

LIFE SCIENCE

Photosynthesis

Sunlight

Glucose
 $C_6H_{12}O_6$

Carbon

Oxygen

Hydrogen

Underside of the leaf



26865

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Blackline masters of all worksheets may be found in the back pocket of the binder



Credits and Thanks

Thanks to the Lexington Educational Foundation, Lexington, MA, for funding the LEGO biology field tests. This innovative organization paid for the production of the prototype educational materials and for the Lexington Public School teachers to meet outside of school time.

Founded in 1989, the Lexington Education Foundation is an independent, nonprofit community organization supporting educational excellence in Lexington Public Schools, Lexington, MA. The Foundation provides grant funding for ongoing professional development, teacher mentoring, experts-in-residence, and curriculum innovations outside the regular school budget. Directed by a non-salaried board of community members and supported by contributions from Lexington residents and local area businesses, LEF manifests the spirit of a community that takes pride in, and responsibility for, the public education of its children.

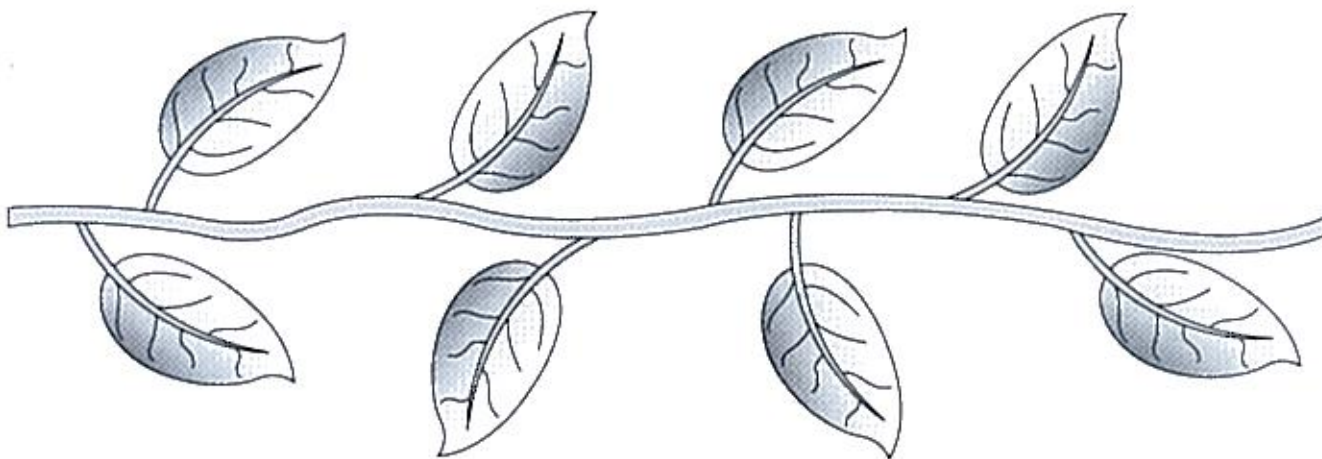
To learn more about LEF, please visit www.lexedfoundation.org, or e-mail info@lexedfoundation.org.

Thanks to the LEGO Educational Division, Enfield, CT, for the donation of LEGO elements to the Lexington Public Schools, Lexington, MA.

Thanks to the teachers in the Lexington Public Schools who tested the LEGO *Photosynthesis* lessons: Christopher Carter, Susan Kirkland, Laura Krich, Audra Tullock, and Mark Waldeck. Thanks also to the following teachers who reviewed the *Photosynthesis Teacher's Guide*: Jennifer Burgin, Chris Carter, Rick Comeau, Luis Fernandes, Joanne Hennessy, Susan Offner, Robert Pohlman, and Mark Waldeck.

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Kathleen Vandiver, Ph.D.



Introduction

Purpose of Set

The objective of the first two lessons in this LEGO Photosynthesis Teacher's Guide is to have the students build a model of the basic chemical reaction that takes place in photosynthesis and cellular respiration. The objective of the third lesson is to have the students build models of starch and cellulose. This third lesson demonstrates how carbon dioxide molecules in the photosynthesis reaction become incorporated into the plant.

The photosynthesis set allows students to create a concrete model of the process of photosynthesis. Before, the chemical equation for photosynthesis may have been too abstract for many students. As a consequence, the principles of photosynthesis are often illustrated with living plants. While these activities may be helpful to students in a global way, such experiments do not help the student attain an understanding of the basic chemical transformation that is taking place in plants.

LEGO Photosynthesis Lesson Sampler

In groups of two, students will use LEGO elements to build models of the molecules in the photosynthesis/respiration equation. The student's visual mind will be stimulated by the process of translating the symbolic chemical notation into a three-dimensional molecular structure. Students place the structures next to the symbols they have written on the papers provided.

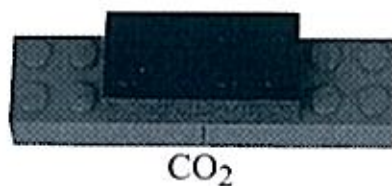
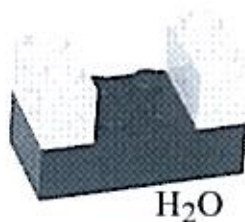
After the equation has been illustrated by creating the LEGO molecules, the students are asked to remove the molecules from the right side of the equation and provided with a challenge. The challenge includes answering, "Can you do what plants do? Can you take water and carbon dioxide and make the products that are made in photosynthesis?"

Students start with the six H_2O molecules and the six CO_2 molecules they have already assembled, and they build one molecule of sugar from these starting materials. When the glucose molecule is complete, students discover they have six O_2 molecules left over!

Lesson Outcome – "I Get It!"

The kinesthetic experience of building the molecules enhances "the making of meaning." Students discover that building the large $\text{C}_6\text{H}_{12}\text{O}_6$ molecule takes effort. For the plant, this molecule is also built by an elaborate process that also requires energy from the Sun. When the students have built all the molecules in the equation, the second activity of transforming the reactants into the products by manually rearranging the same atoms is a very meaningful activity.

With this kinesthetic experience, many students discover for the first time what a chemical reaction really is. Excitedly, students have been known to stand up and yell, "I get it!"



LEGO Learning Philosophy: The 4 Cs

The design of the *Photosynthesis* curriculum is the learning philosophy of the LEGO Educational Division, and the objective is to inspire learning through design, construction, simulation, exploration, and discovery. This curriculum provides an innovative, accessible, and educationally sound method for exploring content areas of math and science in the classroom.

The development of this curriculum follows a philosophy established by the LEGO Educational Division that can be represented with a cyclical model based on four educational principles:

Connect: Learning only becomes real and relevant when new learning experiences can be connected to previous knowledge and experiences of the learner or when the learner is exposed to initial learning experiences that are stimulating and can be used as a seed or the start of a new framework of knowledge. Providing a learning environment where students can be creative and make their own emotional and mental connections to the content being introduced will contribute to a deeper understanding and retention of concepts, knowledge, and skills.

Construct: Learning by doing and building involves the organization and construction of ideas and models. Robotics activities offer three types of construction:

- 1) **Open-Minded Exploration:** Before making assumptions and decisions about how/why things are done, students are given the opportunity to freely explore concepts in order to make connections from previous learning experiences. This free exploration allows students to organize ideas before beginning construction of models.
- 2) **Guided Investigation:** By observing the performance of a robot and understanding the tasks that need to be accomplished in order to successfully complete the challenge, students will discover the necessary steps needed to design and build models for specific tasks.
- 3) **Open-Ended Problem Solving:** As students become confident with designing and building based upon steps learned and practiced, they begin to use lessons learned to design and build models to meet other challenges.

Contemplate: Reflection is an integral part of any successful learning process. In this curriculum, you will find structured opportunities for students to reflect both verbally and in writing about their programming and engineering ideas, their plans for modification and adjustment, and on successes and programs encountered. As students become familiar with the procedure used for contemplating, they implement the process into each mission and use reflection as a tool for improving performance and results.

Continue: Photosynthesis is designed to offer students opportunities to extend their learning experience beyond the basic activities into other content areas.

The 4 Cs are identified throughout this curriculum, and it is our hope this learning philosophy assists you as you make your plans to implement this curriculum in your classroom.

List of Materials

Set contents:

- Yellow bin with insert and lid
- Student Building Instructions
- Photosynthesis Mat
- 24 1 x 2 white bricks
- 2 gray connector pegs
- 48 2 x 4 bricks
 - 36 red
 - 12 black

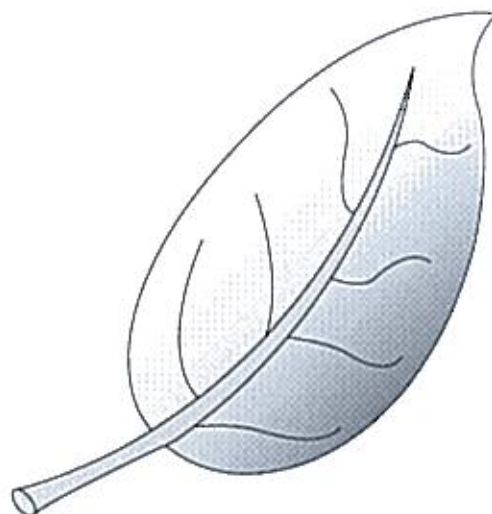
Set assembly instructions:

Place the correct elements into the insert trays as shown on the underside of the box lid. Place the Student Building Instructions and the box lid on top of the tray before closing the lid.

Other Materials:

- Plant Cells and Molecules (poster)
- Plants from Thin Air? (poster)
- Plants Are Made from Thin Air? (overhead)
- What Happens in a Plant Cell? (overhead)
- Molecules Made from Glucose (overhead)
- Teacher demonstration magnets*
- Blackline masters of worksheets
 - Plant Growth (front and back)
 - Team Equation Sheet 1
 - Photosynthesis and Cells (front and back)
 - Writing Chemical Formulas (front and back)
 - Photosynthesis Learning Assessment (front and back)
 - Photosynthesis and Soil (front and back)

* The best way to cut the magnets apart is to score the top with a utility knife and break the pieces apart. Alternately, you can use scissors to cut apart the magnets.



Lesson Planner

As outlined below, the photosynthesis content can be taught in three 45-minute blocks. An additional and optional 45-minute (stand-alone) lesson is provided to reinforce basic concepts in chemistry and chemical notation skills.

Dr. V.'s comment

The purpose of the worksheet "Plant Growth" is to have students recognize their own misconceptions by experiencing a discrepant event. Students are more likely to revise their mistaken beliefs after a surprising discovery exposes the error.

Photosynthesis Lesson 1 (45 minutes)

Topic: Discovering plants do not utilize soil as food. Decoding the symbols in the photosynthesis equation.

- | | |
|----------|--|
| 10 min | • "Plant Growth" worksheet |
| 5-7 min | • Set check |
| 5-7 min | • Whole class chemistry review |
| 15 min | • Decode the photosynthesis equation |
| | • Build the molecules to illustrate the equation |
| 5 min | • Wrap-up |
| Homework | • "Photosynthesis and Soil" worksheet |

Photosynthesis Lesson 2 (45 minutes)

Topic: Chemical reactions produce new molecules by rearranging atoms. Cells can get energy from glucose molecules.

- | | |
|----------|---|
| 3-5 min | • Set check |
| 10 min | • Write and build photosynthesis equation |
| 15 min | • Challenge 1 – Show Photosynthesis in Action |
| 10 min | • Challenge 2 – Show Cellular Respiration in Action |
| 5 min | • Wrap-up |
| Homework | • "Photosynthesis and Cells" worksheet |

Photosynthesis Lesson 3 (45 minutes)

Topic: The message in the photosynthesis equation is a plant's substance comes mostly from the air.

- | | |
|----------|--|
| 3-5 min | • Set check |
| 7 min | • Discussion: Where do plants get their atoms from?
How do water and carbon dioxide get into the plant?
What does it mean, "Plants make their own food?" |
| 20 min | • Challenge 3 and Challenge 4 |
| 5 min | • Discussion: The carbon dioxide molecules are now part of the structure of the plant. |
| 5-7 min | • Wrap-up |
| Homework | • "Photosynthesis Learning Assessment" |

Dr. V.'s comment

Reading the students' comments about their own learning should provide some insight. These insights may help you decide what to keep and what to change when you teach photosynthesis next year.

Additional Basic Chemistry Lesson (45 minutes)

Topic: Practice formula writing and depicting elements, compounds, and mixtures.

- | | |
|---------|---|
| 3-5 min | • Set check |
| 15 min | • Project A: Build and exchange small molecules. Write and check the formulas. |
| 20 min | • Project B: Teams build chemicals, then circulate, write formulas for displayed constructions. |
| 5 min | • Wrap-up |

Detailed Plans for Lesson 1

Terms:

atoms
elements
compounds
carbon dioxide molecule
water molecule
oxygen molecule
glucose molecule
chemical formula
subscript
chemical equation

Dr. V.'s comment

Avoid pairing students who have widely different learning aptitudes. With hands-on materials, teamwork is important for learning and more teamwork occurs if the students are not too divergent in ability. Also if you use this teaming technique, you will be free to spend more time with those teams of students who really need your help.

Lesson 1 (45 minutes)

Topic: Discovering plants do not utilize soil as food. Decoding the symbols in the photosynthesis/cellular respiration equation.

Objectives:

Students should be able to:

- Recognize that plants do not utilize soil as food.
- Explain and demonstrate that atoms combine to form molecules.
- Explain and demonstrate that atoms in a molecule fit together in a particular way. Each kind of molecule has a specific shape. For example, all water molecules look the same.
- Explain and demonstrate that chemical formulas represent the number and kinds of atoms in a molecule.
- Copy, decode, and build all the molecular models that are written in the balanced equation for photosynthesis.

Preparation Prior to Class

Assemble the sets.

Choose student teams. Two students per team is best. Each team will work with one LEGO Photosynthesis Set.

Photocopy:

Team Equation Sheet (one per team)

"Plant Growth" worksheet (one per student)

"Photosynthesis and Soil" worksheet (one per student)

Designate a container as lost and found for LEGO elements.

Display the two teaching posters.

Precut the magnets.

Check Materials needed for Lesson 1:

- LEGO Photosynthesis Sets
- Team Equation Sheets
- "Plant Growth" worksheets
- Teacher demonstration magnets
- "Photosynthesis and Soil" worksheets

Introduction (10 minutes)

Explain to your class that it is useful for them to find out how much they already know about plant growth. In order to track their own progress on the topic of photosynthesis, have the students take a few minutes to complete the worksheet called "Plant Growth." Instruct the students to be as honest as possible when answering the questions. Also, let them know that the papers will be collected, but not graded.

Collect the papers. (Read the papers later to gain an understanding of the students' common knowledge.) You may wish to return these

worksheets during Lesson 3 when the students complete a worksheet called "Photosynthesis Learning Assessment" as homework or class work.

Set Check (5-7 minutes)

- 1) Introducing this activity set includes checking the piece count and building three molecules. Each student team will have in front of them: a LEGO set and the Student Instructions. Have the students wait until given permission to open the LEGO sets.
- 2) Before opening the sets, preview pages 2 and 3 in the Student Instructions with the students. The instructions direct them to count the bricks. Explain that every element is needed for the LEGO activities. There are no extra elements in the set. Page 3 directs the students to build three different molecules. Explain that these are the standard LEGO shapes for: CO_2 , H_2O , and O_2 .
- 3) Allow the students to open the set and follow the instructions. Students who finish early could be directed to make as many water molecules as they can with the set.

These activities will help the students become familiar with the bricks' connectivity and help them learn the key for the atoms. Most students enjoy having something to build right away.

Whole Class Chemistry Review (5-7 minutes)

First, review the key for the atoms. Try to get rapid participation. Add a quick confirming comment to help the students remember the color code for each atom. Do not ask a lot of interactive questions – do not stretch out this part of the lesson. This review needs to be directly on target, because you need time for the main activity.

- Have each person hold up one hydrogen atom. Verify that each person holds up a white brick.
- Have each person hold up one carbon atom. Verify that each person holds up a black brick.
- Have each person hold up one oxygen atom. Verify that each person holds up a red brick.
- Have each person hold up one oxygen molecule. Verify that each person holds up two correctly connected red bricks. The correct layouts are shown on the mat.

Briefly explain that a molecule is two or more atoms bonded together. The oxygen atoms in our air are always bonded in twos, like the example they created. That is the way the oxygen atoms prefer to be. The word *molecule* means little lump. A molecule is a little lump of matter.

Lesson 1

Dr. V.'s comment

To help students make a good connection between the LEGO model and reality, it may be effective to lift up a glass of water when you are pointing out that water has only H_2O molecules in it. You can also place LEGO water molecules inside a second glass. This will help the students to imagine lots of separate H_2O molecules in the substance they know as water.

- Have each person hold up one water molecule. Verify that each person holds up correctly connected bricks. Briefly explain that water is a compound because it has two different kinds of atoms bonded together. Ask the students if the oxygen molecules they made earlier are a compound. No, they are not; however, they are still examples of an element. Oxygen molecules have two of the *same* kinds of atoms bonded together.
- Have each person hold up one molecule of carbon dioxide. Verify each person holds up correctly connected bricks.

For students who have little chemical background you can explain formulas quite simply right now. Write CO_2 on the board. Ask the students if they have two carbon or two oxygen. Suggest that they look at their LEGO models. Chemists write a chemical formula for a molecule with the number of atoms written *after* the symbol. The number of atoms in the molecule is also written as a subscript, a little lower than the letters.

Write H_2O on the board. Explain that water is written as H_2O . Ask the students how many hydrogen atoms are in a molecule of water. Ask the students how to show 10 water molecules. Write a 10 in front of the H_2O .

Now write $4\text{H}_2\text{O}$ on the board. Ask each team to hold up the equivalent. If one of the student teams has connected all the water molecules into one large molecule, this is a very teachable moment. Hold up the incorrect sample of four water molecules joined together or borrow four water molecules and connect them for the sake of a demonstration. Ask the students the formula for this molecule. Write H_8O_4 on the board. Explain that this compound is *not* water; it is something else. Water has only H_2O molecules in it.

Decoding the Photosynthesis Equation (15 minutes)

- 1) The teams should locate the Student Instructions in the set. Briefly preview pages 4-16. Mention that the green print highlights biology information.
- 2) Model the students' task. Show a completed "Team Equation Sheet" using the teacher's demonstration magnets. Place the magnets below the sheet next to each chemical's symbol.
- 3) Distribute the "Team Equation Sheet." Instruct the students to follow the directions on the sheet. The students write the photosynthesis equation.

Dr. V.'s comment

If you choose not to use the "Team Equation Sheet," use this format:

Have the students write the photosynthesis equation on a large blank piece of paper.

- 1) Begin by requesting that the students make a vertical dotted line down the middle of the paper to create a left and right side of the paper.
- 2) Next, have students place the reaction arrow over the dotted line, *before* writing anything else.
- 3) Have the students copy the symbols on the right side and the left side of the equation.
- 4) This technique creates enough space to place the LEGO models next to each formula and avoids having the students run out of space. Remind the students not to "wrap" the equation.

- 4) Ask the teams to begin building. They can follow the directions in the Student Instructions. Ask them to raise their hands when they have completed the task of building all LEGO molecules for the equation. Check to be sure they are placing each LEGO structure in the equation near its chemical notation.
- 5) Have the student teams give you a brief description of each kind of molecule. Ask them to double check the number of the water molecules, carbon dioxide molecules, glucose molecules, and oxygen molecules present in the equations. (There should be six O_2 and one glucose molecule after photosynthesis occurs.)

Wrap-Up (5 minutes) (See classroom management tips)

Have students pack the sets after you have checked the team's equation models. Collect the "Team Equation Sheets." Be sure the students' names are written on them. Student teams reuse these sheets in Lesson 2.

Distribute the "Photosynthesis and Soil" worksheets. Students who finish early could help other teams or could start the "Photosynthesis and Soil" worksheet, which is the homework assignment.

Detailed Plans for Lesson 2

Terms:

mixtures vs. compounds
plant cell
chloroplast
chlorophyll
mitochondrion/mitochondria
nucleus
cell wall
photosynthesis
cellular respiration
energy
cycle

Dr. V.'s comment

You may be surprised. Some students may attach the CO_2 molecules with H_2O molecules. You could ask these students what the formula would be for this particular molecule. Make the point that in a mixture all the components are just mixed up together. They are still the same molecules. They keep their original properties. That's why mixtures of compounds can be separated by physical steps.

Lesson 2 (45 minutes)

Topic: Chemical reactions produce new molecules by rearranging atoms. Cells can get energy from the glucose molecules.

Objectives:

Students should be able to:

- Demonstrate and distinguish between compounds and mixtures.
- Describe and demonstrate the process of photosynthesis and demonstrate a balanced chemical equation.
- Describe and demonstrate the process of cellular respiration.
- Distinguish between a mitochondrion and a chloroplast and describe the function of each.
- Explain the transfer of energy from the sunlight to the glucose molecule and from the glucose molecule to the cell.

Preparation Prior to Class

Choose to keep the same student teams or make adjustments.

Designate a container as lost and found for LEGO elements.

Display the two teaching posters.

Obtain an overhead projector.

Photocopy:

“Photosynthesis and Cells” worksheet (one per student)

Materials needed for Lesson 2:

- LEGO Photosynthesis Sets
- “Team Equation Sheets” (saved from Lesson 1 or copy a new set from the masters)
- Teacher demonstration magnets
- Transparencies
- “Photosynthesis and Cells” worksheets

Set Check (3-5 minutes)

Have each team verify all the elements are present in the set.

Chemistry Review Activities (10 minutes)

Introduce that you will be doing two LEGO chemistry warm-up activities.

- 1) Activity 1: Ask the students to build a model of carbonated water (fizzy water) and explain that carbonated water is a mixture of carbon dioxide and water molecules. Explain they should make the model with ten H_2O and four CO_2 . Ask them to arrange the mixture on the table in front of them and raise their hands when done. You circulate. Check for 14 separate molecules.

Dr. V.'s comment

The question "Where does photosynthesis occur in the cell?" is important. The answer helps students connect what they are learning (a cellular process) to a particular part of the cell (chloroplast). Giving the process a fixed location will make the process more concrete. Furthermore, if the students have previously learned about chloroplasts and chlorophyll, this will help them connect the new knowledge to something they already know. Information is better retained this way.

Fabulous Fact

"Each year terrestrial and marine plants make enough glucose to fill a freight train 30 million miles long." Source: Mahlon Hoagland and Bert Dodson, *The Way Life Works*, 1995, Time Books, NY.

different gas molecules.

Ask the students to show you a model of a mixture of two gases. The gases are carbon dioxide (CO_2) and oxygen (O_2). Include four of each kind of molecule. Ask them to arrange the mixture on the table in front of them and raise their hands when done. You circulate, checking for correct construction. Remember that the molecules must be in their standard shapes. There should be eight total molecules.

In closing, mention that air is a mixture of molecules, approximately 80 percent N_2 and 20 percent O_2 with a very small amount of other molecules including CO_2 and H_2O . Plants will be taking in both CO_2 and O_2 molecules from the air.

Students will learn what plants do with gases. Plants take in the carbon dioxide to build the sugar molecules, and they take in the oxygen to burn the sugar molecules for energy.

Challenge 1 (15 minutes)

Show Photosynthesis in Action

Start by rebuilding the six water, six carbon dioxide, one glucose, and six oxygen molecules for the equation. After students have shown you the correctly completed photosynthesis equation, point out Challenge 1 on page 17 in the Student Instructions. Model the task. Using the teacher demonstration magnets, demonstrate removing the molecules from the right side of the equation. This helps students understand what they are being asked to do. Challenge 1 emphasizes the *process* of photosynthesis. Students are asked to construct the products of the reaction (glucose and oxygen) only from the previously constructed reactants (water and carbon dioxide). Tell the students they are doing what a plant does.

Help the students begin Challenge 1 by clearing away the LEGO elements from the right side of the equation. Tell students to put these elements into the box. Be sure to tell the students that the glucose need not be built from memory – they can use the directions on pages 7-16 in the student instructions.

When student teams have successfully built a glucose molecule out of the six CO_2 and six H_2O molecules, and have one glucose molecule with six O_2 molecules left, they should raise their hands. Check the results. Congratulate the students for doing what a plant does every day – it makes glucose from water and carbon dioxide.

At the end of this activity, a question is posed to the students. Ask each team to name the part of the cell *where* the process of photosynthesis occurs.

Lesson 2

Dr. V.'s comment

Where cellular respiration occurs is important to emphasize because it helps students connect new knowledge to something they already know. It also helps to make the point that most living things need oxygen. Oxygen is used in mitochondria. Mitochondria are found in both plant and animal cells.

Also remember to emphasize that plant cells can make glucose molecules first and then can turn around and use them for energy! (Making your own food is pretty convenient!)

The process of photosynthesis occurs in the “chloroplast.” This organelle is the subcellular location where photosynthesis occurs. The chloroplasts contain chlorophyll molecules which trap the light energy. The sugars are manufactured here.

Use the top half of the transparency “What Happens in a Plant Cell?” Having the “Plant Cells and Molecules” poster on display will be a helpful reference.

Challenge 2 (10 minutes)

Show Cellular Respiration in Action

In the instructions, students are directed to add a new arrow to the equation, going from right to left, and to show that this reaction will give off energy. This reaction should be labeled “Cellular Respiration.”

Students are instructed to model the process of cellular respiration by taking the previously assembled glucose molecule and the six O_2 molecules and converting them back into six CO_2 and six H_2O molecules.

At the end of Challenge 2, students are asked *where* the process of cellular respiration is occurs. The correct answer might be in both plants and animal cells but you are looking for the more specific answer: mitochondria. Use the bottom half of the transparency to aid in your explanation.

When student teams have successfully taken apart a glucose molecule and used the six O_2 molecules to produce six CO_2 molecules and six H_2O molecules, they should raise their hands.

Check to be sure students understand that this reaction produces energy. You could ask, “What’s this arrow for?” (Shows that the reaction gives off some energy for the cell to use.)

Check for student understanding about cycles, “Why are the processes of photosynthesis and cellular respiration considered part of a cycle in nature?” (The atoms get recycled.)

Wrap-Up (5 minutes) (See *classroom management tips*)

Have student count the elements and replace them in the insert trays. Have the student place the Student Instructions and the box cover on top of the tray before closing the lid.

Distribute the “Photosynthesis and Cells” worksheets. Have students begin this worksheet which they can complete as homework.

Detailed Plans for Lesson 3

Terms:

starch
cellulose
wood
cell wall

Fabulous Fact

Experiments have been done with radioactive oxygen atoms to trace the flow of oxygen atoms during photosynthesis. It is a complicated process. Water molecules that come up from the roots actually produce the oxygen atoms that are released back into the air by the plant (O_2). So plants split the oxygen off the water molecules and release them. Therefore we know that the oxygen atoms found in glucose must come from the CO_2 molecules!

Lesson 3 (45 minutes)

Topic: The message in the photosynthesis equation is a plant's substance comes mostly from the air.

Objectives:

Students should be able to:

- Explain and demonstrate that starch and cellulose molecules are formed by linking glucose molecules into long chains.
- Describe and demonstrate the difference between starch and cellulose.
- Explain and demonstrate that carbon dioxide is the source of much of the plants' mass or material.

Preparation Prior to Class

This lesson has student teams working together to build two large molecules, a molecule of starch and a molecule of cellulose. Because the cellulose molecule is more challenging, you should choose only two to three teams of students who are your expert builders. (These students will have become apparent to you from the previous lesson.)

Most of the class teams will build the starch molecule together.

Designate a container as lost and found for LEGO elements.

Display the two teaching posters.

Obtain an overhead projector.

Determine a location for building the starch molecule.

Determine a location for building the cellulose molecule.

Photocopy:

“Photosynthesis Learning Assessment” (one per student)

Write the photosynthesis equation on a classroom board.

Check Materials Needed for Lesson 3:

- LEGO Photosynthesis Sets
- Transparencies
- Posters
- “Photosynthesis Learning Assessment” worksheet

Set Check (3-5 minutes)

Have each team verify all the elements are present in the set.

Discussion: (7 minutes)

- Where do plants get their atoms from?
- How do water and carbon dioxide get into the plant?
- What does “plants make their own food” mean?

Lesson 3

Dr. V.'s comment

What about a student who has been absent for the last lesson? Or the student who did not complete that last activity and did not have the "Ah-ha" experience of converting water and carbon dioxide into sugar with six molecules of oxygen left over? These students can do this activity now (Challenge 1). Then, if they have time, they can contribute a glucose to the growing class chain. If they don't participate in the starch building this is OK, because they will definitely be able to see the starch and participate in the discussion.

Start the class with a discussion. Direct the students' attention to the photosynthesis equation, written on the board. Ask the students to explain:

- Where do plants get the atoms to make the glucose?

Check by answering the following:

- What three kinds of atoms make up glucose? (carbon, hydrogen, and oxygen)
- Where does the plant get the carbon atoms to make the glucose? (from carbon dioxide, CO_2)
- Where does the plant get the hydrogen atoms to make the glucose? (from the water, H_2O)
- Where could the plant get the oxygen atoms to make the glucose? (Two possible sources of oxygen are CO_2 and H_2O . Experiments show that plants take the oxygen molecules from the carbon dioxide molecule to build glucose.)

Review photosynthesis over again, but this time point out the places where water and carbon dioxide enter the plant using the teaching poster "Plants from Thin Air?" Point to a live plant, if available, after doing the poster work or using the overheads.

Review how CO_2 gets into the plant. Point to the leaves. Explain how CO_2 from the air comes in the openings on the underside of the leaf. The plant cell gets the carbon and the oxygen atoms from the air.

Review how H_2O gets into the plant. Point to the soil. It comes from the soil, in the roots, and up to the leaf. The plant cell gets the hydrogen atoms from the water molecules.

Ask the students to explain:

"Scientists say that – plants make their own food."

- What are plants making?
(glucose molecules/sugar)
- What do they make their food from?
(carbon dioxide and water)
- Do plants make glucose from soil?
(No, what comes out of the soil is water.)
- Compare the food for plants with food for animals.
(Animals have to find food to eat.)
- How do plants and animals use food?
(Animals build strong bodies with nutrients from their food.
Plants build body structures with their food.)

Introduce the activity of the day with the statement, "In Challenge 3, you are going to build plant structures with the glucose food, like plants do."

Note: The science question at the end of the instructions in "Making Starch Molecules," asks: "How would you write the formula for the class' starch molecule?"

**Fabulous
Fact:**

"Commercial plant food" is really only some minerals (phosphorous, nitrogen and potassium.) You could read a package label. Explain that these minerals are to plants what vitamins are to you. Vitamins and minerals are not real food, but you need them to be healthy. Plants need soil – only to take out of the soil – a very small amount of minerals. Plants do *not* need the soil to make glucose (food) because they get their molecules from the air and from water.

Challenge 3 (20 minutes)

Introductory Remarks Before Opening the LEGO Boxes

Use the posters or the transparencies to explain the three main things that plants can do with glucose: use it for energy, build starch, and build cellulose.

- 1) Explain that after the plant cell has produced – by photosynthesis – many sugar molecules they are often made into new structures by connecting the sugars into long chains.

Starch molecules are long chains of glucose molecules. Starch molecules are one way a plant can store food (glucose) for later use.

Cellulose molecules are long chains of glucose molecules as well. Cellulose is a tough fiber found in plant cell walls. Cellulose can be used for protection and building plant structures such as leaves and wood.

- 2) Tell the LEGO teams in the class which molecule they will be constructing – starch or cellulose. (You decided this earlier, based on students' skill level. Cellulose teams need more skill – so have only two-three teams doing cellulose together.)
- 3) Tell all student teams to begin by first constructing two glucose molecules. See "Student Instructions. Next, tell them to use the instructions "Making Cellulose Molecules" on page 19 or "Making Starch Molecules" on page 31 for the assembly.
- 4) Reminder: Teams building the cellulose use the gray connector pegs found in the sets. Cellulose is different from starch in that every other glucose molecule in the chain is inserted upside down. The gray connector pegs make this possible.

During the Independent Work Period

Some students will be fascinated with determining the molecular subscripts for different sized starch molecules. You can assign problems of different difficulty according to the individual students' math skills. (Example: one team could figure out the formula for two glucose molecules in a starch chain and another team could figure out the answer for 10 glucose molecules. Also, if teams do several starch samples they can figure out a system for arriving at the correct subscripts. You could have successful teams coach others to keep students engaged.) A table is included on page 19.

Starch building teams –

Students will probably be highly successful at bonding glucose

Lesson 3

Dr. V.'s comment

When the building is complete, you may wish to tell students to put all their extra LEGO bricks in the box and close the boxes. Have them focus on the formulas.

molecules and making a starch molecule. Teams who are having difficulty may not be removing the OH and the H before trying to attach the glucose molecule. Instruct the students to leave this H₂O molecule in front of the glucose. This will facilitate the retrieval of the set pieces at cleanup time. A large chain of glucose molecules should be forming, as student teams bring their own shorter segments of starch to be connected to the growing chain.

Cellulose building teams –

Student teams working on bonding glucose molecules to make the cellulose chain will need to work in physical proximity to each other. Choose a place where their cellulose molecules can be displayed for the whole class.

Teams finish at different times –

Because different teams will be finishing at different times, the filler activity for all students is calculating the formula for a given starch molecule. Cellulose teams could figure out the formula for the cellulose they built. Circulate among the teams. Have teams record their work. Then, direct the students to return to their seats for a discussion.

Teacher Answers – Formulas for Starch

A generalized method for calculating the formula for starch (C₇H₇O₇) or a cellulose molecule is:

$$\text{starch or cellulose} = (n)(\text{C}_6\text{H}_{12}\text{O}_6) - (n-1)(\text{H}_2\text{O})$$

where n is the number of glucose molecules, C₆H₁₂O₆ is glucose, and H₂O is water. Remember that a water molecule is lost from in between the glucose molecules and must be subtracted from the total.

Dr. V.'s comment

Do not spend too much time on the formulas. The main message is yet to come. Save time for major conclusions and some time to disassemble the LEGO molecules.

Number of Teams	Number of Glucose	Final Formula
1 team	2 glucose	= C ₁₂ H ₂₂ O ₁₁
2 teams	4 glucose	= C ₂₄ H ₄₂ O ₂₁
3 teams	6 glucose	= C ₃₆ H ₆₂ O ₃₁
4 teams	8 glucose	= C ₄₈ H ₈₂ O ₄₁
5 teams	10 glucose	= C ₆₀ H ₁₀₂ O ₅₁
6 teams	12 glucose	= C ₇₂ H ₁₂₂ O ₆₁
7 teams	14 glucose	= C ₈₄ H ₁₄₂ O ₇₁
8 teams	16 glucose	= C ₉₆ H ₁₆₂ O ₈₁
9 teams	18 glucose	= C ₁₀₈ H ₁₈₂ O ₉₁
10 teams	20 glucose	= C ₁₂₀ H ₂₀₂ O ₁₀₁
11 teams	22 glucose	= C ₁₃₂ H ₂₂₂ O ₁₁₁
12 teams	24 glucose	= C ₁₄₄ H ₂₄₂ O ₁₂₁
13 teams	26 glucose	= C ₁₅₆ H ₂₆₂ O ₁₃₁

Table 1: Correct Formulas for Starch/Cellulose Molecules

Now the students are back in their seats, the large glucose chains of starch and cellulose are displayed, and the extra LEGO bricks are back in the closed boxes. We are ready for discussion time.

Briefly review the results of the formula calculations – as time permits. Actually hundreds of glucose are linked together in starch and cellulose molecules and the subscript numbers will be really big. This is the main point: the molecules are large.

Discussion: (5 minutes)

The carbon dioxide molecules are now part of the structure of the plant.

Where can we find starch in plants?

Starch is a food storage molecule. Where do plants store food for themselves? (In root structures and/or in seed structures or most plants put starch molecules into their seeds so the young plants inside the seeds will have enough food to start to grow.)

What plants do you eat that are primarily starch?

(Beans, all kinds of grains, corn, potatoes, sweet potatoes, turnips, beets, and so forth.)

Lesson 3

Next, move to the cellular level to talk about cellulose. Using the posters or transparencies, show the cell wall that is around each and every cell in the plant. The cell wall is made of cellulose molecules. The cell wall makes up the woody material in trees and branches.

Where do the atoms come from to make wood?

(Glucose, and originally from carbon dioxide in the air and from the water taken in by the roots.)

Teaching Parts of the Cell

Leave the teaching posters from this set on display in the room. These posters will be very helpful when the functions of the chloroplast and the mitochondrion are described. Students will no longer be so totally mystified by the functions of these organelles.

The posters and overheads will allow you to focus on how energy changes form. Light energy becomes chemical energy that is locked up in the bonds of the glucose molecule.

Wrap-up (5-7 minutes) (See *classroom management tips*)

Be sure to leave enough time for clean up because the elements must be returned to many sets. Begin by separating the starch and cellulose molecules into two glucose segments (disaccharides) for retrieval. Each team will need two glucose molecules to complete their set.

Teams should recheck their sets using the underside of the box lid. Students place the Student Instructions and the box lid on top of the tray before closing the lid.

Additional Basic Chemistry Lesson (45 minutes)

Topic: Practice writing and depicting elements, compounds, and mixtures.

Preparation Prior to Class

Photocopy the "Writing Chemical Formulas" worksheet (one per student)

Set Check (3-5 minutes)

Distribute one worksheet for each student and one set to each team. Have each team verify all the elements are present in the set.

Open-Ended Activity to Practice Chemical Formula Writing

Students will want to build their own LEGO structures with the bricks, so tell them chemists actually build designer molecules, too. Chemists often need to construct molecules, like pharmaceutical drugs, in a particular shape. If the students build airplanes, puppy dogs, and so forth as their structures, this is OK. Just tell them that molecules do come in some strange shapes!

Project A (15 minutes)

Demonstrate a simple example like C_2H_4 first. Build this structure and write out its formula.

Tell the students they should follow the directions on the "Writing Chemical Formulas" worksheet. They construct and write the formulas for compounds, exchanging LEGO structures with their teammate. Both students write the chemical formula for the LEGO structures and compare answers. Students repeat this process a second time.

Project B (20 minutes)

The students create chemicals and place the team's molecules on their desk for display. Give teams a set length of time to build, for example, seven minutes.

Have one person from each team circulate and record the chemical formulas of other teams' structures for five minutes. Page 2 of the worksheet has the space for this. The team member remaining with the molecule checks the "visiting" students' results. When they are finished (or time is called), have the team members switch roles. When time is called, students will return to their seats.

Dr. V.'s comment

If the students are more advanced, you may give them the following bonding rules for the atoms. Write this on the board first:

- Carbon can attach to a maximum of four bricks.
- Oxygen can attach to a maximum of two bricks.
- Hydrogen can attach to only one other brick.
- Write your formula like this: $C_xH_xO_x$

Additional Basic Chemistry Lesson

Teaching Points (5 minutes)

1) **The arrangement of atoms can give substances interesting properties.** Have any two students build something out of carbon atoms (only black bricks). Is the brick arrangement different between the two? Hold up the structures the two students have built, if they have used only the carbon atoms.

Example: diamonds, charcoal, graphite.

The difference between an expensive diamond and a piece of charcoal is actually not related to the kinds of atoms they contain. Both diamonds and charcoal are made of carbon atoms. The difference is in the arrangement of the carbon atoms. They are packed differently and have different properties.

A third example of a substance that is also made up of carbon atoms is graphite. The carbon in graphite is arranged in layers, or sheets. Unlike diamonds, the hardest substance known to man, graphite is very soft and it even loses the scratch test to a piece of paper! (Graphite is the lead in modern-day pencils and it is scratched off by ordinary paper.)

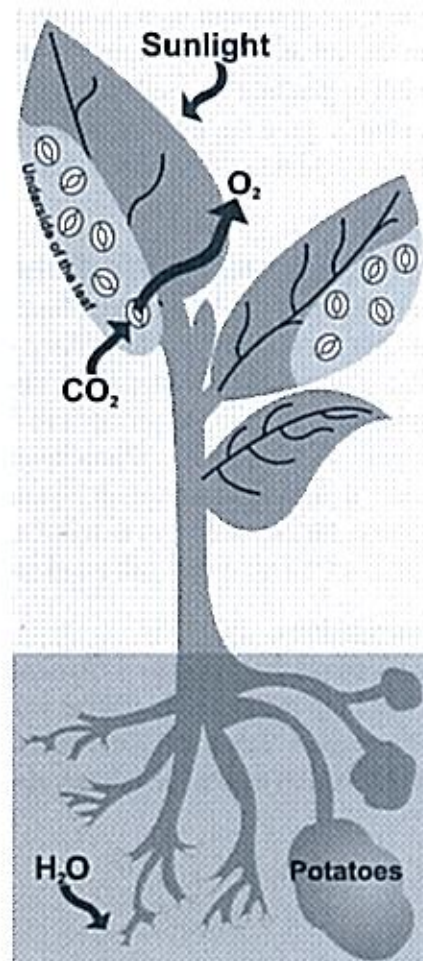
- 2) **Molecular shape is very important.** Hold up the structures that have an interesting 3-D shape (such as an airplane).
- Molecular shape is how your taste buds work. Taste bud cells have receptors on their surfaces that can be activated by certain molecular shapes.
 - Molecular shape is very important for enzymes to work. Think of a lock and key diagram.
 - Molecular shape makes it possible for cells to send signals to each other. The cell surface is covered with receptors that can be triggered only by certain shapes.
- 3) **Big molecules are often formed by smaller (repeating) units that join together.** Hold up a student's LEGO structure if it has repeating parts, for example the LEGO bricks are assembled into subunits that are then connected to each other.
- Fat molecules have chains of repeating carbon and hydrogen units.
 - Proteins are made from chains of amino acids.
 - Starches are made from chains of sugar molecules.
 - Cellulose is made from chains of sugar molecules.
 - Chitin, the molecule in the exoskeletons of arthropods, is made from chains of sugar molecules.

Wrap-Up (5 minutes) (See *classroom management tips*)

Students retrieve the structures and put away the elements. Collect papers to check for correct position of subscripts in the formulas.

Related Photosynthesis Activities

- 1) Demonstrate the presence of starch in seeds. Use iodine as a starch indicator. Drop iodine on opened lima bean seeds.
- 2) Do the experiment with geranium leaves that show the correlation of leaf starch production to areas of the leaf exposure to sunlight.
- 3) Have students see where in the plant photosynthesis takes place – look for chloroplasts in Elodea plant cells under the microscope.
- 4) Have the students see where air molecules can enter and exit the leaf. Some kinds of leaves have easy-to-spot stomata because the guard cells are a different color from the other cells. For example, *Setcreasea* or “Purple Queen” leaves need no preparation. They may be placed directly on the light microscope stage for viewing without a slide or coverslip. This common plant may be purchased from greenhouses or nurseries.
- 5) Starch and osmosis experiments. Starch is often used in experiments as the large molecule that will not cross the membrane. Your students will be able to visualize the size comparison between starch molecules versus water molecules after these LEGO lessons.



Assessment Tips

Pre-Lesson Assessment Worksheet

The purpose of the worksheet “Plant Growth” is to alert students to their own misconceptions concerning photosynthesis. By experiencing a situation where naive thinking leads to an incorrect conclusion, students become ready to reshape their own understanding with the subsequent lessons. The learner’s awakening experience is called a discrepant event. It is best used at the beginning of the Photosynthesis unit.

The worksheet “Plant Growth” produces a discrepant event for most students. It would be best if the worksheet could be completed the day before Lesson 1. However, it can be used any time at the beginning of the Photosynthesis unit to improve motivation. With this worksheet, students become aware that soil does not significantly contribute mass to a growing plant. Naturally, this leads to the question, “What does contribute to the mass of a growing plant?”

Specific recommendations:

- 1) Be sure to set a climate in the classroom that is friendly and tolerant of mistakes made while learning. For instance, you could reassure students that the results of Van Helmont’s soil experiment are surprising to many adults as well! (Suggest they ask their parents the question, “What contributes to the mass of a growing plant?”)
- 2) Some students always rush to erase wrong answers from their papers, so remind the class that these answers should not be corrected. Remind students this paper will not be graded – in fact, students can use the paper to show improvement.
- 3) Do collect the papers and scan through them for your own edification. Collecting the papers also increases the value of the work in the students’ eyes.
- 4) If you wish to produce an evaluation of the student thinking before and after the photosynthesis lessons, simply give the students the same worksheet again at the close of the unit. Record and contrast the numbers of students mentioning CO₂ and soil as major molecular sources.

Post-Lesson Assessment Worksheet

Two options are offered as worksheet post-lesson assessments.

- 1) The same photocopy master, the “Plant Growth” worksheet, could be used again at the end of the unit. The advantage here is the students will be able to notice a change in their own understanding – they no longer believe that soil produces the mass of tree.
- 2) Alternatively, the worksheet “Photosynthesis Learning Assessment” can be used as a post-lesson assessment. It is designed to produce student reflection on a broader spectrum of ideas associated with photosynthesis. With this assessment worksheet, you will be able to see what they have learned well and what areas still need more attention.

Specific recommendations:

1. The directions on the worksheet list sample topics for reflection. If possible, read this list out loud. It will help the students realize what they could reflect upon.
2. Collect the papers. For your own evaluation, review which topics remain problematic for the students and which topics have been mastered by the students.

Classroom Management Tips

When customizing this guide's lesson plans for your own class, consider the following tips:

Plan When You Will Do the "Teacher Talk"

Please plan ahead on your lesson sequence or use the instructions in this guide. The delivery of your biological explanations, or "teacher talk," should occur only:

- A) when all the LEGO bricks are in the closed box, or
- B) when all the LEGO bricks have been utilized and the construction is complete.

Otherwise, you will discover students will have difficulty disengaging from building with the LEGO bricks. If you plan your lesson sequence well, you can avoid unnecessary teacher-student friction over this issue and you will have fewer off-task LEGO constructions.

Set Rules

Make it clear to the students that they may not open the LEGO sets until told to do so. This saves time and energy. It will help the students begin on task, when you have set the task.

Not Feeling Very Confident?

What should you do if you have little experience with LEGO bricks or if this set seems like an activity that is not in your preferred learning style? Relax. Just remember there will be students who will be very facile builders and quick learners with these materials. This is a win-win. Encourage these students to be your assistants and help others in the class. It is not necessary that you be the LEGO expert.

Cleanup

Get great cooperation. Tell students directly that if they enjoyed the lesson, a great cleanup helps convince a teacher to do more hands-on lessons like this one. Remember to save adequate time so your students can perform this good cleanup step. (Remind them to check the floor.) Also, if you can, let the custodians know about the LEGO activities and tell them where to put any lost pieces they may find.

Understanding Student Misconceptions

Misconception 1

Students believe plants make sugar only for the purpose of producing energy. This is a major problem. Students need to learn what plants do with the sugar molecules they produce. In the third LEGO lesson, students will see that sugar molecules are the subunits of starches and cellulose fibers. These molecules make up much of the total mass or total substance of plants. For example, seeds such as wheat and beans are full of starch. Tree branches and tree trunks are made of cellulose. If the students can understand that plants use the glucose molecules to construct their own structures such as seeds, leaves, and trunks, the students will avoid another prevalent misconception.

Misconception 2

Students believe plants get their food from the soil. This is naive thinking. However, the transformation of carbon dioxide into glucose molecules and then into wood (cellulose) may be difficult for students to believe. (Carbon dioxide being a gas makes it a less tangible substance than a liquid or solid would be.) Furthermore, our common language about plant food adds to the confusion. For instance, we buy commercial plant food and add it to the soil. Plant food basically contains phosphorus, nitrogen, and potassium. Amazingly, 55 percent of the substance of a plant is carbon. The source of this carbon is the carbon dioxide found in air.

Misconception 3

Students believe plants do not need oxygen and that plants only take in CO_2 and breathe out O_2 . Photosynthesis is *not* a method of breathing. Photosynthesis is a food-making process. Plants still need to respire, or take in oxygen to breathe. Just as in animal respiration, plants take in oxygen and give off carbon dioxide. During respiration, the glucose molecules are burned when they combine with the oxygen. This process releases the chemical energy stored in glucose and the reaction by-products are carbon dioxide and water.

Often teachers emphasize the differences between plant and animal cells and they may forget to emphasize a major similarity here – cellular respiration occurs in both plants and animals. Therefore, when you teach the parts of the cell, you can help remove this misconception by pointing out the structure where photosynthesis occurs (the chloroplast) and the structure where cellular respiration occurs (the mitochondrion). Mitochondria are present in both plant and animal cells. Connecting each process with a cell structure helps make the lesson more concrete.

Reference

“The Private Universe Project in Science” from www.learner.org “Workshop 2: Biology. Why Are Some Ideas So Difficult?” Annenberg Foundation/ CPB. This show examined the scope of student ideas by exploring the central idea of photosynthesis that the substance of plants comes mostly from the air.

Note: The student activities in this LEGO Photosynthesis Set are designed to help your students attain a clear understanding of photosynthesis and avoid these major misconceptions.

Frequently Asked Questions

Please Explain the LEGO Brick Configuration of Glucose.

- 1) Overall, the configuration of the LEGO glucose molecule follows the bonding rules of the atoms: carbon can form four bonds, oxygen two, and hydrogen one. If you check the LEGO glucose, you will find these rules have been followed.
- 2) The ring structure of glucose is there, but it is very tight. (See Student Instructions.) Each brick in the ring is only attached to two others in the ring. The ring doesn't have an opening because the structure needs to be very stable. If the bricks were spaced farther apart and had an opening, the LEGO structure would fall apart easily and there would be a lot of frustrated students (and teachers).
- 3) In glucose, the side groups (like the OH, H, and CH₂O) come off the ring structure with an orientation – by convention – that is called up or down. In the LEGO structure, the side groups' orientation up or down is indicated by the orientation of the bricks. This explains why there are two brick versions for the OH group. (See page 2 of the instructions.) The hydrogens are attached to one side of the oxygen or the other in order to indicate whether it is the up OH or the down OH.
- 4) Using the information given in Step 3 above, it can be determined that the LEGO glucose we have presented in this lesson is β glucose (versus α glucose molecule). The difference between the two glucose is this: on a β glucose, Carbon 1 has the OH in the up position; on α glucose, Carbon 1 has the OH in the down position. Yes, we know that β glucose is the configuration found in cellulose and that the α glucose is the configuration found in starch. To keep it simple, we used the same β glucose configuration for both the LEGO cellulose and LEGO starch molecule. Both versions are still glucose. It seemed unnecessary to make a distinction to the students at this point in their education. For more information refer to *Biology*, Fifth edition, by Neil A. Campbell, Jane B. Reece, and Lawrence G. Mitchell and published by Benjamin Cummings.

Why Should I Teach Cellular Respiration with Photosynthesis?

- 1) You have the LEGO sets open and it will take less time right now!
- 2) You will be explaining the parts of the cell and the functions of the parts soon. Cellular respiration occurs in mitochondria. This activity will help the students understand what cellular respiration is.
- 3) You want to be sure the students realize that plants do cellular respiration too. You are in the plant unit right now and this would help make the point.
- 4) You view this occasion as a good opportunity to emphasize cycles in nature. Cellular respiration and photosynthesis form a cycle in nature. These processes are part of the carbon cycle.

Frequently Asked Questions

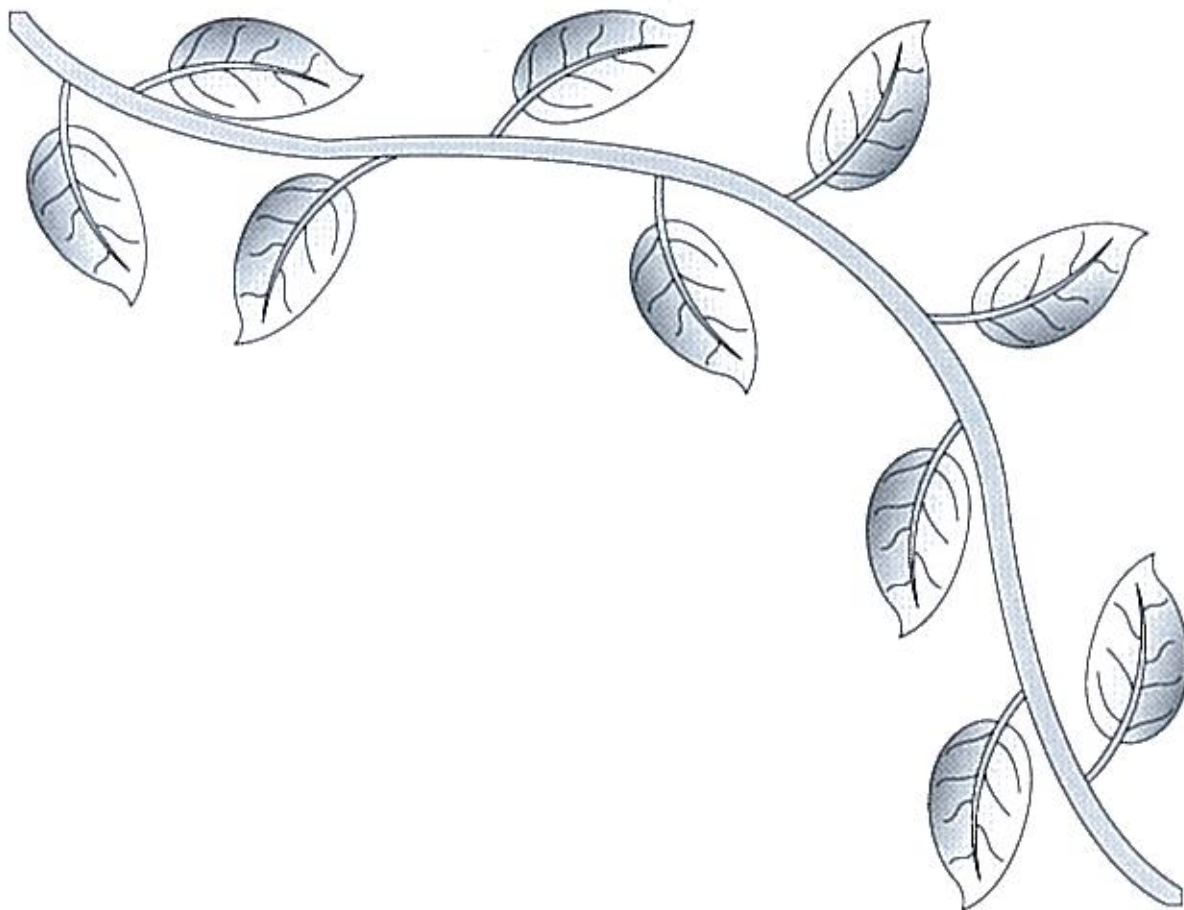
Why Should I Repeat the Photosynthesis Equation in Lesson 2 and 3?

- 1) Repetition helps learning.
- 2) Some students may have been absent and will need the experience.
- 3) Day 3 requires each student team to have two glucose molecules. This is a good way to review and produce the first glucose molecule.
- 4) Familiarity builds confidence.

Why Wasn't the Equation for Photosynthesis Written as:



Some biologists would prefer to see the equation written this way because they want to be sure the oxygen atoms all originate from the water molecules, as is the case in nature. If you have a mature class, you could mark some red LEGO bricks and perform this feat or give it to your students as a problem to be solved. However, this LEGO Photosynthesis Set was designed as an introductory lesson and the potential confusion extra molecules would cause was considered not to be worth the point about the source of oxygen molecules given off in the process.



Plant Growth

Answer Key for Student Worksheet

Name _____

Class _____ Date _____

1. Introduction

2. Make a Hypothesis

Source of molecules:	% of plant's weight from source (20% ?)
1. (rain) water (H_2O) _____	40 _____ %
2. air (CO_2) _____	60 _____ %
3. soil (minerals – N, P, K) _____	less than 0.1 _____ %
4. _____	_____ %
	total = 100 %

Do not give out answers (1-3). The percents given above are only general estimates.

Note: Here is the main thing to look for as a teacher: Do students think soil molecules contribute in a major way to the plant's weight?

3. Experiment

4. Results with the Soil

Circle the statement below that is close to the percent weight that you had predicted. The best answer on the page is the lowest percentage.

If the Plant Received from the Soil

1% of its weight, then the soil should now weigh 198.35 pounds. ($200 \text{ lb} - 1.65 \text{ lb} = 198.35 \text{ lb}$)

Note: The real answer is (10 times) smaller than any of the options given on the paper. Therefore, not a single person in the class will actually have the correct answer.

Less than 1% of the plant's weight came from the soil. How close was your own prediction?

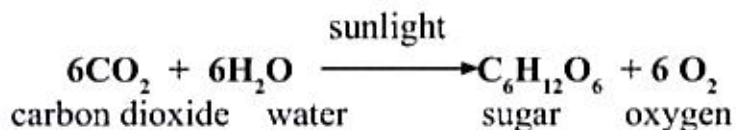
Students will reflect on how close their prediction was. Most students will not be close. It is good if they acknowledge this. Then they can build a new understanding.

5. Conclusion

6. Further Discussions

- A) Students will reflect on why they did or did not consider air as a possible source of the plant's molecules.
- B) This section reviews why some students may not have considered air as a possible source of molecules for plants. Some students may find it hard to believe that gas has weight.

C) Let's look at the equation for plant photosynthesis to understand this.



Sugar molecules are produced. These sugar molecules are put together to make wood and other plant molecules. This adds weight.

- 1) Where did the carbon dioxide molecules come from? the air
- 2) What (besides oxygen) does photosynthesis produce? sugar
- 3) What can sugar become? wood and other plant molecules
- 4) Energy is needed for photosynthesis to take place. Where did the energy come from?
the Sun or sunlight

7. Reflection

What idea became clearer to you with this worksheet? _____

This worksheet has been carefully designed to help a student discover that soil does not contribute significantly to a plant's weight.

- 1) Please do not give out the answers! It is OK to discuss this paper after it has been completed. You may wish to tell your students *not* to change their original answers and that this paper will not be "graded" for the correct answers.
- 2) Most students will experience a discrepant event. A discrepant event is an unexpected finding that helps students recognize that they do indeed have a misunderstanding!
- 3) After the misconception has been identified, this worksheet leads students to correct the misconception and reinterpret the information. (Students can see how the carbon dioxide molecules actually get incorporated into the plant tissues by doing the lessons with LEGO Photosynthesis Sets.)

Photosynthesis and Soils

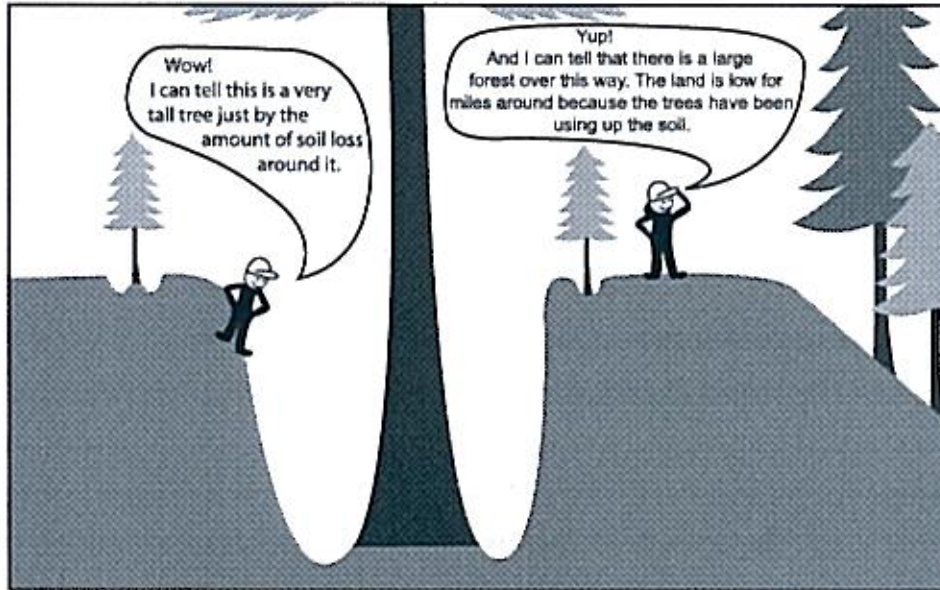
Answer Key

Classwork/homework due _____
circle one

Name _____

Class _____ Date _____

Directions: Read the cartoon. Answer the question "What is wrong with this picture?"



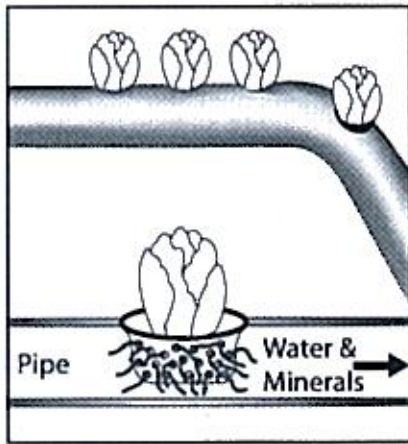
What is wrong with this picture? There are deep depressions under the trees. The trees seem to be taking up a large amount of soil.

Directions: Read the following paragraphs and answer the review questions.

As the cartoon illustrates, plants do not actually need large amounts of soil to grow! OK, then what do roots take from the soil? A plant's roots absorb water. The roots can also absorb tiny amounts of dissolved minerals in the water as well. These minerals are used in trace amounts by the plant in the same way vitamins and minerals are used by your body in trace amounts. The minerals are not used for food.

Plants manufacture their own food by taking in molecules from the air; they do not use soil molecules. The leaves of plants have many tiny openings where the air molecules can enter and exit. Plants use carbon dioxide molecules from the air and some water molecules from the soil to make their own food molecules. This food making process is called *photosynthesis* and occurs in the leaves of the plant. The food made in the leaf is *glucose*, a kind of sugar molecule. Isn't it interesting we don't notice plants taking in lots of carbon dioxide molecules to make their own food? We can't see the gas, so we don't think of it. Air has lots of available molecules in it.

Growing Plants Without Soil



Did you know that plants can be grown without any soil at all? This technique of growing plants without soil is called *hydroponics*. Hydroponic lettuce and other vegetables can be purchased at some grocery stores.

To grow this lettuce, the roots are immersed in water with dissolved minerals or fertilizers. Fertilizers are sometimes called plant food, but they are not really plant food! They are minerals like phosphorous, zinc, nitrogen, and potassium. Many vegetables are now grown without soil in greenhouses.

Review Questions

- 1) Very tall trees do not create deep depressions in the ground. Why not? _____
Because trees do not take up much soil, only dissolved minerals in water.

- 2) What does a plant take from the soil? Dissolved minerals, H₂O
- 3) Where does a plant's food come from? From the air, from CO₂, and from water

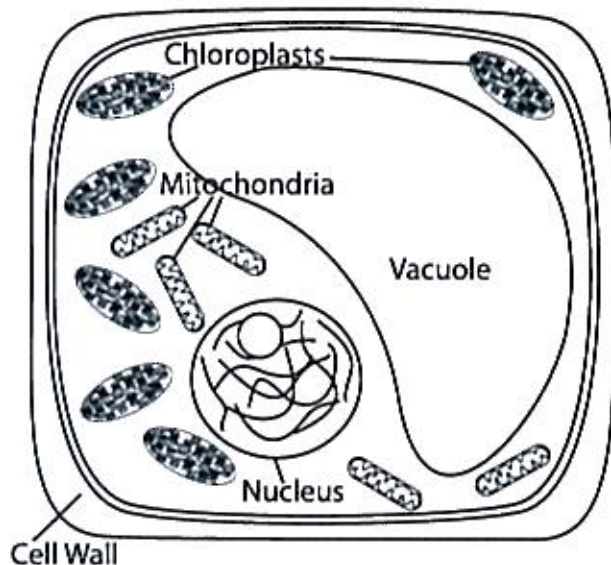
- 4) What is the food making process called? photosynthesis
- 5) What kind of food molecule is made in the leaves of a plant? glucose
- 6) Name the molecule that plants take from the air to make food. carbon dioxide
- 7) What is hydroponic lettuce? Lettuce that has been grown without soil. (The roots are placed in a mineral solution with H₂O.)

Photosynthesis and Cells

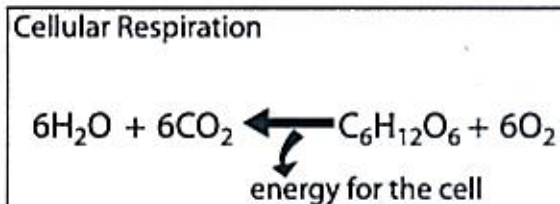
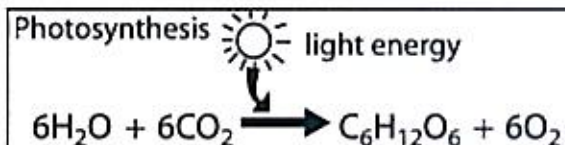
Answer Key

Name _____

Class _____ Date _____



Colors: chloroplasts – green; mitochondria – yellow; cell wall – brown; nucleus – purple



Both Plant and Animal Cells Need Oxygen

Did you notice that mitochondria need oxygen to break down glucose? (Look at the formula for cellular respiration again.) Both plants and animal cells have mitochondria and need oxygen. Many students do not realize that plants need oxygen because they are only thinking about photosynthesis, where CO_2 is the gas that plants need. Remember – plant cells have mitochondria and need oxygen to get the energy out of food molecules.

Mitochondria and Chloroplasts Recycle Atoms

You probably have noticed that photosynthesis and cellular respiration are opposite reactions. So, the atoms in these processes are continually being recycled in nature. This cycle is powered by the Sun's energy.

Questions

1. What part of the plant cell is responsible for photosynthesis? chloroplast
2. What molecule is produced in photosynthesis and is called food? (It stores energy.) glucose
3. What part of the cell is called the powerhouse? mitochondrion
4. What process occurs in the powerhouses of the cells? cellular respiration
5. What two molecules are required for the process of cellular respiration? glucose and oxygen
6. What else is produced besides H_2O and CO_2 from cellular respiration? energy
7. Do both plants and animals need oxygen molecules? (Yes) or No. Explain. Both plant and animal cells need oxygen in order to get the energy out of glucose (food) by the process of cellular respiration.