COSMOS LESSONS

Chemistry

Photosynthesis: A quantum leap for solar power

All living organisms need energy. Plants have been using energy from sunlight for a very long time and scientists keep learning more about some of their light harvesting tricks.

In this lesson you will investigate the following:

- Why do plants need the Sun?
- How are solar cells similar to plants?
- How are solar cells different to plants?
- What are some of the factors that affect the energy efficiency of solar cells?

It's time to shed some light on this hot topic and get started!

This is a print version of an interactive online lesson. To sign up for the real thing or for curriculum details about the lesson go to **www.cosmosforschools.com**

Introduction: Photosynthesis (P1)

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Plants are really little green factories, converting sunlight into energy they can use – just like solar cells. So scientists had the idea to take a closer look at how plants do it to see what we can learn from them.

What they have just discovered could lead to a new breed of cheap, flexible, transparent solar cells made from thin plastic film. We could put them anywhere to harness the Sun's energy and create lots of green, cheap electricity.

Overall, plants are significantly less efficient at converting sunlight into usable energy than solar cells. But it turns out that they do a great job at what scientists call "charge separation". When light hits a chlorophyll molecule in the plant, it displaces an electron. The plant then quickly funnels this charge away from the molecule, giving it an electrically-charged particle that it can use in the process of photosynthesis.

Scientists now hope to do the same thing with solar cells, copying nature's tricks to further improve the efficiency of artificial light-harvesting devices.

Read or listen to the full *Cosmos* magazine article here.

Question 1

Interpret: What do you think the cartoonist is trying to express in the cartoon on the right?

"It's the new energy-efficient bougainvillea"

For best results when printing activities, enable your web browser to print background colours and images.

Gather: Photosynthesis (P1)

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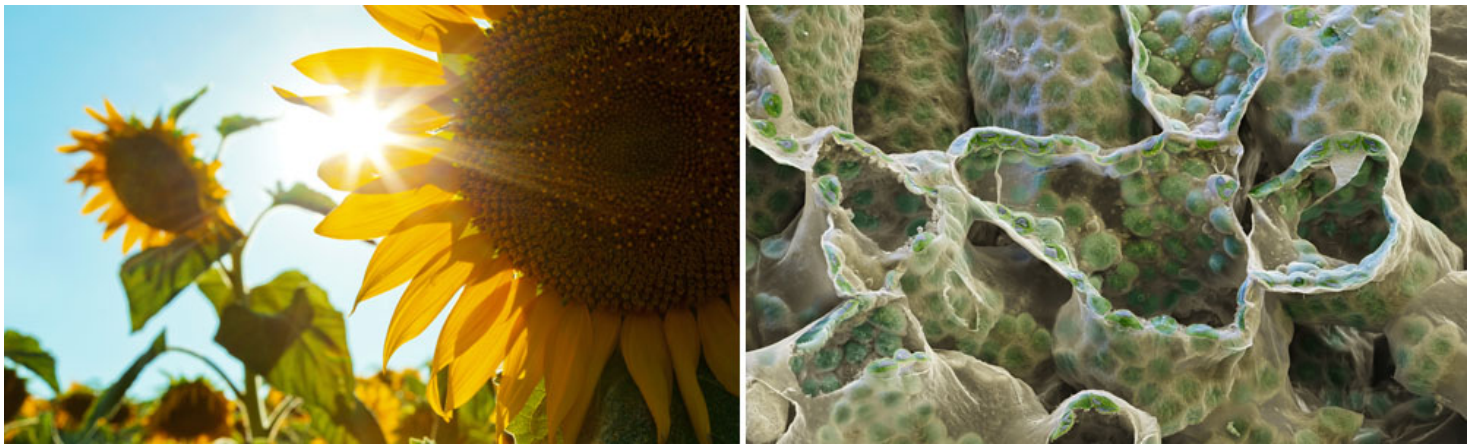


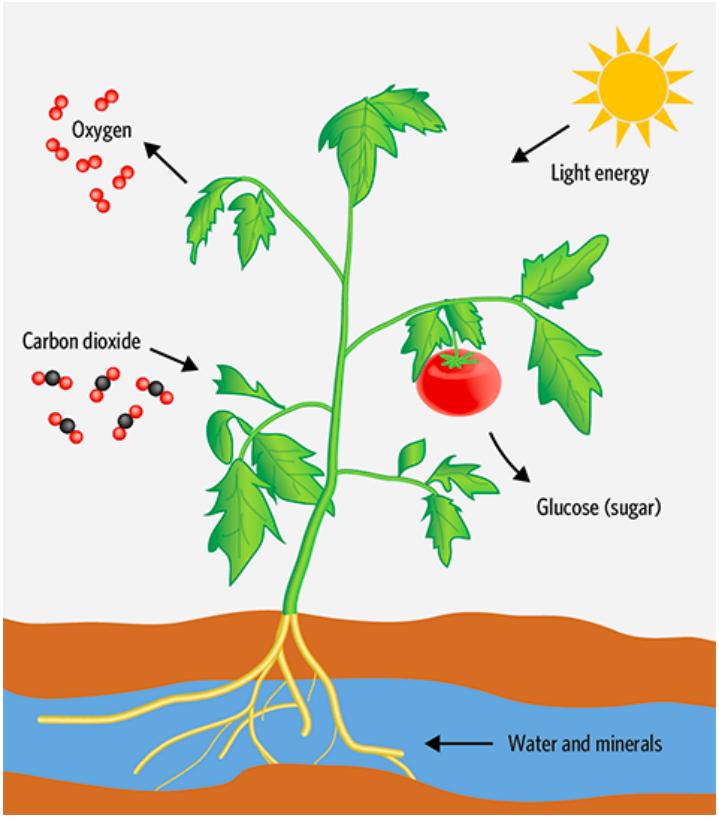
Left: In its vegetative stages (that is, before flowering) sunflowers tilt their leaves towards the Sun as it travels across the sky. This helps them make the most of the day's photosynthesis-enabling sunlight. Right: Coloured scanning electron micrograph of leaf cells containing numerous green, round chloroplasts. Chloroplasts are the site of photosynthesis. Credit: iStock and Eye of Science / Getty Images.

The *Introduction* section mentions the term *photosynthesis.* Photosynthesis is the process by which plants capture energy from sunlight to create their own food. Photosynthesis involves a series of chemical reactions. A *chemical reaction* is a process that involves the rearrangement of atoms of *reactant* chemical substances to form at least one new *product*.

The chemical reaction for photosynthesis is:

$$6CO_2 + 6H_2O \xrightarrow[chlorophyll]{sunlight} C_6H_{12}O_6 + 6O_2$$

Note that sunlight and chlorophyll are required for the reaction to occur so are written in line with the reaction arrow.



Question 1

Match: Use the chemical reaction for photosynthesis and the above illustration to match the molecular formulas of the molecules involved in photosynthesis with their appropriate names. The first one has been done for you.

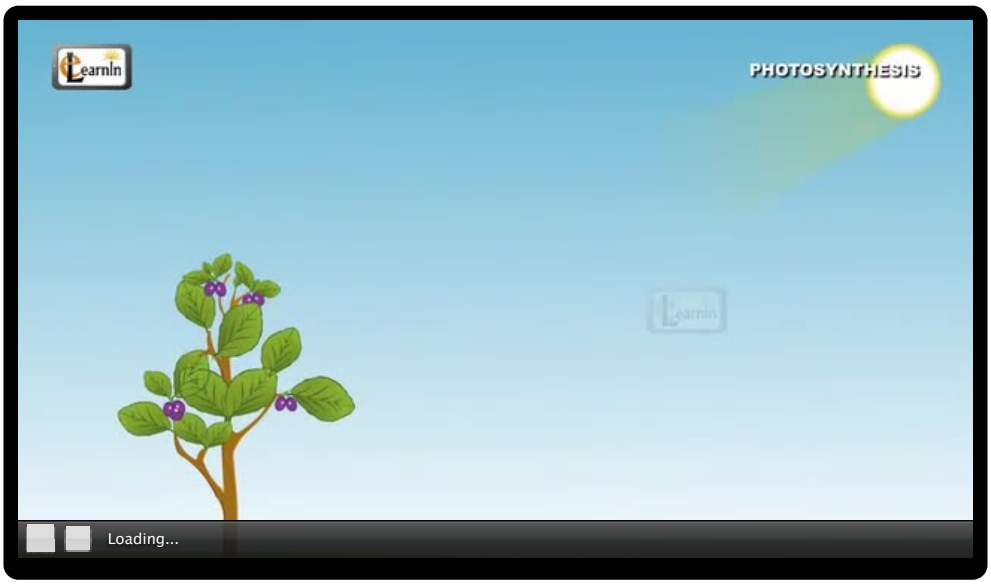
Name	Molecular formula
Water	H_2O
Oxygen	
Carbon dioxide	
Glucose	

Question 2

Describe: Give two everyday examples in which a chemical reaction will only occur if more energy is added.

Question 3

Count: In the process of photosynthesis, how many molecules of carbon dioxide and water are required to produce one molecule of glucose? Why do you think these numbers (known as coefficients) need to be indicated in the chemical equation?



Credit: Elearnin / YouTube.

Question 4

Remember: Plants convert chemical energy into light energy in a process known as photosynthesis.

- ○ True
- ○ False

Question 5

Recall: Which of the following is NOT an essential requirement for photosynthesis to occur?

- ☐ water
- ☐ light
- ☐ carbon dioxide
- ☐ oxygen

Question 6

Research: Plants use glucose to produce larger molecules such as cellulose and starch. Research what plants use these larger molecules for and summarise your findings below. List your sources.

Process: Photosynthesis (P1)

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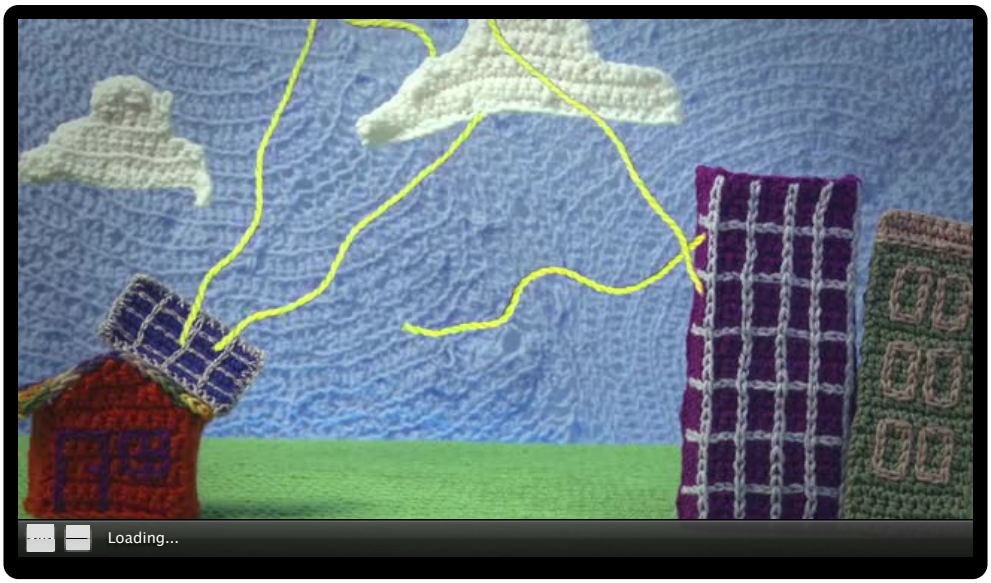
Credit: iStock

Plants and solar cells (also known as photovoltaic cells) both harvest energy from sunlight, but they use the energy in different ways: plants convert the light energy into chemical energy, whereas solar cells convert it into electrical energy, or electricity. Scientists, like the ones mentioned in the *Cosmos* article, are currently investigating ways in which to improve the energy conversion efficiency of both types of solar energy harnessing systems.



Credit: TED-Ed / YouTube.

Question 1

Define: Use the information in the video clip to define the terms in the table.

Term	Definition
direct irradiance	
diffuse irradiance	
reflected irradiance	

Question 2

Hypothesise: The video clip describes solar towers and solar cells. Which of these do you think would be best installed at your school in order to generate the most electricity? Justify your response.

Question 3

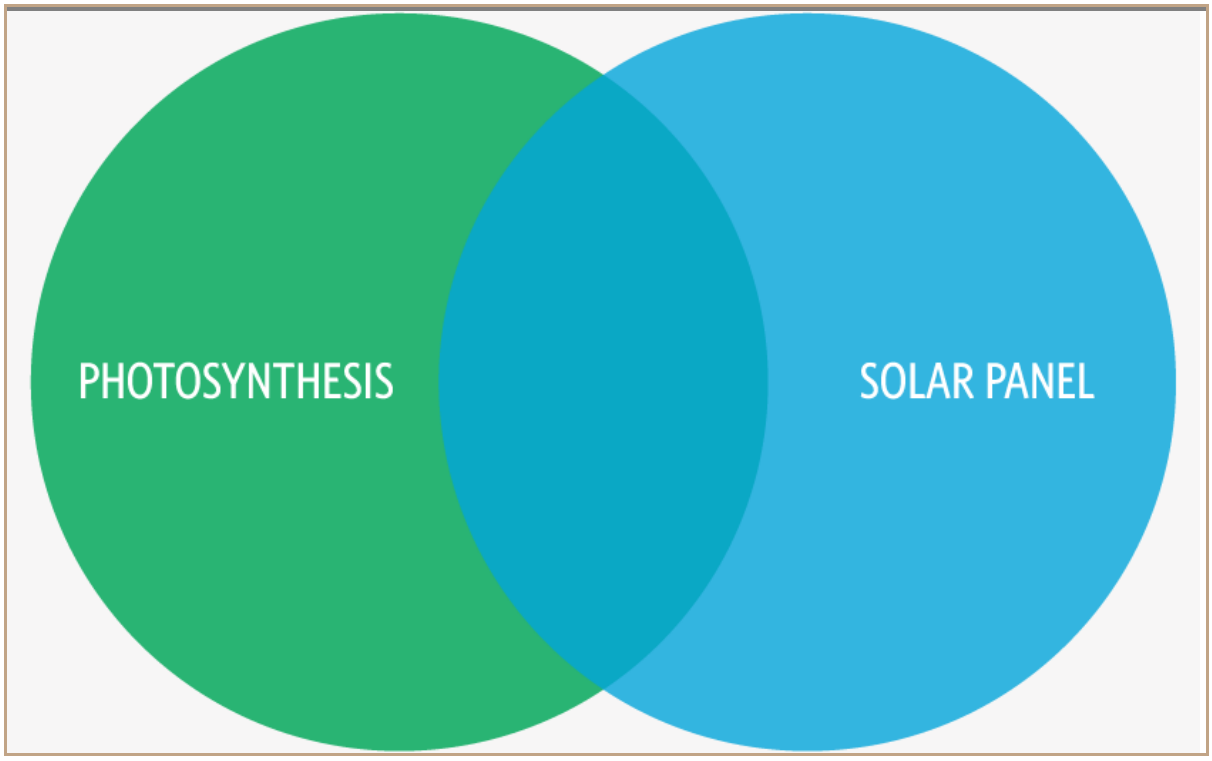
Judge: Decide whether you think the following features of solar cells are advantages or disadvantages by typing an "X" into the relevant column.

Feature of solar cells	Advantage	Disadvantage
They harness a renewable energy source. Solar energy will be available for millions of years and there is more than enough to supply all of the world's energy needs.		
They cannot generate electricity at night time, and are severely affected by heavy cloud cover.		
They operate without noise.		
They can be used in remote areas where there is no access to an electricity grid.		

Question 4

Compare: Using what you have learned in this lesson add the following terms into the Venn diagram below.

- Light energy converted into chemical energy
- Light energy converted into electrical energy
- Harnessed energy is stored in molecules such as glucose
- Requires water
- Requires sunlight
- More efficient at converting sunlight into usable energy
- Particularly good at charge separation



Question 5

Calculate: Imagine that you have installed brand new solar panels on the roof of your house. The panels generate an average of 300 kWh (kilowatt hours) of electricity every month. If your electricity provider charges 22 cents per kilowatt hour, calculate how much your solar panels will reduce your monthly power bill.

Question 6

Calculate: Imagine that the discovery mentioned in the *Introduction* led to a new line of solar cells that produce 5% more electricity than the ones you just installed. Unable to resist upgrading to the latest technology, you hastily replace your old solar panels with these new, more energy-efficient ones. Calculate the average number of kilowatt hours your new solar panels would generate every month, as well as the additional reduction to your power bill.

Question 7

Argue: Your local government has proposed to close down 80% of its coal-fired power stations in favour of installing a large solar farm, in an initiative funded by foreign investors. Decide whether you support this proposal and write a letter to your local government representative to explain and justify your stance.

Apply: Photosynthesis (P2)

COSMOS LIVE LEARNING

Experiment: Optimising the power output of solar panels

Background

The lesson introduction refers to new ways in which scientists are attempting to improve the energy efficiency of solar cells by learning from plant photosynthesis. This experiment will look at other, more simple methods of improving solar power efficiency.

Aims

There are two parts to this experiment:

Part 1: Discover what angle solar panels must be positioned relative to the light source in order to produce the maximum power output.

Part 2: Investigate the effect of dirt and other pollutants on the power output of a solar panel.

Materials

- Solar panel
- Light source of constant light intensity (lamp)
- Connecting wires
- Power supply
- Voltmeter (0 – 20 V)
- Ammeter (0 – 200 mA)
- Resistor (16 or 22 Ω)
- Ruler
- Protractor
- Blue tac or sticky tape

- "Pollution sheets" – transparent plastic sheets with small black ink dots.

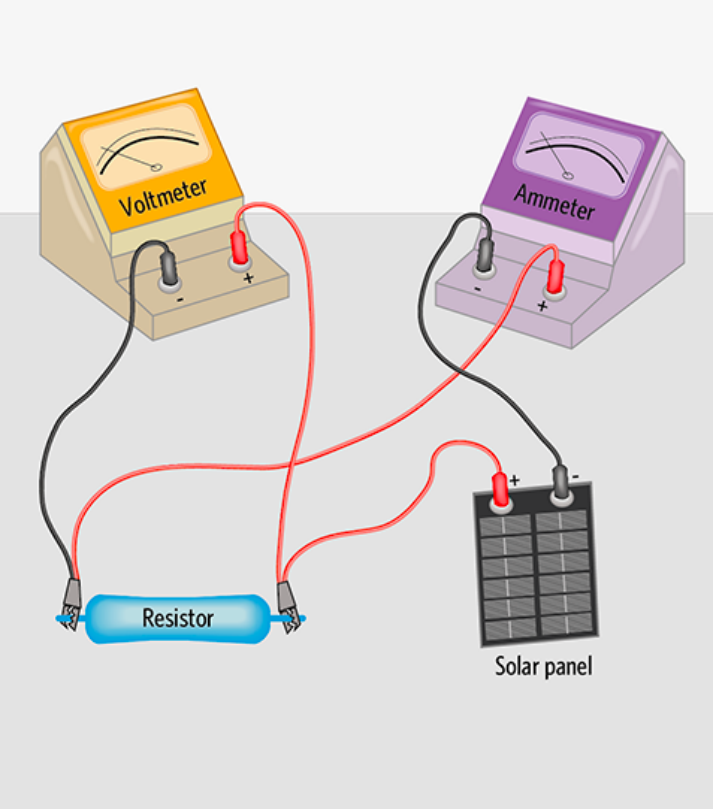
Procedure

Part 1:

1. Connect the solar panel, voltmeter, ammeter and resistor as illustrated in the circuit diagram on the right.
2. Position the lamp 30 cm away from the solar panel and at an angle of 90 degrees to it (in other words, facing it).
3. Record the voltage and current in *Question 3*.
4. Repeat steps 2 – 3, using the protractor to measure and accurately position the solar panel at 80, 70, 60, 50, 40 and 30 degrees to the light source. Record your results.

Part 2:

1. Part 1 represented the power output with zero pollution. Keep the circuit unchanged but set the solar panel at the angle that produced the highest power output.
2. Simulate the effect of air pollution by placing the pollution sheets over the solar panel one at a time.
3. Record your results for each instance in *Question 5*.



Hypothesis

Question 1

Hypothesise: Before you begin, predict what you believe the optimum angle will be in *Part 1*. Similarly, predict the effect of increased pollution on the power output of your solar panel in *Part 2*.

Variables

Question 2

Identify: For *Part 2* of the experiment, complete the table to identify the variables involved

Independent Variable *(what you are changing each time)*	**Dependent Variable** *(what you are measuring or observing each time)*	**Controlled variables** *(what you are keeping the same each time)*

Results

Question 3

Calculate: For Part 1, complete the table below by entering all of your observed data for voltage (*V*) and current (*I*) and use this information to calculate the power output of your solar panel, where:

P = VI

P = Power Output (watts, W)
V = Voltage (*volts, V*)
I = Current (*amperes, A*)

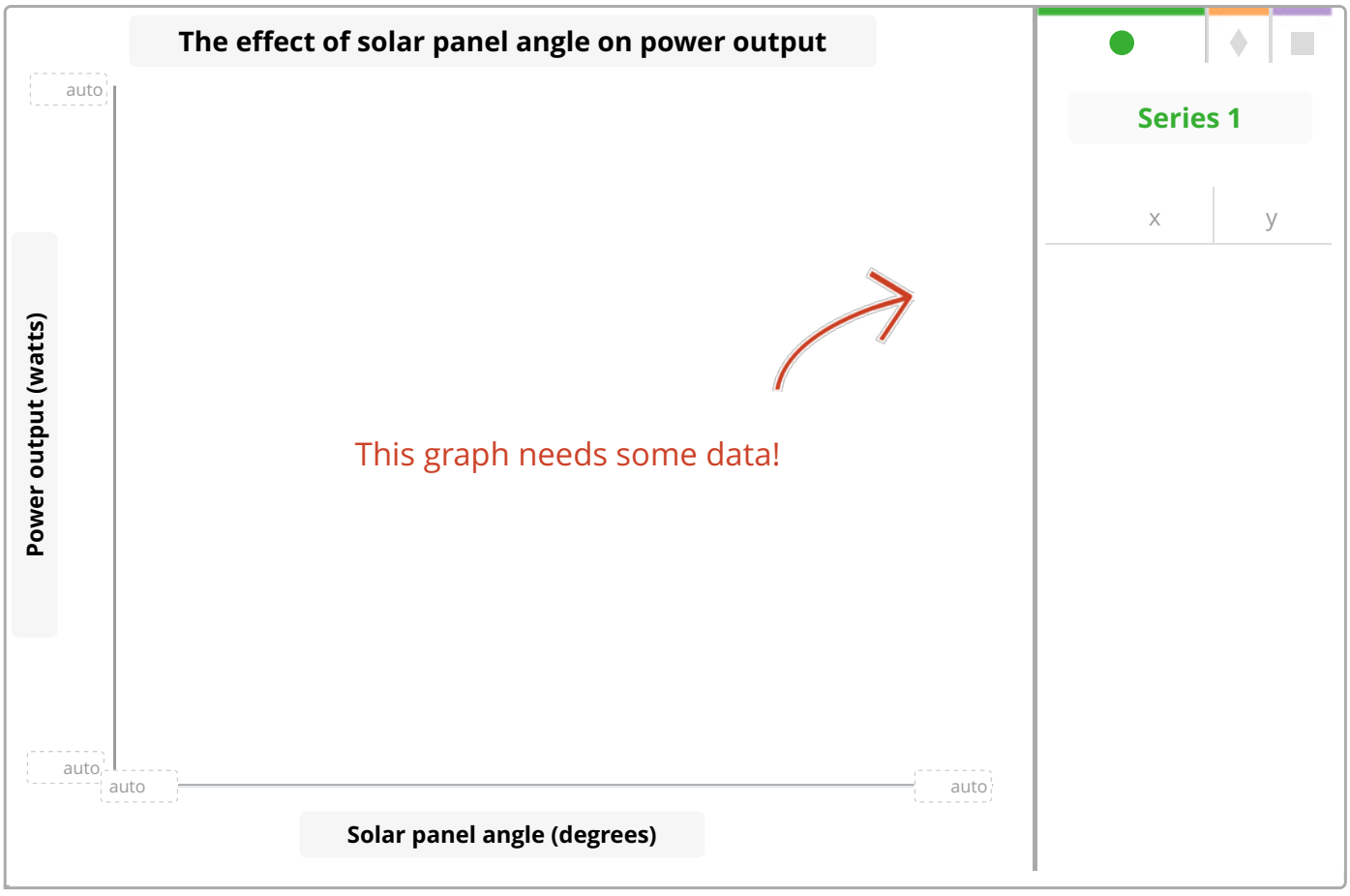
Hint: You will need to convert the current from milliamps to amps (1 amp = 1000 milliamps).

Angle of solar panel to the lamp (degrees)	Voltage (*V*) (volts)	Current (*I*) (amps)	Power output (P) (watts)
90			
80			
70			
60			
50			
40			
30			

Question 4

Illustrate: Plot the power output against the angle of the solar panel to the light source.

Hint: You will need to enter this data into the columns to the right of the graph.



Question 5

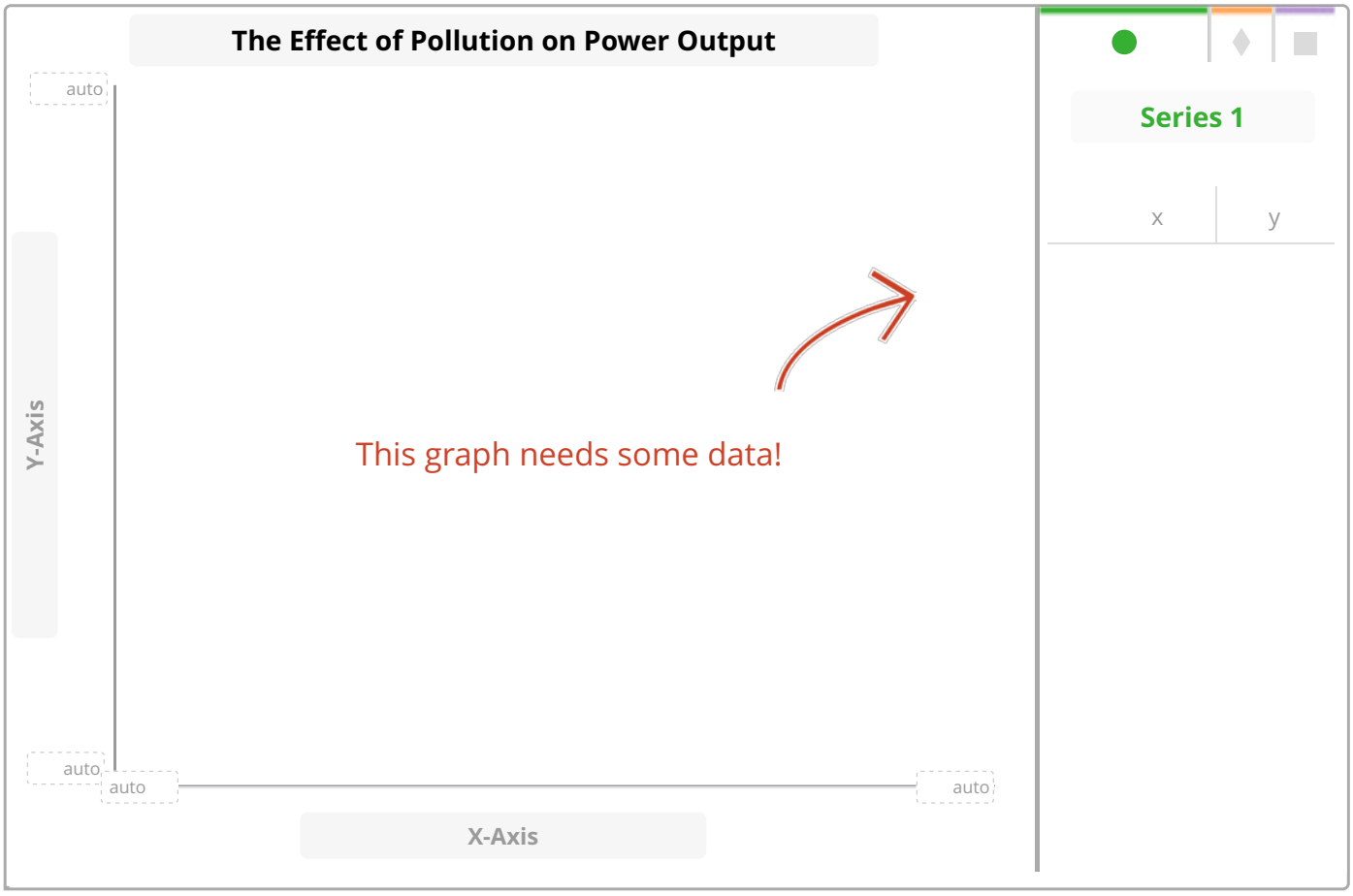
Complete: Positioning the solar panel at the angle that provided the maximum power output in Part 1, commence Part 2 and complete the table below.

Pollution Transparency Sheet	Voltage (*V*) (volts)	Current (*I*) (amps)	Power output (*P*) (watts)
1			
2			
3			
4			
5			
6			

Question 6

Illustrate: Plot the power output against amount of "pollution".

Hint: The axes haven't been labeled for you. Make sure to label them!



Question 7

Conclude: Use your results to respond to the aims of this experiment.

Question 8

Extend: Propose modifications to the experimental design that might deliver an even greater power output.

Question 9

Apply: With the aid of an internet search, find out at what angle solar panels are generally installed onto buildings and summarise your findings below.

Career: Photosynthesis (P2)

THE UNIVERSITY of ADELAIDE

Brought to you by the University of Adelaide

While most people grow up with pet dogs and cats, Ros Gleadow lovingly tended rows of pot-plants. She even gave the plants names.

Ros' parents were doctors who worked in Aboriginal communities, and Ros always assumed she would follow in their footsteps. She didn't consider a career in science until a geneticist came to talk to her high school science class. "I just thought, wow, I'm going to be a scientist!" Ros recalls fondly. "It was awesome."

As a plant physiologist at Monash University Ros spends her days in large glasshouses surrounded by potted cassava plants, not unlike her childhood. You may know cassava as tapioca, the chewy starchy substance sometimes found in desserts, but cassava is an important food source that feeds nearly a billion people around the world every day. Ros wants to find out how changes in the environment might affect the nutritional value of the plants we eat.

Although plants need carbon dioxide for photosynthesis there can be too much of a good thing. Plants grown in high carbon dioxide environments produce less protein, making them less nutritious. And that's not all – to keep pests away cassava plants produce a compound called cyanide. Cyanide is a deadly poison and cassava must be prepared carefully before it can be eaten. Ros' experiments have shown that high carbon dioxide levels cause cassava plants to make more cyanide and become even more toxic.

While she isn't a medical doctor like her parents, Ros helps the world in her own way by ensuring that it will be able to feed itself in the future. Outside of the lab Ros loves sharing her passion for science with the public. She appears on radio and television and regularly tweets about her love for science.

Question 1

Imagine: Ros' research involves investigating how changes in carbon dioxide levels affect the protein and cyanide content of cassava. Picture yourself as a research scientist working in the same laboratory as Ros; if you were able to direct a plant to manufacture a particular product or nutrient, what would you choose? Give reasons for your answer.

COSMOS LIVE LEARNING

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