# Teacher Overview Triangle P: Photosynthesis

***Transition in:***We now know how we get energy we need to survive and the matter we need to grow and maintain our bodies. But what about plants? Do plants have the same needs and processes? NOTE: This is where questions about plants that were “parked” in previous triangles can be very useful. There will be questions about whether or not plants need food, use O2, and/or produce CO2 - perfect motivation for the photosynthesis model!  
   
**Overview:** We established in previous triangles that living things take in food and oxygen, rearrange them for matter and energy, and release carbon dioxide and water. But what about plants? Do plants need food? Plants don't eat, so how do they get food?  To develop this model students explore how plants capture energy from the sun to build biomolecules (food!) in photosynthesis. Early on in the triangle design and conduct a lab to see how CO2 is involved in plants. Their results suggest CO2 is taken in when a plant is in the light and released in the dark. However, through discussion and activities, students ultimately reason that plants must be doing cell respiration all the time, but in light the effect is masked by photosynthesis. Students can now use this model, with the Chemical Reaction, Cellular Respiration, and Biosynthesis models, to explain where all the “stuff” comes from to when a seed grows into a tree. (Seed to Tree Challenge Question).  
   
***Transition out:*** We now understand the substances and important processes needed for individual organisms to survive, and we know species survival depends on individual survival. But can a species survive on its own, without other species?

**Overall Time:** 7 days

**P-Q-M for Model P: Photosynthesis**

**Phenomenon**: Plants don’t eat yet they have matter to grow and somehow they have energy to live.

**Question:** How do plants get the matter they need for energy, growth and other life processes?

**Model:**

As we move through the remainder of the Red Loop and develop ideas about matter and energy flow in organisms, we explicitly develop two models in parallel. In our work with cellular respiration, we primarily add ideas to a model for Energy from Food.*.*

**Energy from Food:**

Ideas from Our Model for Chemical Reactions

Energy is conserved, neither created nor destroyed. Energy is transformed in chemical reactions.

When the reactants have more potential energy than the products, energy is released in the reaction (“downhill” reaction).

[electrolysis classrooms only]

When the products have more potential energy than the reactants, energy must be added to the reaction (“uphill” reaction).

Food has energy in the form of calories.

Living things get energy by rearranging food and oxygen molecules.

Ideas from the Cellular Respiration Triangle

Living things rearrange food (specifically glucose - C6H12O﻿6﻿) and O2 into CO2 and H2O

(C6H12O6 + O2) have higher energy than (CO2 + H2O) so this rearrangement releases energy.

- The rearrangements occur in a series of steps rather than all at once.

- Collectively the reactions are called cellular respiration.

- Usable cellular energy is released in the form of ATP.

UNITY AND DIVERSITY: Other reactions (such as fermentation) can produce biologically usable energy, but they are usually less efficient. We see these reactions in some groups of organisms that have evolved under different environmental conditions and in our own bodies during times when oxygen is not readily available.

Ideas from the Biosynthesis Triangle:

[ethanol classrooms add] When the products have more potential energy than the reactants, energy must be added to the reaction (“uphill” reaction).

*Building new biomolecules (proteins, fats and carbs) from the products of digestion requires energy. [also for “Matter from Food”]*

If you run out of glucose your body can pull from fat stores and then as a last resort, amino acids to provided fuel for cellular respiration.

New Ideas in Photosynthesis

Plants take in low energy molecules (CO2 + H2O) and use energy from the sun to rearrange them into high energy molecules, glucose (C6H12O6 = food!) and O2. The reactions involved are collectively called photosynthesis.

Plants respire using the same cellular respiration reaction as other organisms to acquire the energy they need.

**Matter from Food**

Ideas from Our Model for Chemical Reactions

Matter is conserved, neither created nor destroyed. Matter is rearranged in chemical reactions.

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.

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.

Some of this matter (especially much of the water but also some indigestible material) basically passes through us.

Ideas from the Cellular Respiration Triangle

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.

Ideas from the Biosynthesis Triangle:

Some of our digested food is used for repair and to build new body tissue.

*Building new biomolecules (proteins, fats and carbs) from the products of digestion requires energy. [also for “Energy from Food”]*

Food consumed in excess of what we need for energy and growth/repair is converted to fat and stored.

**New Ideas in Photosynthesis**

Plants take in low energy molecules (CO2 + H2O) and use energy from the sun to rearrange them into high energy molecules, glucose (C6H12O6= food!) and O2. The reactions involved are collectively called photosynthesis.

Over a 24 hour period, the rate of photosynthesis in a plant is greater than the rate of cellular respiration. As a result:

Plants use more CO2 than they give off.

Plants produce more O2 than they use.

This means that a plant produces more glucose than it uses for energy.

Glucose not used for energy is used to build biomass.

P Photosynthesis at a Glance (approximately 7 traditional class days):

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Seg | Model Move | Est Time  (min) | Overview | Resources | What did we figure out? |
| 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. | * P Doodle Sheet | We’ve established some ideas around matter and energy in plants, but we have a number of questions, especially regarding the role of CO2. |
| 2 | **Q🡪P** | 110 | We set aside some of our questions in favor of addressing a central idea, “What is the role of CO2 with plants?” Students design, set-up and execute an investigation to look at CO2 output and uptake in an aquatic plant in both light and dark conditions. | * P Doodle Sheet * P 02 Photosynthesis Lab TEACHER GUIDE * P 02 Photosynthesis Lab * Lab Supplies as outlined in the TEACHER GUIDE | We’ve decided on an experimental design that will help us answer our questions about CO2 and light. We await the results. |
| 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. | * P Doodle Sheet * P 03 Gallery Walk Feedback Sheet | We come away with some key ideas about photosynthesis: we recognize that plants use CO2 in the light because they are doing photosynthesis. In the dark, plants give off CO2 because they are doing cell respiration. But we still wonder about whether plants may be respiring in the light too. |
| 4 | **P🡪M** | 55 | Here we examine the phenomena from the lab more deeply to refine our model ideas. We debate some lingering unsettled ideas using “Light and Dark” Four Corners activity and data from some additional experiments. | * P Doodle Sheet * P 04 Light and Dark Four Corners Handout | We conclude that plants only do photosynthesis in the light, but they do cell respiration all of the time. Since photosynthesis happens at a much faster rate than cell respiration under light conditions, the net effect of a plant on the environment over time is to reduce the amount of CO2 in the atmosphere. |
| 5 | **M** | 10-15 | We apply the chemical reaction model to photosynthesis, specifically to reason about the nature of the energy change involved. | * P Doodle Sheet | We see that photosynthesis requires energy, specifically the energy in sunlight. The sun’s energy is used to rearrange low energy reactants into high energy products. |
| 6 | **M** | 20 | We know the products of photosynthesis are glucose and O2, and we know that one of the reactants is CO2. We once again put our model ideas about matter to work and determine the other product, glucose. Photosynthesis is the opposite chemical equation to cellular respiration. | * P Doodle Sheet | We now have the reactants and products and have realized that chemical equation for photosynthesis is the reverse of cellular respiration. 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. |
| 7 | **M** | 30 | We summarize the model. | * P Doodle Sheet | We’ve added language to our two models: Matter from Food and Energy from Food. |
| 8 | **M🡪P** | 110 | 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. | * P Doodle Sheet * P 08 Seed to Tree Handout | The majority of the mass of a tree comes from the CO2 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. We related the seed to tree phenomenon to the Biggest Loser. |

## Learning Segments in Detail:

We recommend that you have the PowerPoint slides open while you review the details of this document.

## 1. **M🡪P:** **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.**

Estimated time: 55 min

Resources:

Sprout to Tree student handout.

A large whiteboard, markers and eraser for each group.

Poster paper and markers for final group explanations.

Details: You likely have other ways of entering the conversation about plants, most readily through a return to any Parking Lot questions and ideas students have raised about plants in the past two triangles. Feel free to incorporate those questions in the course of this Learning Segment.

Here we present a motivating phenomenon, Seed to Tree, and frame it as really an “opposite case scenario” to the Biggest Loser Challenge.

We consider, “Where did the matter come from?” Students will return to this Challenge Question at the end of the triangle, but this is an opportunity to recognize that (1) the class may already have some ideas about plants and (2) there are a lot of lingering questions.

Students work on their Doodle sheets and in groups to generate both the ideas and questions. They are also asked to EVALUATE their ideas against the models for Matter from Food and Energy from Food before bringing them to the class. In this way, you have some formative assessment for students understanding of the models we’ve been building.

Once students have written their own explanations, they go to groups, share their explanations (using Talking Sticks) and work together to develop a ”best” explanation. Once they have their thoughts organized they write their explanations on poster paper. Provide an opportunity for them to see the work of other groups, either via a Gallery Walk, or by sharing with the whole class as you prefer and time allows. Provide a way for them to give constructive feedback on each other’s work.

Follow the sharing with a whole-class discussion. The idea that the majority of the mass of the tree comes from CO2 almost always emerges from at least some groups. Depending on the other ideas that arise, you may need to tweak the discussion in that direction. Students often include water too, and that is not technically incorrect. However you might want to compare the molecular masses of water and CO2 to help them see the much greater contribution of CO2.

After the whole-class discussion, give students the opportunity to revise their explanations in groups first, then individually. The final individual explanation is graded for correctness and completeness.

**New idea:**

**What did we figure out: We’ve established some ideas around matter and energy in plants, but we have a number of questions, especially regarding the role of CO2.**

## 2. **Q🡪P: We set aside some of our questions in favor of addressing a central idea, “What is the role of CO2 with plants?” Students design, set-up and execute an investigation to look at CO2 output and uptake in an aquatic plant in both light and dark conditions.**

Estimated time: 110 min

Resources:

* P 02 Photosynthesis Lab
* P 02 Photosynthesis Lab TEACHER GUIDE
* Per Lab Group:
* Dark and Light Test Tube Coloring Pages
* Markers, poster paper, etc. as outlined in the teacher guide

Details: This learning segment gives students a chance to engage in the science and engineering practice of designing an investigation. Students plan and execute an experiment to determine whether plants give off and/or take in CO2 and to establish the role of light. All of the information needed to prepare the classroom and students for the lab is in the separate Teacher Guide. The objective of this segment is to give students experience designing an experiment.

They must figure out how to set it up so it will provide the information they need to answer the experimental questions. They must grapple with what controls they will need. They first think it through individually on their prelab, then share their thinking with their group members before deciding on a final plan. Typically they do the prelab for homework, then spend about 30 minutes sharing their ideas and deciding on their final plan. Once groups have decided on their plan they color the “Start” row of their Dark and Light test tube coloring sheets accordingly. These will ultimately be pasted on the poster they will create at the end to show their results.

Not all groups will come up with perfectly designed experiments, of course. A common mistake is to leave out one or more controls. It is tempting to try to guide them to fix the problem before they set up the experiment, but far better to let them discover the problems for themselves when they are not able to make sense of their results at the end. Struggling with this will help them understand why that control was needed in the first place and will make a far more enduring impression than if the teacher had just told them at the outset. The class is usually able to work together to make sense of what is happening with the lab even if a couple of groups make some procedural mistakes.

**What did we figure out?**

We’ve decided on an experimental design that will help us answer our questions about CO2 and light. We await the results.

3. **P🡪M: 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.**

### Estimated time: 55 min

Resources:

* P 02 Photosynthesis Lab
* P 02 Photosynthesis Lab TEACHER GUIDE
* Per Lab Group:
* Dark and Light Test Tube Coloring Pages
* Markers, poster paper, etc. as outlined in the teacher guide
* P 03 Gallery Walk Feedback Sheet

Details: This learning segment builds directly off the Photosynthesis Lab completed in the last one. On day two of the experiment, groups break down the lab and color the “End” rows on their test tube coloring pages to show their results. They paste these on their poster paper and then add their analysis of their results (per directions on the PowerPoint). The poster can serve as the “conclusion” to the lab at your discretion.

Here students must grapple with making sense of results that are not completely straightforward – namely, the results usually make it appear that plants do photosynthesis in the light and cell respiration only in the dark.Because it is important for them to be exposed to the thinking of as many classmates as possible, and because they may have set up their own experiment without controls or with other problems, we do a Gallery Walk. Finally we come together as a class to discuss the data. Usually at this point everyone agrees that our data shows plants do both photosynthesis (because the plant removed CO2 in the light) and cell respiration (because the plant released CO2 in the dark), but some questions still remain. Note: Slides with pictures of typical results are provided in case you need them for class discussion.

We hope during the all-class discussion, questions that can’t be answered by the data emerge.

We saw in the lab that plants give off CO2. But we’ve been taught they remove CO2 from the atmosphere. How can that be?

Since we only see evidence of CO2 production at night does that mean plants only do cell respiration at night? Don’t they need ATP in the daytime too?

If questions like these don’t come up, you may need to ask probing questions to draw them out.

**What did we figure out?** We come away with some key ideas about photosynthesis: we recognize that plants use CO2 in the light because they are doing photosynthesis. In the dark, plants give off CO2 because they are doing cell respiration. But we still wonder about whether plants may be respiring in the light too.

### 4. **P🡪M: 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 CO2 is released in the light.**

Estimated time: 55 min

Resources:

* P Doodle Sheet
* P 04 Light and Dark” Four Corners Handout

Details: Students readily recognize that the results of the lab show that cell respiration happens in plants, but often are still confused about when it happens. Because only the dark test tubes show the effect of CO2 release, many students understandably come to the conclusion that cell respiration only happens in plants in the dark. This is the intuitive idea that we take up and examine with the 4 corners activity.

It is an excellent formative assessment not just because it exposes this thinking, it also allows students to clear up the idea themselves rather than being “told” by the teacher. Students first respond individually to the prompt, then go to the corner of the friend with whom they most agree. Directions for this and the next steps are on the student slide. Teachers using this activity often find that it winds up in a standoff between Calvin and Mika’s corners. The Calvin group argues “that’s what the data shows”, while the Mika group says that cells can’t live all day without energy. If this happens, slide 31 usually helps break the stalemate. In any case, we don’t stop until all students are convinced that photosynthesis occurs only in the light, but cell respiration occurs all of the time.

However, students still should wonder about the results we got in the light. If in fact plants are always doing cell respiration and giving off CO2, how can we explain the fact that the test tube that started blue with a plant in the light stayed blue. If it is releasing CO2, why didn’t it turn yellow? We have groups brainstorm this, then share out with the class. Usually at least a couple of groups suggest that since photosynthesis is also happening in the light, it must be removing the CO2 as fast or faster than cell respiration is producing it. Ask students if they can now answer all of the questions they had initially. This almost always included “Do plants really lower CO2 levels in the atmosphere?.” It is very important that you get these answers from students and not just tell them – so do not move forward with the animations on the slides until you do!! You may need to ask some leading questions if they seem stuck, but they can do it!

**What did we figure out?**

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 CO2. However, we reasoned that photosynthesis happens at a much faster rate than cell respiration so CO2 taken in greatly exceeds CO2 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 CO2 in the atmosphere.

### 5. **M: We apply the chemical reaction model to photosynthesis, specifically to reason about the nature of the energy change involved.**

Estimated time: 10-15 min

Resources:

* Photosynthesis Doodle

Details: Students sketch the energy diagram they think applies to photosynthesis on doodle sheets, pair/share, then share out. This should go quickly because students know that sunlight is energy and that without it photosynthesis will not occur. This sets the stage for making the connection between photosynthesis and cell respiration, and for tracing all biological energy back to the sun.

**What did we figure out?** Photosynthesis requires energy, specifically the energy in sunlight. The sun’s energy is used to rearrange low energy reactants into high energy products.

**6. M: We know the products of photosynthesis are glucose and O2, and we know that one of the reactants is CO2. Now we reason about the other reactant and complete the equation.**

### Estimated time: 20 min

Resources:

* Photosynthesis Doodle

Details: Students speculate about the remaining unidentified reactant (water) on doodle sheets, pair/share, then share out. Usually this goes quickly for several reasons: 1) students know that plants need water, and 2) they reason (due to conservation of matter) that the remaining reactant must contain hydrogen.

Once we have the complete reaction for photosynthesis we ask students to compare/contrast it to cell respiration on doodle sheets. Let them figure it out! Most students notice that they are the reverse of one another – the products of photosynthesis are the reactants of cell respiration and vice versa. We also invoke conservation of energy and ask students to trace the energy used by organisms (ATP) back to its origin. Most students are able to recognize that it all starts with the sun.

**What did we figure out?** The reactants of photosynthesis are H2O and CO2. The products are glucose and O2. 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.

**7. M🡪Q: We summarize the model before moving on to seed to tree…**

Estimated time: 30 min

Resources:

* Photosynthesis Doodle

Details: The goal of this segment is closure. We summarize our model ideas. We also want to address any lingering questions.

**What did we figure out?** Plants use any extra glucose they produce beyond what they need for ATP to produce more body tissue (grow!). In the ecosphere the shrimp depend on the algae for the food and O2 it produces in photosynthesis. The shrimp breakdown the food and O2 into CO2 and H2O in cell respiration in order to get ATP. The CO2 and H2O produced by the shrimp are the reactants that the algae need in order to do photosynthesis. The only thing needed to keep the ecosystem in the ecosphere alive is the right amount of sunlight.

### **8.** **M🡪Q: We return to Seed to Tree and ask students to explain using their models.**

Estimated time: 110 min

Resources:

* Sprout to Tree student handout.
* A large whiteboard, markers and eraser for each group.
* Poster paper and markers for final group explanations.

Details: First students respond to the Sprout to Tree question individually, either as homework or in class. Remind them to base their explanations on the models. The objective is to write an explanation that integrates the ideas from the 4 recent models. This is very challenging, even for students who understand the models well. One obstacle can be the common misconception that plants only use soil and water to grow. The last 2 slides may help address those ideas if needed.

Once students have written their own explanations, they go to groups, share their explanations (using Talking Sticks) and work together to develop a ”best” explanation. Once they have their thoughts organized they write their explanations on poster paper. Provide an opportunity for them to see the work of other groups, either via a Gallery Walk, or by sharing with the whole class as you prefer and time allows. Provide a way for them to give constructive feedback on each other’s work.

Follow the Gallery Walk with a whole-class discussion. The idea that the majority of the mass of the tree comes from CO2 almost always emerges from at least some groups. Depending on the other ideas that arise, you may need to tweak the discussion in that direction. Students often include water too, and that is not technically incorrect. However you might want to compare the molecular masses of water and CO2 to help them see the much greater contribution of CO2.

After the whole-class discussion, give students the opportunity to revise their explanations in groups first, then individually. The final individual explanation is graded for correctness and completeness.

**What did we figure out?** The majority of the mass of a tree comes from the CO2 it takes in from the environment. The tree uses the energy in sunlight to rearrange that CO2, along with water from the environment, to form glucose and O2. Some of the glucose and O2 produced is used by the tree to obtain ATP by doing cell respiration. Any extra O2 produced is released to the environment. Any extra glucose produced is used to build new body tissue, in other words, to grow. Hence the majority of the matter that makes up the tree originally came into the tree from the environment as CO2.