This is a precursor to ideas we’ll develop about the net production of glucose. (But first we’ll have to figure out that glucose is actually a product of photosynthesis.)
5	M	10	We apply the chemical reaction model to photosynthesis, specifically to reason about the nature of the energy change involved.	Photosynthesis requires energy, specifically the energy in sunlight. The sun’s energy is used to rearrange low energy reactants into high-energy products.	Photosynthesis requires energy, specifically the energy in sunlight. The sun’s energy is used to rearrange low energy reactants into high-energy products.
6	Q→M	30 - 100	Now that we’ve defined photosynthesis as an energy-consuming reaction, we turn to think about the matter involved in the reaction: what are the reactants and the products?  (There is an optional activity, a “glucose and photosynthesis” demo or lab you can run here. It can take anywhere from 10 to 90 additional minutes.)	The reactants of photosynthesis are H <sub>2</sub> O and CO <sub>2</sub> . The products are glucose and O <sub>2</sub> . Photosynthesis is the reverse of cellular respiration: the products of photosynthesis are the reactants of cellular respiration and vice versa. All cellular energy (ATP) comes from glucose, and all glucose is made in photosynthesis using the sun’s energy. Therefore, all energy for life originally comes from the sun.	We’ve added the identity of the products and so have a full equation related to the nascent model idea in the last learning segment.  Plants take in low energy molecules (CO <sub>2</sub> + H <sub>2</sub> O) and use energy from the sun to rearrange them into high energy molecules, glucose (C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> = food!) and oxygen. The reactions involved are collectively called photosynthesis.

Seg	Model Move	Est Time (min)	Overview	What did we figure out?	Model Ideas Generated
7	M→Q	30	We summarize the model ideas we've pulled together so far and add them to our two running models.	We've added language to our two models: Matter from Food and Energy from Food.	<p>We take stock of all of our model ideas in this learning segment, explicitly leveraging our earlier realization that plants take in more CO<sub>2</sub> than they give off to reason that:</p> <p>We also recognize this means that plants produce more O<sub>2</sub> than they use.</p> <p>And it also means a plant produces more glucose than it uses for energy.</p> <p>Glucose not used for energy is used to build biomass.</p>
8	M→Q	50 - 100	We return to the Seed to Tree Challenge Question and answer the question, "Where did all of the matter come from?" In explaining this phenomenon, we apply both the model for Matter from Food and the model for Energy from Food.	The majority of the mass of a tree comes from the CO <sub>2</sub> it takes in from the atmosphere. The plant turns it into glucose through photosynthesis. Any glucose the plant doesn't respire for energy can be used to generate the carbon-containing matter that makes up the plant.	N/A