BLOSSOMS MODULE

Roots, Shoots and Wood

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Hello everyone! Welcome to the Blossoms program on photosynthesis from MIT. My name is Dr. Kathy Vandiver and I'm pleased to be with you today. I know that many of the Blossoms programs have you speaking with your neighbors and discussing many details. But today I'm going to start with something different. I'm going to ask for you to think by yourself about a particular question. And it's going to be about photosynthesis so I brought in something to help you start thinking about plants.

This is a very large log that came from a tree in my back yard. I brought it here as an example… just to get you thinking about what trees are made of, because my question has to do with soil and plants. Here is the question I'm going to ask for each person to respond to, by secret ballot. So you will probably get a piece of paper and you'll write your answers down on the paper.

So here's the question. Are you ready? OK. What percent of a plant's weight comes from the soil? You could choose 60%, 40%, 20%, 10% or 1%. I'd like for you to just choose what you think is the closest answer. Then I'm going to have everybody write down their answers and then I'm hoping your teacher will tally the results. Then I'll come back after you've done that. Remember not to discuss the details of the question with anyone else. We'd just like to know what YOU think. I'll be back and I'll be wondering what your class decided.

Hello! Welcome back. I hope everyone has voted and that your teacher has counted up your results and that you know what the results are. So what is the answer to this question about what percent of the plant's weight comes from the soil? Well, it's a serious question that people have been considering for many years.

I'd like to start by telling you about an experiment, a beautiful experiment that was done in the 1600s by a gentleman whose name is Von Helmut. Von Helmut started off with the question about what percent of the plant's weight comes from the soil. So he started off by weighing the soil. He put it in a big bin like this and then he added a small tree that was five pounds at the start. Then he actually continued this experiment for five years. So he continually watered the plant and five years later, he dried the soil and re-weighed it, and found out that the soil had only lost a little bit, two ounces. However the tree itself, when it was dried and re-weighed, weighed 170 pounds. And so his results really showed that the tree gained 165 pounds. The soil only lost one-eighth of a pound. So there was not very much coming from the soil at all!

In fact, if we look at our answers here, I didn't even provide the answer that it really is. The percent of a plant's weight that comes from the soil—which has been verified by many other experiments as well—is actually 0.1% or less. So it's a surprise to many people because when I looked up many classes' results, I found that most classes were voting in the range of 40-20%.

Before we go further in the program I'd like you know that Von Helmut never did figure out that most of the mass of a plant actually comes from the carbon dioxide molecules in the air. It's rather an unusual thought, if you're walking around and thinking about plants, and you come to realize that plants are taking atoms out of the air and making more of themselves from it. So the roots and shoots and wood that you might see in plants actually have appeared out of thin air!

Why do you think someone like your younger brother and sister might have trouble believing that a plant like this is getting most of its matter from the air? Why don't you talk about it, share ideas with your friends and I'll get back to you in a little while.

OK, I'm back. And I'm guessing what you talked about. I'm guessing that you probably mentioned that the molecules are invisible and that makes it really hard for some people to imagine them. But also that the molecules are so small it really makes it hard to think that they have any weight at all. But a lot of molecules add up-- like pieces or grains of sand, each individual sand particle would be very small, but you'd still need to have a very large and strong truck to move the weight of a huge mountain of sand. So the numbers do matter.

Then there's another factor. If you stop and think a little bit about it, you'll probably remember that chemistry does point out that these atoms have some weight. You've got atomic numbers here. For instance even for carbon here, it has atomic weight of 12. And you could figure out what a carbon dioxide molecule would weigh. So altogether you've got all these molecules and when we put them together we can get something that does have some mass to it, or weight that we can recognize as a tree.

Looking at photosynthesis here is the equation that you are familiar with. Here are six water molecules, plus six carbon dioxide molecules and the presence of light produces this molecule of glucose with six oxygen molecules left over. And when you stop and think about it, this glucose molecule here can be used in the plant (and this is shown in this diagram over here) in three different ways. This is a glucose molecule I've shown here built out of LEGO bricks, but we'll get back to that a little bit later. Right now the glucose molecule could be used either for energy or it could be made into a very long chain, like here, this molecule of starch which is stored in the plant in places in the roots such as potatoes. Or it could also be stored in seeds and fruits. The third way a plant can use its glucose is actually to make its own structure. This is a molecule of cellulose, which is a chain of glucose put together. This structure is what I showed you originally when we started off. This tree, this trunk, has a lot of cellulose in it. The other example I brought just to show right now, is to remind you also that roots can also store a lot of glucose as starch, right here.

Now talking about starch and cellulose, I'd like to point out that they're all made of glucose molecules, but interestingly they're put together in different ways. So, for example, if this was a glucose molecule and this was a second glucose molecule, starch would look like this. It would be a long chain of regular molecules of glucose put together. However, cellulose is different. Still glucose, but the second in the chain is added upside-down like this, and the whole chain continues in a long fashion alternating glucose molecules. So the connection here is really very important. In starch, what I've got here, our human bodies can digest this but our bodies cannot digest the bond that is like this. We cannot break this one. Luckily there are critters out there that do know how to digest cellulose. Those are bacteria. Bacteria can be found in cows and help them get some energy of these long cellulose molecules that are in grass.

So we've talked a little bit about cellulose and starch and how they started off originally as being made from glucose. And we'd like to now stop and think a little bit more about the chemical reaction itself. And I'm going to suggest that we do an activity and talk to you a little bit more about those details next.

OK. Before you start this activity, I just want to point out something about the carbon dioxide. The carbon dioxide actually enters the plant on the underside of the leaf and you can't see these small openings, but the picture back here indicates that the carbon dioxide is coming through those openings that are called stomata.

So carbon dioxide is going to be modeled in our activity here and we're going to model it with these bricks. If you don't have bricks, you can also use small papers, but I'd like to let you know that the bricks that we have here; each one represents an atom. And the atoms that they represent are listed over here. We have carbon as being black. These are the regular chemistry colors. The hydrogen is being white and the oxygen is being red. So if you were going to make a compound like water here, you can easily join them together. That's one of the nice things about bricks. They can be easily combined just like atoms can. So coming back to the equation here, you can see that you can actually model the entire equation through using bricks.

What I'd like you to do is, to do it step-wise, and quite similar to the way the plant would do it. So I'd like you first to start off with obtaining six water molecules. You make and build them here, laid out on a piece of paper. Then what you'd do next would be to make the six carbon dioxide molecules. Then what I'd like you to do is to only use these atoms to do what the plant does -- put them together to make one molecule of glucose, that's over here. And these six oxygen molecules are left over.

Now the glucose is a rather difficult looking structure so we have instructions for how to build this in the module with this video. And overall we're really hoping that if you practice doing this, you'll remember it much better. And that's one of the basic things about learning, if you can recall the basic idea very easily that's great. And doing an activity sometimes makes it a lot easier. So let's give it a try.

Hello! So I'm back and I hope you've had a very good time building this molecule of glucose. I know it's a little bit difficult but I'm hoping that you were able to accomplish it, and that you discovered that you did have six oxygen molecules left over. Now this is a very important reaction in nature and many textbooks oftentimes have this diagram, which shows photosynthesis in this way. The fact is that the carbon dioxide is entering the leaves and the plant is giving off oxygen, and this is great for the animals because they end up using the oxygen and giving off the carbon dioxide. And this process, this cyclic process, is sometimes called the carbon and oxygen cycle. The reason why I'm mentioning it to you right now is I'm wondering if you would take a few moments and if you'd talk with your neighbor and discuss whether or not you think that plants need to use oxygen. So that's the question. Do plants use oxygen?

So I'm back and the tape is on and I know you've been talking about whether plants use oxygen. So it's true, plants do use oxygen but we've been focusing mostly on the fact they use carbon dioxide because we are focusing on the process of cells making their own food, which is what plant cells can do. So the carbon dioxide is utilized to build the glucose molecule. However the glucose molecule is food for the plant as well, so it needs oxygen in order to burn those molecules and get the energy back out. And that process is called cellular respiration. Over here we can see cellular respiration. We've got the glucose molecule and when you add oxygen, the energy can come out-- when the reaction goes in that direction.

So thinking about cellular respiration…. Let's think about where you first thought about it. Perhaps you had connected it with parts of the cell. So here we have a plant cell and the mitochondria are here. And they're called the powerhouses of the cell. And also we do have the chloroplasts that are shown here as well, full of green chlorophyll, ready for the plants to make lots and lots of glucose molecules. And this is an important point--that the plants actually make a lot of glucose, so much that our planet has plenty for animals to utilize as a source of food as well.

So in thinking about our whole project today about photosynthesis, we started off with a question, asking why do plants need soil at all? Soil is actually used as a source of minerals. Minerals are dissolved in the water and they come on up through the roots to different parts of the cell that need the minerals.

So I hope you've enjoyed learning about the basics of photosynthesis and thank you for joining us in this lesson

Hello again! This is Kathy Vandiver. And this is the teacher guide section for roots, shoots, and wood. And that name is really hard to say as an introduction. And the video is about photosynthesis. I began to design this lesson because I first saw another video and that video was made by the Harvard Smithsonian Annenberg Foundation. It points out that many students don't capture the information we really want them to know about photosynthesis and that they hold onto their naive ideas that plants actually are using the soil to make most of their matter. So the purpose of the lesson, first of all, is to make sure that the students have an opportunity to really confront this misconception they have. They may understand perfectly your chemical equations, be able to say them, but when you ask them a point blank question about the involvement of soil, many times they'll come back with thinking that soil is involved in making the plant itself.

So in this first section I just want to make sure that you follow through with suggesting the secret vote because many students will just copy what other people are doing if you ask them to raise their hands. So it's essential that you capture the information that every student is thinking at the beginning. Then from there it's much easier to have the video and the lesson itself evolve so there's more clarity in the information, that they can confront the fact that they had a misconception to begin with.

Now some of the misconceptions that have occurred and are documented are that plants may use photosynthesis to get energy, but they use soil to make their structures, which we've spoken of. The second one is that plants do not need oxygen because photosynthesis is a kind of breathing. The third one is that plants cannot be made from air because air has no mass. Those are the major misconceptions that oftentimes occur.

I'm going to suggest that you use this lesson after you've done an introductory piece on photosynthesis. I think that's a good time to catch the misconceptions.

And how our videotape here breaks down the lesson "Roots, Shoots, and Wood" is:

Part one is the secret voting, and I propose the question.

Part two is that I will come back and talk a little bit about a lesson because a famous experiment was done in the 1600s which was asking the same question, it was Von Hulmut's investigation, and it was pretty interesting. He came up with the recognition that 0.1% of the soil could be taken up by the plant, so less than 1% soil was in the plant's mass. So we can use that for the second part. The follow-up question from part two is: I ask the students to please say why it was hard to believe that carbon dioxide is being used by the plants. I couch it in the question pretty much like "Your younger brothers, why would they find it hard to believe this?" And it may be that the students actually find it hard to believe, and so we're making it into a question they could answer for their younger brother or sister. And that makes it easier to discuss. So they should come up with a few suggestions for that. And I think they could be that air just doesn't feel like very much mass and how could it be turned into a solid?

The major length of time, however, on the pauses will be used to do some modeling. And although this modeling sounds rather simple, I think it could be a really important key for having students have a better recall about what actually happens in photosynthesis. So I'm going to show you here some of the things that you'd have to do in advance. I want to make sure you realize that there is quite a bit of preparation for this lesson.

The first thing is that you'll need to have a box that has some bricks in it and bricks of three colors. I chose the colors red and black and white obviously because these are the colors in chemistry. White being hydrogen and smaller, black is the carbon, and red the oxygen. You could, if you don't have these colors it's fine to use something that's different. But you need to have two large ones and two small ones. The point is that you're going to use these directions for creating this rather complicated molecule of glucose here. We have made the models have exact shapes. So this is carbon dioxide and you are going to ask you students to write this out on a piece of paper or two pieces of paper if that's easier. And to illustrate the equation in exactly with the right numbers and the right bricks and the right shape. And the glucose as well. The glucose is pretty complicated so besides the instructions—by the way the instructions are made so a group of students can work with them. It is sometimes the best thing to do is to have one student actually read out loud the instructions for each step and the other person actually be adding the brick by brick as you go along. And in case your students are not too familiar with using bricks, we actually are providing something called a layout mat or a check mat, and I'll show you this in just a second. Winds up like this and the students can literally put their pieces on here to check and see if they're exactly the right configuration to build them and add them on to the glucose.

Now you might wonder why this Lego structure is actually meant to represent glucose. This design was done with a small ring represented here and with these pieces being the side chains which are added on later. So there is a resemblance to glucose even though it may not be immediately obvious.

OK. So this activity will take up most of the lesson time. And when your students are done we will come back for one more question and that question has to do with more about whether plants actually use oxygen. Because students are so used to seeing photosynthesis taking place and not thinking so much about whether plants use oxygen. So that's the last question on that time frame.

At the end we close the video with the explanation finally of what do plants get from the soil, why would they be growing in soil, and that is the minerals that the soil would provide. So I'm hoping that you will consider using these materials even if you do a much more sophisticated explanation about photosynthesis because by coming back and looking at these and the actual atoms, the students can see this in a very concrete way that they don't forget. The actual brick here shows the carbon and they can see that the only place where the carbon appears, and that there's carbon over here as well, and it had to come from doing this process of photosynthesis.

Actually what you can do to even accentuate this is to have the equation illustrated but then remove the first side of the equation and have your six water molecules, you six carbon dioxide molecules. Have your students actually reassemble those pieces and find out that this carbon has actually appeared again in the glucose.

But the reason to do this, back to my main point, is that you really have an opportunity to make it a tremendous memorable experience and students will not forget after this that the carbon can contribute to the cellulose and the matter that they see in the plants, which is really important for us to understand, for understanding ecology and the future of the planet is understanding the source of the carbon and how the carbon goes through the cycles on our planet.

So I hope you enjoy this lesson. And I hope you enjoy the other Blossoms modules as well.

END OF TAPE