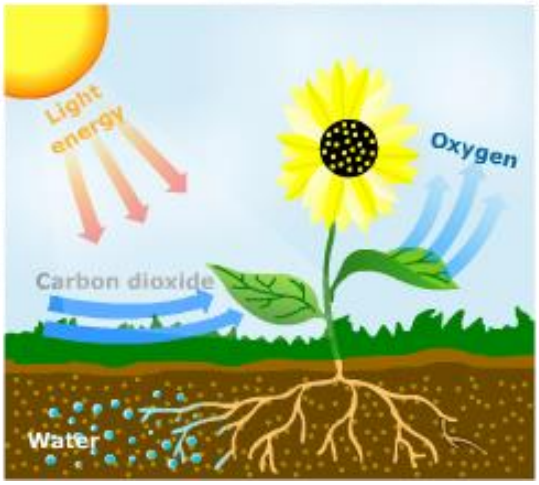
Photosynthesis and Respiration

Autotrophic Nutrition in Plants

Leaves are the food factories of plants. They are the sites where the synthesis of food occurs in plants.

But why do only leaves manufacture food for plants? What process is involved in the synthesis of food?

The leaves of plants contain a green pigment called chlorophyll. This pigment captures the sun's energy, which is used to prepare food from carbon dioxide and water. The process of synthesis of food using sunlight, carbon dioxide, and water is known as photosynthesis.



Since solar energy is essential for plants to prepare food, we can say that sun is the ultimate source of energy for plants.

What happens during photosynthesis? During the process of photosynthesis, the leaves containing chlorophyll convert carbon dioxide and water into carbohydrates in the presence of sunlight. This process can be represented in the form of the following equation:

Carbohydrates, which are produced during photosynthesis, are ultimately converted into starch to be stored in plants.

Know Your Scientists:

Year	1770	1779	1854
Name of scientist	Joseph Priestley	Jan Ingenhousz	Julius Von Sachs
Discovery/Finding	Concluded that air is necessary for the growth of a plant. He discovered the fact that plants restore oxygen in the air.	Concluded that sunlight is essential for plant processes that purify the air. He also discovered that the green parts of plants release oxygen.	Discovered that the chlorophyll is located in special bodies called chloroplast. Green parts of plants are where glucose is made, which is stored as starch.

Curiosity Corner:

Now, not all leaves are green in colour. Does photosynthesis take place in these leaves too?

Yes, Leaves which are not green in colour also contain chlorophyll. They are not green in colour because they contain other pigments such as red, brown, yellow etc, which mask the green colour of leaves.

Can you tell why potted plants are advised to be placed in well-lit areas?

Plants require sunlight to manufacture food. Without sunlight, photosynthesis cannot take place in plants, and can even lead to the death of plants. Hence, it is advisable to place potted plants in areas receiving sufficient sunlight.

Let us perform the following activity to test the production of food in plants.

We now know that plants require water and carbon dioxide, in the presence of sunlight, to carry out photosynthesis. How are raw materials supplied to plants?

The tiny pores found on the underside of leaves are called **stomata**. It allows the entry of CO_2 from the atmosphere so that it can be used for photosynthesis and releases the oxygen produced by the plants.

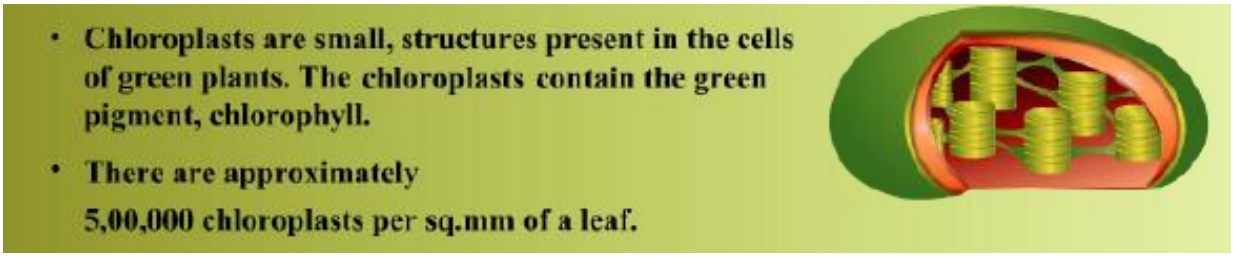
Leaf Leaf section Stomata

Structure of stomata:
Stomata are small openings present on the lower surface of leaves. These openings are surrounded by two bean shaped cells called guard cells. These guard cells contain chloroplast. In guard cells, the outer wall is thin while the inner wall is thick.

Regulation of stomata:
Opening and closing of stomata is regulated by these guard cells. During day time, in the presence of sunlight, water moves into the guard cells making them to swell up. As they swell up, their outer thin walls bulge outward, as a result of which the inner walls move apart from each other. This results in the opening of stomata.

During night, the water moves out of the guard cells which makes them flaccid. This causes the inner walls to come together, as a result of which stomata closes.

Do you know the cell organelle of the plant cell that carries out the process of photosynthesis? It is **chloroplast**.



Chloroplast is divided into two regions namely, **grana** and **stroma**.

In the **grana** region, reactions which depend on sunlight take place. These reactions are also known as light dependent or light reactions. In these reactions, water molecules break down into oxygen and hydrogen ions on absorption of energy from sunlight.

Plants release oxygen gas in this phase and chemical energy obtained from light energy is stored in the form of ATP. This chemical energy is required in the preparation of starch in the reactions independent of light.

In the **stroma** region, light independent or dark reactions take place in which chemical energy produced in the grana region is used to convert carbon dioxide into starch.

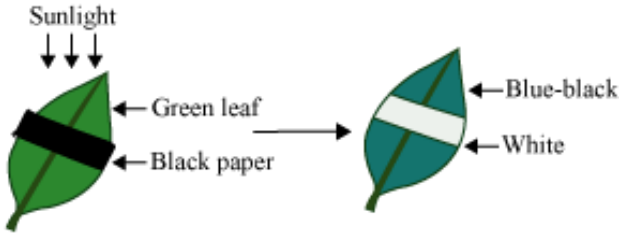
Photosynthesis is affected by various factors, such as:

- **Light**: Photosynthesis can occur only up to a certain level of concentration of light. Above that level of light, chlorophyll is destroyed and photosynthesis is affected.
- **Temperature**: At higher temperatures, photosynthesis does not take place and similarly at lower temperatures the rate of photosynthesis is less.
- **CO_2**: CO_2 levels also affect the rate at which photosynthesis is carried out. Low levels of CO_2 means lower rate of photosynthesis.

Experiments Related to Photosynthesis

We know that raw materials are utilized by plants to prepare food. **Do plants prepare food at all times? Are there any essential conditions required for photosynthesis?**

1. **Sunlight is essential for photosynthesis**



Place a healthy green potted plant in a dark room for 1-2 days. This is done to ensure that the plant consumes all its reserve food and the leaves do not contain any starch. Then, cover a portion of a leaf of this plant on both sides with two uniform pieces of black paper, fixed in position with two paper clips.

Now, expose this plant to bright light. After a few hours, remove the leaf, decolourize it with alcohol, and test the presence of food (starch) with iodine solution.

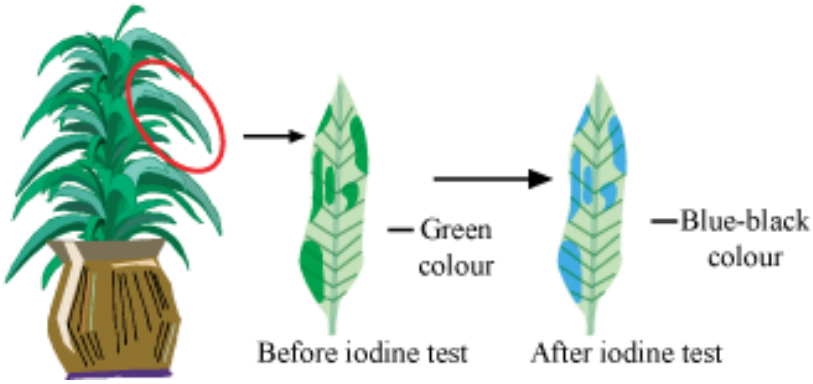
You will observe that the portion of the leaf covered with black paper does not show any presence of starch (food).

Explanation of the activity:

The food prepared by plants (carbohydrates) through the process of photosynthesis is stored as starch. This starch reacts with the iodine solution to change to blue-black colour. Only those portions of the leaf that were exposed to sunlight could photosynthesise and hence, change to blue-black colour when tested with iodine.

2. Chlorophyll is essential for photosynthesis

Place a variegated plant (i.e., a plant which has both green and non-green areas, for e.g., croton or money plant) in a dark room for 2 – 3 days. This is done to ensure that all the reserve food (starch) is utilized.



Place this plant in sunlight for six hours to allow photosynthesis to take place.

Then, pluck a leaf from this plant and trace the green areas on a sheet of paper.

Now, decolourize the leaf using alcohol and dip it in a dilute solution of iodine for a few minutes. Wash this leaf with water and compare it with the tracings of the leaf done earlier.

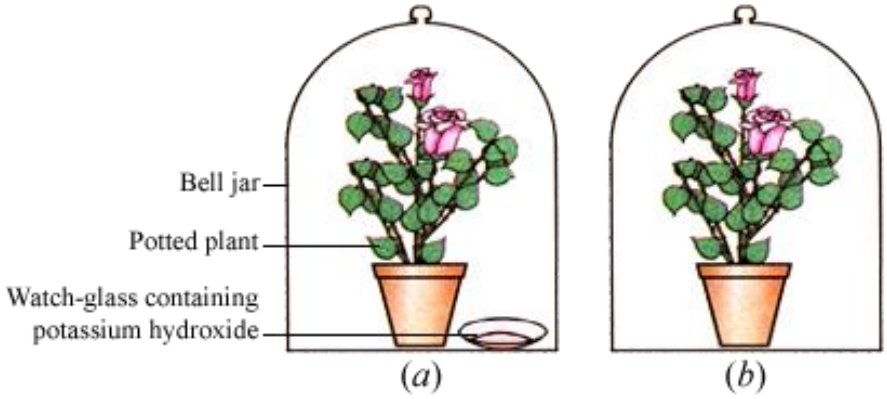
It will be observed that only the green areas of the leaf could photosynthesize.

Explanation:

The leaf is treated with alcohol so that it loses its green colour (chlorophyll pigment) and blue-black colour (in presence of starch) obtained after treatment with iodine.

The green parts of a variegated leaf contain chlorophyll. Therefore, only these parts could photosynthesize and manufacture food. Thus, the change in colour was observed only in these parts.

3. CO_2 is essential for photosynthesis



Select two healthy potted plants of nearly the same size and label them as **A** and **B.** Place them in a dark room for 2-3 days. Then, place two glass plates under both the plants. Place a watch-glass containing potassium hydroxide besides pot **A**.

Cover both the plants by inverting separate bell jars over them. Potassium hydroxide, as we know, is used to absorb CO_2. Therefore, CO_2 is not available for plant **A**.

Now, seal the bottom of the jars to the glass plates with the help of Vaseline. This prevents the entry of CO_2 into the set up. Then, place the plants under sunlight for 2 – 3 hours.

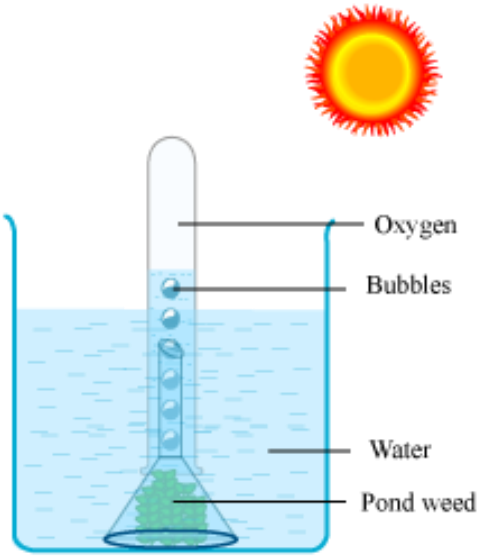
Test one leaf each from both plants for the presence of starch, using alcohol and iodine (as explained in the previous activity). It will be observed that plant **B** has a higher amount of starch as compared to plant **A**.

Explanation of the activity:

This happens because potassium hydroxide present besides plant **A** absorbs all the CO_2. Therefore, plant **A** is not able to photosynthesize and manufacture food. Hence, the amount of starch present in plant **B** is higher than plant **A**.

Photosynthesis in a laboratory

Place an aquatic plant (hydrilla) in a beaker filled with water. Cover the plant with a transparent funnel. Then, invert a test tube over the open end of the funnel.



While inverting the test tube, make sure it does not contain any air bubbles. Place this apparatus in sunlight and observe the changes.

It will be observed that after sometime, air bubbles (O_2) emerge in the test tube.

Aerobic and Anaerobic Respiration

You know that all activities performed by the body require energy. **Where does the body get energy from?** The food we eat contains stored energy.

How is the energy stored in food released to be used by the body?

You know that during the process of breathing, we take in air. Oxygen is taken in, while carbon dioxide is released out of the body during breathing. Oxygen is then circulated to all cells of the body. Food (glucose) is broken down in the cells with the help of oxygen.

The process in which food is broken down in the cells to release energy is known as **cellular respiration**.

Have you ever wondered what will happen if no or very little oxygen is available to cells? Will the process of cellular respiration stop?

Two types of respiration take place in the cells. One occurs in the presence of oxygen, while the other occurs in the absence of it. The process of breakdown of food (glucose) in the presence of oxygen is known as **aerobic respiration**. It takes place in all organisms and leads to the production of carbon dioxide, water, and energy.

$$\text{Glucose} \xrightarrow{\text{Oxygen}} \text{Carbon dioxide} + \text{Water} + \text{Energy}$$

Food is also broken down in the absence of oxygen. This process is known as **anaerobic respiration.** It occurs in organisms such as yeast. This process leads to the production of alcohol and carbon dioxide.

$$\text{Glucose} \xrightarrow{\text{Without oxygen}} \text{Alcohol} + \text{Carbon dioxide}$$

Difference between Aerobic and Anaerobic respiration

Aerobic respiration	Anaerobic respiration
It occurs in the presence of O_2.	It occurs in the absence of O_2.
It involves the exchange of gases between an organism and outside environment.	Exchange of gases is absent.
It occurs in the cytoplasm and mitochondria.	It occurs only in the cytoplasm.
It always releases CO_2 and H_2O.	End products may vary.
It yields 38 ATP.	It yields 2 ATP.
Example: Cells in our body	Example: Yeast and muscle cells

Have you experienced pain in your arms or legs after exercising for a long time?

When you exercise, your body experiences a temporary deficiency of oxygen and the muscle cells begin to undergo anaerobic respiration to provide energy to the body. This leads to the production and accumulation of lactic acid, which leads to muscle cramps and pain in the body.

Do you know why yeast is used for preparing wine and beer?

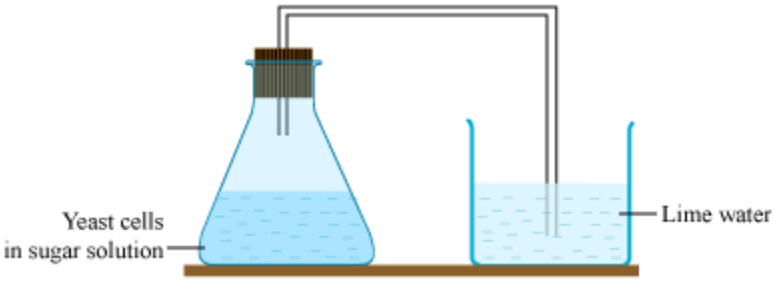
Yeast performs the process of anaerobic respiration, which leads to the production of alcohol by incomplete breakdown of sugar. It is for this reason that yeast is used in the production of wine and beer.

How do we confirm that carbon dioxide is produced during respiration?

Let us perform the following activity to find out.

Yeast in a beaker

Take some yeast in a beaker with sugar solution. Close the lid of the beaker and pass a glass tube from the beaker into another beaker containing lime water.



What do you observe? What process do you think is responsible for this observation?

Lime water turns milky in the presence of carbon dioxide. This is the standard test for checking the presence of carbon dioxide. This test indicates that the process of respiration occurs in yeast, which leads to the release of carbon dioxide gas in the beaker.

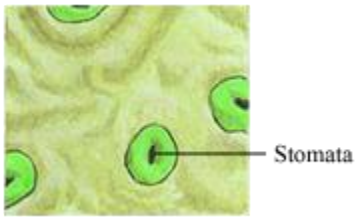
The anaerobic conversion of sugar to carbon dioxide and alcohol by yeast is called **fermentation.**

Respiration in Plants

Do you think plants also respire like other organisms? If so, then how do plants take in oxygen?

Just like all other living organisms, plants too respire. They respire through the tiny pores on the surface of their leaves called **stomata**. Oxygen enters the plant, while carbon dioxide leaves the plant through these pores.

The roots of plants also respire.

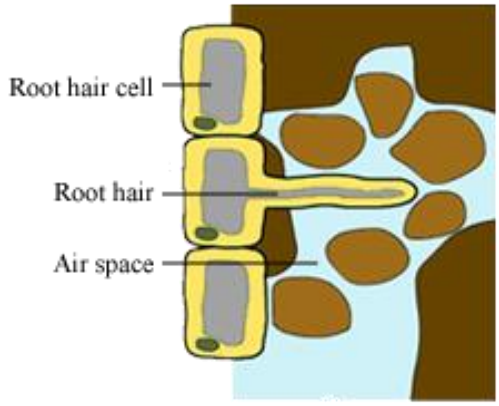


They do so by taking in oxygen from the **air spaces** present in soil by the process of diffusion. Oxygen is taken in and carbon dioxide moves out with the help of diffusion only. This type of gaseous exchange takes place in the younger roots only, and not in the older roots.

In the older roots, the exchange of gases occurs by **lenticels**. The lenticels are thin walled loosely arranged cells with intercellular spaces present for gaseous exchange.

In plants growing in mangroves or saline swamps, the root is modified to **pneumatophores**. They bear breathing pores (lenticels) and emerge out of the soil for gaseous exchange.

In some trees, the trunk of the trees bear small openings called **lenticels**. Through these openings in the bark, gaseous exchange takes place. The lenticels look like scars on the tree bark.



The part of oxygen that is produced by the plant in photosynthesis is utilized by the plant for breathing and rest of the oxygen is given out by plants through stomata which we use for breathing.

Can you tell why farmers are advised against adding too much water to their fields?

They are advised to do so because too much water fills up the air spaces present in soil by replacing the air in it. Lack of oxygen can lead to the death of plants.

My potted plant!

Take a potted plant and keep watering it continuously for a week with more than the required amount of water.

What do you observe after a week? Does the plant survive? What is the reason behind your observation?

You will observe that the plant does not look healthy. This is because excess water blocks the pores of soil and does not allow oxygen to enter the plant body.

Large forests are called the '*lungs of the world*' because the oxygen produced by plants is used by humans and animals for respiration.

Activities

Activity 1

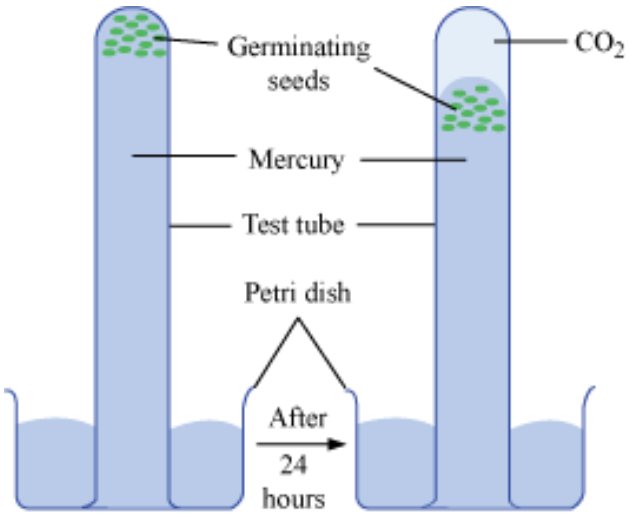
Aim - To demonstrate anaerobic respiration.

Procedure

1. Take about 6-7 germinating seeds of pea or gram and remove their outer layer (testa)

so that diffusion of CO_2 from the seeds takes place.

2. Invert a test tube filled with mercury over a petri dish half filled with mercury.



3. Introduce the germinating seeds in the test tube with the help of forceps. The seeds will move to the top of the test tube. We name this set up as A.

4. Prepare other set up B in the same manner as set up A, but taking germinating seeds which have been killed by boiling. This set up serves as the control experiment.

5. Keep both the set ups (A and B) for a few hours and then observe.

Observation
Level of mercury in set up A falls while in set up B it remains as such.

Explanation
Carbon dioxide gas liberated in set up A has pushed down the mercury.

In set up B, no gas is produced.

To check that the gas liberated is carbon dioxide introduced a crystal of potassium hydroxide in tube of set up A. The mercury level will again rise, indicating that the gas carbon dioxide is produced during anaerobic respiration.

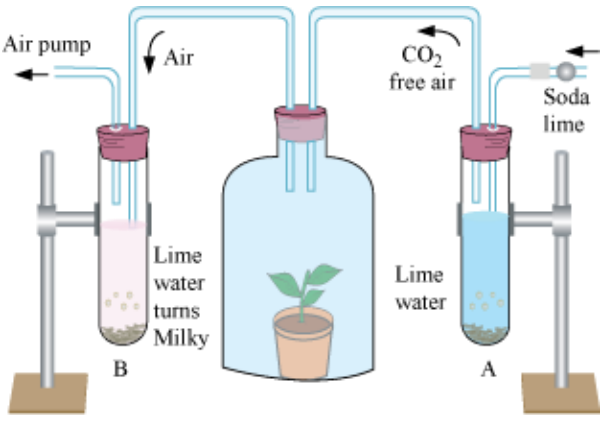
Activity 2

Aim - To demonstrate aerobic respiration or to demonstrate that green plants produce CO_2 during aerobic respiration.

Procedure

1. Take a small potted green plant and cover it with a bell jar.

2. Connect the bell jar on both sides with U-glass tubes to test tube/conical flasks containing lime water.



3. Vaseline is applied to make the set up air free.

4. Cover the bell jar with a black cloth, to prevent photosynthesis. So, CO_2 evolved during respiration will not be consumed in photosynthesis.

5. Introduce air into the apparatus with the help of an air pump and pass it first through soda lime. The soda lime will absorb any CO_2 present in the incoming air. As a result, when the air passes through the lime water in test tube A, it does not turn milky.

6. The air free from CO_2 enters the bell jar and comes in contact with the green plant.

7. The air from the bell jar now enters the test tube B containing lime water. The test tube B is also attached to the air pump.

Observation
It turns milky

Explanation
Lime water turns milky because the air coming from the bell jar contains CO_2 (while the air entering the bell jar is free from CO_2). This shows that CO_2 is produced by green plants during respiration.

Differences between Photosynthesis and Respiration

Photosynthesis	Respiration
Occurs in cells that have chlorophyll	Occurs in all living cells
Occurs in the presence of light only	Can occur all the time
Manufactures food	Breaks down food
Uses carbon dioxide and water	Uses oxygen and glucose
Liberates oxygen as one of the end products	Liberates carbon dioxide as one of the end products

Now as we have studied all the aspects of respiration in plants, can you figure out some differences between respiration in plants and animals?

Respiration in Plants	Respiration in Animals
Respiratory gases travel by simple diffusion.	Respiratory gases are transported across the body through blood.
End products of anaerobic respiration include ethanol.	End products of anaerobic respiration include lactic acid.
Lesser amount of heat is produced.	More amount of heat is produced.