7 RESPIRATION IN PLANTS

Syllabus : Respiration in plants : outline of the process, gaseous exchange.

A brief outline of the process mentioning the terms Glycolysis and Krebs cycle and their significance. A reference to be made to aerobic and anaerobic respiration with chemical equations in each case. Experiments on gaseous exchange and on heat production.

Like all other organisms, plants too require energy for carrying out body activities. In this chapter you will learn about the two kinds of respiration (aerobic and anaerobic), the manner in which diffusion of respiratory gases occurs, as well as a number of interesting experiments to demonstrate respiration in plants.

7.1 WHAT IS RESPIRATION?

All living cells in a plant, as well as those in animals, require energy for various body activities. *For example*, building up proteins from amino acids, making starch from glucose, absorbing minerals from the soil, or the laying down of cell walls by the plant cell, are all such activities that require energy. This energy is made available by the breakdown of glucose a simple carbohydrate. This chemical breakdown occurs by utilizing oxygen and is represented by the following overall reaction :

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

There are three important characteristics of respiration in this equation.

1. The **breakdown of glucose** ($C_6H_{12}O_6$) to carbon dioxide and water does not occur in a single step, but **in a series of chemical steps.** These steps occur in two major phases- (i) ***glycolysis*** (glucose $\rightarrow$ pyruvate) occurring in cytoplasm and (ii) ***Krebs cycle*** (pyruvate $\rightarrow CO_2 + 6H_2O +$ ATP) occurring in mitochondria.
2. Each breakdown step is due to **a particular enzyme.**
3. The energy liberated in the breakdown of the glucose molecule is not all in the form of heat, but a large part of it is converted into **chemical energy in the form of ATP** - a chemical substance called **adenosine triphosphate.**

When energy in the form of ATP is used, the ATP is converted to ADP (adenosine diphosphate) and again when more energy is available by further breakdown of glucose, the ADP is reconverted to ATP and so it goes on and on (Fig. 7.1). One mole of glucose on complete oxidation yields 38 molecules of ATP.

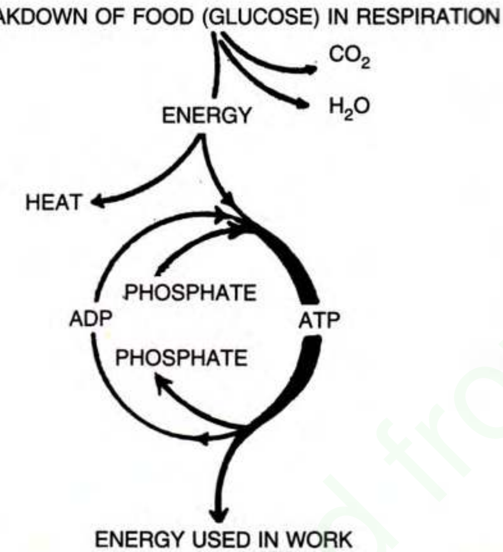


Fig. 7.1 Diagrammatic representation to show the use of energy liberated in respiration

> **ATP – The energy currency of the cell**
> **All activities inside a living cell need energy which is available in the form of ATP as the immediate source. Hence, this chemical compound ATP is described as "The energy currency of the cell".**

> **Respiration is a catabolic process of releasing energy from simple sugar glucose for carrying out life processes.**

Living organisms show two types of metabolic activities :

(i) **anabolic** (constructive or biosynthetic processes), it consumes energy.

(ii) **catabolic** (destructive or breaking down processes), it gives out energy for use by the organism.

Respiration is a breaking down process by which a living cell oxidises organic substances (glucose) and releases carbon dioxide, water and energy.

7.2 RESPIRATION vs. BURNING (Combustion)

Sometimes, respiration is compared with burning such as the burning of coal. Both liberate energy, and both give the end products CO_2 and water. But this comparison is only superficial. The differences between the two are as follows :

Respiration	Burning/Combustion
1. Occurs in a **series of chemical steps**	Occurs in a **single step**
2. Carried out by **enzymes**	Carried out by **heat**
3. **Biochemical** process	**Physico-chemical** process
4. Energy liberated as **ATP and some heat**	All the energy liberated as **heat and light.**
5. No light energy is produced	Light is produced
6. **Cellular** process	**Non-cellular** process
7. Occurs **at body temperature**	Occurs **at high temperature** (at ignition point)

7.3 THE ENTIRE PLANT RESPIRES

Every part of a plant such as the leaves, stem, roots and even the deepest placed cell in any region respires. Oxygen is obtained from the atmosphere through three inlets :

- **stomata** in leaves
- **lenticels** in stem
- **general surface** of the **roots**

Ploughing or tilling of the soil creates tiny air spaces around soil particles and provides the source of oxygen for the roots. Water-logged and compact soil does not have air spaces which affect respiration of the roots.

During daytime, due to photosynthesis, the leaves produce oxygen, some of which is used in respiration and the rest is diffused out. The carbon dioxide produced during respiration in the leaves serves as a raw material for photosynthesis.

At night, even the leaves obtain oxygen from the atmosphere and give out carbon dioxide. Hence, **there *appears* to be some truth in the belief that one should not sleep under a tree at night** (*also see the box at the end of this chapter page 62*). (But actually, there is more carbon dioxide inside our houses than under a tree at night). Sleeping under a tree during hot mid-day is definitely good as one gets both oxygen due to photosynthesis and coolness due to transpiration.

?

PROGRESS CHECK

1. What are the three important aspects about the overall chemical equation of respiration, pertaining to the following?
   (i) Single or several steps ______________________
   (ii) Direct or enzyme-catalysed ______________________
   (iii) Forms of energy liberated ______________________

2. List three ways in which respiration is different from burning :
   (i) ______________________
   (ii) ______________________
   (iii) ______________________

3. Name the three inlets of oxygen for respiration in plants.
   (i) ______________________
   (ii) ______________________
   (iii) ______________________

7.4 TWO KINDS OF RESPIRATION – AEROBIC AND ANAEROBIC

A. AEROBIC RESPIRATION

Normally, free oxygen is used in respiration and there is complete oxidation of glucose with the formation of *carbon dioxide* and *water* as end-products. This is clearly represented by the following overall reaction (actually there are numerous steps in the entire process) :

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 38\ ATP$$

(energy/heat)

Respiration proceeds only when oxygen (a constituent of air) is available and is therefore called **aerobic** (or **oxybiotic**) **respiration.**

B. ANAEROBIC RESPIRATION

Sometimes certain parts of the plants (including fruit and seeds) may temporarily respire even in the absence of oxygen. In this type of respiration, the glucose molecule is incompletely broken down into ethanol (**ethyl alcohol**) and carbon dioxide with the release of a small quantity of energy. This chemical reaction can be represented in the following manner :

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2 + 2\text{ ATP}$$

This type of respiration is called anaerobic respiration (or **anoxybiotic**) as it proceeds even without oxygen. Anaerobic respiration in any part cannot continue in a plant for more than a few days and the part ultimately dies. But there are certain microscopic organisms such as certain bacteria and fungi which normally respire only anaerobically. Even the germinating seeds when deprived of air respire anaerobically as described in Experiment No. 5 Fig 7.7(p. 54).

Table 7.1Major differences between aerobic and anaerobic respiration in plants

Aerobic respiration	*Anaerobic respiration*
1. Proceeds in the presence of oxygen.	Proceeds in the absence of oxygen.
2. Complete break-down of glucose.	Incomplete breakdown of glucose.
3. End-products are carbon dioxide and water.	End-products are ethyl alcohol and carbon dioxide.
4. Energy liberated in large quantity (38 ATP) from one mole of glucose.	Energy liberated in small quantity (2 ATP) from one mole of glucose.
5. Occurs normally throughout life.	Occurs temporarily for short periods.

? ***PROGRESS CHECK***

1. Give the overall chemical equation for the two kinds of respiration in plants :
   (i) Aerobic ____________________
   (ii) Anaerobic ____________________
2. Mention any one difference other than those reflected in the two chemical equations given above.
3. Certain organisms respire only anaerobically throughout their lives. Name any two such organisms.
   (i) ____________ (ii) ____________

7.5 EXPERIMENTS ON RESPIRATION IN PLANTS

1. ***Experiment to prove that oxygen is used up in respiration.***

An apparatus is arranged as shown in Fig. 8.2. Flask

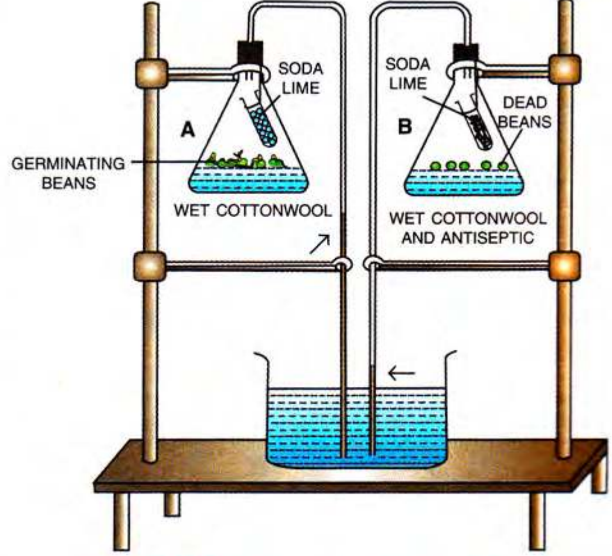


Fig. 7.2 Experiment to show the utilisation of oxygen in respiration.

(A) contains germinating bean seeds and Flask (B) has dead (boiled) seeds together with some antiseptic to avoid bacterial decay. Wet cotton provides water to both samples. A small tube containing soda lime (a mixture of sodium hydroxide and slaked lime) is suspended in each flask for absorbing any carbon dioxide released by the seeds. After a few days, the delivery tube connected with flask (A) will show a greater rise in water level. When a burning paper is introduced into each flask after removing their corks, the flame is immediately put off in flask (A), but it continues for a short while in flask (B). This proves that oxygen was absent in flask (A) showing thereby that it was used up by the germinating seeds and the volume of oxygen so used up was indicated by the rise of water level in the delivery tube. There are two simple questions which surely you can answer. Why is there a slight increase in the level of water in the delivery tube of flask (B)? Which of the two flasks, (A) or (B), is a control?

A Proper Experiment Must Have Two Components :

EXPERIMENTAL and CONTROL

An experiment consists of two set-ups – an experimental **set-up** and a **control set-up**. Both are identical in which every condition is the same **except one**. *The set-up in which the condition under study is missing* is called the **control**.

2. ***Experiment to prove that carbon dioxide is produced during respiration in germinating seeds.***

Take two flasks A and B. Place some wet cotton-wool at the bottom of each flask. Soaked seeds (such as pea or

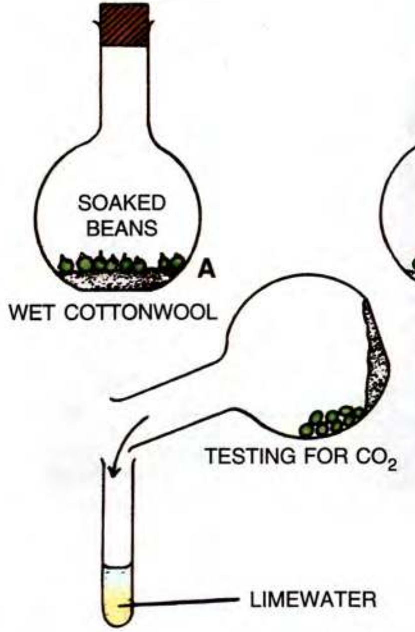


Fig. 7.3 Experiment to show the production of carbon dioxide in germinating seeds.

bean) are placed in flask (A) and an equal number of boiled (dead) seeds are placed in flask (B) (Fig. 7.3).

A little antiseptic (such as carbolic acid) is added to flask (B) to prevent bacterial growth on dead seeds, which would otherwise respire and release carbon dioxide. The flasks are securely corked and left in similar conditions of light and temperature. A few days later, the seeds in flask (A) will be found to have clearly germinated and those in flask (B) showing no signs of any germination (as they are dead). The gases in each flask are then tested by removing the cork and tilting the flask over a test-tube containing limewater and then shaking up the test-tube. The expected gas carbon dioxide being heavier than air would "flow down" into the test-tube. The gas from flask (A) would turn the lime- water milky, showing the presence of carbon dioxide in it, while the gas in flask (B) will show no effect. Therefore, the conclusion is that the germinating (respiring) seeds give out carbon dixoide.

An alternative method for the same experiment

A similar more directly observable experiment to show that carbon dioxide is produced during respiration in germinating seeds (pea or gram seeds) is arranged as shown in Fig. 7.4. The air drawn in conical flask A is cleared of any CO_2 present in it. The clear limewater in flask B confirms that the air entering flask C is CO_2 free. The limewater in flask D turning milky doubtless proves that the source of CO_2 was only the germinating seeds.

3. *Experiment to prove that carbon dioxide is produced by green plants during respiration.*

Set up an apparatus as shown in (Fig. 7.5) using a small potted plant such as Geranium. The bell-jar should be placed on a glass sheet and its rim as well as all other connections should be vaselined to make them air-tight. The outside air is drawn into the apparatus with the help of an air pump. This air passes through the soda-lime which absorbs any carbon dioxide present in the incoming air, and the limewater (Flask A) through which it passes will not turn milky. As the air leaves the bell-jar, and passes through another sample of limewater (Flask B), the carbon dioxide present in it would turn the limewater milky. It is

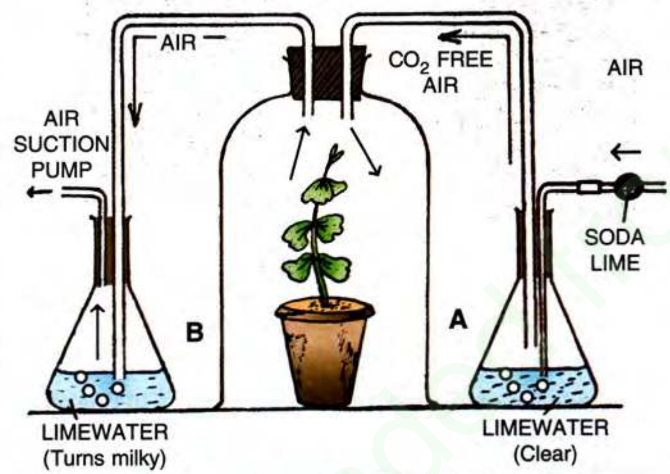


Fig. 7.5 Experiment to show that carbon dioxide is given out by a green plant in the dark.

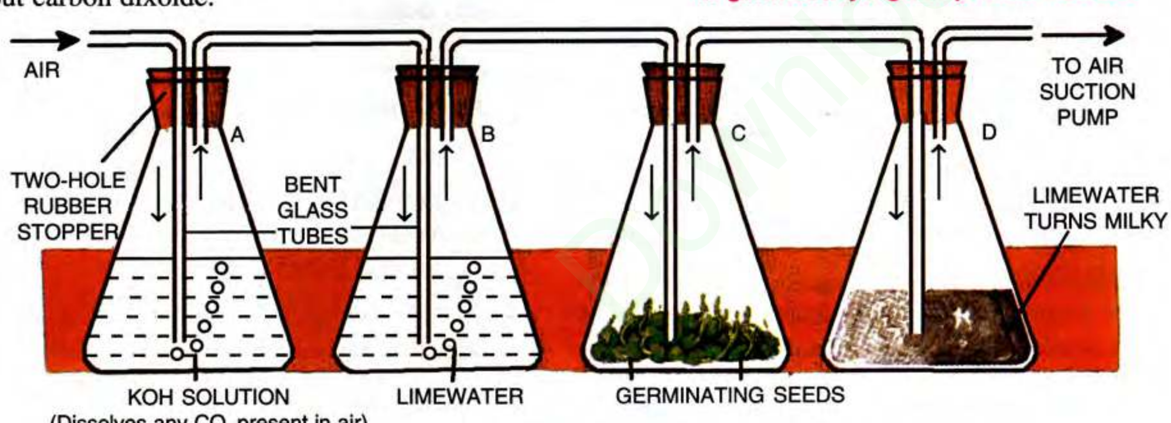


Fig. 7.4 To show that carbon dioxide is given off from living plant material during respiration.

necessary that this experiment is **carried out in the dark**, or the bell-jar is completely covered by a piece of **black** cloth to prevent photosynthesis (so that the carbon dioxide liberated in respiration is not used up in the synthesis of starch).

4. *Experiment to show that heat is evolved during respiration* (Fig. 7.6).

Take two thermos-flasks and mark them (A) and (B). Take about 200 seeds (pea or bean) and soak them in water for more than 24 hours.

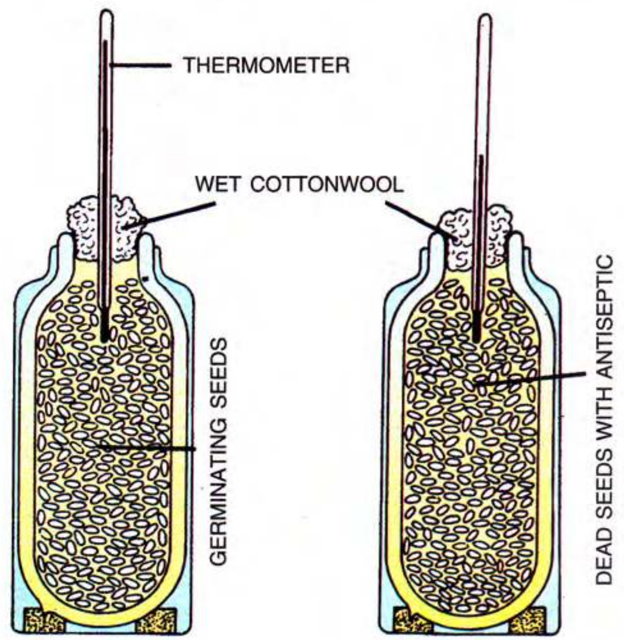


Fig. 7.6 Experiment to show liberation of heat during germination.

Divide the seeds into two equal groups. Kill one group of seeds by boiling them, and then wash them with dilute formalin or carbolic acid to prevent bacterial decay. Put the live germinating seeds in flask (A) and the killed ones in flask (B). Insert a thermometer in each flask and plug their mouths with cotton wool. After a few hours, the thermometer in flask-A will show a higher reading, thus indicating that the germinating (live and respiring) seeds give out heat. The thermometer in flask (B) will not show any rise in temperature.

5. *Experiment to demonstrate anaerobic respiration.*

Take eight to ten soaked and peeled off peas and push them into the mouth of a test-tube filled with mercury and inverted in a beaker of mercury. The seeds will float to the top and will be completely surrounded by mercury. After about two days, the level of mercury in the test-tube will fall (Fig. 7.7) and the liberated gas will be found to be

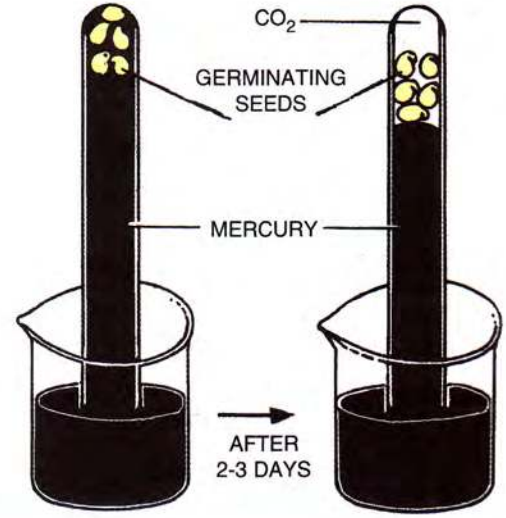


Fig. 7.7 Experiment to demonstrate anaerobic respiration.

carbon dioxide. Carbon dioxide can be tested by introducing a stick of potassium hydroxide into the test-tube, which will float up through mercury and on coming into contact with the gas, will absorb the carbon dioxide and the level of mercury will again rise. A similar control experiment could be set up in which the seeds may be kept after killing them by heating and sterilizing them with some antiseptic. No gas will be liberated in the control. *[Note :* ***Peeling off the seed coat of the germinating seeds before introducing them into the test-tube may hasten the outward diffusion of*** CO_2*]*

? ***PROGRESS CHECK***

1. In experiments on respiration, the seeds taken as control are boiled. Why ?

____

____

2. What is the use of the following in the experiments on respiration ?

   (i) Soda lime _______________

   ____

   (ii) Limewater _______________

   ____

3. Suppose we conduct an experiment to demonstrate respiration in a green plant. what special precaution is required to be taken in it ?

4. In experiment No. 5 we are using mercury in the test-tube and the beaker. Why can't we use water instead ?

____

____

7.6 RESPIRATION CONTRASTED WITH PHOTOSYNTHESIS

In many respects, respiration and photosynthesis in plants are **distinctly opposite processes**. The requirements of one are the products of the other and therefore, they are complementary to each other. This is the reason why we cannot conduct an experiment on plant respiration during daytime, in light. The fundamental differences between plant respiration and photosynthesis are given in Table 7.2.

Respiration opposite of photosynthesis.

In the differences mentioned in Table 7.2 below, there are at least five points in which photosynthesis and respiration are exactly opposite to each other. Can you make out these points?

Table 8.2 Photosynthesis and Respiration Contrasted

	PHOTOSYNTHESIS	RESPIRATION
1.	Occurs only in the presence of chlorophyll.	Occurs in all living cells.
2.	Occurs only in the presence of light.	Occurs at all times.
3.	Uses carbon dioxide and water.	Uses oxygen and glucose.
4.	Oxygen is released as an end product.	Carbon dioxide is released as end product.
5.	Light energy is converted into chemical energy and stored.	Chemical energy is partly converted into heat and partly into useful energy for various activities.
6.	Results in gain in weight.	Results in weight loss.
7.	Food (glucose) manufactured. (Constructive process, anabolic)	Food (glucose) broken down (oxidised, destructive or katabolic)

7.7 RESPIRATION IN PLANTS COMPARED WITH RESPIRATION IN ANIMALS

The basic aspects of respiration are same in all organisms. However, there are some differences in respiration in plants and animals. *For example*, **in plants** :

(i) there is **no gaseous transport**, the respiratory gases simply diffuse in and out by cell to cell diffusion. (In animals, the blood transports respiratory gases).

(ii) one of the end products of anaerobic respiration in plants is **ethanol/ethyl alcohol** while in animals it is **lactic acid**.

(iii) in plants the process produces **little heat** as compared to animals.

? PROGRESS CHECK

1. Fill in the blanks.
   In anaerobic respiration in plants, the end product is .... and .... instead of lactic .... in animals.

2. The table below is intended to give certain differences between photosynthesis and respiration, but a few points are given **wrongly**. Strike out the wrong ones and write the correct words instead.

	PHOTOSYNTHESIS		RESPIRATION
(i)	Results in loss in weight	—	Results in gain in weight
(ii)	Sucrose is the product	—	Sucrose is broken down
(iii)	Occurs in green cells only	—	Occurs in all cells
(iv)	Uses water and oxygen	—	Uses glucose and oxygen

Why one should not sleep under a tree at night — CO_2 or something else ?

The carbon dioxide released by trees during respiration at night is too little to cause any harm (we have much more of this gas in our bed rooms). However, the droppings of the perching birds and the night-active insects, spiders, snakes, etc., are real dangers. But believe it there are no ghosts or spirits resting on the trees.

POINTS TO REMEMBER

- ***Respiration is the breakdown of glucose to yield energy in the form of ATP.***
- ***The breakdown of glucose occurs in two major phases : glycolysis and Krebs cycle.***
- ***Respiration occurs in a series of steps carried out by enzymes***
- ***The plants have three inlets of oxygen from the atmosphere — stomata in leaves, lenticels in stem and the general surface of the root.***
- ***There are two kinds of respiration — aerobic using oxygen and releasing CO_2, H_2O and energy (ATP), and anaerobic, in absence of oxygen, releasing ethanol (C_2H_5OH), CO_2 and energy.***
- ***Aerobic respiration occurs normally thoughout life, whereas anaerobic respiration occurs temporarily for short periods.***
- ***Respiration in plants is opposite to photosynthesis in several features e.g. gases used and released, gain or loss in weight.***

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

1. **Glycolysis** is a process
   (a) in which glycogen is broken down into glucose
   (b) which occurs in mitochondria
   (c) in which glucose is broken down into pyruvate
   (d) that occurs next to Krebs cycle.
2. One same **common function** is performed by ?
   (a) Stomata and veins
   (b) Stomata and lenticels
   (c) Lenticels and sepals
   (d) Lenticels and hydathodes
3. Anaerobic respiration **normally** occurs in
   (a) Grass (b) Cactus
   (c) Coconut (d) Baker's yeast

B. VERY SHORT ANSWER TYPE

1. Do the plants **respire** all day and all night or only at night ? ....
2. **Name** the following :
   (a) Energy currency of cell.
   (b) Oxidative breakdown of carbohydrates to release energy.
   (c) An organism which respires throughout life anaerobically.
   (d) A common phase in both aerobic and anaerobic respiration.
   (e) Aerobic respiration requires ....
   (f) A chemical which removes CO_2 from the air.
3. **Mention** if the following statements are ***true*** or ***false***. If false, rewrite them correctly.
   (a) Aerobic respiration of one mole of glucose yields 138 ATP (T/F)
   (b) Anaerobic respiration in plants yields lactic acid. (T/F)
   (c) Carbon dioxide readily dissolves in lime water. (T/F)
   (d) All leaves of a green plant normally respire anaerobically at night. (T/F)

C. SHORT ANSWER TYPE

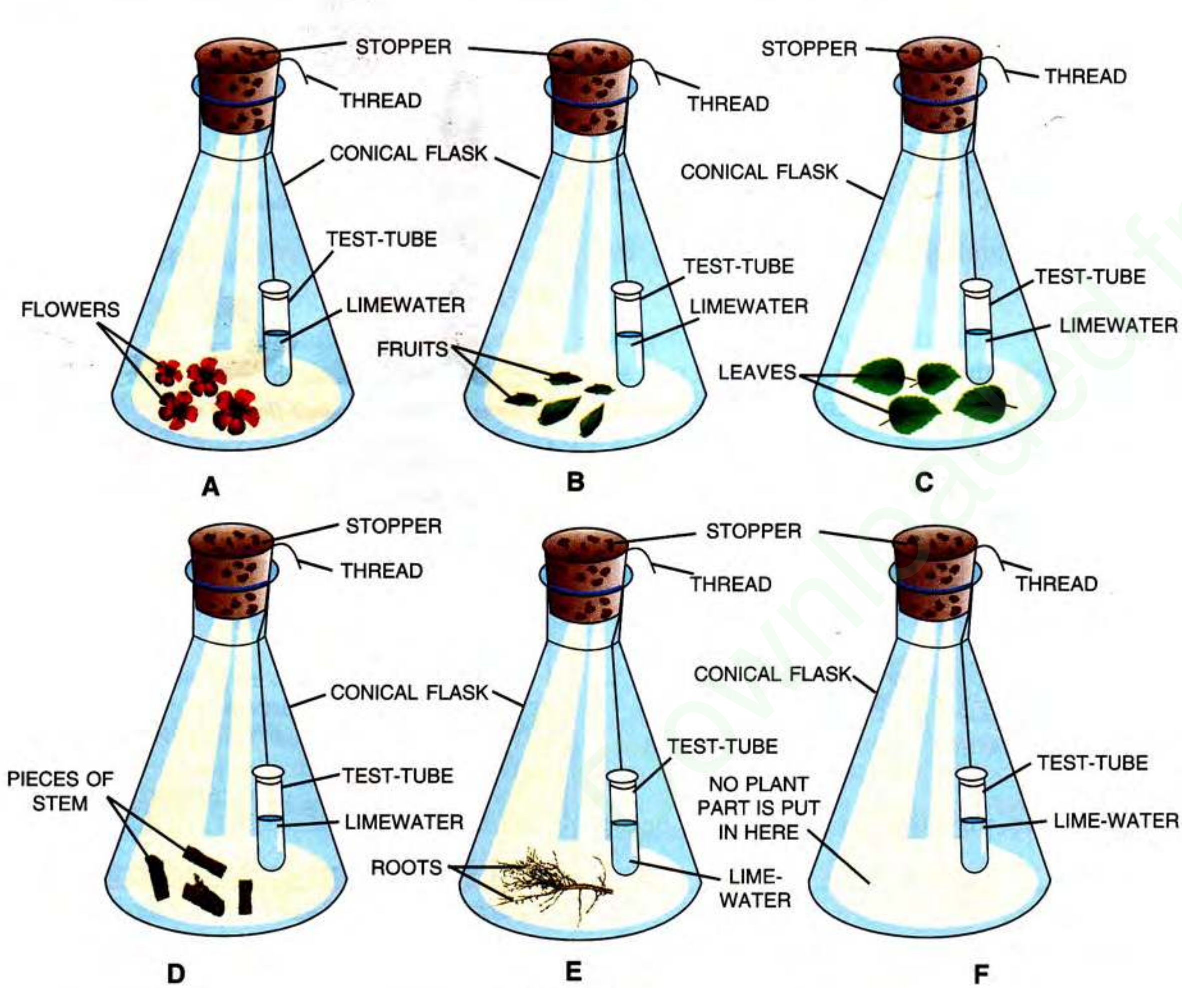
1. What happens to the **energy liberated** in respiration ?
2. **Why** is it usually difficult to demonstrate respiration in green plants ?
3. **Explain** why respiration is said to be the reverse of photosynthesis.
4. **How** is the tilling of the soil useful for the crops growing in it ?
5. Write the **full form** of ATP and ADP.
6. Can **cell respiration** occur in any organism at a temperature of about 65°C ? Give reason.
7. **Fill** in the blanks :
   (a) .... are the openings found on older stems.
   (b) Glycolysis occurs in the .... of the cells.
   (c) .... is a respiratory substance.
   (d) Rate of .... is more than the rate of .... in the daytime in the case of green plants.
   (e) .... is a chemical which absorbs oxygen of the air.
   (f) .... is used to create vacuum to show anaerobic respiration.

D. LONG ANSWER TYPE

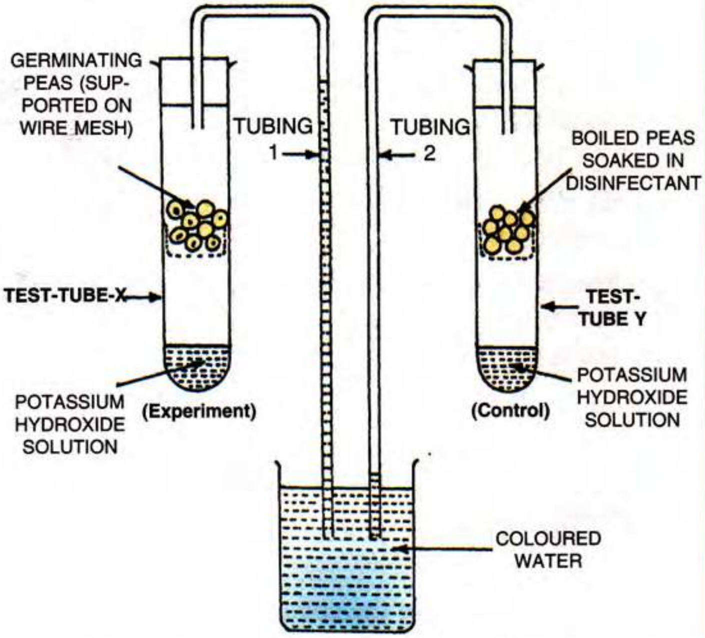
1. What is **respiration** ? How are respiration and burning **similar** and how are they **different**?
2. How are aerobic and anaerobic respirations **different** in plants ?
3. **Describe** one experiment each you would perform to demonstrate the following phenomena : The germinating seeds (a) produce heat, (b) give out carbon dioxide, (c) can respire even in total absence of air.
4. **How** do the following structures help in respiration in plants?
   (a) Lenticels ____________
   (b) Stomata ____________
   (c) Root hairs ____________

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Given below is a set of six experimental set-ups (A-F), kept in this state for about 24 hours.
   (a) In **how many flasks**, the different plant parts have been kept under observation?
   (b) What is the **purpose** of keeping a test-tube containing limewater in each flask?
   (c) In which **tube/tubes** the limewater will turn milky?
   (d) What is the **purpose** of the **set-up** F?
   (e) What **conclusion** can you draw from this experiment?
2. The following two chemical reactions are supposed to indicate a certain process occurring in the green plants under two different conditions :
   (a) $C_6 H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + ... + 38$ ATP
   (b) $C_6 H_{12}O_6 \rightarrow .... + 2CO_2 + 2$ATP
      (i) **Fill in the blank** in each reaction.
      (ii) **Name** the process represented by the two reactions.
      (iii) **What are the conditions** under which the two reactions (a) and (b) are occurring respectively?



3. The following diagram refers to an apparatus which is used to demonstrate a physiological process :



(a) What is the **purpose** of keeping potassium hydroxide solution in the test tubes X and Y?

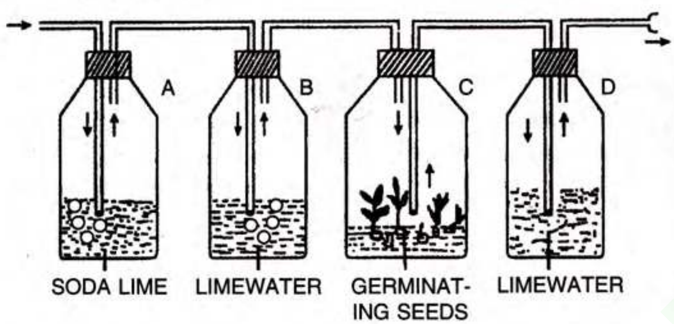
(b) Why has the coloured water risen in **tubing** 1?

(c) What is the **purpose** of keeping boiled peas soaked in a disinfectant in test tube Y?

(d) **Name** the biological process which causes the above rise.

(e) **Define** the biological process shown in the experiment.

4. In order to study and prove a particular physiological process in plants, the following experiment was set up. Study the same and then answer the questions that follow :



(a) **Name** the physiological process being studied.

(b) What is the **function** of soda lime in the bottle 'A' and why is limewater placed in bottle 'B'?

(c) What **change** would you expect to observe in bottle 'D'?

(d) Represent the physiological process named in (a) above in the form of a **chemical equation**.

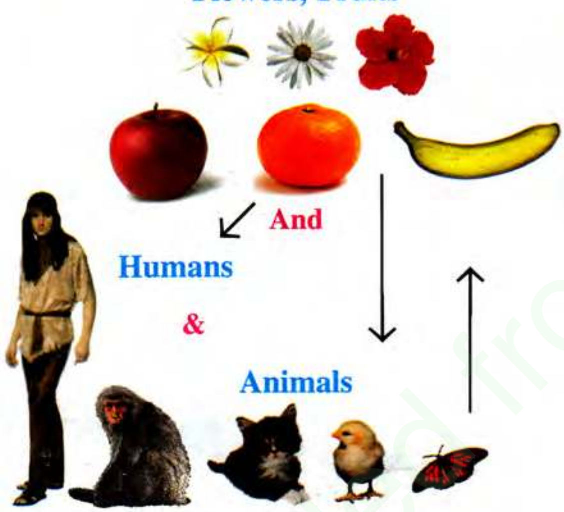
(e) In order to obtain accurate results, the bottle 'C' should be covered with a piece of black cloth. **Why**?

(f) If bottle 'C' was fitted with a 3-holed rubber stopper and a thermometer were introduced in such a way that its bulb reaches close to the germinating seeds, what would you observe? Why?

JUDGE THE TRUTH

The relationship between

Flowers, Fruits



Flowers : ***Plants produce flowers with***

- Colour
- Fragrance
- Nectar (honey)

} To attract insects and birds to **feed on nectar**

"Selfish interest" of plants — Pollination

Fruits : ***Plants produce fruits with***

- Tasty flavour
- Fleshy pulp (as food)

} Humans and animals are attracted and eat them

"Selfish gain" to the plants — Seeds thrown away here and there. **(Dispersal)**

So, Are the plants kind and benevolent ?

OR

Truly **Selfish?**

[Answer ....]