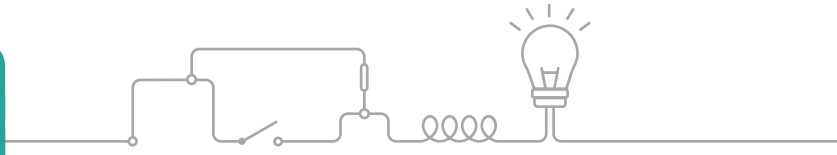
LESSON A5

LEARNING MORE ABOUT CARBON CYCLE TRANSITIONS – PHOTOSYNTHESIS AND RESPIRATION



MAIN SUBJECTS
Natural sciences / Physics / Chemistry

DURATION
~ Preparation: 30 min
~ Activity: 1h (+ a few hours to let the experiments run)

AGE GROUP
12-15 years

LEARNING OUTCOMES
After the introduction to the carbon cycle provided by the last lesson, this worksheet illustrates, through experiments, how carbon moves between two reservoirs – plants and atmosphere.

During this lesson, students will learn that:
~ Plants capture CO_2 from the atmosphere through photosynthesis, and release CO_2 into the atmosphere through respiration.
~ Photosynthesis occurs only in the presence of light, while respiration occurs in both light and darkness.
~ Photosynthesis plays a major role in the carbon cycle at a global scale.

KEYWORDS
Photosynthesis, respiration, carbon cycle

TEACHING METHOD
Experimentation

PREPARATION 30 MIN

TEACHER TIP
This optional lesson focuses on some flows of the carbon cycle: photosynthesis and respiration. It is better if this lesson follows the previous one on the carbon cycle, and it can be given along with lesson A6, which focuses on other carbon flows.

EQUIPMENT
- Test tubes or small bottles with plugs or corks (2 for each group of 4 students).
- Water.
- Red cabbage juice (used for measuring the pH; can be replaced by a pH metre if available). See the background for teachers on next page.
- Limewater.
- Lamp or sunlight.
- Aluminium foil or a cupboard to put some of the test tubes in darkness.
- Small aquatic plants (seaweed, for example).
- Large sheets of paper (one for each group).

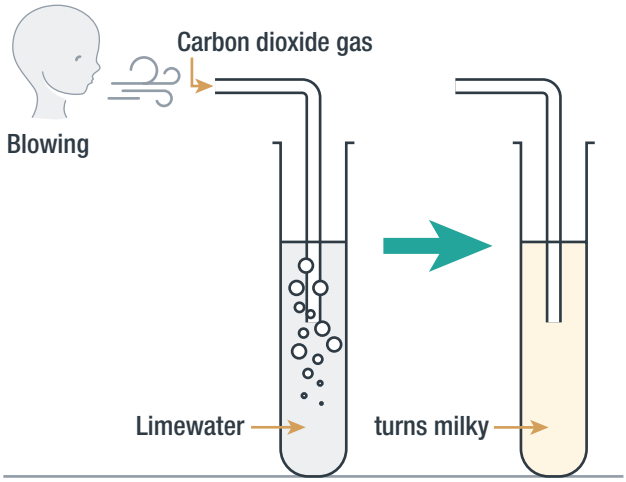
INTRODUCTION 10 MIN

1. During the previous lesson, students learned how carbon atoms are exchanged between different reservoirs on Earth. Ask students to discuss what they learned about carbon reservoirs and the flows between them. Hold a classroom discussion on the movement of carbon between plants and the atmosphere.

Some questions to guide the discussion:
- *How do you think carbon moves from the atmosphere to plants (both land and aquatic)?*
- *Do you think these atoms can move the other way round? How?*
- *What conditions do you think are necessary for plants to take carbon from the atmosphere and to release it back into the atmosphere?*

2. Write the students' responses on the board. Common answers include the requirement of light for photosynthesis and oxygen for respiration. The students may also mention carbon dioxide as the gas that is exchanged.

- *How can we demonstrate the presence of CO_2 even though it is invisible?* Students will probably mention the use of limewater, as shown in the picture on the next page. Ask the students to blow with a straw into red cabbage juice, so they can see there is a colour change. In the next experiment, the students may consider that the colour change is due to an alteration in the CO_2 concentration.



REACTION BETWEEN LIMEWATER AND CARBON DIOXIDE

Adapted from http://solomonsnow.weebly.com/carbon-dioxide.html

PROCEDURE 45 MIN

1. Once students have understood the link between carbon dioxide and the colour changes of the red cabbage juice, you can let them conduct the experiments. Divide the class in half (two broad groups), and then into teams of 4 students. Teams in one group will conduct the experiment in the light-exposed setup, and teams in the other group in the setup placed in darkness.

2. Distribute the equipment and give the students some instructions:

- In one of the bottles, put a few leaves/twigs of seaweed and then seal both bottles.
- Pour the same amount of red cabbage juice into the 2 tubes or bottles (enough for your seaweed to be fully immersed).
- Put both the bottles in sunlight or in the darkness, depending on which group you belong to, as shown in the figure next page.

BACKGROUND FOR TEACHERS

For the experiments in this lesson, you will need to put one aquatic plant in darkness for a few hours, up until the point of use, to remove any residual reactions of photosynthesis and ensure that gas exchange occurs only through respiration for that duration.

TO MAKE RED CABBAGE JUICE

→ Chop the red cabbage into small pieces, place them in a container and put the container in the freezer for at least 3 hours. This will break up the cell walls of the red cabbage and give an even more intense colour to the juice.

→ Pour boiling water onto the red cabbage pieces. The water turns dark purple. Pass this red cabbage juice through a strainer.

TO TEST THE RED CABBAGE JUICE

Blow through a straw into a glass with some juice, and check whether the **colour changes** from a dark violet to a more pinkish violet. If you add **vinegar** the solution should turn a bright magenta colour, whereas adding **sodium bicarbonate** (baking soda) makes the solution greenish blue. You should test the red cabbage juice in advance to make sure it works. It works best if it is fresh and not stored for too long before using (one day). If you store it in the freezer, it can last for months. Make sure your container is tightly sealed to avoid oxidation.

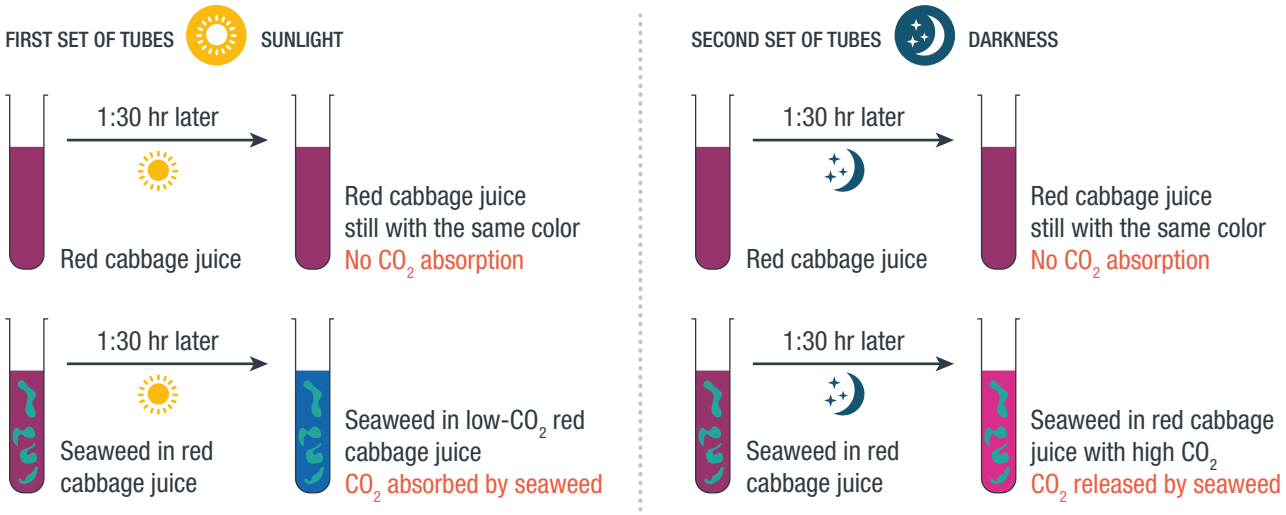
Source: Académie de Nantes.

pH	2	4	6	8	10	12
Colour	Red	Purple	Violet	Blue	Blue green	Greenish yellow

OUTCOME OF THESE EXPERIMENTS

In the **light-exposed setup,** you will see that the colour of the red cabbage juice containing the seaweed will turn **more bluish** (alkaline), suggesting that **carbon dioxide has been absorbed.** On the other hand, in the setup placed in **darkness,** the colour of the red cabbage juice containing the seaweed will turn **pinkish violet** (acidic), indicating that **carbon dioxide has been released.**

In both light and dark situations without the seaweed, the colour of the juice will remain the same, showing that there is no change in the pH (and no addition or removal of carbon dioxide).



EXPERIMENT ON PHOTOSYNTHESIS AND RESPIRATION

TEACHER TIP

It is important to emphasise the influence of light on these experiments. If the students have put the plant in the dark, they will see the effect of respiration; whereas if they place it in sunlight, the effect of photosynthesis will be observed. Students should also consider proper controls for this experiment, which will demonstrate that the change in colour is due to plant activity. This can be done using the bottles containing only juice. Please note that for better results, **these experiments may have to sit for a few hours.**

3. Once the students have set up the experiments, ask them to take photographs of the bottles and record their predictions about what will happen.

- In the bottles containing only red cabbage juice, the colour should stay unchanged in both light and dark conditions.
- For the plant placed in sunlight, the colour should change to a more bluish shade, showing that some CO_2 has been consumed.
- For the plant placed in darkness, the colour should change to a more pinkish shade in the same way as it did when the students blew into the juice, showing that some CO_2 has been released into the water.

4. After each group has completed their experiments, ask the students to form new teams of 4, composed of 2 students from the "light" group and 2 from the "dark" group, so they can explain to each other what they found. Provide each group with one large sheet of paper so they can draw a diagram/poster to represent their understanding of the movement of carbon during photosynthesis and respiration.

5. After a few minutes, come back to the suggestions that they made at the beginning of the lesson about the movement of carbon between plants and their environment (the ones written on the board) to see if they need to be changed.

WRAP-UP 5 MIN

To conclude, you may show a video about the impact of photosynthesis at a global scale to emphasise the importance of this process (for example, you can use this one[1]). You may also add that plants, because they only need mineral carbon (CO_2), are always at the beginning of the food web. You may then show some examples of aquatic and land food webs, like the ones available on our website.

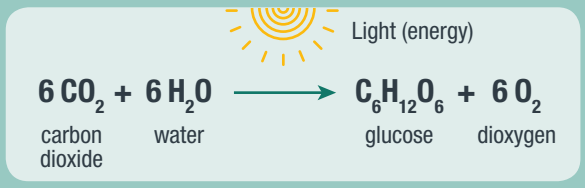
Whole class discussion:

- *How do plants exchange carbon with the atmosphere?* If exposed to light, plants use the carbon dioxide from their environment (atmosphere or water) to carry out photosynthesis; in both light and darkness, they carry out respiration leading to the production of carbon dioxide.
- *How do you think these processes impact the whole planet?* At a global scale, vegetation may be considered as a carbon sink since it removes carbon from the atmosphere or the oceans.

1 Timelapse: Photosynthesis Seen from Space (Educator version) California Academy of Sciences. https://www.youtube.com/watch?v=Nsmdzd2NSjQ

BACKGROUND FOR TEACHERS

Plants, both aquatic and terrestrial, exchange carbon dioxide with their environment (water or atmosphere) through two major mechanisms: **respiration and photosynthesis.** In daylight, plants use the sun's energy to transform carbon dioxide into organic molecules, a process called **"photosynthesis"**. They produce a sugar (glucose), which is stored in the cells in the form of a bigger molecule called **starch** (which we find in huge quantities in potatoes). This chemical reaction **needs water and produces oxygen.** Photosynthesis only occurs in the green parts of plants–the only parts able to convert light energy into chemical energy which is stored in the form of carbohydrates.



At the same time, plants also carry out **cellular respiration:** their cells use **oxygen and sugars** (which they produce through photosynthesis) to **extract energy.** This also leads to the **production of carbon dioxide,** which is released into the atmosphere or in the water.

During the day, both processes occur simultaneously. But since photosynthesis takes more carbon dioxide from the atmosphere than is released by respiration, the result is a **net removal of atmospheric carbon dioxide.**

Conversely, during the night or when the plant is kept in darkness, photosynthesis cannot take place while cellular respiration continues to happen. This results in a **net carbon dioxide influx into the atmosphere.**

At a global scale, photosynthesis is the process that allows mineral matter (carbon dioxide) to turn into organic matter (sugar) that may then be used by animals as a source of food.

Some mitigation measures are also based on this process, using the plant's capacities to extract atmospheric carbon dioxide and to store it in their trunks or in the soil (see lesson B4, page 126 to explore this further).
Photosynthesis always lies at the base of any food web (see lesson C4, page 182 to explore this further).