UNIT 6

Living World of Plants - Plant Physiology

Learning Objectives

At the end of this unit the students will be able to understand,

- that Plants too have certain autonomic movements
- how do plants produce their food through the process of photosynthesis?
- that Plants are the primary producers that feed the rest of the living organisms

Introduction

Animals move in search of food, shelter and for reproduction, even microorganisms show movement.

Do plants show such movement?

We see a branch of a tree shaking in heavy thunder storm; and leaves dancing in gentle wind. These movements are caused by an external agency.

6.1 Do they Move on their own Accord?

In short, do plants have spontaneous movements without external agency? Do they breathe? In this chapter we will study some of the biological functions of plants.

6.2 Do Plants Move?

The leaves of *Mimosa pudica* (touch-me-not plant) closes on touching, and in like manner, the stalk of *Helianthus annuus* (sunflower) follows the path of the sun from dawn to dusk, (from east to west) and during night it moves from west to east. The dance of *Desmodium gyrans* (Indian telegraph plant) leaf is mesmerizing.

Mimosa pudica

Helianthus annuus

Desmodium gyrans

These movements are triggered by an external stimuli. Unlike animals, plants may not move on their own from one location to another, but can move their body parts for getting sunlight, water and nutrients and are sensitive to external factors like light, gravity, temperature etc.

More to Know

In *Desmodium gyrans* (Indian telegraph plant), the compound leaf shows three leaflets, one terminal large leaflet and two very small lateral opposite leaflets. The two lateral leaflets move up, move back and then move down and finally back to the original position showing rhythmic movement. *Desmodium gyrans* is also called the dancing plant. This plant was used by Indian scientist Jagadish Chandra Bose for his experiment.

DO YOU KNOW?

Mimosa pudica is called as *Thotta surungi* and *Desmodium gyrans* is called as *Thozhu kanni* in Tamil.

Activity 1

Roots grow down and shoots grow up

You can do this experiment with some of your friends.

Step -1

It is easy and fun. Take four or five earthen cups or small pots and fill them with soil from a field. Add a little cow dung to the soil. Make sure the cups have a hole at the bottom. Label them as A, B, and C. Put some seeds of green gram in all the cups, water them daily. As soon as the seeds sprout, select a shoot of same height from each of the cups. Remove all the other shoots from the cups.

Step-2

You will need a rectangular box with a small window in one of its sides. A shoe box would be ideal. Cut a 1 × 1 cm window in one side. When the shoots are 10 cm long, cover the plants in all the cups except cup A with the rectangular box. When covering the cups, place the box such that opening in each of them face different directions. Keep all the cups including 'A' in open sun light.

Step-3

Wait for three to four days. Remove the box and look at the plants again. Are the plants tilted? To which side are the plants tilted? With opening facing different direction, did all the plants tilt the same direction?

Compile the results and discuss with your friends.

Perhaps you have done such experiments in earlier classes and have found that plants do grow towards the sunlight.

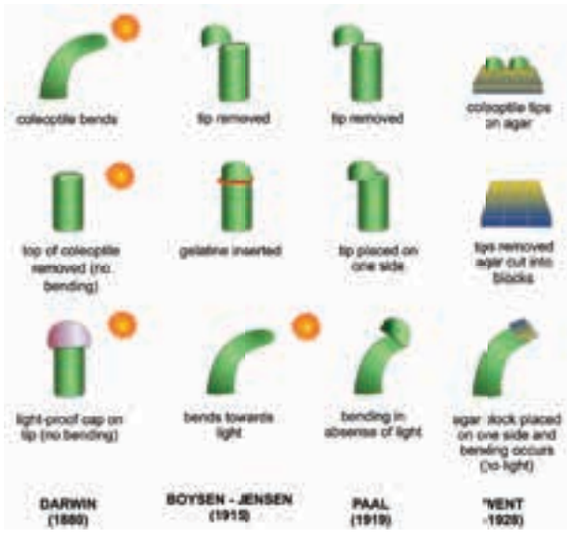
6.3 Do Plants Actually Sense Light?

You would have studied in earlier classes about seed germination. In monocot plants like grass, there is only one first leaf (called cotyledon). Once germinated, the embryo sends a primary root downward into the soil and pushes the primary shoot to the soil surface. The tip of the embryonic shoot (plumule) is covered by a protective sheath called coleoptile. It is the coleoptile covered embryonic shoot that grows above the ground.

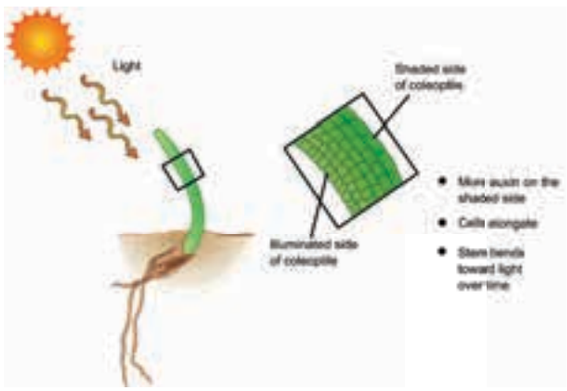
In one of the experiments initially Darwin noticed that germinated seeds also grow towards light. If, in a dark room light is placed in one end, the growing seedlings bend towards the light. In the next experiment, he carefully removed the tip from growing seedlings. The shoot did not bend towards the light. When he covered the tip (Coleoptile) with foil, preventing light from entering, the shoot did not bend. In the next step, he covered the elongating part of the shoot, but left the tip open. Now the bending could be noticed. Covering the elongating part of the shoot did not affect the response to light at all! Darwin concluded "some **'influence'** is transmitted from the tip to the more basal regions of the shoot thereby regulating growth and inducing curvature". This demonstrated clearly that something within the tip of the coleoptile controlled growth of the plant.

Charles Darwin **Peter Boysen-Jensen**

What is this **influence**? In 1913 Peter Boysen-Jensen, a Danish Botanist further developed Darwin's experiments. He found that if he removed the coleoptiles, plant growth stopped. Then he inserted a piece of agar and then placed the coleptile on top of it the plant again was able to curve towards the light. Hence this chemical was predicted to be water soluble. He reasoned that chemicals that controlled the light sensitive movement (phototropism) moved through agar.



In his next experiment he replaced the agar block with butter. The above mentioned water soluble chemical did not dissolve in butter, as expected the chemical did not pass through butter. This water soluble "influence" was later identified as the plant hormone **Auxin**. In response to light, auxin elongates the cells on the dark side of a stem so that the plant literally bends towards the light source.



Bending of the stem towards light

6.4 Types of Tropisms in Plants

Tropism is a growth movement, the direction of which is determined by the direction of the stimuli. Unidirectional movement of plant part to light stimulus is called **Phototropism**. Heliotropism or motion of plant parts like flowers or leaves in response to the direction of the sun is a kind of phototropism. The plant may also respond to gravity and it is termed **Geotropism** or **Gravitropism**. The response to water is called **Hydrotropism**. Climbing vines have to find a suitable support shortly after germination. Once the shoot touches a suitable support, it grows towards the surface it is touching. This is called **Thigmotropism**. Growth or movement of a plant in response to chemical stimuli is called **Chemotropism**. During fertilization, pollen tube grows down the style in response to the sugars in the style is an example of chemotropism.

EX1SPL

Phototropism

Info bits

- Tropism allows plant to get the best conditions for its survival.
- Tropic movements are slow, directional movements towards or away from the stimulus and it depends on growth.
- Nastic movement is an immediate action.

Tropism is generally termed "positive" if growth is towards the signal and "negative", if it is away from the signal. While the shoot in a plant moves towards the light, the roots move away in the opposite direction. Thus the shoots are said to have **positive phototropism,** while the roots have **negative phototropism**. Can you think of an example of a negative hydrotropism?

Positive phototropism (negatively geotropic)

Negative phototropism (positively geotropic)

Activity 2

Experiment to demonstrate phototropism

i) Take pea seeds soaked in water overnight.

ii) Wait for the pea seeds to germinate.

iii) Once the seedling has grown put it in a box with an opening for light on one side.

iv) After sometime, you can clearly see how the stem has bent and grown towards the light.

Info bits

Some halophytes produce negatively geotropic roots (E.g. *Rhizophora*). These roots turn 180° upright for respiration.

Water or gravity?

When a seed germinates the primary shoot, (plumule) goes up while the primary root, (radicle) goes down. What stimulus is making the primary root to go down? Is it gravity or water that is principally responsible for the direction of the growth of a primary root? We can do an interesting experiment to find out for ourselves.

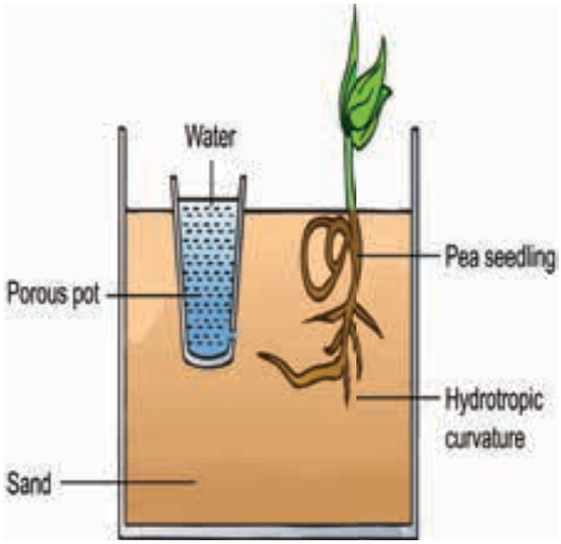
What do you need? Glass trough, sand, flower pot, plugged at the bottom, pea or bean seeds and water.

How to do?

1. A glass trough is taken and is filled with sand. A flower pot containing water, plugged at the bottom is kept at the centre of the glass trough.
2. Soaked pea or bean seeds are placed around the pot in the sand, what do we observe after 6 or 7 days?

What do you observe? It will be observed that radicle has grown towards the pot and moisture instead of growing vertically downward.

What do you conclude? It proves that primary root is positively hydrotropic and that hydrotropism is stronger than geotropism in this case.



Activity 3

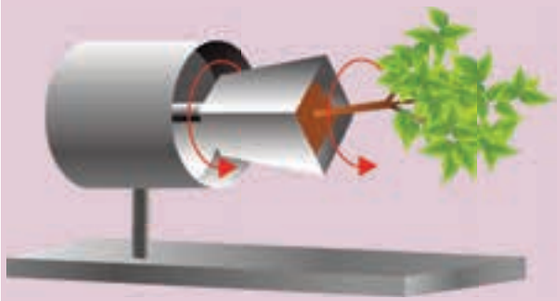
Experiment to demonstrate Geotropism

i) Two Clinostats are taken and a potted plant on each is fixed on a horizontal position.

ii) One Clinostat is rotated and the other is kept stationary.

Observations made after sometime will show that the shoot of the plant fixed on the stationary clinostat bends upwards showing negative geotropism and the root bends downwards showing positive geotropism.

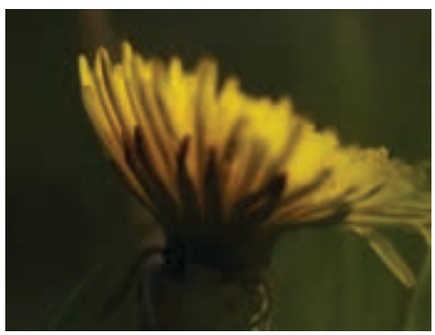
But there is no bending in the root and shoot of the plant fixed on the rotating clinostat. This is due to the fact that gravitational stimulus is not unilateral as it affects the sides of the rotating organs equally.



6.5 More to Movement than Growth

The flower of ***Taraxacum officinale*** (common Dandelion) blooms in the morning and evening it closes (**Photonasty**). ***Ipomoea alba*** (Moon flower) does exactly the opposite. They open in the night and hence the name moon flower and closes in the day time. Just a casual touch is enough to make the ***Mimosa pudica*** (Touch-me-not) leaves fold up and droop (**Seismonasty or thigmonasty**).

Day



Night

Photonasty in Dandelion

Day

Night

Photonasty in Moon flower

The root and shoot move towards the direction of the stimuli, whereas the movement of the opening and closing of the flowers are not directed towards stimuli. Such movements in plants are called as **Nastic movements**. Unlike tropic movement, nastic movements are independent of the stimuli direction and may or may not be growth movement.

Some plants feed on insects and small animals, even a frog. (Example: *Nepenthes, Drosera* and Venus flytrap). The Venus Flytrap (*Dionaea muscipula*) presents a spectacular example of thigmonasty. It exhibits one of the fastest known nastic movements.

Types of Nastic movements

1. Thigmonasty or Seismonasty – touch - Example: *Brunnichia ovata* and *Mimosa pudica*

2. Nictinasty – darkness - Example *Leucaena leucocephala*

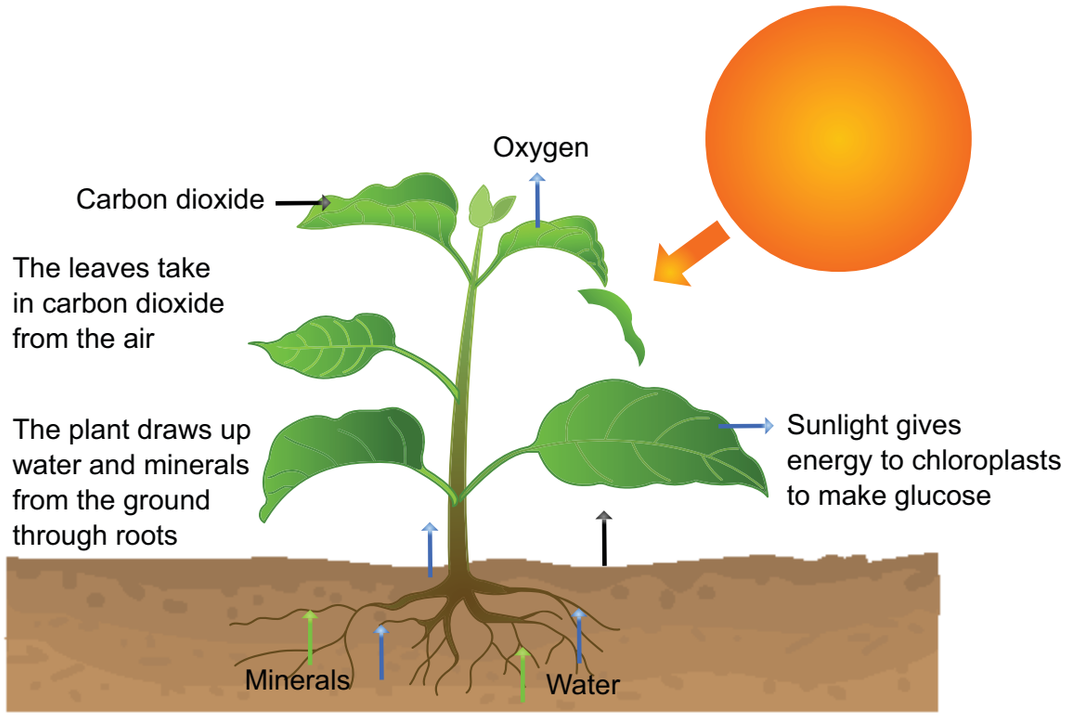
3. Thermonasty – temperature Example: *Tulipa sp*

4. Photonasty – changes in light intensity - *Samanea saman*

Plant parts move as they have clear adaptive advantages. Roots going down are more likely to find water and minerals they need. Stem growing up and towards light is more likely to get sunlight for photosynthesis and display its flowers prominently for pollinators to arrive. It also has better chance of spreading its seeds (Table 1).

Table 1 Differences between tropic and nastic movements

Tropic movements	Nastic movements
Unidirectional response to the stimulus	Non-directional response to the stimulus
Growth dependent movements	Growth independent movements
More or less permanent and irreversible	Temporary and reversible
Found in all plants	Found only in a few specialized plants
Slow action	Immediate action



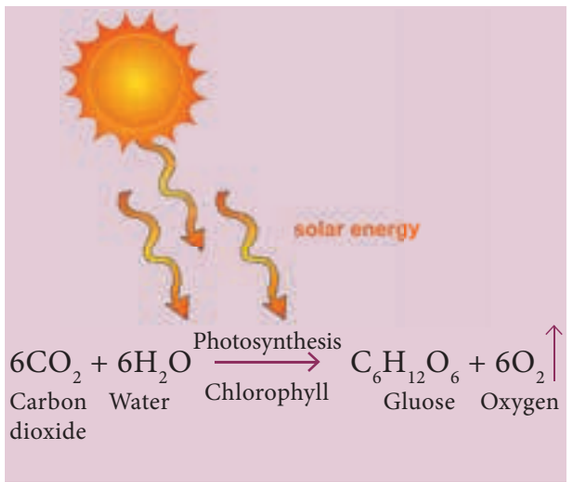
6.6 What is Photosynthesis?

'Photo' means **'light'** and **'synthesis'** means **'to build'** thus photosynthesis literally means **"building up with the help of light"**. During this process, the light energy is converted into chemical energy. Green plants are autotrophic in their mode of nutrition because they prepare their food materials through a process called photosynthesis.

Info bits

Only plants can photosynthesize and release oxygen (O_2). This is converted into ozone (O_3), which protects our mother Earth.

The overall equation of photosynthesis can be given as follows:



The end product of photosynthesis is glucose which will be converted into starch and stored. Plants take in carbon dioxide for photosynthesis; but for its living, plants also need oxygen to carry on cellular respiration.

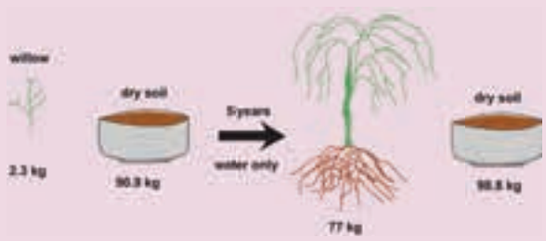
$$\underset{\text{Glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{Starch}}{(C_6H_{12}O_6)_n}$$

More to Know

Look at a gigantic banyan tree. Many years ago it would have been just a sapling. It has grown into a huge tree. How did it gain the mass? Whether it is from soil/water/air? A Belgian scientist, Jan Baptist van Helmont was intrigued by this question and performed an experiment in 1648 to test how much the plant gains from extracting materials out of soil. He devised an interesting experiment to find out.

He took soil and heated it to make it dry. He then measured the weight of the soil. It was 90.9 kg. Can you guess why he first dried the soil? He placed this soil in a container which can transport water through its pores but without soil. He took a small sapling of willow tree, cleaned it and measured its weight. The tree weighed 2.3 kg. He closed the container with a lid having number of holes permitting free movement of air and light, but not dust. The experiment went on for five years, and he added only water to the pot. After five years the sapling grew into a small tree. He uprooted the tree carefully, cleaned it and measured its weight. Now the tree weighed 77.0 kg. Once again he dried the soil in the container and measured its weight. Soil weighed 90.8 kg.

Jan Baptist van Helmont



He was able to see that the plant gained 74.7 kg (77.0 – 2.3 = 74.7) in five years, but the soil had lost only 0.1 kg (90.9 – 90.8 = 0.1 kg) in five years. So, we can see that soil is not the major contributor to the gaining of the mass of the plant. Perhaps like vitamins in Humans, soil may supply vital elements and crucial, but that is not how plants make their food is clear. Van Helmont thought water alone was the cause of the increase in weight. Do you agree? Can you think of any other factor that could have added mass to the growing tree? The next step in our understanding is the process by which plants produce food came from the experiments of Joseph Priestley.

Priestley devised an extraordinary experiment in 1771. First he burned a candle inside a jar and converted all the oxygen into carbon dioxide. (How can you be sure that all the oxygen inside the jar has been converted into carbon dioxide?) Now he placed a sprig of mint inside the jar, without outside air mixing with the gases inside the jar. He waited for ten days. Using a lens he re-lit the candle from outside. (Why he did not use a matchstick?) The candle burned. This means that oxygen was once again inside the jar. Priestley concluded that sprig of mint had absorbed the carbon dioxide and released oxygen. That is why, he said, the candle was lit again. Priestley concluded that the plant was converting the carbon dioxide back into oxygen.

Joseph Priestley

6.6.1 What else is needed for photosynthesis?

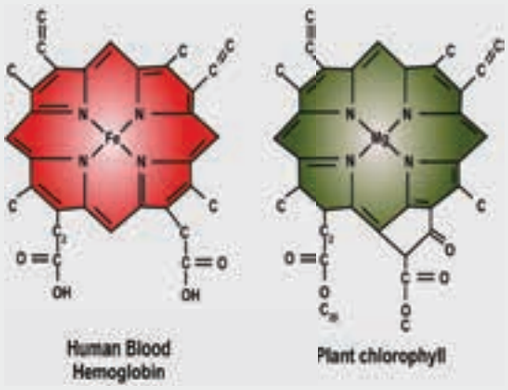
Photosynthesis is the process by which plants make their food. A small speck of seed grows and gains weight into a giant tree, due to photosynthesis. Almost all the other organisms rely on plants for their food directly or indirectly. Even a carnivore depends ultimately upon plants for its food, how? Can you highlight? Four important things needed by plants for photosynthesis:

1) Chlorophyll - Green pigment present in leaves
2) Water
3) Carbon dioxide (from air)
4) Light

Let us examine two of these factors

Info bits

Structurally chlorophyll resemble haemoglobin but differ with the central molecule.



Chlorophyll

Aim: To show that chlorophyll is essential for photosynthesis.

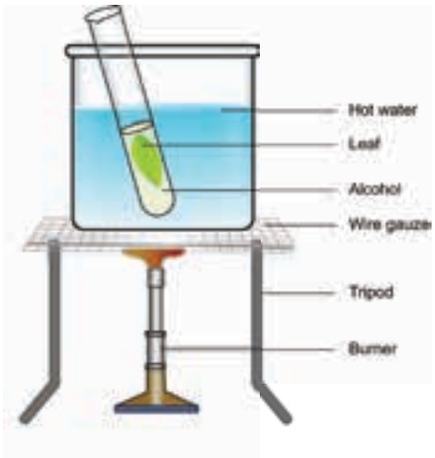
We need *Coleus* (croton) plant with variegated leaves, boiling water, alcohol and iodine solution.

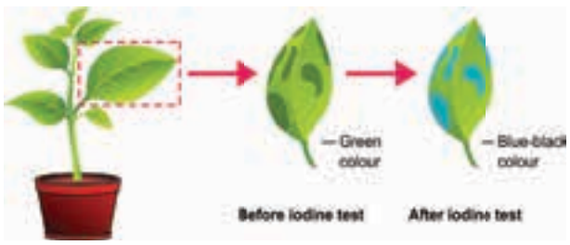
How to do?

Variegated leaf is plucked from *Coleus* plant kept in sunlight after de-starching by keeping it in dark room for 24 hours. The picture of the leaf is drawn and the patches of cholorphyll on the leaf are marked. After immersing the leaf in boiling water then in alcohol it is tested for starch with iodine solution.

What do you observe? The patches of the leaf with chlorophyll turn blue-black. The other portions remain colourless.

What you conclude? The chlorophyll is essential for photosynthesis.





Plants take up water through their roots and air through stomata of their leaves. Chlorophyll is present in the leaf. What else is needed for photosynthesis? The question that remains to be answered is whether the process of forming starch by combining carbon dioxide and water also requires light. Let us do an experiment.

Light

Aim: To show that sunlight is necessary for photosynthesis.

What do you need? potted plant, black paper, boiling water, alcohol and iodine solution.

How to do?

A potted plant is placed in a dark room for about 2 days to de-starch its leaves. One of its leaves is covered with the thin strip of black paper as shown in the picture. make sure that the leaf is covered on both sides.

The potted plant is kept in bright sunlight for 4 to 6 hours. The selected covered leaf is plucked and the black paper is removed. The leaf is immersed in boiling water for a few minutes and then in alcohol to remove chlorophyll. The leaf is now tested with iodine solution for the presence of starch. The covered part of the leaf does not turn blue-black whereas the uncovered part of the leaf turns blue-black colour. The covered part of the leaf which did not receive the sunlight was unable to synthesize starch. Hence it does not turn blue-black colour. But the uncovered part of the leaf which received sunlight was able to synthesise starch and so it turns blue-black in colour.

DO YOU KNOW?

Scientists have discovered a brilliant emerald green sea slug, *Elysia chlorotica* that was photosynthetic to produce energy. The sea slug consumes alga *Vaucheria litorea*, which is not fully digested. Instead, the algae remain in the creature's system and continue to provide food for the slug through continued photosynthesis.

DO YOU KNOW?

Sunlight can penetrate 100 m to 200m into the oceans, gradually dims as the depth increases. Is it possible for the organisms that live deep into the ocean to do photosynthesis?

A team of researchers including a photosynthesis expert from ASU (Arizona State University, USA) have found that photosynthesis taking place deep within the Pacific Ocean. They discovered a green sulphur bacteria living near hydrothermal vents nearly 2400m deep into the ocean of Mexico. This bacteria lives in the razor-thin interface between extremely hot water (350° C or 662° F) and very cold water (2°C or 36° F) surrounding it. "This is just one example of life in extreme environments."

All these four things must be in the leaf, the site where plants make their food. That raises an interesting question. Of the four,

chlorophyll is present in the leaf. Sunlight falls on the leaf. But how do plants take air and water to its leaf? How does the water reach the leaves from the roots? What path does it follow? How does air enter the leaf?

6.6.2 Exchange of gas

Roots of the plant take the water from the soil and transport it to leaves. How water and other nutrients reach the leaf from the roots? Is the only question that we need to find out? We will see this later. This leaves us with only one question? How does the plant get air? The leaves have tiny holes, called **stomata**, through which the exchange of air takes place. These holes are so minute that we need a microscope to see them. The air exchange takes place continuously through the stomata. Plants inhale and exhale continuously through these stomata.

6.6.3 Transpiration

The loss of water in the form of water vapour from the aerial parts of the plant body is called as transpiration. There are three types of transpiration:

1. Stomatal transpiration - This is the most dominant form of transpiration being responsible for most of the water loss in plants. It accounts for 90-95% of the water transpired from leaves.
2. Cuticular Transpiration – This type of transpiration is responsible for the loss of water in plants via the cuticle.
3. Lenticular Transpiration – This type of transpiration is the loss of water from plants as vapor through the lenticels. The lenticels are tiny openings that protrude from the barks in woody stems and twigs as well as in other plant organs.

More to Know

Plant absorbs water from soil and uses it for photosynthesis. A chemical analysis shows that 100 grams of water reacts with 260 grams of carbon dioxide to form 180 grams of carbohydrate. 180 grams of oxygen is created in this process. But the plant does not use all the water it absorbs through its roots to produce carbohydrates. Actually, most of this water evaporates in the air.

Experiment 1

If you tie a plastic bag over a leaf and place the plant in light, you will be able to see water condensing inside the plastic bag. The water is let out by the leaves.

The leaves have tiny, microscopic holes called stomata. Water evaporates through these stomata. Each stomata is surrounded by guard cells. These guard cells help in regulating the rate of transpiration by opening and closing of stomata.

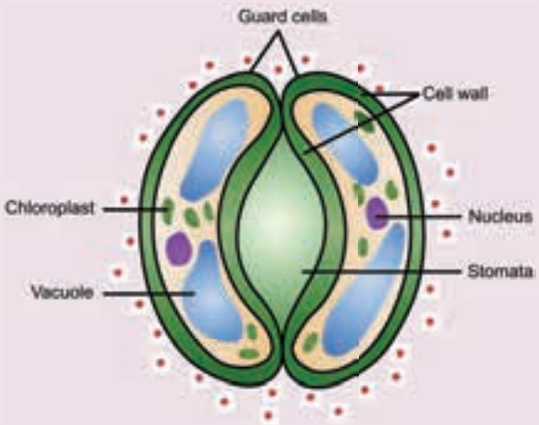
Typically, only 0.1 percent of water taken up by the plant is used by the plant for producing carbohydrates. That is, if a plant absorbs one litre of water, only one millilitre will be used to produce carbohydrate. The remaining 999 millilitres evaporates from the leaf. You will be able to see how much water a plant releases in the air.

DO YOU KNOW?

Guard cells of stomata are green but can't photosynthesize.

Why?

It is Because, Enzymes RUBISCO and NADP-dehydrogenase are absent.



Info bits

Plant use only 1% of water absorbed and remaining 99% is lost through transpiration. A maize plant transpire 54 gallons of water during its life span.

Activity 4

To observe the impression of stomata.

Nail polish is applied on the lower surface of the leaves of a potted plant. After a few minutes, the nail polish is gently peeled off. This nail polish peeling is placed a drop of water on a slide. The cover slip is placed and the peeling is observed under the microscope. Through the microscope, we can see the impression of the cells and the stomata. We know that more water evaporates when the weather is hot. In such a situation, the stomata begin to close. This lessens the amount of water that evaporates from the leaves. Like manner plants adapted to dry land and desert habitat have special adaptations to ensure conservation of water.

Transpiration is a necessary evil

- creates a pull in leaf
- creates a pull in stem
- creates an absorption force in roots, so takes more water

But

- this is necessary for continuous supply of minerals
- This regulates the temperature of the plant.

DO YOU KNOW?

The conifers have a pyramid shape - Isn't it wonderful? Coniferous trees like spruces, pines and firs have a unique geometrical three-sided pyramid shape. They rely on the sunlight all around the year for photosynthesis. Their pyramidal shape allows all the branches to receive more sunlight since the top branches don't shade the bottom branches. The major branches of the conifers are layered with an open area between the layers. This helps in passing through light and the tree to get enough light especially when sunlight comes in at a low angle during the winter months.

DO YOU KNOW?

Why do we get more rainfall in the Amazon? The Amazon is the most biodiverse terrestrial place on the planet. In the Amazon, deep-rooted trees increase local transpiration and high tree cover increase local interception evaporation. These increased evapotranspiration fluxes have positive effects on forests as they stimulate rainfall. ¾ of the rainfall received by the Amazon tropical rainforest comes from plant transpired water vapour, which is visible as a mist.

Suppose the weather is hot and the stomata close; what would be the effect of such a situation in the absorption of carbon dioxide? Will the rate of photosynthesis be the same? If the plant does not get water at this time, what effect would this have on its growth? Relate your answer to the problem of drought affecting agricultural growth. Global warming implies increased level of average temperature. Can you reason what all the effect it can have on photosynthesis?

6.6.4 Macronutrients and micronutrients for plants

Nutrients such as carbon, hydrogen, oxygen, nitrogen, potassium, calcium, magnesium, sulphur and phosphorus, are required in substantial quantity and are called **macronutrient**. Plants also require many other nutrients like iron, manganese, copper, boron, molybdenum, chlorine, silicon, cobalt, and zinc, but only in minute quantities, hence, they are called **micronutrients**. The water transportation systems of the plants take these nutrients from the soil and circulate it in the plant.

DO YOU KNOW?

The plants trap solar energy for photosynthesis. Do the insects also trap solar energy? Tel Aviv University Scientists have found out that *Vespa orientalis* (Oriental Hornets) have similar capabilities to trap solar energy. It has a yellow patch on its abdomen and an unusual cuticle structure which is a stack of 30 layers thick. The cuticle does not contain chlorophyll but it contains the yellow light sensitive pigment called xanthopterin. This works as a light harvesting molecule transforming light energy into electrical energy.

6.7 Food chain: the Link between Plants, Animals and Microorganisms

Plants are called primary producers. They produce starch, protein and fats from sunlight, water and carbon dioxide and other nutrients. Some of the animals and microorganism consume the plants and grow and gain weight. The carnivorous animals eat the animals that graze and gather energy from the plants. The dead plants and animals are decomposed by microorganisms. Some of the microorganisms decompose and make some of the nutrient available in a manner for the plants to absorb from soil. Thus a series of organisms each dependent on the next as a source of food. This link is called as food chain.

6.8 Respiration in plants

Like animals, plants too respire. During respiration, plants inhale oxygen and exhale carbon dioxide like animals. This process goes on 24 hours of the day and night. It is during the photosynthesis that it uptake carbon dioxide and exhale oxygen. Obviously photosynthesis occurs in most plants only during the daytime.

A-Z GLOSSARY

1. **Tropism** Growth movement whose direction is determined by the direction of the stimulus.
2. **Phototropism** The unidirectional movement of a plant part to light stimulus.
3. **Geotropism** Response of a plant part to gravity stimulus.
4. **Hydrotropism** Response of a plant part to water stimulus.
5. **Thigmotropism** Response of a plant part to touch stimulus.
6. **Chemotropism** Response of a plant part to chemical stimulus.
7. **Nastic movement** Non-directional, response of a plant part to stimulus.
8. **Thigmonasty** The non-directional movement of a plant part in response to the touch of an object.
9. **Photonasty** The non-directional movement of a plant part in response to the light.
10. **Photosynthesis** The process by which plants prepare their food material.
11. **Transpiration** The loss of water in the form of water vapour from the aerial parts of the plant body.
12. **Stomata** Minute opening on the leaves.

EXERCISE

EXANR9

I. Multiple Choice Questions (MCQs)

1. A big tree falls in a forest but its roots are still in contact with the soil. The branches of this fallen tree straight up. This happens in response to _____.
   a) water and light
   b) water and minerals
   c) gravity and water
   d) light and gravity

2. The tropic movement that helps the climbing vines to find a suitable support is _____.
   a) phototropism
   b) geotropism
   c) thigmotropism
   d) chemotropism

3. The chemical reaction occurs during photosynthesis is _____.
   a) CO_2 is reduced and water is oxidized
   b) water is reduced and CO_2 is oxidized
   c) both CO_2 and water are oxidized
   d) both CO_2 and water are produced

4. Transpiration is best defined as _____.
   a) loss of water by the plant
   b) evaporation of water from the aerial surfaces from the plant
   c) loss of water in the form of water vapour from the underground parts of the plant body
   d) release of water from the plant into the atmosphere

II. State whether the following statements are true or false. If false, write the correct statement

1. The response of a plant part to the chemical stimulus is called phototropism.
2. Shoot is positively phototropic and negatively geotropic.
3. Scientific term used to represent the bending of roots towards water is called geotropism.
4. Joseph Priestley devised an experiment to find out that water alone was the cause of the increase in the weight of the plant.
5. When the weather is hot, water evaporates lesser which is due to opening of stomata.

III. Fill in the blanks

1. The shoot system grows upward in response to _____
2. _____ is positively hydrotropic as well as positively geotropic.
3. The green pigment present in the plant is _____
4. The minerals like nitrogen, potassium and phosphorus, are required in substantial quantity by the plants are called _____

IV. Match column A with column B

	Column A	Column B
1.	Roots growing downwards into soil	Positive phototropism
2.	Shoots growing towards the light	Negative geotropism
3.	Shoots growing upward	Negative phototropism
4.	Roots growing downwards away from light	Positive geotropism

V. Analog

1. Towards a stimulus :_____ Away from the stimulus : Negative tropism
2. Hydrotropism : Response towards water Phototropism : _____
3. Photosynthesis : _____ Transpiration : Stomata

VI. Answer in a word or two

1. Give an example for a plant whose leaf shows a mesmerizing movement.
2. Write the scientific terms used to represent the following:
   a) Growing of roots towards the gravity.
   b) Bending of roots towards the water.
3. **Observe the given picture.**
   a) Identify this plant. What type of special movement is shown by this plant?

   b) What are the other movements seen in this plant?
4. What is the end product of photosynthesis?
5. Name the minute openings seen on the lower surface of the leaf.

VII. Answer the following in one or two sentences

1. What is nastic movement?
2. Name the plant part
   a) Which bends in the direction of gravity but away from the light.
   b) Which bends towards light but away from the force of gravity.
3. Differentiate phototropism from photonasty.
4. Photosynthesis converts energy X into energy Y.
   a) What are X and Y?
   b) Green plants are autotrophic in their mode of nutrition. Why?
5. Define transpiration.

VIII. Answer in detail

1. Design an experiment to demonstrate hydrotropism.

WORK BOOK

I. Multiple Choice Questions

1. The bending of root of a plant in response to water is called _____.

a) thigmonasty

b) phototropism

c) hydrotropism

d) photonasty

2. A growing seedling is kept in the dark room. A burning candle is placed near it for a few days. The top part of the seedling bends towards the burning candle. This is an example of _____.

a) chemotropism

b) thigmotropism

c) phototropism

d) geotropism

3. The root of the plant is _____.

i) positively phototropic but negatively geotropic

ii) positively geotropic but negatively phototropic

iii) negatively phototropic but positively hydrotropic

iv) negatively hydrotropic but positively phototropic

a) (i) and (ii)

b) (ii) and (iii)

c) (iii) and (iv)

d) (i) and (iv)

4. The plant part which exhibits negative geotropism is _____.

a) root

b) stem

c) branch

d) leaves

5. The non-directional movement of a plant part in response to temperature is called _____.

a) thermotropism

b) Thermonasty

c) chemotropism

d) thigmonasty

6. Dandelion flowers open the petals in bright light during the day time but close the petals in dark at night. This response of Dandelion flowers is called _____.

a) geonasty

b) thigmonasty

c) chemonasty

d) photonasty

7. During photosynthesis plants exhale _____.

a) Carbon dioxide

b) oxygen

c) hydrogen

d) helium

8. Chlorophyll in a leaf is required for _____.

a) photosynthesis

b) transpiration

c) tropic movement

d) nastic movement

9. A plant is kept in a dark room for about 24 hours before conducting any experiment on photosynthesis in order to _____.

a) remove chlorophyll from the leaf

b) remove starch from the leaves

c) ensure that photosynthesis occurred

d) to prove transpiration

10. Transpiration takes place through _____.

a) fruit b) seed

c) flower d) stomata

II. Fill in the blanks

1. The solar tracking of sunflower in accordance with the path of sun is due to _____.
2. The response of a plant part towards gravity is _____.
3. When the leaves of a sensitive plant are touched with a finger, they fold up and when light fades at dusk the petals of a Dandelion flower close. These two plants show _____ and_____ movements.
4. Opening and closing of Moon flower is not a tropism because the movement in this is _____.
5. The raw materials for photosynthesis are _____ and _____.
6. When iodine solution is added for testing starch, part of the leaf with _____ turn blue-black colour.
7. In leaves, the food is stored in the form of _____.
8. Plants may inhale carbon dioxide for photosynthesis but need _____ for their living.
9. Plants utilize only _____% of the absorbed water for photosynthesis and the other activities.
10. Plants inhale and exhale continuously through the _____.

III. State whether the following statements are true or false. If false write the correct

statement:

1. When the leaves of ***Mimosa pudica*** plant are touched with the finger, they fold up quickly.
   This is an example of thigmonasty.
2. The petals of moon flower open up in morning and closes in the evening. This is called photonasty.
3. Photosynthesis produces glucose and carbon dioxide.
4. Photosynthesis is important in releasing oxygen to keep the atmosphere in balance.
5. Plants lose water when the stomata on leaves are closed.

IV Match the following

S. No.	Column A	Column B	Column C
1.	Photonasty	Response to temperature	*Tulipa sp*
2.	Thigmonasty	Response to light	*Mimosa pudica*
3.	Thermonasty	Response to touch	Moon flower

V. Answer in a word or two

1. Give the technical terms for the following:
   a) Growth dependent movement in plants.
   b) Growth independent movement in plants.
2. Study the pictures below and then complete the table by putting a plus (+) if the shoot or root grows towards the stimulus and a minus (-) if it grows away from it.

Stimulus	Light	Gravity
Shoot	+	_
Root	?	+

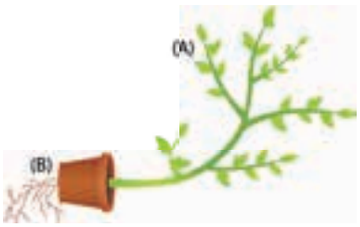
3. Name the movement seen in Pneumatophores of *Avicennia*.
4. What is the other name for thigmonasty?
5. Which flowering plant shows photonasty just opposite to that of Dandelion?
6. Give an example for negative hydrotropism.
7. Fill in the blanks:

$$6CO_2 + \_\_\_ \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \_\_\_ + 6H_2O + 6O_2\uparrow$$

8. Which gas is evolved during photosynthesis?
9. What is chlorophyll?
10. Give an example for micronutrients.

VI. Answer the following in one or two sentences

1. Name the part of plant which shows positive geotropism. Why?
2. What does a *Mimosa pudica* plant do in response to touch? What is the phenomenon known as?
3. i) What happens to the dandelion flower
   a) during the daytime?
   b) at night?
   ii) What is the phenomenon known as?
4. What is the difference between movement of flower in sunflower plant and closing of the leaves in the *Mimosa pudica.?*
5. Define photosynthesis.
6. Suppose you have a rose plant growing in a pot, how will you demonstrate transpiration in it?
7. Draw the diagram of open stoma and label the parts.
8. A potted plant is kept horizontally for a considerable time. The three positions of the part A and B of the potted plant are shown in the following figures.
   (i) Potted plant with shoot and root growing downward. (Diagram to be drawn)
   (ii)



   (iii) Potted plant with shoot and root growing upward (Diagram to be drawn)
   a) Which figure shows the correct position taken by the parts A and B of the plant?
   b) What type of phenomenon is exhibited by the figure by (A) in the figure (ii)?

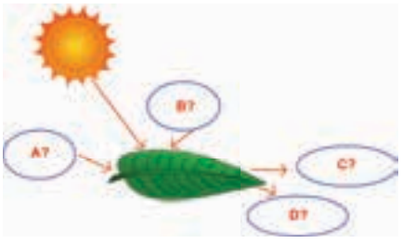
9. Complete the following table with the different types of tropism:

Stimulus		Gravity	Unilateral light	Water
Tropism		Geotropism	?	Hydrotropism
Response	Shoot	?	Positive	No response
	Root	Positive	?	?

10. Cover the tip of the shoot with tin foil cap and light it from the side as shown in the given picture. What would you expect to happen? Why?

11. In the given photosynthetic experiment, what will happen to the leaf closed with black paper in starch test? Why?

12. Label the diagram with the raw materials and products of photosynthesis.



13. Mention the differences between stomatal and lenticular transpiration

14. Give an example for the movement plant part which is very quick and can be observed easily.

15. To which directional stimuli do (a) roots respond (b) shoots respond?

16. Name the cell that surrounds the stoma.

VII. Assertion and reason

1. Assertion (A): If the plant part moves in the direction of gravity, it is called positive geotropism.

   Reason (R) : Stem shows positive geotropism

   a) A and R are incorrect
   b) A is incorrect, R is correct
   c) A is correct, R is incorrect
   d) Both A and R are correct

2. Assertion (A): The loss of excess water from the aerial parts of the plant in the form of water vapour is known as transpiration.

   Reason (R) : Stomata of the leaf perform transpiration.

   a) A and R are incorrect
   b) A is incorrect, R is correct
   c) A is correct, R is incorrect
   d) Both A and R are correct

VIII. Higher order thinking questions (HOTS)

1. There are 3 plants A, B and C. The flowers of A open their petals in bright light during the day but close them when it gets dark at night. On the other hand, the flowers of plant B open their petals at night but close them during the day when there is bright light. The leaves of plant C fold up and droop when touched when fingers or any other solid object.

   a) Name the phenomenon shown by the flowers of plant A and B.

   b) Name one flower each which behaves like the flowers of plant A and B.

   c) Name the phenomenon exhibited by the leaves of plant C.

   d) Name a plant whose leaves behave like those of plant C.

2. While conducting experiments to study the effects of various stimuli on the plants, it was observed that the roots of a plant X grow and bend towards two stimuli A and B but bend away from a third stimulus C. The stem of the plant X however bends away from stimulus A and B but bends towards the stimulus C. The stimulus B is known to act on the roots due to factors related with Earth. Keeping these points in mind, answer the following questions:
   a) What could be stimulus A ?
   b) Name the stimulus seen in B.
   c) What could be stimulus C ?
3. An organism A which cannot move from one place to another makes a simple food B from the substances C and D available in the environment. This food is made in the presence of green coloured substance E present in organs F in the presence of light energy in a process called G. Some of the simple food B also gets converted into a complex food H for storage purposes. This food gives blue-black colour with iodine solution?
   a) What is (i) organism A (ii) food B and food H?
   b) What are C and D?
   c) Name (i) green pigments E and organ F.
   d) What is the process G?
4. Imagine that student A studied the importance of certain factors in photosynthesis. He took a potted plant and kept it in dark for over 24 hours. In the early hours of the next morning, he covered one of the leaves with dark paper in the centre only. Then he placed the plant in sunlight for a few hours and tested the leaf which was covered with black paper for starch.
   a) What aspect of photosynthesis was being investigated?
   b) Why was the plant kept in the dark before the experiment?
   c) How will you prove that starch is present in the leaves?
   d) What are the other raw materials for photosynthesis?

REFERENCES

1. Plant physiology by Devlin and Witham first Indian edition 1986.
2. Modern practicals botany B.P. Pandey vol. II. New print 2003.
3. Plant physiology by V.K. Jain first edition 2003.

INTERNET RESOURCES

1. http://web.mit.edu/esgbio
2. http://www.cellbiol.com/bioinformatics_web_development
3. http://www.bioedonline.org/
4. http://www.biology.arizona.edu/default.html
5. https://www.gbif.org/