Photosynthesis

Aim: To investigate a factor that affects the rate of photosynthesis. A piece of pondweed will be cut and placed into a beaker containing water and sodium hydrogen carbonate. A lamp will be shined on to the pondweed and the amount of bubbles released from the plant will be counted. The lamp will be adjusted to different distances from the plant to try and obtain different results.

Green plants are the only living things that can make their own food. They do this using a process called photosy nthesis, which means, "making things with light." During the process of photosynthesis, the energy from the sun is turned into chemical energy. The chemical energy is used to join carbon dioxide and water. In the process, sugar and oxygen are created. Thi s process takes place mainly in the leaves of the plant. Leaves contain a substance called chlorophyll that traps the sun's energy. The chlorophyll is a bright green colour, which explains why plants are green.

Through the process of photosynthesis, plants convert the light energy into stored energy. Because green plants can manufacture their own food, plants are called autotrophs or self -nourishing. Photosynthesis is possible because green plants contain an energy - capturing substance called chlorophyll. The plant gets its green colour because chlorophyll is green. Many types of seaweed and other plants that do not appear to be green also have chlorophyll and therefore can convert the sun's energy into food. In these plants the greenness is hidden by other pigments.

The chlorophyll captures the light energy and uses this energy to build carbohydrates from simple raw materials (water, carbon dioxide and minerals). Carbohydrates are complex energy -storing materials that the plant can use to sustain its life pr ocesses. The raw materials that are needed for photosynthesis are the same raw materials that make up carbohydrates -carbon, hydrogen and oxygen. The carbon dioxide (C02) breathed out by animals is the source of carbon (C) and oxygen (02). Hydrogen (H2) is taken from water (H20). These raw materials enter the plant through its roots and leaves. Carbon dioxide is taken in through pores, called stomata, in the leaf's surfaces. Water enters the plants through the roots and is channelled up the stem and into the veins of the leaves. In the case of water plants, there is water all around the plant. The raw materials are dissolved in the water and taken into the plant simply through any surface.

Leaves are like small factories that produce food for the plant. Diff erent parts of the leaf have different jobs. The veins in a leaf are bundles of tiny tubes that carry water and minerals to the leaf and return food from the leaf to the rest of the plant. Veins also help to support the leaf.

On the underside of the leaf are small openings or pores called the stomata. The stomata serve as the lungs of the leaf allowing air to enter. The stomata allow the evaporation of water and the release of oxygen during the night.

The outer layers of the leaf are covered with a waxy lay er, which prevents the leaf from drying out.

Leaves are green because they contain small bodies in the cells called chloroplasts. The chloroplasts contain a green pigment called chlorophyll. This green material gives the leaf its colour.

With the help of chlorophyll and energy from the sun, a leaf can change lifeless substances into food. Plants need water (H2O) and carbon dioxide (CO2) to make food through the process of photosynthesis. The plant's roots gather the water. Carbon dioxide is gathered from th e air through the stomata.

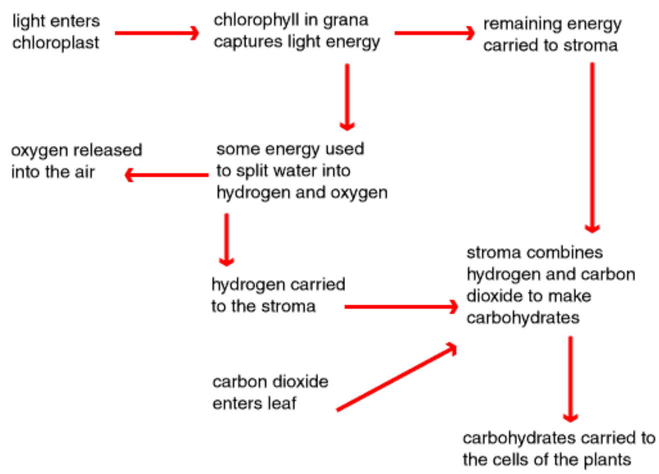
The leaf uses chlorophyll and sunlight to change the water and carbon dioxide into oxygen and glucose (sugar). This sugar is mixed with water and sent to other parts of the plant to be used by the plant as food. The oxygen is rel eased into the air through the stomata. This is usually written as:

$$CO^2 + H^2O \xrightarrow[\text{in the presence of}]{\text{light and chlorphyll}} O^2 + C^6 H^{12} O^6$$

This is usually read as carbon dioxide plus water in the presence of light and chlorophyll produces oxygen and sugar glucose.

Diagram to explain photosynthesis

The diagram below is directly quoted from the website: www.photosynthesis.co.uk



Prediction

I predicted that as the intensity of light increased, so would the rate of photosynthesis. Furthermore, I hypothesised that if the light intensity increases, the rate of photosynthesis will increase at a proportional rate until a certain level is reached, and the rate of increase will then go down. Eventually, a level will be reached where an increase in light intensity will have no further effect on the rate of photosynthesis, as there will be another limiting factor, in this case probably temperature.

Hypothesis

When chlorophyll absorbs light energy, the light energy cannot be immediately used for energy conversion. Instead the light energy is transferred to a special protein environment where energy conversion occurs. During this reaction, ox ygen is produced as a by-product and it is the oxygen bubbles that are being measured in the experiment. The greater the light intensity, the more light energy that can be transferred and harnessed to fuel reaction in photosynthesis.
Light intensity is inversely proportional to the distance squared because the light energy spreads out as it travels further and further from its source. Light energy travels along the circumference of an expanding circle. When light energy is released from a point, the energy is dispersed equally along the circumference. But since the circle is expanding, the circumference increases and the same light energy is distributed along a greater surface.

The factors that limit photosynthesis

Three factors limit photosynthesis from go ing any faster.

Light intensity

Sometimes light is a limiting factor. A plant may have lots of water and carbon dioxide, but it will not photosynthesise very fast if there is not enough light; increasing the light intensity will make photosynthesis faster until other factors become limiting and the rate of photosynthesis levels off.

Carbon dioxide concentration

Carbon dioxide is the major limiting factor in photosynthesis. There may be plenty of light but the plant cannot photosynthesise because it has run out of carbon dioxide and as carbon dioxide concentration increases, the rate of photosynthesis increases.

Temperature

As temperature increases up to a specific optimum, the rate of photosynthesis increases. This is due to the fact that photosynthesis is a n enzyme-controlled process and enzymes, being proteins, are temperature sensitive. The rate of photosynthesis will be limited if it is too cold for the enzymes to work properly.

Chlorophyll concentration

If there is a reduction in chlorophyll concentration due to mineral deficiency or disease, the rate of photosynthesis decreases. However, chlorophyll concentration is not normally a limiting factor in photosynthesis.

Water

Photosynthesis cannot occur in the absence of wat er.

Variables

Experimental Variable

Light intensity is to be the variable explored in this investigation. Increasing or decreasing the distance from the light source to the plant can vary light intensity.

Fixed Variables

Light Wavelength (colour) - Light energy is absorbed by pigments in the leaf such as chlorophyll. Chlorophyll easily absorbs blue light and also easily absorbs red light. Chlorophyll does not absorb green light or yellow light effectively but tends to reflect them, decreasing the amount o f light absorbed and decreasing the rate of photosynthesis. Why the rate of photosynthesis increases or decreased from the amount of light energy absorbed is what is being investigated in this experiment. The light colour can be fixed by using the same lamp throughout the experiment.

Carbon Dioxide- CO2 concentration can affect the rate of photosynthesis since the more CO2 in the air, the more CO2 that can diffuse into the leaf. This variable can be fixed by adding a fixed amount of sodium hydrogen carbonate to the beaker and plant. The experiment should also be completed in one session and under two hours so the plant does not use up a significant percentage of the CO2.

Water- Water is required in the photosynthetic reaction. When plants lack water, their stomata close to prevent further water loss. At the same time, closing the stomata cells doesn't allow CO2 to diffuse into the leaf. Water is also therefore, linked to the carbon dioxide factor. Water can be kept a constant by keeping the same amount of water in the beaker.

Plant- Different plant species have different photosynthetic rates due to the different leaf structures of the plants. Even plants of the same species may have slightly different rates of photosynthesis since there may be more or less chlorophyll in the leaves to absorb light. The size of the plant is also important since this would affect the amount of surface area for gas exchange. The only solution to controlling this variable is by using the same plant throughout the experiment.

Temperature – Enzymes are used in the photosynthesis reactions of a plant. Therefore, temperature will increase the rate of photosynthesis, until a point at which the enzymes denature. I am therefore going to perform the experiment at room temperature, check ing the temperature frequently, in case the heat given off from the light should slightly raise the temperature, in which case I shall simply refill the beaker with more water after each experiment.

Method

1.Set up the apparatus as shown in the diagram but leaving out the pond weed, funnel, test tube, water, and the sodium hydrogen carbonate.

2. Fill the beaker with 200 ml of water and 50 ml of NaHCO3.

3. Select 1 piece of pond weed roughly 17 cm long and cut off the stems.

4. Place the pond weed in the beaker and secure the funnel upside down over (on top of) the pond weed.

5. Place a water-filled test tube upside down and over the funnel (see diagram).

6. Place the ruler so that the "0cm" measurement is aligned with the side of the beaker. (distance measured from side of beaker to edge of light bulb)

7. Place the lamp directly in front of the plant so that it is 100 cm away from the beaker.

8.With the light shining on the plant, record the number of bubbles emitted in a 1 minute duration. Switch off the lamp and wait for another minute before taking another reading.

9. Take 3 readings at the current distance and move the lamp 5 cm further away from the plant.

10. Repeat steps 8 and 9 until 3 readings from at least 5 intervals of 20 cm have been take n.

Graph analysis:

From the results that I have gathered I can state that an increase in light intensity certainly does increase the rate of photosynthesis. As was also expected in my prediction, the rate of photosynthesis increases at an exponential rat e. I have one major anonymous result, which is when my graph jumps from an average number of bubbles of 12 to an average of 78.

Conclusion:
From the results that I have gathered I can state that an increase in light intensity certainly does increase the ra te of photosynthesis. As was also expected in my prediction, the rate of photosynthesis increases at an exponential rate.
When measuring light intensity in terms of distance, the greater the distance, the slower the rate of photosynthesis. As light intensi ty increases the photosynthetic rate is being limited by certain factors such as carbon dioxide and temperature. As light intensity increases further, these factors limit the rate of photosynthesis even more until photosynthesis is completely limited and t he graphed line become horizontal. This is when photosynthesis is being carried out at a constant rate.

Evaluation:
Overall, I would state the experiment as a success since my predictions were supported by my results. This photosynthesis investigation was probably not performed as accurately as it could have been due to some controllable and uncontrollable conditions. Some mistakes can be corrected.
The negative effects from this problem may be inaccurate data for some readings. These would show up on my graph. However, there seemed to be few anomalies than was expected when the experiment was being performed. Almost all readings were in correlation with each other and the anomalie was in the high photosynthetic rate end of the results. This was when the distance from plant to light source was 200cm.
A large factor in determining data accuracy is the amount of human error during experiments. The rate at which oxygen bubbles were being produced by my plant was so high that I found it difficult to count the amount of bubbles. To improve the accuracy of the results, the readings would have to be taken several more times. The entire experiment could have been performed again, and the new results could be combined if the same plant is used. But the photosynthetic rate of the same piece of pondweed would eventually decrease over time anyway. Repetitions would, however, improve the overall reliability of the results.
There are quite a few factors that could affect the results of my experiment. Some of these are varia bles that were mentioned earlier and could not be controlled, or they were variables that were not initially considered.
While performing the experiment, some of the oxygen produced from photosynthesis may have dissolved into the water. Some oxygen may have even been used by microorganisms living on the pondweed. The amount of oxygen dissolved or used by microbes is probably insignificant to my results since the degree of accuracy at which I measured was not high enough. Some oxygen is also used during the respiration of the plant. But since only bubbles were counted, the volume of bubbles was not as important. But to volume of oxygen produced is important, since it was volume in terms of bubbles that were measured. For a more accurate analysis of the collec ted data, volume should have been measured instead of bubble quantity since the size of bubbles can vary. Using a capillary tube in place of the test tube so that the volume of each bubble could have been measured.
During the high intensities I had experienced counting difficulties of the bubbles being produced. There are also factors affecting accuracy at low light intensities. With low light intensity, the pondweed receives some light energy from background light such as sunlight seeping through curtains or the light from the lamp of another student's experiment. To eliminate most all background light, the experiment must be performed in a completely dark room. Even then, some of the light from the lamp in my experiment would reflect of the table and reach the plant though this amount of light is probably insignificant in affecting the rate of photosynthesis.
Temperature was also another factor that was controlled by the lamp being used. The extra heat, however, did not affect the temperature of the water.
The method of the experiment could probably also be improved to obtain more reliable results. As already mentioned, a capillary tube should be used in place of a test tube to accurately measure the volume of the oxygen produced. Due to the high rates of ph otosynthesis of the pondweed, readings should be taken within shorter time periods. I had originally chosen to count the number of bubbles in one minute but these produced miscounts in the readings. If during a repeated experiment, counting bubbles is stil l used, there is a smaller chance for human error when counting within a smaller time frame. If the capillary tube option was to be chosen, volume should be measured for a smaller time frame to reduce the overall time to complete the experiment. Also, duri ng high rates of photosynthesis, it would still be difficult and impractical to measure the volume of oxygen produced for a long duration.
Due to the nature and convenience of the experiment, it could be easily modified to investigate another variable of p hotosynthesis. Since sodium hydrogen carbonate ($NaHCO_3$) is used to provide the pondweed with carbon dioxide. Performing the experiment with different volumes of $NaHCO_3$ could vary the amount of CO_2. The plant would be kept at a constant distance from the la mp and a constant volume of water would be added to the sodium hydrogen carbonate. Another experiment using almost identical apparatus would be to vary the colour of the light the plant absorbs. Using translucent colour filters in front the lamps could var y this. Since light wave length has already been identified as a variable of photosynthesis, it would be interesting to actually test it. The only problem of this experiment is that there is no way to define or "measure" the colour of light. Wavelength wou ld be a solution but this cannot be measured with available equipment. We only have a general idea of how to class colours. Because of this, the coloured light experiment should not be taken as seriously as light intensity or carbon dioxide.

Results Table

Distance from lamp (cm)	No. Of bubbles			Average
	1	*2*	*3*	
100	1	2	2	1.6
80	3	6	6	5
60	5	8	9	7.3
40	14	10	11	11.6
20	17	17	200	78