An investigation to determine the effect of light intensity on the rate of photosynthesis in Eledeo

Introduction

The process of photosynthesis is the transfer of light energy into chemical potential energy of organic molecules.

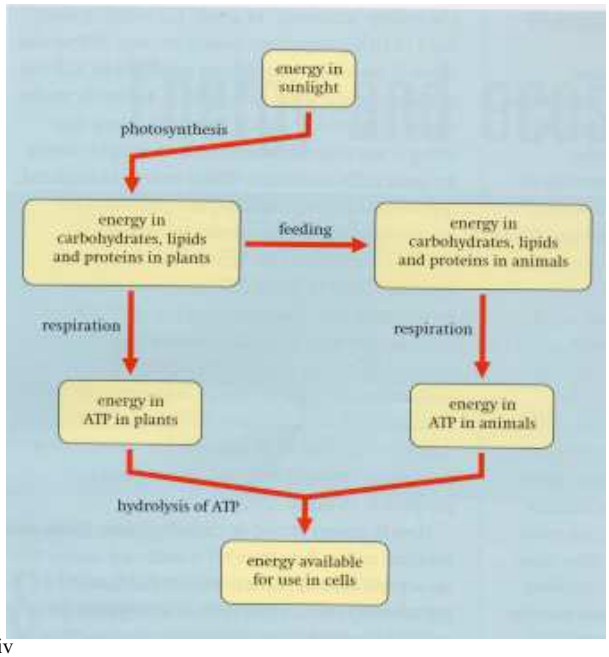
An equation for photosynthesis is:

$$nCO_2 + nH_2O \xrightarrow{\text{light energy in the presence of chlorophyll}} (CH_2O)n + nO_2$$
[i]

Photosynthesis is vital for existence of both plants and animals, as they are dependent on energy that is provided by the sun.

'Green plants and other photosynthetic organisms have the essential role of providing the entire input of energy to an ecosystem.'[ii]

'Photosynthesis in plants converts light energy to chemical energy in organic molecules. Animals eat plants, obtaining some of the chemical energy in the molecules they taken in.'[iii]



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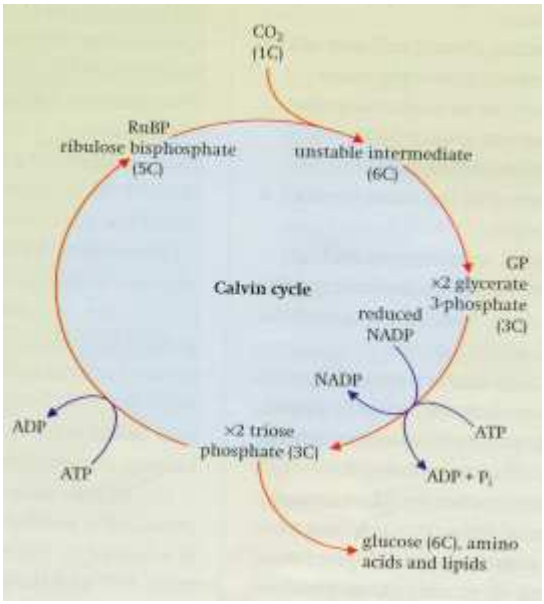
[i] Cambridge Advanced Sciences Biology 2 Chapter 2 Page 17
[ii] Cambridge Advanced Sciences Biology 1 Chapter 7 Page 94
[iii] Cambridge Advanced Sciences Biology 1 Chapter 7 Page 93
[iv] Cambridge Advanced Sciences Biology 1 Chapter 7 Page 94 Figure 7.1

In photosynthesis, there are two sets of reactions involved:

-The light independent reaction (Calvin cycle), which take place in the chloroplast stroma. Its role is the fixation of carbon dioxide, which is reduced to carbohydrates, using hydrogen and water. The carbon dioxide combines with a pentose sugar to produce ribulose biphosphate (RuBP). This continues to form two molecules of a three-carbon molecule called glycerate-3-phosphate. From this, two triose molecules are created due to the presence of ATP and reduced NADP, of which some condenses to form hexose phosphates such as starch. The remainder regenerates RuBP.



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I am going to concentrate on the light dependant stage of photosynthesis as I am going to investigate the effect of light intensity on the rate of photosynthesis.

In the light dependent stage of photosynthesis, light energy is trapped. Energy from sunlight causes electrons to be emitted form the chlorophyll molecules. Some of the energy given from those electrons produces APT (Adenosine triphosphate) and some is used to produce reduced NAD. Water molecules are then split (photolysis) to produce free electrons, which are used to replace those that were emitted by the chlorophyll molecules. The hydrogen ions produced are used for the production of ATP and oxygen is given off as a waste product.

$H_2O \rightarrow 2H^+ + 2e^- + \frac{1}{2}O_2$ [vi]

The light energy is trapped in the lamellae by the photosynthetic pigments called chlorophylls and carotenoides. Different pigments absorb different wavelengths of light.

Pigment		Colour
Chlorophylls:	chlorophyll *a*	yellow-green
	chlorophyll *b*	blue-green
Carotenoids:	β carotene	orange
	xanthophyll	yellow

[v] Cambridge Advanced Sciences Biology 2 Chapter 1 Page 8
[vi] Cambridge Advanced Sciences Biology 2 Chapter 2 Page 20

The photosynthetic pigments are arranged as photo systems. A photo system is a light-harvesting cluster.

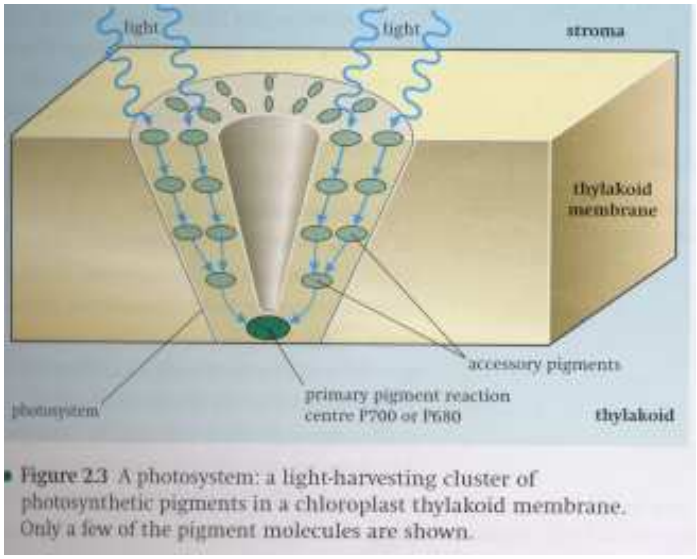

Figure 2.3 A photosystem: a light-harvesting cluster of photosynthetic pigments in a chloroplast thylakoid membrane. Only a few of the pigment molecules are shown.

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A method of investigating the effect of light intensity on the rate of photosynthesis is by measuring the amount of oxygen evolution from aquatic plants. Aquatic plants are easier to use as the bubbles can be seen when the plant photosynthesise as the oxygen bubble is ejected. With land plants, oxygen cannot be measured, as it cannot be seen. Another accurate method to investigate the effect of light intensity on the rate of photosynthesis is by measuring the volume of gas given off by the plant in a given period of time.

Factors that affect the rate of photosynthesis:

- Light intensity
- Temperature
- Availability of CO_2 and H_2O which are the raw materials used in photosynthesis.
- Plant structure- for example the amount of chlorophyll in the leaves.

At any one time, there can only be one limiting factor. For example, when a plant has sufficient light and carbon dioxide but not enough water, then water is the limiting factor. There is also a time when photosynthesis rate will not increase although the variable (light) is at its maximum photosynthesis is occurring at an optimum rate.

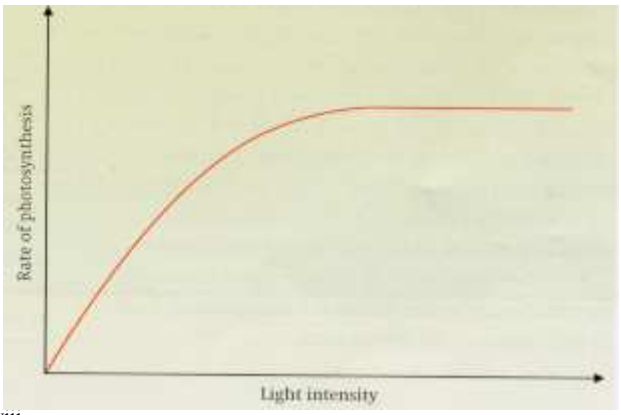
Aim

To conduct an investigation to show the effect of light intensity on the rate of photosynthesis.

[vii] Cambridge Advanced Sciences Biology 2 Chapter 2 Page 19

Hypothesis

The greater the light intensity, the faster the rate of photosynthesis, until the rate of photosynthesis has reached its optimum. The light intensity is the limiting factor. If the light intensity is limited then this will have a direct effect on the amount of APT and NADH produced, therefore there will be insufficient amount of ATP and RUBP to be dispatch onto the light independent reaction. This will the lead onto inadequate sum of hexose phosphate produced and thus making light a limiting factor.



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Preliminary Test

These tests will be conducted to determine appropriate conditions. This test will also help me determine which variables will be difficult to control. Such as:

- The temperature of the surrounding
- Surface are of the pond weed
- The time required for the pond weed to adjust to the environment
- Controlling the outside light
- Any flaws that may lead to the inaccuracy of my results

Experimental Procedures

In an attempt to keep temperatures the same even though light intensity varies (the light from the lamp gives off heat as excess energy). I will place my test tube with the pondweed into a beaker full of water and add cold water every time the temperature rises. To keep the surface area of the pondweed the same throughout the experiment, I will use the same pondweed, throughout the investigation.

I will also allow 5 minutes for the pondweed to adjust to the environment and that is why I have timed my experiments for 15 minutes, to obtain accurate results.

[viii] Cambridge Advanced Sciences Biology 2 Chapter 2 Page 25

In an attempt to control the outside temperature, I will conduct my experiment in the dark, resulting in photosynthesis not occurring at the maximum rate.

Apparatus

Elodea
Stopwatch
Beaker
Lamp
Thermometer
Water
Potometer
Clamp Stand
15cm measuring cylinder
Scalpel
Sodium Hydrogen carbonate

Elodea is used as it enables us to see the bubbles being emitted as it is an aquatic plant. Sodium Hydrogen Carbonate stimulates photosynthesis if there are no obvious signs of bubbles being produced (this increases carbon dioxide availability).

Apparatus to be set up as shown in diagram 1.

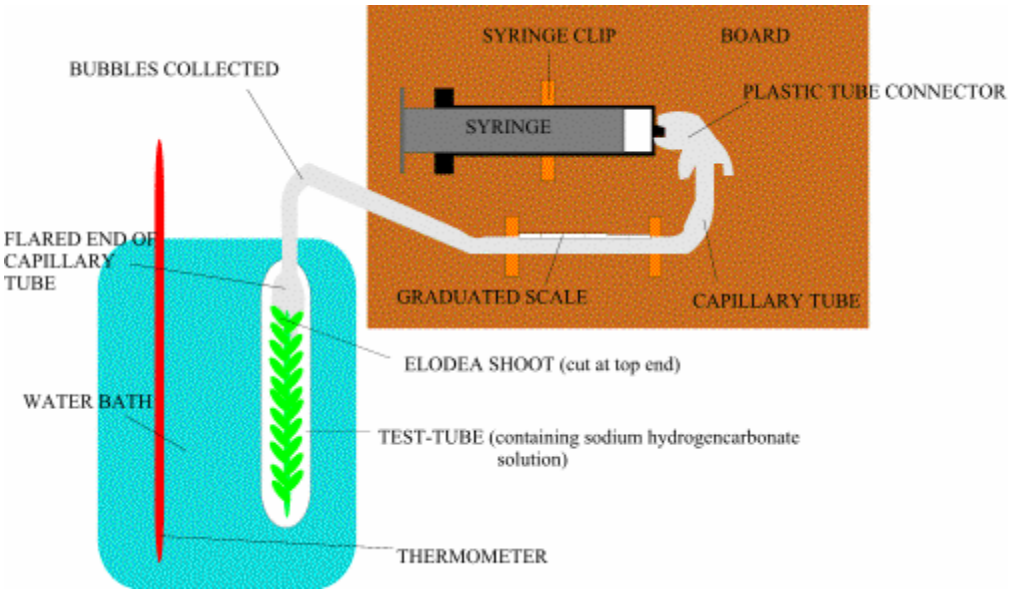

Diagram 1

Safety Procedures

- Potometer must be securely fixed to clamp.
- Make sure that the apparatus are not close to the edge of the table
- When conducting the experiment, do not sit down as the apparatus may fall on you
- Do not consume any of the chemicals
- Make sure that all bags and coats are put away tidily
- All spillage's must be cleaned up

- Care and attention is required when handling the lamp as it may be hot
- Care must be taken when weighing and handling $NaHCO_3$

Method

1. Using a scalpel cut the stem of Elodea to 5cm under water. This prevents air from blocking the Xylem.
2. Make a solution of 75cm of 0.08-moldm3.
3. Add 15cm of this solution to a test tube containing the Elodea and place in a beaker of tap water. Ensure that water is kept at room temperature and remains constant throughout the experiment, replacing water if necessary
4. Fill the potometer with diluted ink making sure no air bubbles are trapped and push the plunger right out to the end of the syringe.
5. Darken the laboratory and place the lamp 10cm from the Elodea
6. Allow the Elodea to adjust to new conditions by leaving to stand for 2 minutes. Then position the Elodea so bubbles are collected in the capillary tube of the potometer and leave for 15 minutes.

7. Once the bubbles have been collected, it needs to be drawn into plastic tubing and the length of the bubble needs to be recorded. This procedure needs to be repeated by increasing distance between the light source and the Elodea, to 20,30 and 40cm. For each distance, the experiment needs to be repeated 3 times to obtain an average for each distance.

Calculation

The calculation is used to work out the mass of $NaHCO_3$ that must be added to 75cm3 of pond water to obtain a certain concentration.

Two formulas required are:

1. Number of moles = concentration x volume or n=cv

   and

2. Mass = number of moles x molecular mass or M = n x Mr

To obtain the mass of 0.08moldm3, we have:
The required volume is 0.075dm3 (75cm3)
The required concentration is 0.08moldm3

Results

A results table to show the amount of oxygen collected as the distance increases

	Oxygen collected cm^3			
Distance (cm)	Experiment 1	Experiment 2	Experiment 3	Average (1dp)
10	5.7	5.5	4.3	5.2
15	3.5	4.1	3.9	3.8
20	3.7	3.9	4.1	3.9
30	2.9	3.2	3.3	3.1
40	1.9	2.2	1.5	1.9
Correlation	0.963051501	0.935371049	0.653611053	0.885329205

A table to show how distance is converted to light intensity using the formula $1/d^2$

Distance (cm)	Light intensity (2dp)
10	0.01
15	0.004
20	0.0025
30	0.0011
40	0.000625

A table to show the average volume of O_2 collected with increasing light intensity

Light intensity	Oxygen collected (cm^2)
0.000625	1.9
0.0011	3.1
0.0025	3.9
0.004	3.8
0.01	5.2

Analysis

The results from my investigation show that increasing the light intensity increases the rate of photosynthesis. Increasing the light intensity will cause pigments to absorb more light, therefore more electrons get excited and more ATP and NADPH is produced and hence the light independent reaction more hexose phosphate can be produced. There also comes a point when light does however stop being a limiting factor as a line on the graph begins to level off. This means that increasing the light intensity further will have no effect on the rate of photosynthesis as all the light that can be observed by the pigment is already been done. There are no more electrons that can be excited and no further ATP can be synthesised.

The light intensity of light on a given object from a constant source, in this case the spot light, is inversely proportional to the square of the distance between them so:

Intensity = I/d2.

By observing the results table and graph the optimum temperature, light intensity seems to be 0.01. Statistical analysis was done by using Pearson's product moment correlation co efficiency. The statistical test shows the strength of the relationship between the independent and dependant variable.

By observing the graph, an anomalous result can be identified, as it does not fit on the line of best fit. This anomalous result may be due to fact that some of the oxygen that was meant to obtain dissolved into the water and the Elodeo stem not placed completely up the collecting tube so some of the oxygen was lost.

The level of significance, which is 1% for the tailed hypothesis, has a value of 0.93437. The value obtained in this experiment was less than 0.93437. However 2.5% results will be due to chance as the value at 2.5% is 0.8783 and the value obtained in this experiment is greater than that.
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[ixixix] reference made from Cambridge Advanced Sciences Biology 1 & 2
MEI Structure Mathematics (2nd Edition) Statistics 2 – Anthony Eccles, Nigel Green & Roger Porkess

Evaluation

Some of the results obtained had a lower level of significance than that of others. The results obtained for my third set of group experiments, had a correlation of 0.653611053, where as my first and second set had a correlation of 0.963051501 and 0.935371049. The experiment therefore had many limitations; some of them may be;

- Some of the oxygen obtained dissolved in the water.
- The higher light intensities caused temperature effects even though it was controlled as much as possible.
- The smaller light intensities could have been more effective by background light.
- The design of the experiment was carefully conducted however it was not possible for all the oxygen produced to be collected.

The experiment could have been improved by:
- Conducting the experiment in a completely darkened room.
- Repeating the experiment more times to get rid of the anomalies.
- The design could have been changed by using an inverted funnel method however using plastacine at the rim of the funnel makes it air tight and prevents oxygen from being lost.

My results obtained where reliable due to the fact that the statistical analysis test resulted in the correlation value of 0.885329205. This resulted to the value of 2.5% chance in error.

Further investigations could include:
- The effect of temperature on photosynthesis.
- The effect of different concentrations of sodium hydroxide.
- Testing whether the pH has an effect on the rate of photosynthesis.
- Testing to see whether the surface area of a plant effects the rate of photosynthesis.

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[x] references made from Cambridge Avanced Sciences Biology 1 and 2
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