Investigating photosynthesis

STEM 2023 conference resource

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Contents

[Investigating photosynthesis 3](#_Toc143771575)

[Information for teachers 3](#_Toc143771576)

[Stage 5 Outcomes 3](#_Toc143771577)

[Learning intentions and success criteria 4](#_Toc143771578)

[Teaching notes 5](#_Toc143771579)

[Part 1 – observing photosynthesis and respiration in spinach 5](#_Toc143771580)

[Part 2 – greenhouse research and development 8](#_Toc143771581)

[Student resources 14](#_Toc143771582)

[Resource 1 – observing photosynthesis and respiration in spinach 14](#_Toc143771583)

[Resource 2 – greenhouse research and development 18](#_Toc143771584)

[References 22](#_Toc143771585)

**Note:** this resource is an early-release draft. It is currently undergoing consultation and editorial processes. For additional support or advice, or to provide feedback, contact the Science Curriculum team by emailing [Science7-12@det.nsw.edu.au](mailto:Science7-12@det.nsw.edu.au).

# Investigating photosynthesis

## Information for teachers

### Stage 5 outcomes

* develops questions or hypotheses to be investigated scientifically **SC5–4WS**
* produces a plan to investigate identified questions, hypotheses or problems, individually and collaboratively **SC5–5WS**
* undertakes first-hand investigations to collect valid and reliable data and information, individually and collaboratively **SC5–6WS**
* processes, analyses and evaluates data from first-hand investigations and secondary sources to develop evidence-based arguments and conclusions **SC5-7WS**
* applies scientific understanding and critical thinking skills to suggest possible solutions to identified problems **SC5-8WS**
* presents science ideas and evidence for a particular purpose and to a specific audience using appropriate scientific language, conventions and representations **SC5-9WS**

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**This activity could be adapted for:**

* Stage 4 Science: **SC4-14LW** relates the structure and function of living things to their classification, survival and reproduction. For example, part 1 of this activity may be suitable for Stage 4.
* Stage 6 Biology: **BIO11-8** describes single cells as the basis for all life by analysing and explaining cells’ ultrastructure and biochemical processes.

### Learning intentions and success criteria

Students:

* conduct an investigation to observe photosynthesis and respiration
* develop a recommendation for an agricultural company about greenhouse construction based on evidence collected through an investigation.

Students [can/will]:

* identify the inputs and outputs of photosynthesis
* develop a valid and reliable investigation
* present a recommendation based on evidence collected in an investigation.

**Differentiation consideration**: learning intentions should not be differentiated. All students need to access to the same core content, big ideas and concepts. Differentiation should be evident in the success criteria, or the activities/support needed to achieve the success criteria (Wiliam and Leahy 2015). Teachers may co-construct the success criteria with students or adjust them to suit their class context, for example, using the strategies and resources for curriculum planning on the [Planning, programming and assessing 7-12](https://education.nsw.gov.au/teaching-and-learning/curriculum/planning-programming-and-assessing-k-12/planning-programming-and-assessing-7-12) webpage.

## Teaching notes

Part 1 can be conducted as a class demonstration or a group activity depending on sensor availability. This activity is designed to introduce the students to the concepts of photosynthesis and respiration through the collection of first-hand data.

Part 2 goes beyond simple verification and emphasises experimental design while students explore a factor that affects photosynthesis more deeply.

### Part 1 – observing photosynthesis and respiration in spinach

**Equipment**

* **extra-large snap lock bag**
* **baby spinach leaves (6-10)**
* **carbon dioxide gas sensor**
* **oxygen gas sensor**
* **dish of water**
* **paper towel**
* **bright light source (800 lumens) preferably fluorescent or LED.**
* **aluminium foil**
* **digital balance accurate to 0.01 g**

**Note: this investigation can be conducted with just the carbon dioxide sensor if an oxygen gas sensor is not available. Adjust the student worksheet accordingly.**

**Procedure**

1. **At least 20 minutes before the lesson place spinach leaves flat in a dish of water to ensure that the cells are turgid.**
2. **Set up a lamp so that it will shine evenly across the snap lock bag of leaves. Leave it turned off for now.**
3. **Carefully remove the leaves from the water and pat them dry with a paper towel. Be careful not to bend or crush the leaves. Trim the stems to the edge of the leaf.**
4. **Turn the gas sensors on and place them inside the zip lock bag.**
5. **Arrange the spinach leaves in the zip lock bag so that upper side of the leaves are facing up and the leaves are not overlapping. Seal the bag.**
6. **On the data logging interface, connect the sensors, and set the graph to record the carbon dioxide and oxygen (if used) gases in parts per million (ppm). Set the time interval for measurements to be taken at 1-minute intervals.**

**Note: it is important to ensure the units are being measured in parts per million (ppm) particularly for the oxygen gas. If % concentration is used a change may not be observed.**

1. **Position the lamp directly above the leaves and turn it on.**
2. **One minute after turning the lamp on, press start on the data logging interface and start collecting data.**
3. **Collect data for 10 minutes. Stop the run on the data logging interface.**

**Note: there should be a decrease in the amount of carbon dioxide gas and an increase in the amount of oxygen gas. This is because photosynthesis is occurring.**

1. **Cover the leaves with a sheet of foil to block the light.**
2. **After one minute, start to collect data in the dark.**
3. **Collect data for 10 minutes. Stop the run on the data logging interface.**

**Note: there will likely be an observable decrease in the amount of oxygen and an increase in carbon dioxide. This is because photosynthesis is no longer occurring, and respiration is continuing to occur.**

**Extension:** a confirmatory test could be conducted to show that photosynthesis has occurred by looking for starch in the leaves. Expose the leaf to light and then remove the pigment from the spinach leaves by boiling them in methylated spirits using a water bath. Once the pigment is removed from the leaf, rinse the leaf and place it on a watch glass. Add drops of iodine solution on the surface of the leaf. Black spots will show where starch is present.

**Sample results for carbon dioxide and oxygen levels for spinach leaves in presence and absence of light.**

Figure 1– the graphs above show the change in concentration of carbon dioxide and oxygen gases for N=10 spinach leaves placed in a zip lock bag exposed to light for 10 minutes. Spinach leaves exposed to light reduced the concentration of carbon dioxide

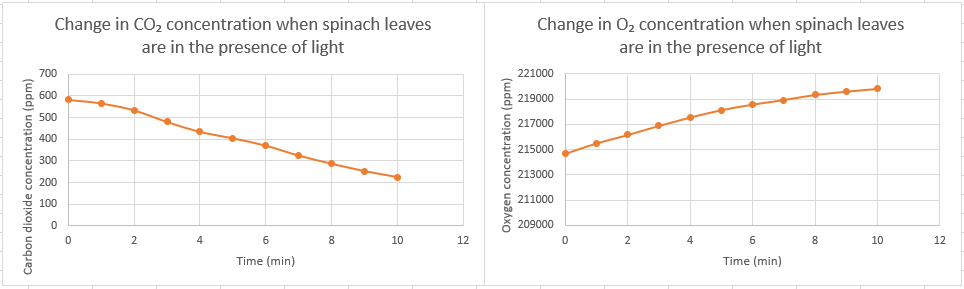
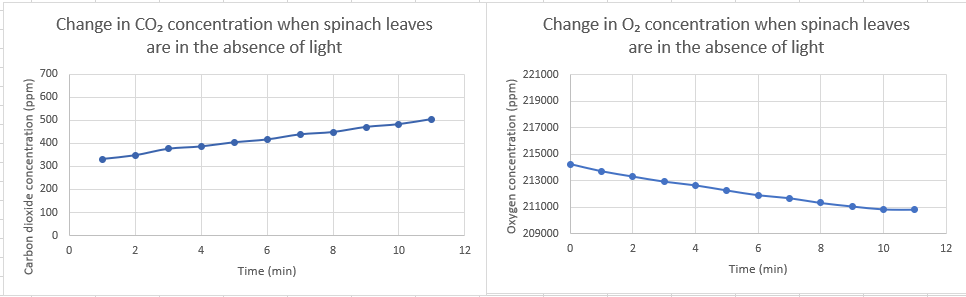


Figure 2 – the graphs above show the change in concentration of carbon dioxide and oxygen gases for N=10 spinach leaves placed in a zip lock bag in the absence of light. Spinach leaves exposed to dark conditions caused the concentration of carbon dioxide to increase and oxygen to decrease. Photosynthesis is no longer occurring; however, respiration continues to occur causing the change in gas composition.



**Note:** in light, both photosynthesis and respiration are occurring. So, both processes will be causing a change in the composition of the gases. In this investigation, photosynthesis is occurring at a greater rate than that of respiration, and therefore the carbon dioxide levels reduce, and the oxygen levels increase. In the dark conditions, the oxygen levels decrease, and the carbon dioxide levels increase. Respiration is occurring and the light dependent photosynthesis reactions are not occurring.

### Part 2 – greenhouse research and development

Once students have been shown how to measure photosynthesis using the gas sensors, they should then be able to go on to develop an investigation into a factor that affects photosynthesis.

The investigation may be completed by small groups of students or as a full class, depending on the availability of sensors.

Students should be provided with some time to brainstorm ideas for one of the scenarios they have chosen. Alternatively, the teacher may unpack each scenario with the class and decide on which one they will be investigating as a class.

Table 1 – question prompts that could be used in the lesson to promote discussion about scientific method

|  |  |
| --- | --- |
| Question | Possible solutions/problems |
| When conducting an investigation, we should use repetition. How can we control the variability of the spinach leaves in each repeated trial? | * Select leaves of a certain size and shape. * Make sure the leaves are not damaged, as this can cause them to respire at a faster rate. * Measure the surface area (SA) of the leaves and ensure the same SA is used in each trial. * Use a certain mass of spinach leaves (trim stalks so they don’t contribute to variation). * Cut the leaves into the same size disks or squares. |
| Can the same leaves be used for multiple trials? Explain your reasoning. | * As the leaves are photosynthesising, they will use up water in the cells. This may need replenishing, by re-soaking the leaves in water. * Carbon dioxide inside the bag will be consumed throughout a trial. Opening the bag to re-fresh the air inside the bag will help ensure the starting CO2 is close to the same level for each trial. |

Table 2 – suggested strategies that could be provided to students to manipulate the different variables

|  |  |  |
| --- | --- | --- |
| Investigation | Strategies to manipulate the variables | Illustration |
| Which colour glass is most suitable for the greenhouse? | * Coloured cellophane can be used to represent the different coloured glass. * Coloured cellophane can be simply placed over top of the bag containing the leaves. | Eight leaves in a bag with a piece of coloured cellophane over the top to represent the different coloured glass. |
| What light intensity is most suitable to maximise photosynthesis? | * Light intensity can be changed by adjusting the distance of the light from the leaves, or by using a dimmable light source. * The light intensity can be measured using a lux meter. A lot of phones can do this with the help of an app like Physics toolbox. | Bag containing 6 leaves to the right of a light bulb, separated by a 2-sided arrow indicating that the light intensity can be changed by adjusting the distance between the leaves and the light bulb. |
| What level of CO2 will maximise photosynthesis? | * CO2 can be produced in a beaker with a small amount of bicarbonate of soda and white vinegar. A syringe can then be placed inside the beaker and certain volumes of gas measured. The gas can then be expelled into the bag of leaves through a small opening. | A beaker with a small amount of bicarbonate soda and vinegar. A syringe is placed inside the beaker above the carbon dioxide region to collect carbon dioxide. |

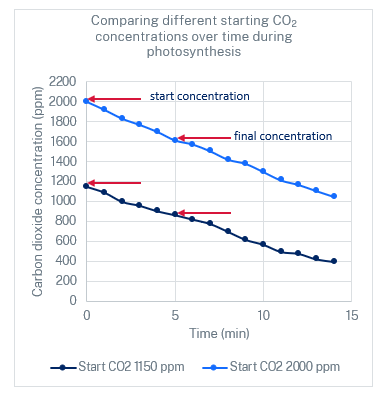
**Sample data logger output: investigating the effect of different light filters:**

Figure 3 – sample data logger output showing the change in carbon dioxide gas levels in a closed environment with spinach leaves. The same spinach leaves were first exposed to light with no filter, which can be seen to reduce the CO2 levels the quickest by approximately 390 ppm over 10 minutes. The bag was then opened to re-fresh the air inside it, and a blue filter applied. The amount of CO2 reduced by approximately 40 ppm in 10 minutes. The red filter was then tested after re-opening the bag again and the CO2 reduced by approximately 320 ppm in 10 minutes.

**Sample data logger output: investigating starting concentrations of carbon dioxide:**

|  |  |  |
| --- | --- | --- |
| Time (min) | Start CO2 concentration (1150 ppm) | Start CO2 concentration (2000 ppm) |
| 0 | 1150 | 2000 |
| 1 | 1092 | 1920 |
| 2 | 1000 | 1832 |
| 3 | 961 | 1770 |
| 4 | 905 | 1700 |
| 5 | 867 | 1615 |
| 6 | 823 | 1575 |
| 7 | 778 | 1506 |
| 8 | 700 | 1423 |
| 9 | 620 | 1381 |
| 10 | 571 | 1300 |
| 11 | 499 | 1216 |
| 12 | 480 | 1171 |
| 13 | 425 | 1110 |
| 14 | 400 | 1052 |

**You can see from the slope of the line that the higher starting concentration of the CO2 increases the rate of photosynthesis. The rate of photosynthesis can be calculated from this data using 2 points on the line graph. An example is shown below.**



**= 77 ppm/min**

**Note: in this investigation the independent variable is the starting concentration of carbon dioxide and the dependent variable is the rate of carbon dioxide intake. Measuring the carbon dioxide levels for both the independent variable (starting CO2) and the dependent variable (rate of CO2 intake) may be confusing for students and it is a better option to use the increase in oxygen as the marker for the rate of photosynthesis.**

## Student resources

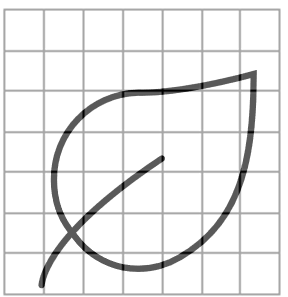
### Resource 1 – observing photosynthesis and respiration in spinach

**You are going to observe the changes in the composition of oxygen and carbon dioxide during photosynthesis and respiration in spinach leaves.**

Read the method. Why do you think it is important to place the spinach leaves in water prior to the investigation?

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Calculate the surface area of the leaves by tracing them onto grid paper.



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Predict what will happen to the levels of carbon dioxide and oxygen inside the bag when the **light is on**. Explain your reasoning in the table below.

|  |  |  |
| --- | --- | --- |
| Gas | Prediction | Explanation |
| Oxygen (O2) |  |  |
| Carbon dioxide (CO2) |  |  |

Predict what will happen to the levels of carbon dioxide and oxygen inside the bag when the **light is turned off**. Explain your reasoning in the table below.

|  |  |  |
| --- | --- | --- |
| Gas | Prediction | Explanation |
| Oxygen (O2) |  |  |
| Carbon dioxide (CO2) |  |  |

**Equipment**

* **Extra-large snap lock bag**
* **Baby spinach leaves (6–10) (evenly sized and undamaged)**
* **Carbon dioxide gas sensor**
* **Oxygen gas sensor**
* **Dish of water**
* **Paper towel**
* **Bright light source (800 lumens) preferably fluorescent or LED.**
* **Aluminium foil**
* **Digital balance accurate to 0.01 g**

**Procedure**

1. **At least 20 minutes before the lesson place spinach leaves flat in a dish of water to ensure that the cells are turgid**
2. **Set up a lamp that it will shine evenly across the snap lock bag of leaves. Leave turned off for now.**
3. **Carefully remove the leaves from the water and pat them dry with a paper towel. Be careful not to bend or crush the leaves. Trim the stems to the edge of the leaf. Record the total mass of the leaves being used.**
4. **Turn the gas sensors on and place inside the zip lock bag.**
5. **Arrange the spinach leaves in the zip lock bag so that upper leaf is facing up and the leaves are not overlapping. Seal the bag.**
6. **On the data logging interface, connect the sensors, and set the graph to record the carbon dioxide and oxygen gases in parts per million (ppm). Set the time interval for measurements to be taken at 1-minute intervals.**
7. **Position the light directly above the leaves and turn it on.**
8. **One minute after turning the light on, press start on the data logging interface and start collecting data.**
9. **Collect data for 10 minutes. Stop the run on the data logging interface.**
10. **Cover the zip lock bag of leaves with a sheet of foil to block the light.**
11. **After one minute, start to collect data in the dark for 10 minutes.**
12. **Stop the run on the data logging interface.**

Collect the data on the changes in Carbon dioxide gas composition in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Light condition | CO2 concentration (ppm) START | CO2 concentration (ppm) FINISH | Time elapsed (min) | Change in CO2 concentration (ppm) | Rate of CO2 concentration change (ppm/min) |
| Light |  |  |  |  |  |
| Dark |  |  |  |  |  |

Collect the data on the changes in Oxygen gas composition in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Light condition | O2 concentration (ppm) START | O2 concentration (ppm) FINISH | Time elapsed (min) | Change in O2 concentration (ppm) | Rate of O2 concentration change (ppm/min) |
| Light |  |  |  |  |  |
| Dark |  |  |  |  |  |

Export the data from the data logging software in a table. Construct a graph showing the concentration of the gases over time under the light and dark conditions.

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Describe what happened to the gas levels over the 15 minutes in light.

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|  |

Photosynthesis is a vital process that converts light energy into chemical energy in green plants, algae and some bacteria. Light energy is captured and used to synthesise glucose and oxygen from carbon dioxide and water. Light is a critical factor in photosynthesis, as it acts as the primary energy source driving the reaction.

Use the information above to write a word equation for photosynthesis.

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Explain how you know that the spinach leaves were photosynthesising when the light was on.

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Describe what happened to the gas levels over the 15 minutes in dark.

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Living organisms need a constant supply of energy to survive and perform their various functions. Respiration is the chemical process that releases energy in the cells of living things. The word equation for respiration is Oxygen + Glucose à Carbon dioxide + Water.

Using this information explain the changes in gas composition in the bag of spinach when the light was turned off and the bag was covered with a piece of foil.

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### Resource 2 – greenhouse research and development

You are part of a team of farmers, scientists and engineers that are working together to propose a solution to maximise the output of fruit and vegetable farms in New South Wales. The proposed solution involves using vertical farms in green houses. You have been employed by an Australian agricultural company, as a scientist, to investigate one of the following:

* Which colour filter is most suitable for the greenhouse to maximise photosynthesis?
* What light intensity is most suitable to maximise photosynthesis?
* What is the optimum starting level of CO2 to maximise photosynthesis?

Your findings will contribute to the advice provided back to the Australian agricultural company.

**Things to think about when planning your investigation:**

* How will you modify the independent variable?
* How will you measure the dependent variable?
* How will you control the other variables?

**Aim**:

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**Hypothesis**:

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**Variables**:

* Independent variable (the variable that is changed on purpose).

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* Dependent variable (the variable that is measured/observed to obtain results).

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* Controlled variables (the variables that are kept the same, so they do not influence the results. Include how the variable was kept the same).

|  |  |
| --- | --- |
| Controlled variable | Control measure |
| The spinach leaves | * Use the same batch of leaves (from the same packet) * Prepare the leaves uniformly (submerge in water without overlapping them) * Use the same number and sizes of leaves for different treatments (you could measure the surface area or the mass). |
|  |  |
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|  |  |

Materials and equipment – don’t forget to include sizes and quantities where relevant.

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|  |

Method – write step-by-step instruction on how to complete the investigation.

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|  |

Risk assessment

|  |  |  |
| --- | --- | --- |
| Items/Chemicals | Hazard | Control measures |
|  |  |  |
|  |  |  |
|  |  |  |

Results

* Process the data from the data logging software to determine the rate of CO2 consumption per minute, from the initial and final CO2 concentrations in a given period of time. Create a table to record your raw data. Units should be in the column headings.

|  |
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* Create a graph of your results if appropriate. Remember the independent variable should go on the x-axis and the dependent variable on the y-axis. Your graph should include the following: a descriptive title, labelled axes, evenly spaced units, and a line of best fit. You can use Excel or graph paper to draw your graph. Include it in the space provided.

|  |
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**Presentation of recommendations**

Present your findings and recommendation to the Australian agricultural company. This can be in the form of student’s choice. Examples include a one-page written summary, a presentation, or a poster.

In your recommendation include:

* an overview of the purpose and objectives of the investigation
* a summary of the of the report capturing key findings
* a summary of the methodology
* a summary of the results of the investigation
* recommendations to the Australian Agricultural Company based on the results of the investigation.

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NESA (NSW Education Standards Authority) (2022) ‘[Proficient teacher: standard descriptors](https://educationstandards.nsw.edu.au/wps/portal/nesa/teacher-accreditation/meeting-requirements/the-standards/proficient-teacher)’, The Standards, NESA website, accessed 02 August 2023.

State of New South Wales (Department of Education) and CESE (Centre for Education Statistics and Evaluation) (2020a) ‘[What works best: 2020 update](https://education.nsw.gov.au/about-us/educational-data/cese/publications/research-reports/what-works-best-2020-update)’, CESE, NSW Department of Education, accessed 02 August 2023.

State of New South Wales (Department of Education) and CESE (Centre for Education Statistics and Evaluation) (2020b) ‘[What works best in practice](https://education.nsw.gov.au/about-us/educational-data/cese/publications/practical-guides-for-educators-/what-works-best-in-practice)’, CESE, NSW Department of Education, accessed 02 August 2023.

Wiliam D and Leahy S (2015) Embedding formative assessment: practical techniques for K-12 classrooms, Learning Sciences International, US.

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