

Light intensity and photosynthesis

Investigate the effect of light intensity on the rate of photosynthesis

For Edexcel GCSE Biology 1BI0 and Combined Science 1SC0. Teacher answers start on a new page.

Name

Date

Aim

To investigate how the distance of a lamp from an aquatic plant affects the rate of photosynthesis, measured by the number of oxygen bubbles released per minute.

Background

Plants make glucose by **photosynthesis**: carbon dioxide + water → glucose + oxygen, using light energy absorbed by chlorophyll. Oxygen is a waste product. In water plants such as *Elodea* (pondweed), the oxygen forms bubbles that escape from the cut end of the stem, so counting bubbles gives an estimate of the rate of photosynthesis.

The rate of photosynthesis can be limited by a shortage of light or carbon dioxide, or by a low temperature. A **limiting factor** is the factor that is in shortest supply, so it stops the rate going any higher. If light is the limiting factor, increasing the **light intensity** increases the rate.

Light intensity falls as you move away from a lamp, so moving the lamp further from the plant is a simple way to change the light intensity. Higher tier: light intensity is inversely proportional to the square of the distance from the lamp (the inverse square law), so doubling the distance makes the light intensity one quarter of its original value.

Hypothesis

As the lamp is moved further from the pondweed, the light intensity falls, so the rate of photosynthesis (bubbles per minute) will decrease, because less light energy is available to make glucose.

Variables

Independent	Light intensity (changed by changing the distance between the lamp and the pondweed)
Dependent	Rate of photosynthesis (number of oxygen bubbles released per minute)
Control	• Temperature of the water (use a heat shield or water bath, or a cool LED lamp) • Carbon dioxide concentration (same amount of sodium hydrogencarbonate in the water each time) • The same piece of pondweed, with the same length of stem, for every distance • The time the plant is left to adjust and the time over which bubbles are counted • Other light sources (close the curtains or work in a dim room)

Equipment

- Fresh pondweed (*Elodea* or *Cabomba*), about 10 cm long
- Sodium hydrogencarbonate solution (about 1 g in 100 cm³ of water) as a source of carbon dioxide
- Beaker (250 cm³ or 500 cm³)
- LED lamp or bench lamp

- Clear heat shield (a tank or beaker of water), if using a filament lamp
- Metre rule
- Stopwatch
- Scalpel or scissors and a tile (to cut the stem)
- Thermometer
- Paper clip or small weight to hold the pondweed down
- Eye protection

Risk assessment

Hazard	Risk	Precaution
Mains electricity near water	Electric shock if the lamp or cable gets wet.	Keep the lamp, plug and cable away from the water. Dry your hands before touching the plug.
Hot lamp	Burns if the lamp or bulb is touched; heat could also crack a glass beaker.	Do not touch the lamp while it is on or just after switching off. Use a heat shield or an LED lamp.
Glassware and sharp cutting tool	Cuts from broken glass or from the scalpel.	Cut the stem on a tile, cutting away from the body. Keep glassware away from the table edge.
Sodium hydrogencarbonate solution	Minor irritant to eyes.	Wear eye protection. Wipe up any spills.

Method

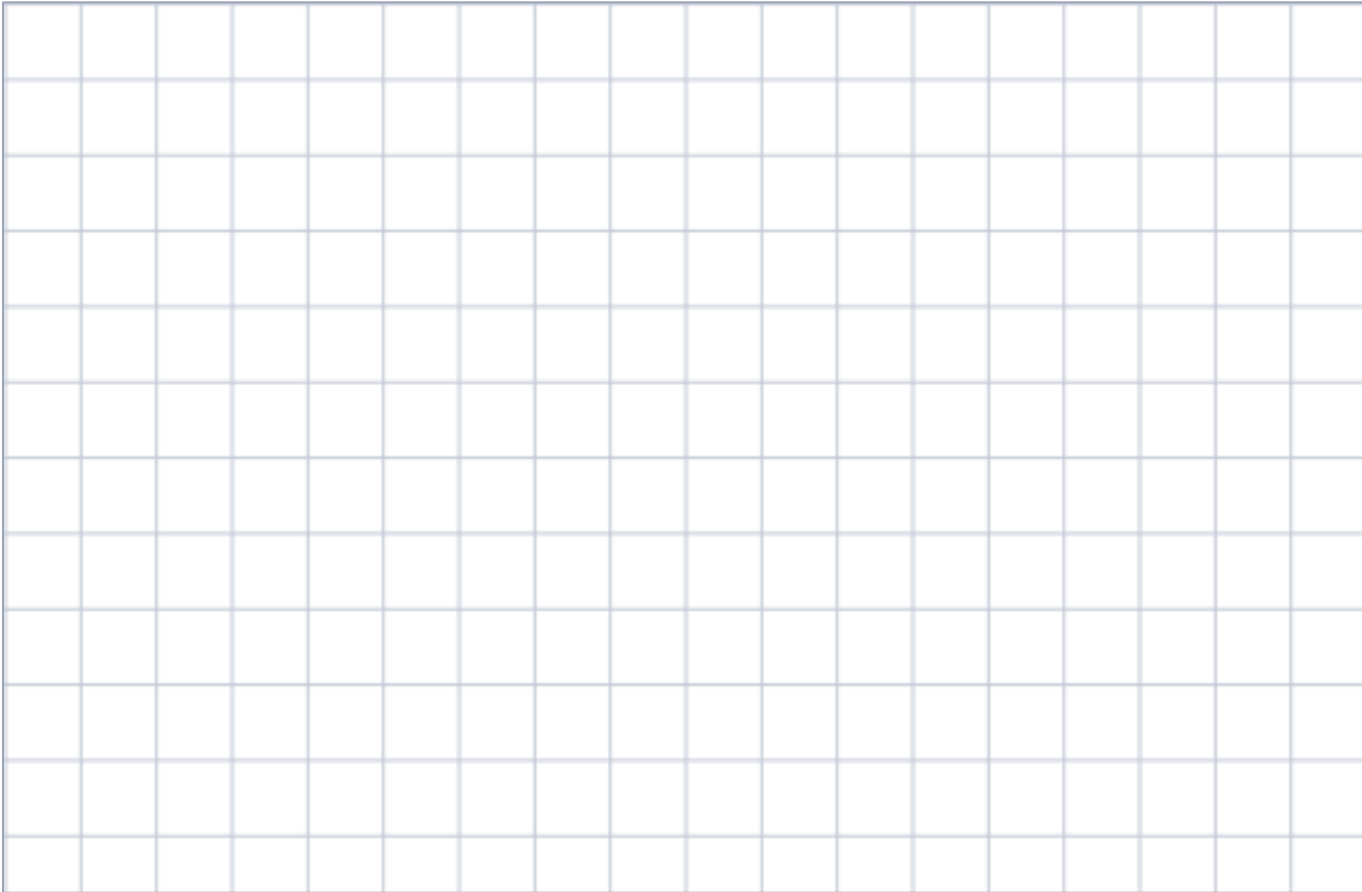
1. Put on eye protection. Half-fill a beaker with water at room temperature, add the sodium hydrogencarbonate and record the temperature.
2. Cut about 1 cm off the end of the pondweed stem, at an angle. Attach a small paper clip near the end and place the weed in the beaker with the cut end upwards.
3. Place the heat shield between the lamp and the beaker (not needed for an LED lamp). Keep the lamp, plug and cable away from the water.
4. Place the lamp so that it is 10 cm from the pondweed, measured with the metre rule. Switch off or shut out other sources of light.
5. Switch on the lamp and leave the pondweed for 2 minutes to adjust to the light.
6. Count the number of bubbles released from the cut end in 1 minute and record it.
7. Repeat step 6 twice more at the same distance and record all three counts.
8. Move the lamp to 20 cm and leave the pondweed for 2 minutes before counting.
9. Count the bubbles in 1 minute, three times, and record the counts.
10. Repeat steps 8 and 9 with the lamp at 30 cm, 40 cm and 50 cm.
11. Record the temperature of the water at the end. If it has risen by more than about 1 °C, repeat with fresh water and a better heat shield.
12. Calculate the mean number of bubbles per minute at each distance and plot a graph of mean rate against distance.

Results

Number of bubbles released per minute at different distances from the lamp				
Distance from lamp (cm)	Bubbles per minute: trial 1	Bubbles per minute: trial 2	Bubbles per minute: trial 3	Mean bubbles per minute
10				
20				
30				
40				
50				

Graph

Draw a line graph with distance from the lamp (cm) on the x-axis and mean number of bubbles per minute on the y-axis. Plot the mean at each distance with a small cross and draw a smooth curve of best fit. (Higher tier: also calculate $1 \div \text{distance}^2$ for each distance and plot mean bubbles per minute against $1 \div \text{distance}^2$. While light is the only limiting factor the points lie close to a straight line; at the highest light intensities the line may level off because another factor, such as carbon dioxide, starts to limit the rate.)



Exam questions 9 questions · 26 marks

1 State the independent variable, the dependent variable and one control variable in this investigation. **[3 marks]**

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

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3 A heat shield was placed between the lamp and the pondweed. Explain why. **[2 marks]**

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4 With the lamp 25 cm from the plant, a student counted 18, 20 and 22 bubbles in three one-minute trials. Calculate the mean number of bubbles per minute. **[2 marks]**

Answer =

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- 5 The table shows a student's mean results. Describe and explain the pattern in the results. [3 marks]

Distance from lamp (cm)	Mean bubbles per minute
10	50
20	26
30	13
40	8
50	5

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- 6 The student counted bubbles. Suggest why this may not give accurate results, and suggest a better way to measure the rate. [2 marks]

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- 7 Light intensity is inversely proportional to the square of the distance from the lamp. A student moved the lamp from 10 cm to 20 cm from the plant. Calculate how many times smaller the light intensity is at 20 cm than at 10 cm. (Higher tier) [3 marks]

Answer =

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- 8 Suggest why the rate of photosynthesis would stop increasing, even if the lamp were moved much closer to the plant. [3 marks]

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9 Describe a method to investigate the effect of light intensity on the rate of photosynthesis **[6 marks]** in pondweed. Include how you would obtain reliable results.

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Teacher answers

Core practical 6: Light intensity and photosynthesis. The example results are practice data, not real measurements.

Example results

Example results (practice data)				
Distance from lamp (cm)	Bubbles per minute: trial 1	Bubbles per minute: trial 2	Bubbles per minute: trial 3	Mean bubbles per minute
10	48	52	50	50
20	27	25	26	26
30	13	12	14	13
40	8	7	9	8
50	5	4	6	5

Conclusion

As the lamp was moved further away, the mean number of bubbles per minute fell from 50 at 10 cm to 5 at 50 cm. This shows that the rate of photosynthesis decreases as light intensity decreases, so light was the limiting factor over most of this range. Less light energy is absorbed by the chlorophyll, so less glucose and oxygen are made. The rate drops most steeply between 10 cm and 30 cm because light intensity changes most quickly close to the lamp. (Higher tier: light intensity is inversely proportional to distance², so moving from 10 cm to 20 cm reduces it to one quarter. The rate only roughly halved, from 50 to 26, which suggests that at 10 cm another factor, such as carbon dioxide concentration, was also starting to limit the rate.)

Errors and improvements

Error	Effect on the results	Improvement
Counting bubbles is subjective: bubbles are different sizes, and some may be missed when they come fast.	The rate is not measured accurately (random error), so the results are less valid.	Collect the gas in a gas syringe or upturned measuring tube and measure its volume per minute.
The lamp heats the water, particularly at short distances.	Temperature rises, which changes the rate of photosynthesis, so light is not the only variable changing.	Use an LED lamp and a heat shield or water bath, and check the temperature at the end.
Carbon dioxide is used up during the experiment, or light from the window affects the plant.	Carbon dioxide or other light becomes a limiting factor, so the rate depends less on the lamp distance.	Use fresh sodium hydrogencarbonate solution, and work in a dim room with the curtains closed.
The pondweed is not left long enough to adjust to each new distance.	The count reflects the previous light level, not the new one.	Wait at least 2 minutes after moving the lamp before counting.
Only five distances and three repeats are used.	The shape of the curve is not clear and anomalies are hard to spot.	Use more distances (for example every 5 cm) and more repeats, and leave out anomalous results when calculating means.

Mark scheme

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

1. [3]

- independent: light intensity (1) allow distance of the lamp from the plant
- dependent: rate of photosynthesis / number of (oxygen) bubbles per minute (1)
- control: any one of temperature, carbon dioxide concentration, same piece of pondweed, time over which bubbles are counted (1) ignore 'amount of water'

2. [2]

- it supplies / is a source of carbon dioxide (1)
- so that carbon dioxide is not a limiting factor (1)

3. [2]

- it stops the water being heated by the lamp / keeps the temperature constant (1)
- because temperature affects the rate of photosynthesis (1)

4. [2]

- $(18 + 20 + 22) \div 3$ (1)
- 20 (bubbles per minute) (1)

5. [3]

- as the distance increases, the number of bubbles per minute decreases (1) allow the rate falls more slowly at greater distances
- because light intensity decreases as the distance increases (1)
- so less light (energy) is available for photosynthesis / light is the limiting factor (1)

6. [2]

- bubbles vary in size / some bubbles may be missed when they are released quickly (1)
- collect the gas and measure its volume (in a gas syringe or an upturned measuring cylinder) (1)

7. [3]

- distance doubles, so light intensity changes by $1 \div 2^2$ (1)
- $= 1 \div 4$ / 0.25 (1)
- the light intensity is four times smaller / a quarter (1)
- Correct answer with no working gains 3 marks
- Allow 1 mark for 'two times smaller' (inverse square not used)

8. [3]

- another factor becomes limiting (1)
- carbon dioxide concentration or temperature becomes the limiting factor (1)
- so increasing the light intensity has no further effect on the rate (1)
- allow the plant overheats / enzymes are denatured because the lamp is so close (1)
- Max 3

9. [6]

Level 3 5-6	A clear, logical method with the independent and dependent variables, control of at least two other variables and a way of making results reliable.
Level 2 3-4	A partly complete method with some control variables or some measurements, but missing detail.
Level 1 1-2	Some relevant points but no clear method.

Indicative content

- pondweed in water with sodium hydrogencarbonate
- lamp placed at measured distances (for example 10, 20, 30, 40, 50 cm)
- leave to adjust for a couple of minutes
- count bubbles per minute (or measure the volume of gas)
- control temperature (heat shield / water bath), carbon dioxide and the same piece of weed
- repeat at each distance and calculate a mean
- plot a graph of rate against distance

Exam tips

- The independent variable is light intensity. Say that you change it by changing the distance between the lamp and the plant.
- Explain why the heat shield and sodium hydrogencarbonate are used: they control temperature and carbon dioxide, which could otherwise limit the rate.
- When describing a graph, give the trend first, then explain it using the idea of a limiting factor.
- Counting bubbles is not very accurate. Suggest collecting and measuring the volume of the gas as an improvement.
- Higher tier: for the inverse square law, square the distance first. Doubling the distance gives one quarter of the light intensity.