Experiment B-10
Photosynthesis

Biology

Objectives

- To observe changes in CO_2 levels during photosynthesis and respiration in different conditions.
- To learn about gross and net photosynthesis rates.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-220 CO_2 logger sensor
- BAT-200 Battery unit (optional)

Equipment and Accessories

▪ Glass bottle for the CO_2 sensor (included with the sensor)
▪ Table lamp
▪ Florescent bulb

Materials

▪ Group of leaves	2
▪ 30 cm of aluminum foil	1

Introduction

Photosynthesis is a process that occurs in the chloroplasts of plants and algae, and in some bacteria species. During this process solar energy is transformed into chemical energy that can be used by biological systems.

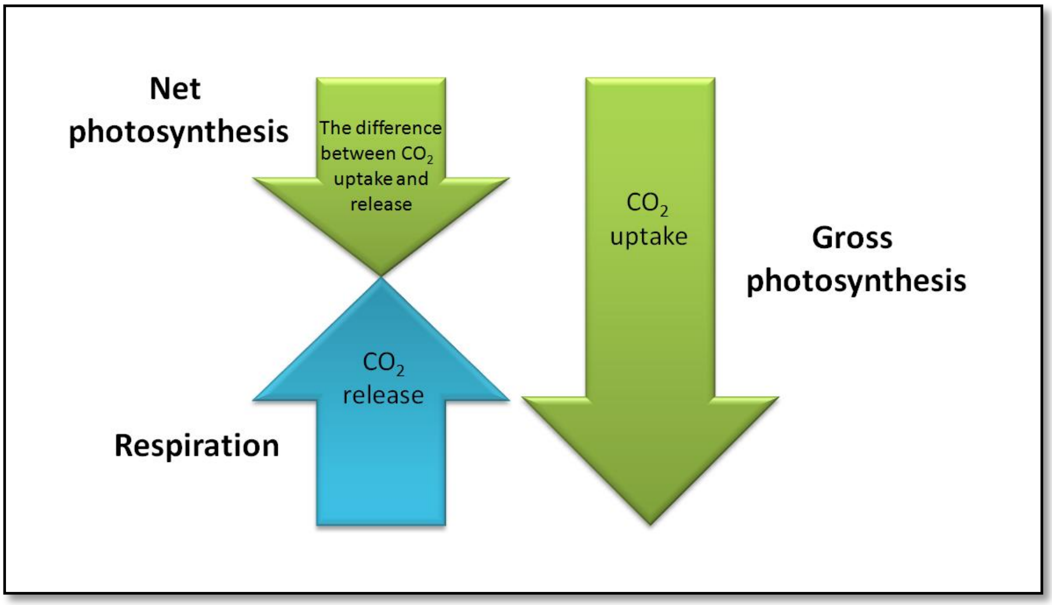
In photosynthesis, CO_2 is reduced to carbohydrates (especially starch and sugar) in a complex set of reactions. The electrons for the reduction reaction come from H_2O, which is oxidized to O_2. Light provides the energy for that oxidation and is absorbed by pigments. In this photosynthesis reaction, the carbohydrate product is glucose:

$$\mathbf{6CO_2 + 6H_2O + light \rightarrow C_6H_{12}O_6 + 6O_2}$$

In cellular respiration, chemical energy stored in carbohydrates turns into energy that can be used by the cell in the form of ATP (adenosine triphosphate). Cellular respiration (with or without the presence of oxygen) occurs in all living cells.
The chemical reaction for cellular respiration (with glucose) is the mirror image of the chemical reaction for photosynthesis:

$$\mathbf{C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + energy\ (ATPs + heat)}$$

The rate of photosynthesis can be expressed as either gross or net rates. **Gross photosynthesis** is the total rate of carbon fixation (reduction of CO_2) without considering that some of the CO_2 is lost in respiration. **Net photosynthesis** is the carbon fixation rate minus the rate of CO_2 loss in respiration.



In this experiment, we will measure the respiration and photosynthesis processes of plant leaves. Respiration will be measured in the dark (photosynthesis cannot occur without any light) and net photosynthesis will be measured under two light conditions (respiration and photosynthesis occur at the same time). We will also calculate the gross photosynthesis; we will get negative values for the photosynthesis rates, so we will subtract the respiration rates from the net photosynthesis rates in order to get gross photosynthesis rates.

Procedure

Experiment setup

1. Set up the experiment as shown in the picture below.

2. Take two equal groups of green leaves from a plant (the type of leaves should be checked beforehand by the teacher). The first group is for the following experiment, and the second group is for the challenge experiment.

3. Wrap the bottle with aluminum foil so that no light can get in it.

Sensor setup

4. Connect the USB-200 module to the PC.

5. Check that the CO_2 sensor is connected to the USB-200 module.

Important:

You must wait at least 30 minutes after connecting the sensor to the USB-200 module or to the battery module before beginning offsetting and measurements.

Note:

The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

6. Run the NeuLog application and check that the CO_2 sensor is identified.

Settings

7. Click on the **Run Experiment** icon and set the:

   Experiment duration to 1 hour
   Sampling rate to 30 per minute

Testing and measurements

8. When offsetting the sensor, the value is set to 380 ppm which is the outdoor air value of CO_2 in most locations. It is recommended to offset the sensor outside (you can get it out through a window) to avoid a shift in the values (if you choose to offset the sensor indoors the calculated rates will still be correct).

9. After the sensor was connected to the USB-200 module or to a battery module for at least 30 minutes, check that the values are relatively stable (remember that your breathing affects the values). If the values are not stable keep the sensor connected for a while and check again.

10. Go outside, wait a few minutes and offset it as follows (if needed, disconnect the sensor from the USB-200 module and quickly connect it to a battery module).

    Press the sensor's offset button continuously (3-5 seconds).

10. Come back inside and make sure again that the CO_2 values are relatively stable (they should be higher than outside).

11. Insert the first group of leaves into the wrapped bottle.

    We will measure respiration of the plant in the dark (photosynthesis cannot occur without any light).

12. Close the bottle using the CO_2 probe and wait for three minutes before starting the measurement.

13. Click on the **Record** icon  to start the measurement.

14. You should see an increase of CO_2.

15. Click on the **Arrows** icon  in order to see the sensor's values during the measurement.

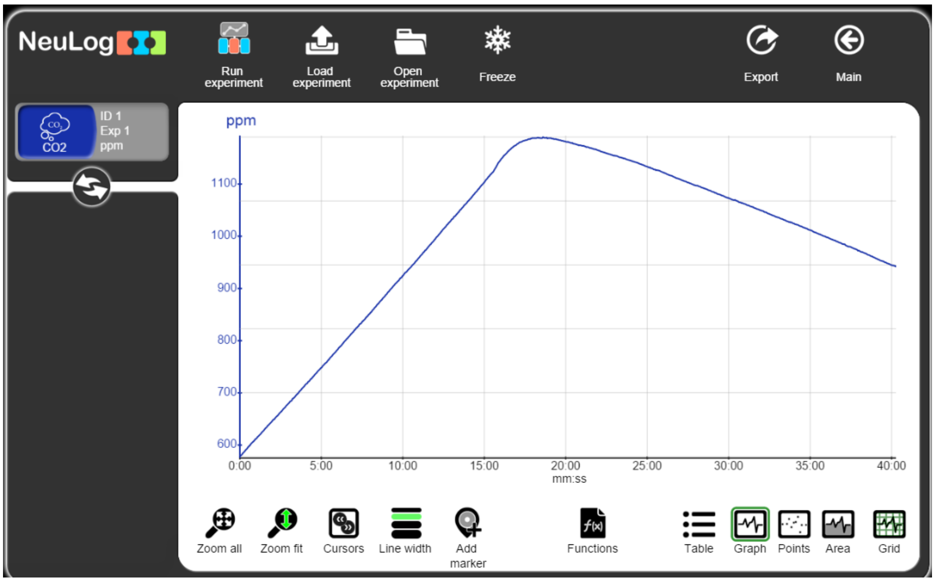
16. To see the entire graph after one minute, use the mouse's scroll wheel.

17. After around 15 minutes, take the aluminum foil off and turn on the lamp (the lamp should be around 8 cm from the bottle). The recommended CO_2 values you should see before starting the photosynthesis part are above 1000 ppm (changes among different plants). If the maximum values are less than 1000 ppm, start the experiment again and blow into the bottle before closing it.

18. Wait until the end of the measurement or until you get 20 minutes of data after removing the aluminum foil; then you can **stop** the experiment.

19. Click on the **Zoom fit** icon.

20. Your graph should be similar to the following:



21. Click on the **Export** Icon  and then on the **Save value table (.CSV)** button to save your graph.

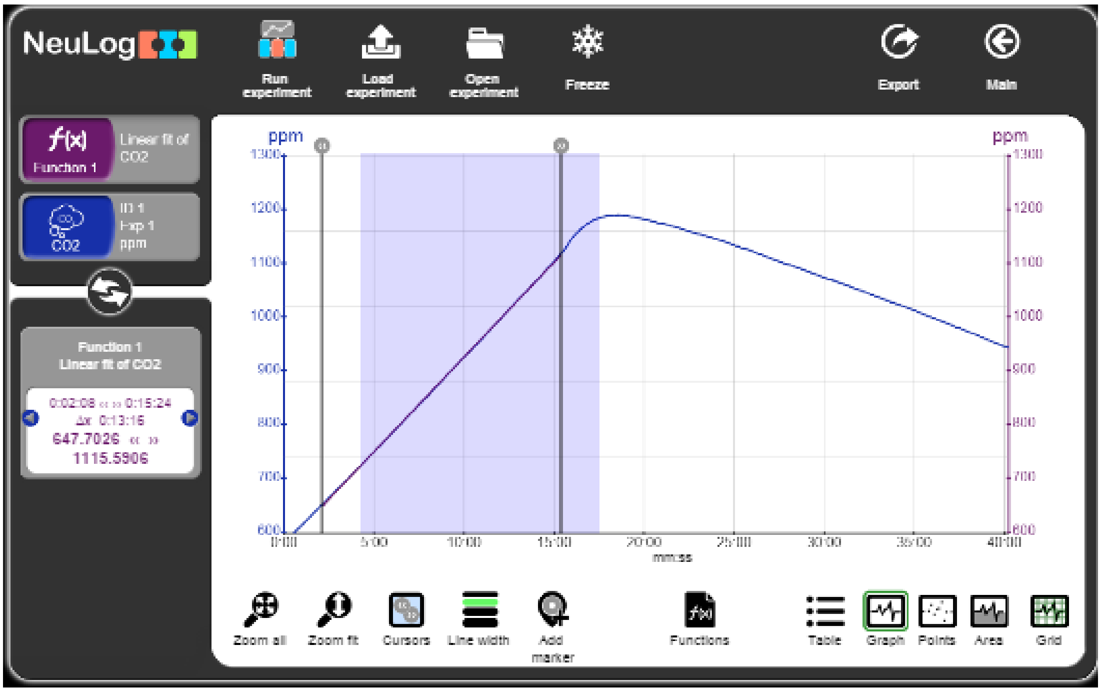
22. Click on the  icon to go back to the graph.

23. To determine the rate of respiration, click on the **Cursors** icon  and select the linear increase part as in the picture below.

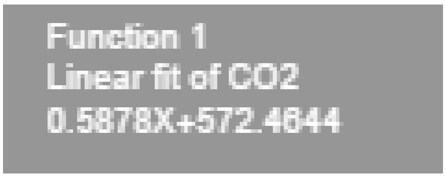
24. Click on the **Functions** icon .

25. Click on the **Functions** button on the left of the screen and then click on the **Linear fit of A** button.

26. Click on the Linear fit module box, you will see the linear fit equation.



27. The respiration equation for the sample experiment is:



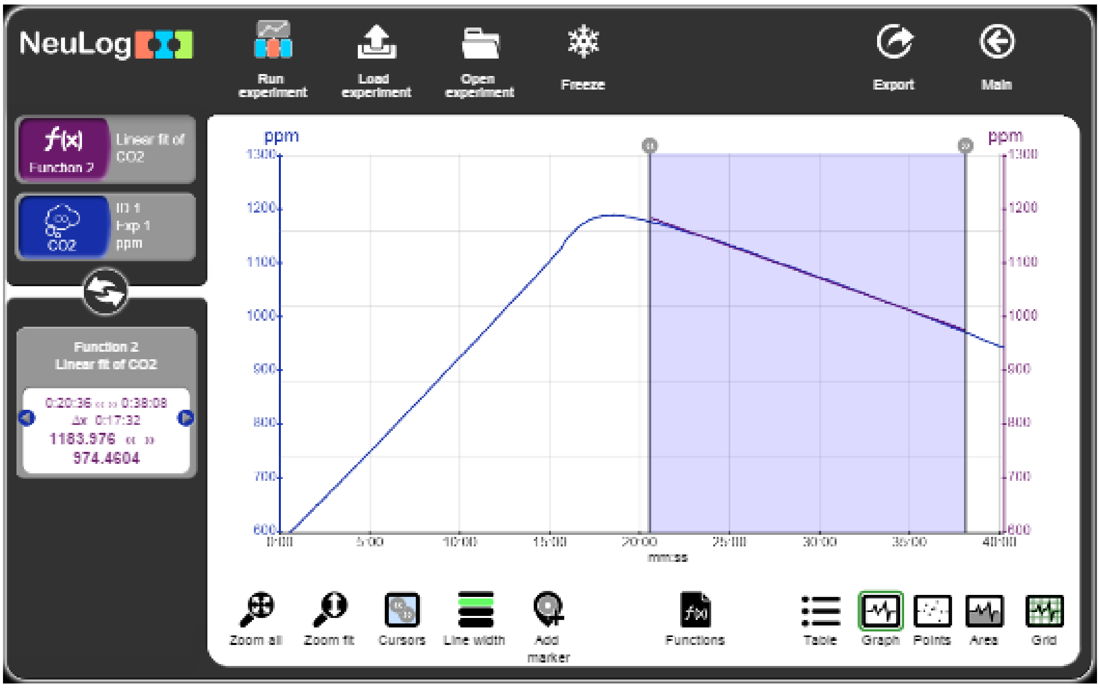
28. The slope of the graph is the rate of respiration in ppm/min.

29. To determine the rate of the net photosynthesis, click on the **Cursors** icon and select the linear decrease part as in the picture below.

30. Click on the **Functions** icon .

31. Click on the **Functions** button on the left of the screen and then click on the **Linear fit of A** button.

32. Click on the Linear fit module box, you will see the linear fit equation.



33. The net photosynthesis equation for the sample experiment is:

34. The slope of the graph is the rate of net photosynthesis in ppm/min.

In our example the respiration rate is 0.59 ppm/min and the net photosynthesis rate is -0.2 ppm/min. The photosynthesis rate is with a minus sign because the CO_2 decreased.

The gross photosynthesis rate is:
-0.2 ppm/min – 0.59 ppm/min = -0.79 ppm/min

Insert your data into the following table (the challenge part will be explained further on):

Process	Rate of CO_2 increase/ decrease [ppm/min]
Dark Respiration	
Net photosynthesis	
Gross photosynthesis	
Dark Respiration (Challenge)	
Net photosynthesis (Challenge)	
Gross photosynthesis (Challenge)	

We can see that when leaves are exposed to light, CO_2 production (dark respiration) changes to CO_2 consumption because of the process of photosynthesis (respiration still occurs).

For this experiment we will assume that respiration in the dark is equal to respiration in the light. A linear photosynthesis rate means that the plant has enough CO_2 (above the plants saturation point).

Challenge research

33. Remove the sensor's probe and the leaves from the bottle, shake the bottle a few times for gas exchange with the surrounding air.

34. Observe how the CO_2 reading in the sensor’s module box changes back to the initial value (or close to it).

35. Repeat the experiment but now put the lamp closer to the bottle. Before the beginning of the measurement, write at least two hypotheses about the possible effects of changing the distance of the lamp from the leaves on the results. What do you think will actually happen?

36. We measured the respiration and photosynthesis rates of the whole group of leaves. Usually photosynthesis rates are calculated in ppm/min per g. If possible, weigh each group of leaves and calculate the rates per gram.

Summary questions

1. Calculate the gross photosynthesis rate for the first experiment and for the challenge experiment, insert your results into the table.

2. Explain the results of the challenge experiment using your hypotheses.

3. Explain the importance of plants to humans and the environment.