

Light intensity and the rate of photosynthesis

Investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.

For AQA GCSE Biology 8461 and Combined Science: Trilogy 8464. Teacher answers start on a new page.

Name

Date

Aim

To find how the distance of a lamp from a piece of pondweed affects the rate at which it photosynthesises.

Background

Photosynthesis is the process that uses light energy to make glucose from carbon dioxide and water. Oxygen is released as a by-product: carbon dioxide + water → glucose + oxygen.

The rate of photosynthesis depends on the **light intensity**, the **carbon dioxide concentration** and the **temperature**. If any one of these is in short supply, it limits the rate. It is called a **limiting factor**.

Pondweed is an aquatic plant. Its oxygen escapes as bubbles from the cut end of the stem, so the number of bubbles (or the volume of gas) in a set time is a measure of the rate of photosynthesis.

Light intensity gets lower as you move away from a lamp. So the distance from the lamp is a way of changing the light intensity: a larger distance means a lower light intensity.

Hypothesis

The closer the lamp is to the pondweed, the higher the light intensity, so the faster the rate of photosynthesis and the more oxygen bubbles are released per minute.

Variables

Independent	Distance of the lamp from the pondweed (cm), which changes the light intensity
Dependent	Number of oxygen bubbles released in one minute (or the volume of oxygen collected in a set time)
Control	• Temperature of the water (use a water bath or a beaker of water as a heat shield, or a cool LED lamp) • Carbon dioxide concentration (same sodium hydrogencarbonate solution) • Same piece and length of pondweed throughout • Same lamp • Time over which bubbles are counted • Other light sources (carry out in a dim room)

Equipment

- Fresh pondweed (for example *Elodea* or *Cabomba*), a piece about 10 cm long
- Sodium hydrogencarbonate solution (about 1%) to supply carbon dioxide
- Boiling tube or 250 cm³ beaker
- LED lamp (or a bench lamp with a heat shield)
- Metre rule or 30 cm ruler and a clamp stand

- Large beaker of water to act as a water bath and heat shield
- Thermometer
- Stopwatch
- Scissors or scalpel (for cutting the stem under water)
- Optional: an inverted funnel and a measuring tube or gas syringe to collect the oxygen

Risk assessment

Hazard	Risk	Precaution
Electrical lamp near water	Electric shock if water gets on the lamp or its cable	Keep the lamp and cable well away from the water. Wipe up spills at once and do not touch plugs with wet hands.
Hot bench lamp	Burns from touching the lamp	Use a cool LED lamp where possible. Do not touch the lamp and let it cool before moving it.
Glassware	Cuts if the glass breaks	Support the boiling tube in a clamp or beaker. Report any breakages and do not pick up broken glass.
Cutting the pondweed stem	Cut from the blade	Cut on a tile, cutting away from the body, using a sharp blade carefully. Wash hands after handling pondweed and water.

Method

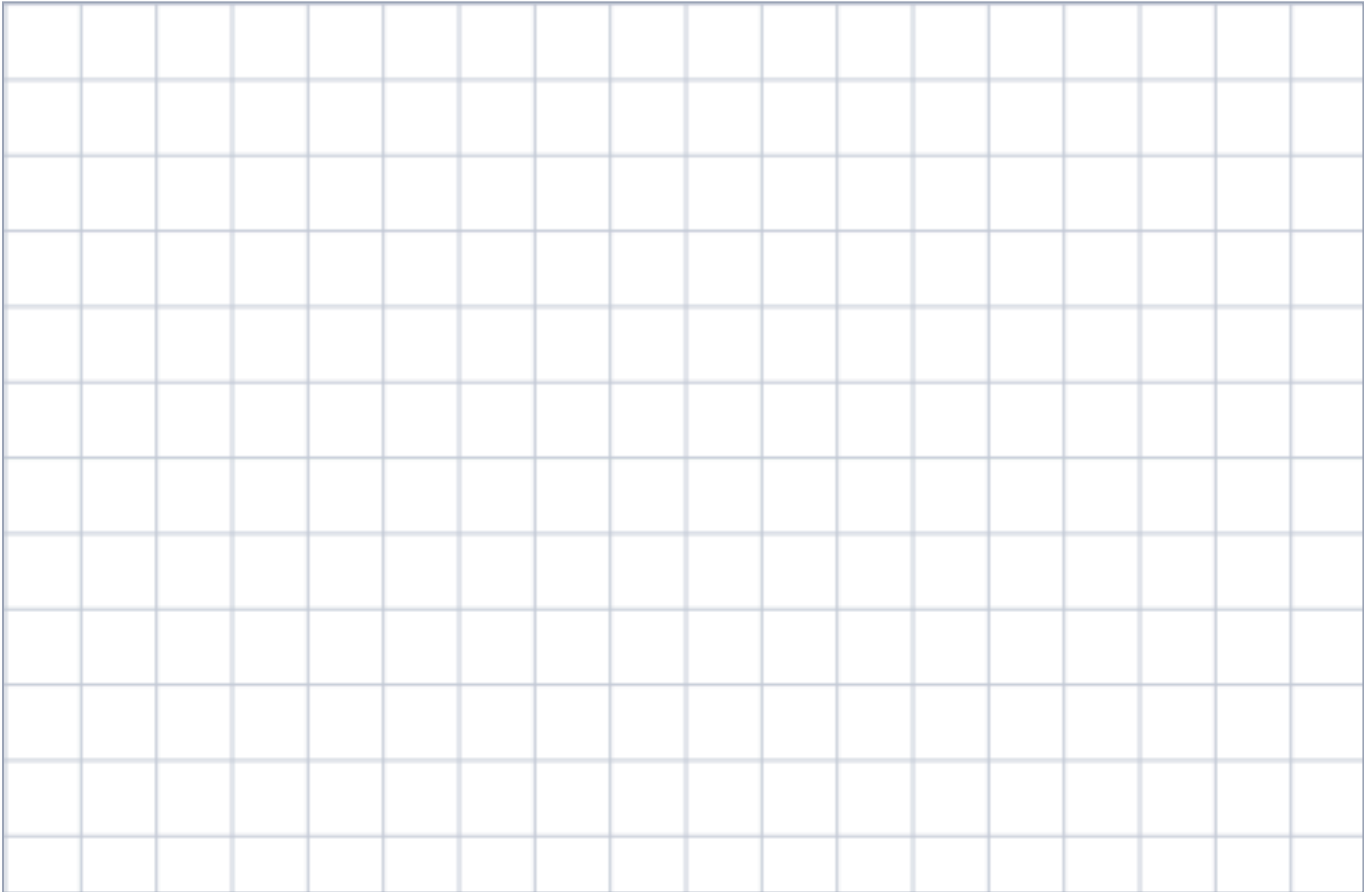
1. Set up a large beaker of water as a water bath at room temperature. This absorbs heat from the lamp and keeps the temperature steady.
2. Pour sodium hydrogencarbonate solution into a boiling tube until it is about three-quarters full. This supplies carbon dioxide so it does not limit the rate.
3. Cut about 10 cm of pondweed. Cut the end of the stem at an angle, under water, so that bubbles come out of the cut end.
4. Place the pondweed in the boiling tube with the cut end at the top, then stand the tube in the water bath.
5. Darken the room as far as you can so the lamp is the main light source.
6. Place the lamp 10 cm from the pondweed. Use the ruler to measure from the lamp to the middle of the pondweed.
7. Switch the lamp on and leave the pondweed for 2 minutes to adjust to the new light intensity.
8. Check the temperature of the water bath with a thermometer and record it. Replace some of the water if it has warmed by more than 1-2 °C.
9. Count the number of bubbles released from the cut end of the stem in one minute. Record the number.
10. Repeat the count two more times at the same distance, and calculate the mean number of bubbles per minute.
11. Move the lamp to 20 cm, wait 2 minutes, and repeat steps 8-10.
12. Repeat for lamp distances of 30, 40 and 50 cm.
13. Calculate the mean number of bubbles per minute for each distance and plot a graph of your results.

Results

Number of oxygen bubbles released per minute at different lamp distances				
Distance of lamp (cm)	Test 1 (bubbles per min)	Test 2 (bubbles per min)	Test 3 (bubbles per min)	Mean (bubbles per min)
10				
20				
30				
40				
50				

Graph

Line graph of mean number of bubbles per minute (y-axis, with the unit) against distance of lamp from pondweed in cm (x-axis). The independent variable goes on the x-axis. Plot each mean as a small cross and draw a smooth curve or line of best fit. The curve should fall as distance increases. Use more than half of the grid for each axis, with equal-sized scale steps. Higher tier: you can also plot rate against $1 \div \text{distance}^2$ (a measure of light intensity), which gives a straight line through the origin while light is limiting.



Exam questions 10 questions • 27 marks

- 1

State the independent variable in this investigation.

[1 mark]
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- 2** A beaker of water was placed between the lamp and the pondweed in some versions of this practical. Explain why. **[2 marks]**

- 3** Sodium hydrogencarbonate solution was added to the water. Explain why. **[2 marks]**

- 4** Light intensity is inversely proportional to the square of the distance from the lamp. A student moves the lamp from 10 cm to 20 cm from the pondweed. Calculate how many times lower the light intensity is at 20 cm than at 10 cm. **[3 marks]**

Answer =

- 5** Use the results in the table to describe the effect of distance on the rate of photosynthesis. **[3 marks]**

Mean bubbles per minute	
Distance of lamp (cm)	Mean number of bubbles per minute
10	44
20	25
30	13
40	8
50	5

- 6** Calculate the percentage decrease in the mean number of bubbles per minute when the lamp is moved from 10 cm to 20 cm. Use the table in question 5. Give your answer to the nearest whole number. **[3 marks]**

Answer =

- 7** Counting bubbles is not a very accurate way of measuring the rate of photosynthesis. **[3 marks]**
Explain why, and suggest a better method.

- 8** At very high light intensity the rate of photosynthesis stops increasing. Name two other **[2 marks]**
factors that could be limiting the rate at this point.

- 9** Explain why the student repeated the count three times at each distance and calculated a **[2 marks]**
mean.

10

A student wants to find how light intensity affects the rate of photosynthesis in pondweed. Describe a method the student could use. Include how the student would make the results valid and repeatable.

[6 marks]

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Teacher answers

Required practical 6: Light intensity and the rate of photosynthesis. The example results are practice data, not real measurements.

Example results

Example results (practice data)				
Distance of lamp (cm)	Test 1 (bubbles per min)	Test 2 (bubbles per min)	Test 3 (bubbles per min)	Mean (bubbles per min)
10	42	45	45	44
20	24	26	25	25
30	14	12	13	13
40	8	9	7	8
50	5	4	6	5

Conclusion

As the lamp moved further from the pondweed, the number of bubbles per minute fell from a mean of 44 at 10 cm to 5 at 50 cm. So the rate of photosynthesis **decreases** as the distance increases, that is, as the light intensity decreases. This is because light provides the energy for photosynthesis. With less light energy, less glucose and oxygen are made each minute, so fewer bubbles are released. The fall is steepest close to the lamp. In these results light was the limiting factor over the whole range. (Higher tier) At very high light intensity the rate would level off, because another factor, such as carbon dioxide concentration or temperature, would then be limiting.

Errors and improvements

Error	Effect on the results	Improvement
Counting bubbles: bubbles are different sizes and several can be released together, so counts are not accurate (random error and a measurement limitation).	Counts are uncertain, so the means are not a precise measure of the volume of oxygen made.	Collect the gas in a gas syringe or an inverted measuring tube and measure its volume in cm ³ over a longer time, such as 5 minutes.
The lamp warms the water, so temperature rises as the lamp gets closer (systematic error from an uncontrolled variable).	Enzymes may work faster at higher temperature, so the rate at short distances looks too high.	Use a cool LED lamp, keep the tube in a water bath and check the temperature before each count.
Light from the room or windows adds to the light from the lamp.	Light intensity is higher than expected, especially at long distances, so the rate is too high.	Carry out the practical in a dim room, or shield the apparatus with a box or black card.
The pondweed does not settle straight away after the lamp is moved.	Counts taken too soon give a rate that belongs to the previous distance.	Wait at least 2 minutes after each move before counting, and keep this time the same.
Carbon dioxide is used up during the experiment.	Carbon dioxide may become a limiting factor, so the rate is too low at high light intensity.	Use fresh sodium hydrogencarbonate solution and do not leave the pondweed for a long time.

Mark scheme

One mark for each point unless a maximum is given. Words in brackets are not needed for the mark.

1. [1]

- distance of the lamp from the pondweed (1) allow light intensity

2. [2]

- the water absorbs heat from the lamp (1)
- so the temperature of the pondweed stays the same / temperature is controlled (1) allow so temperature does not affect the rate of photosynthesis

3. [2]

- it releases / provides carbon dioxide (1)
- so carbon dioxide is not a limiting factor / the rate of photosynthesis is not limited by carbon dioxide (1)

4. [3]

- light intensity $\propto 1 \div \text{distance}^2$ (1)
- $1 \div 10^2 = 0.01$ and $1 \div 20^2 = 0.0025$ (1) allow $(20 \div 10)^2 = 2^2$
- 4 times lower / one quarter of the light intensity (1)

5. [3]

- as the distance increases, the number of bubbles per minute decreases / rate of photosynthesis decreases (1)
- the decrease is fastest / steepest at short distances, and slows down at longer distances (1)
- data quote, for example 44 bubbles at 10 cm and 5 bubbles at 50 cm (1)

6. [3]

- change = $44 - 25 = 19$ (1)
- $19 \div 44 \times 100$ (1)
- = 43 % (1) allow 43.2 %

7. [3]

- bubbles can be different sizes (1) allow bubbles can be missed or two released together
- so the number does not match the volume of oxygen (1)
- collect the gas and measure its volume (in a gas syringe / measuring tube) (1)

8. [2]

- carbon dioxide concentration (1)
- temperature (1) allow chlorophyll / number of chloroplasts

9. [2]

- to identify anomalous results / reduce the effect of random error (1)
- so the results are more repeatable / the mean is closer to the true value (1)

10. [6]

Level 3 5-6	A clear, logical method with all key steps: pondweed in water with a source of carbon dioxide, lamp at measured distances from the pondweed with a ruler, a measurable outcome (bubbles or gas volume per set time), and several repeats with a mean. At least two variables are controlled with reasons. The method could be followed by another person.
Level 2 3-4	A mostly clear method with the main steps. Some details missing, for example only one control variable given, or repeats not mentioned.
Level 1 1-2	A few simple points, for example 'move the lamp and count bubbles', with little detail or no control of variables.

Indicative content

- place pondweed in a tube of water with sodium hydrogencarbonate
- place a lamp at a measured distance (for example 10 cm) from the pondweed
- leave 2 minutes to adjust, then count bubbles / collect gas for one minute
- repeat at the same distance and calculate a mean
- repeat at other distances, such as 20, 30, 40 and 50 cm
- control temperature (water bath / heat shield), carbon dioxide concentration, the pondweed, time and room light
- plot a graph of mean rate against distance

Exam tips

- Say that distance is a way of changing light intensity. If the question asks about light intensity, link it to distance and say what happens to the rate.
- Higher tier: always name the limiting factor and say why the rate levels off, for example 'carbon dioxide concentration is now limiting'. Do not just say 'it has reached its maximum'.
- When asked about bubble counting, say that bubble size varies. Then suggest collecting and measuring the volume of gas.
- If asked why a water bath or heat shield is used, say it stops the lamp changing the temperature, because temperature affects the rate of photosynthesis.
- Higher tier only: light intensity $\propto 1 \div \text{distance}^2$. Doubling the distance gives one quarter of the light intensity, so a graph of rate against $1 \div \text{distance}^2$ is a straight line while light is the limiting factor.