Fascinating Education Script
Introduction to Science Lessons

Lesson 2: Energy

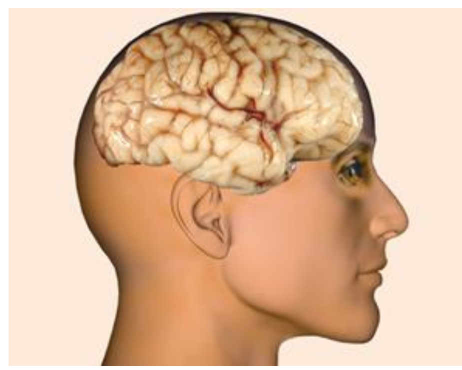
Slide 1: Introduction

Slide 2: How do you know to eat?

Why did you eat breakfast this morning?

I suppose you're going to say you were hungry.

What part of your body told you it was time to eat? Was it your heart that told you? Your stomach? Your brain?



Slide 3: Your brain tells you to eat.

Your brain tells you to eat, but why does your brain tell you to eat? Why do you need food?

What else besides calcium is in food that our bodies need?

Slide 4: We get energy from food.

Energy!

What do we do with the energy stored in food?

Slide 5: Why do we need energy?

We use energy to hear, to think, to see, to run, to smell – everything we do.

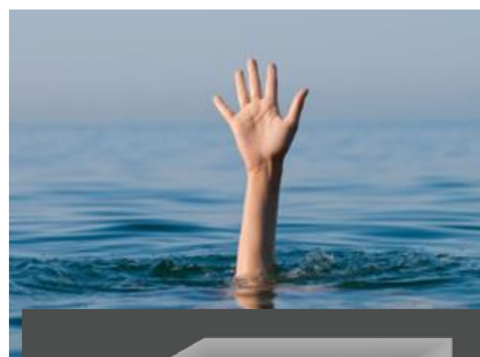
Do all animals need energy?

Slide 6: Do we get energy from air?

Yes, and that's why all animals eat.

But all animals also breathe. Do animals breathe to take in energy from the air just like they eat to take in the energy stored in food?

Slide 7: What happens if you can't get air?



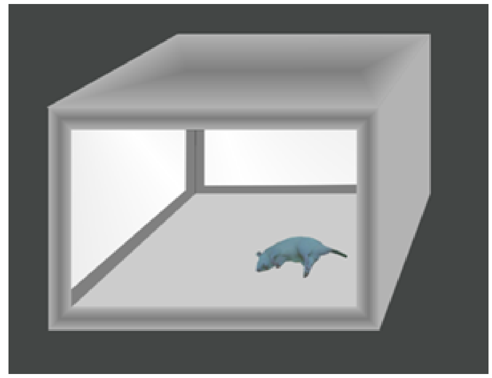
What happens if you can't get air to breathe, say, for example, someone falls off a ship into the ocean and he can't swim? He dies.

Slide 8: Hypothesis: We need air to live.

What if you put a mouse inside this airtight glass box? What do you think would happen to the mouse?

Sure, the mouse would begin to slow down and breathe faster, and then get too weak to move, and eventually die.

But if we keep the mouse inside the glass box only until it begins to slow down and breathe faster, we could still revive him by removing him from the box and letting him breathe some fresh air.



Let's time how long it takes for the mouse to start to slow down and breathe faster.

This mouse took 15 minutes to begin slowing down. What hypothesis can you come up with that explains why animals slow down and eventually die if they cannot get air?

I agree. There is probably something in the air that animals need in order to live.

Slide 9: Do plants breathe?

What about plants? Do plants need to breathe to stay alive? Is there something in the air that plants need, too?

How would test that idea?

Slide 10: Brainstorming your hypothesis.

How about trying to grow a plant inside a closed space?

If your idea is correct, that plants, like animals, need something in the air to live, what do you predict will happen when we try to grow this plant inside a closed space?

The plant should wilt and die, shouldn't it?

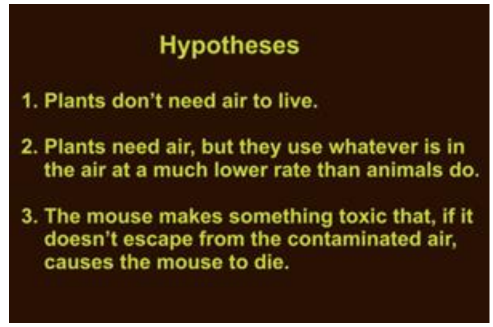
Well it's now 30 days and the plant is still going strong. Why is a plant able to live inside a closed space but not an animal?

I want you to come up with some possible explanations; we'll call these possible explanations "hypotheses." Each explanation is called a "hypothesis."

Slide 11: Choosing your hypothesis.

One hypothesis is that plants don't need air to live.

Another hypothesis is that plants need air, but they use whatever is in the air at a much lower rate than animals do.

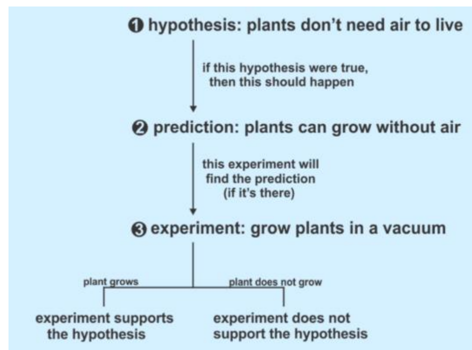


Any other hypothesis to explain why a plant is able to live for a month inside a closed jar but a mouse can't?

How about this for a hypothesis? Maybe the mouse makes something toxic that, if it doesn't escape from the contaminated air, causes the mouse to die.

Slide 12: How to test your hypothesis.

Each one of these hypotheses can explain why animals die in a closed jar but a plant doesn't. To figure out which hypothesis is correct, we need to test each hypothesis. How do you do that?



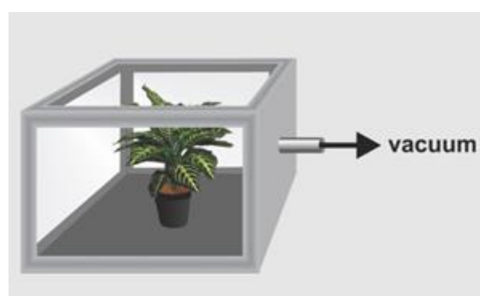
You take each hypothesis and say to yourself, "If this hypothesis were true, then such and such should happen." We then design an experiment to see if your prediction came true.

Let's take the first hypothesis, that plants don't need air to live. How could you show that plants really do need air to live? What kind of experiment would you design?

How about if we suck all the air out of the glass jar and see if the plant lives? How could we possibly suck all the air out of the glass jar?

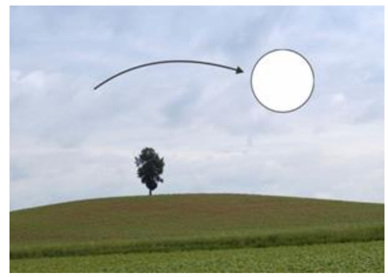
Slide 13: Designing an experiment.

We could design the glass box with a side arm and connect that side arm to something that creates a vacuum. The vacuum would then suck all the air out of the glass jar.



We've all seen a vacuum suck air. It happens when you run a vacuum cleaner, and it happens when you suck on a straw.

How does a vacuum make air in one spot suddenly rush over to another spot? What do you have to do to the air over here on the right to make air over here on the left suddenly want to rush over to the right?



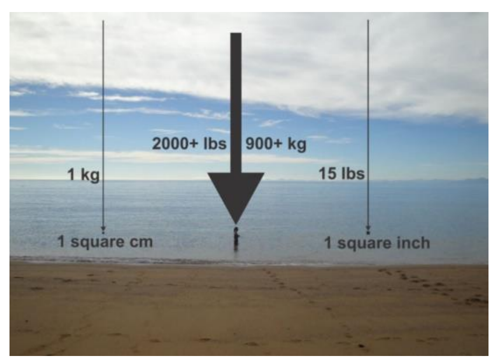
All you have to do is remove the air from the right side. That's what a vacuum is: the absence of air. There's no air in the bubble. Air on the left will now rush over and fill the vacuum.

Why? Why can't a vacuum with no air sit next to an area with lots of air?

Slide 14: Weight and force

Because we sit at the bottom of an ocean of air 5 miles, or 8 kilometers, deep. 5 miles looks pretty thin when viewed from outer space.

Even though it's only air, believe it or not, that air is heavy. One square inch of air weighs down with a force of about 15 pounds. That's practically the weight of a bowling ball.



The air weighing down on every square centimeter weighs a kilogram. When a grown up is standing, the weight of air pressing down on his or her shoulders and head is over 2000 pounds, or over 900 kilograms.

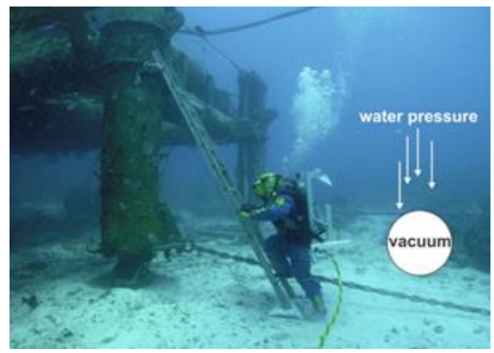
All that weight pressing down on our bodies is why we need strong bones and muscles to prevent being crushed by the weight of air.

Slide 15: What is air pressure?

Removing air in one spot is like trying to create a bubble at the bottom of a load of sand. As soon as you remove the sand, the sand above and to the side of the hollow bubble immediately fills it in.

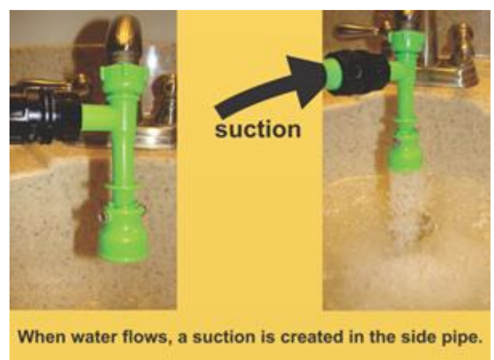
The force created by the weight of the air is called air pressure. A vacuum is an area of low air pressure.

Water is like air, and the force created by the weight of water is called water pressure.



Slide 16: Who is Bernoulli?

Almost three hundred years ago, a man named Bernoulli discovered that when water flows rapidly, the water pressure drops. We could use Bernoulli's discovery to suck air out our plant box.



Let's attach this green plastic pipe with a side arm onto the faucet of a kitchen sink. Place your hand over the side tube.

What do you feel?

Nothing.

Now turn on the water full blast and place your hand over the side tube again. Do you feel your skin being sucked into the side tube?

That suction you feel is because flowing water lowered the pressure inside the green plastic pipe and created a suction.

By attaching the side tube to our plant box, we now have a way to suck air out of the plant box.

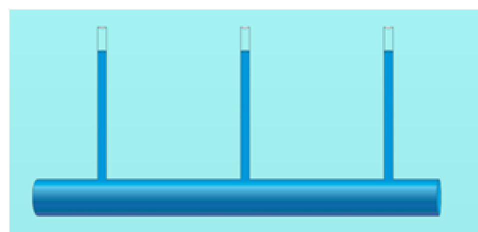
Slide 17: Fast moving water lowers the water pressure.

Wait a minute. What Bernoulli said doesn't make sense. Bernoulli said that fast moving water lowers the water pressure. It seems like it should be the opposite. In order to shoot water out the nozzle of a water hose at high speed, you have to increase the water pressure. Bernoulli says that increasing the water pressure slows down the water inside the garden hose.

Let's take a closer look at what Bernoulli observed about water pipes.

Slide 18: Water pressure

Here is a glass pipe filled with water. Right now water is just sitting in the pipe, because the water pressure at the entrance of the pipe is the same as it is at the exit of the pipe. To make water flow, water pressure at one end of the pipe has to be raised. Water only flows when

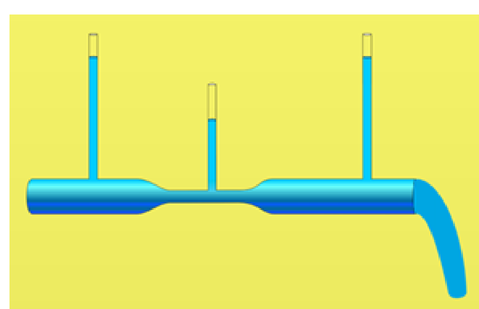


there is a pressure difference.

If we do raise the water pressure at the entrance to the pipe, water will begin to flow through the pipe. Because the pipe is horizontal, the pressure everywhere inside the pipe is the same.

We can measure the pressure anywhere inside the pipe by inserting side tubes. How high up the water reaches in the side tube tells you how high the pressure is in that part of the pipe.

Slide 19: Water is incompressible.



What Bernoulli did was narrow a section of the pipe. When he did that, he noticed that the pressure in the narrowed section dropped.

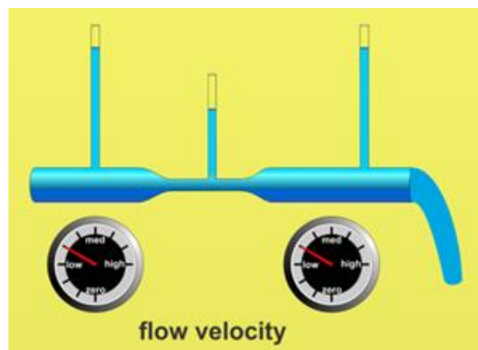
Was the water in that narrowed section flowing faster or slower than water in other parts of the pipe?

Well we know that the same amount of water entering the pipe is also exiting the pipe. How do we know that?

We know that because if less water were exiting the pipe than entering the pipe, water would be accumulating inside the pipe, and that's impossible. Water can never bunch together, because water cannot be compressed.

Fill up a plastic bottle with water all the way to the top. I don't care how hard you push down on the bottle, it won't give.

When these road barriers are filled with water, they're as strong as concrete in preventing cars from crashing through them.



Water is incompressible. Water will not squeeze together and allow you to put more water into a pipe than is coming out of a pipe. The same amount of water going into the pipe has to be the same amount coming out of a pipe.

How can the same amount of water exit a pipe that enters a pipe if there's a narrowed section of pipe between the entrance and the exit?

The only way that can happen is if the same amount of water passes through the narrowed section as passes through every other section of the pipe.

In order for that to happen, water has to pass through the narrowed section at a faster rate.

Slide 20: Curious velocity

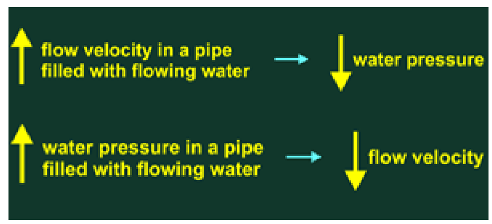
Why, then, does water shoot out further from the end of a garden hose when you put your finger over the nozzle? Aren't you narrowing the hose and increasing the water velocity?

Yes, you are increasing the water velocity, but only after the water has left the hose. Inside the hose the water velocity is actually slower.

Placing your finger over the nozzle slows the flow of water and increases the water pressure inside the hose. Only after the water leaves the nozzle does its velocity increase, because outside the hose the increased water pressure only has to overcome very weak air pressure.

Raising the water pressure inside a garden hose is like putting more explosive behind a cannonball. The higher the pressure, the more punch it delivers to water leaving the pipe.

Slide 21: Flowing water and water pressure



Here's the rule, then: in a pipe filled with flowing water, the faster the water flows, the lower the pressure.

The converse is also true. In a pipe filled with flowing water, the higher you raise the water pressure, the slower the flow of water.

Slide 22: Testing your hypothesis.

So if we attach our airtight grow box to the faucet, and turn on the water all the way, after a few minutes, most of the air should be sucked out of the grow box.

We'll now close off the opening to the grow box and let the plant grow.

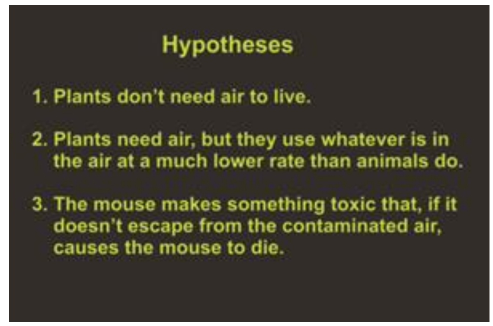
If this plant needs air to grow, what do you think will happen? Sure. It should wilt and die. And

if the plant does not need air to grow, it should just keep on growing.

Slide 23: When the hypothesis is wrong.

The plant wilts and dies. This result says that our hypothesis is wrong. Plants do need air to survive.

Slide 24: Moving on to a second hypothesis.



Now let's look at our second hypothesis, that plants, like animals, need air, but they use whatever is in the air at a much lower rate than animals do, and that's why plants live so much longer in a closed jar than animals do.

How could we test that hypothesis?

What does this hypothesis predict that we could then test?

We know that a mouse becomes very weak within 15 minutes of living in closed jar, and is quickly revived by giving it fresh air. We also know that plants, like animals, also need air to live, but they seem to be able to live within a closed jar for a much longer period than animals.

If we hypothesize that plants use up whatever is in the air at a slower rate than animals, then if a mouse and a plant were placed in the closed jar together, the plant should wilt and die a lot sooner than it did without the mouse.

How come? Because the mouse would quickly use up whatever plants and animals need in the air to survive.

Slide 25: What did our experiment explain?

Here is the mouse and the plant a half hour later. The mouse is beginning to slow down and the plant is doing fine. When we remove the mouse from the box, he quickly begins to react like a regular mouse.

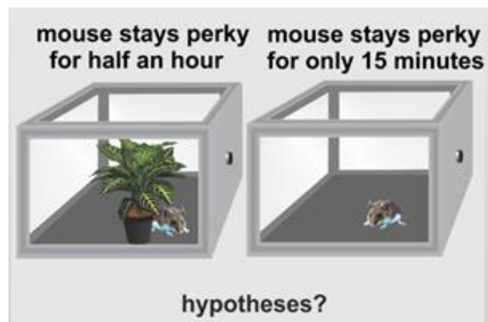
What does this experiment tell you?

We went into the experiment focusing on the plant and how long it would live before wilting, but the little mouse stole the show. We have just stumbled across something unexpected.

What happened that was unexpected?

Yes, the mouse didn't begin to slow down for half an hour. Without the plant, it took only 15 minutes for the mouse to slow down.

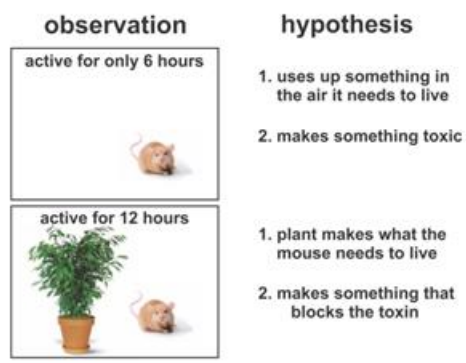
Why should a mouse stay so lively for twice as long with a plant than without a plant?



We need to take a moment here and figure out why animals benefit by living with plants. What are some hypotheses?

Slide 26: How to design an experiment.

We had proposed that mice slow down in an airtight box because they either use up something in the air that they need to live, or because they make something toxic that causes the mouse to slow down and die.



What could the plant be doing to make the mouse survive longer? Is the plant producing whatever the mouse is using up in the air, or is the plant producing something that disables a toxin being made by the mouse?

How can we design an experiment to help us decide whether mice slow down in an airtight box because they run out of something in the air that they need to live, which the plant is now supplying, or because mice produce something toxic that poisons the air, and the plant releases something into the air that disables the poison? Maybe it would help to look at something nonliving. What nonliving thing burns fuel, uses air, and dies out when there is no air?

Slide 27: A candle is non-living.

How about this candle flame? A candle is non-living, but in many ways, it's like an animal. A candle burns the fuel in candle wax to survive, while animal burn up the calories in food to survive. Candles generate heat, and so do animals.

Both candles and animals need air to live and without it, lit candles and living animals soon die.

We even talk about our bodies as if they were candles. "Let's burn up some calories."

When we feed our bodies, aren't we doing the same thing this coal man is doing for his railroad engine?

Slide 28: Who is Joseph Priestley?

Almost 250 years ago, in 1771, just before the American Revolution, Joseph Priestley, a scientist in England, placed a lit candle into an airtight box containing a plant.

When the candle went out, Priestley left the plant and the candle inside the box, and allowed sunlight to shine on them for another few weeks. He then tried to relight the candle. Was he able to relight the candle or not?

Yes.

So what conclusion do you draw? Was Priestley able to relight the candle because the plant made something the candle needed in order to burn, or did the plant destroy a poison that the candle had made when it was lit the first time?

By the way, how do you think Priestley was able to light the candle without opening the box?

He used mirrors to focus sunlight onto the candle wick, and heat up the wick until it caught fire.

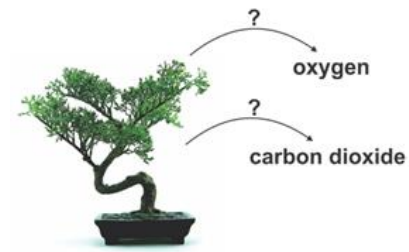
Slide 29: Carbon Dioxide

So let's design an experiment that will help us decide whether plants help animals survive longer without fresh air because plants make something that animals need to live, or because plants make something that blocks a toxin being given off by animals. Or maybe both are true!

I'm tired of saying, "something that animals need to live," and "a poison." Let's give these two substances names. Let's call "something that animals need to live" "oxygen," and the "toxin" we'll call "carbon dioxide."

So if animals need oxygen to live, maybe plants make oxygen.

And if animals produce toxic carbon dioxide, then maybe plants makes something that blocks carbon dioxide.



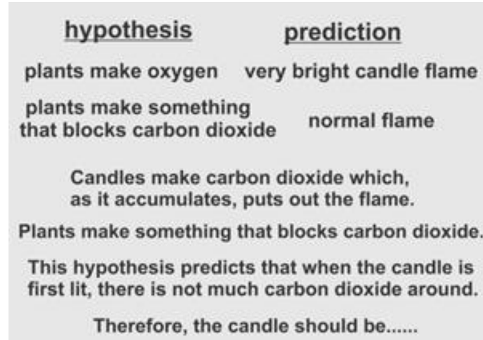
Let's design an experiment using a candle instead of a mouse to help us decide whether plants help animals live longer by making oxygen, which animals need in order to live, or whether plants make something that blocks carbon dioxide, which, as it accumulates in the air, poisons the animal.

Slide 30: A new experiment

Here is a plant that's been growing for a long time inside this airtight box. So if plants make oxygen, there should be a lot of oxygen inside this box.

Also inside the box is an unlit candle. What do you predict will happen when we light the candle with this hot electric welding iron?
If plants make oxygen, what do you predict the candle flame will look like when we light the candle?

And if plants make something that blocks carbon dioxide, what will the candle flame look like when we now light the candle?



Let's think about this for a moment. In the first hypothesis, the box is filled with oxygen. If there is now more oxygen in the air, the candle flame should be overjoyed, because it needs oxygen to burn brightly. What will you notice about the candle flame that tells you it is happy to be burning in a high oxygen environment?

Yes, the candle flame should be brighter.

What does the second hypothesis predict about the brightness of the candle flame? If plants make something that blocks carbon dioxide, will the candle burn brighter when the candle is lit? Let's see. This second hypothesis says that candles make carbon dioxide which, as it accumulates, puts out the flame.

The hypothesis also says that plants make something that blocks carbon dioxide from putting out the flame.

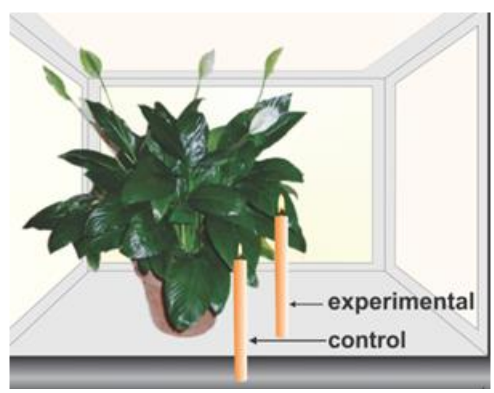
Because it takes time for the carbon dioxide to build up, when the candle is first lit, there is not much carbon dioxide around to be blocked.

Therefore, the candle should be what: brighter than normal, dimmer than normal, or the same?

The candle flame should look normal, no brighter and no dimmer than normal.

Slide 31: Evidence our hypothesis is correct.

Okay, let's light the candle. How does that candle flame compare to the candle flame lit outside the box? The candle inside the box is called the experimental candle and the candle outside the box is called the control candle. The word "experimental" means that something was inside the experiment. "Control" means that something was outside the experiment.



The flame inside the box is a lot brighter. What does the super bright candle flame tell us?

The super bright light is evidence that our hypothesis is correct: plants appear to be making oxygen, which the candle is now using to produce a brighter flame. This experiment doesn't prove that our hypothesis is right, but it does support it. We still need more experiments to be sure that plants really do produce oxygen.