BIOLOGY

TRANSPIEATION

Chapter - 4

CLASS -10

KRISHNAGAR ACADEMY

SYLLABUS

- *The rise of water up to the xylem; a general idea of cohesive, adhesive forces and transpirational pull; demonstrated by the use of dyes.*
- *Transpiration, process and significance; experimental work includes the loss in weight of a potted plant or a leafy shoot in a test tube, the use of cobalt chloride paper. Ganong's potometer and its limitations. The effect of external conditions on the rate of water loss should be stressed.*
- *Mechanism of stomatal transpiration must be explained so that concept of the process is clear. Adaptations in plants to reduce transpiration to be dicussed. A brief idea of guttation and bleeding should be given.*

TRANSPIRATION

Most plants continuously absorb water and minerals from the soil by their roots. The quantity of the water absorbed by plants is huge, but they retain just a very small part of it for their use in vital activities and lose rest of it as vapours to the atmosphere. This water-loss takes place through surface of aerial parts of the plant such as stem, leaves, buds and flowers. However, leaves participate most actively in this loss.

Definition of Transpiration : The loss of water vapours from aerial parts of a plant is called transpiration.

Transpiration is the phenomenon of loss of water in the form of water vapour through the aerial parts of plants. It primarily helps the plants to get rid of the water accumulated in their tissues, but it also cools the plant in hot weather and creates a suction force in the stem which pulls the water through the roots.

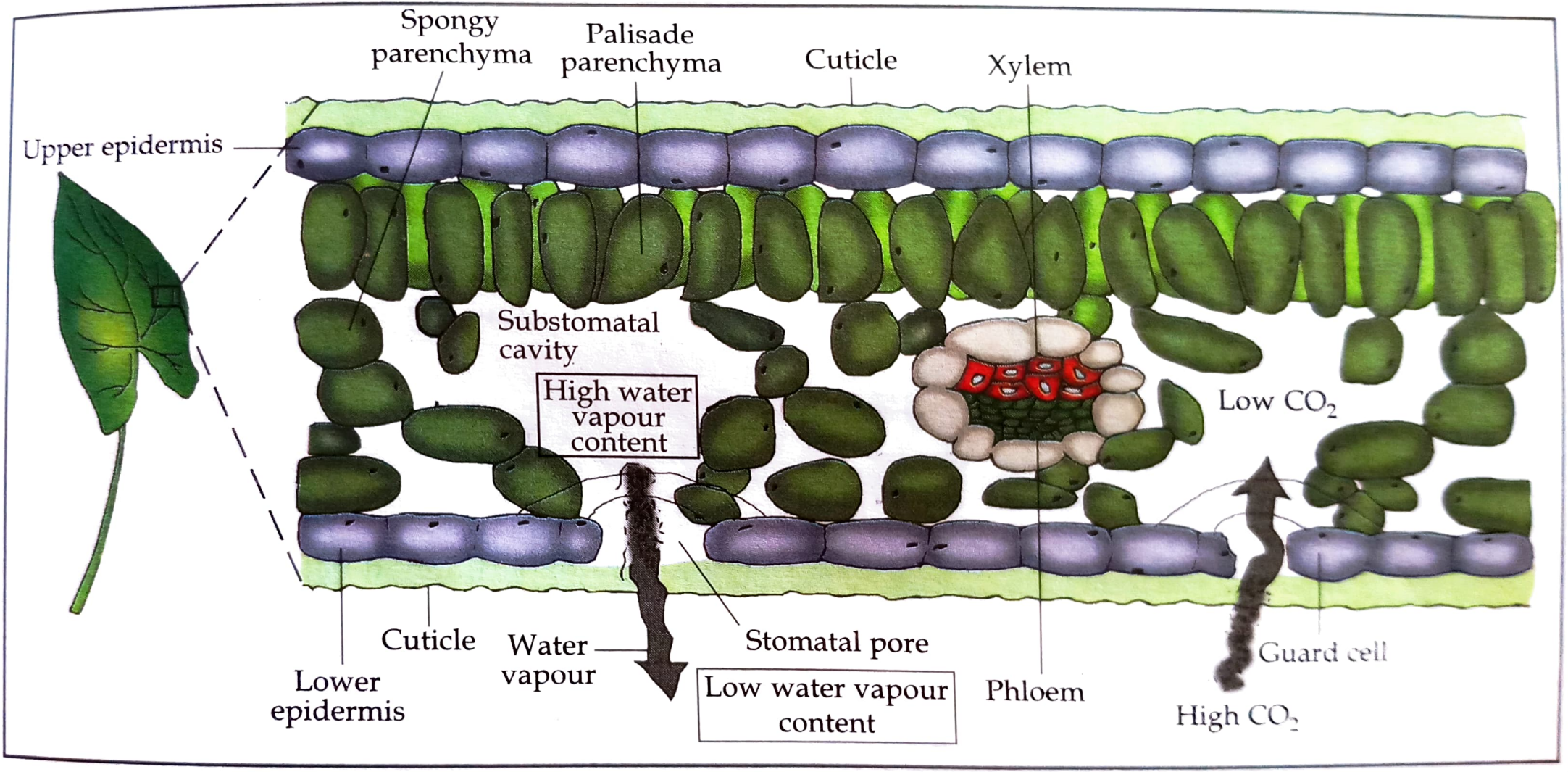


Fig. 5.1: Water escapes through the leaf to the atmosphere in the form of vapour

MODES OF TRANSPIRATION

In a typical plant, transpiration can occur in the following three ways:

(*a*) **Stomatal Transpiration:** Through the stomata present on the surface of leaves.

(*b*) **Cuticular Transpiration:** Through the surface of leaves and stem.

(*c*) **Lenticular Transpiration:** Through the lenticels present on the surface of stem.

Mechanism of Stomatal Transpiration

Stomata are surrounded by two kidney-shaped guard cells. *The wall of the guard cells is thick and inelastic towards the stomatal opening, while it is thin and elastic, away from the opening.* The stomata open into a **substomatal cavity** which is lined by cells. This cavity is interconnected with intercellular spaces present among the mesophyll cells. You have learnt that plants absorb water from the soil which gradually reaches intercellular spaces in the form of water vapours. This arrangement of cells and spaces results in the direct contact of the internal atmosphere of a leaf with the external environment. As a result the water vapours diffuse from intercellular spaces to substomatal space and escape into the atmosphere through stomata.

The entire movement of water during stomatal transpiration occurs due to

(*a*) turgor pressure, and

(*b*) osmotic concentration of the cells.

Cuticular Transpiration

The transpiration in a plant that takes place through the cuticle of leaves and stems is called ***cuticular transpiration.***

The cuticle is a wax-like layer that covers the stems and both the surfaces of a leaf. This layer prevents evaporation of water from the plant and protects it from water loss. In the absence of cuticular layers, plants are unable to retain water and so they wilt and may die. However, a small amount of water loss can take place through cuticle too. The amount of water lost depends on the thickness of cuticle layer. *Greater the thickness of cuticle, lesser is the water loss from the leaves and stem.*

Lenticular Transpiration

Lenticels are small openings in the corky tissues covering old stems and twigs. These are always open and water or air can escape easily through these openings. *The loss of water vapours through lenticels is known as* ***lenticular transpiration.***

During cold season, water absorption by roots is very less and the importance of lenticular transpiration is increased. Thus, lenticular transpiration may cause desiccation in trees that shed their leaves with the onset of winter.

Rate of Transpiration

Stomatal transpiration > Lenticular transpiration > Cuticular transpiration

The amount of water lost through cuticular and lenticular transpiration is insignificant compared to the amount of water lost through stomatal transpiration.

However, under dry conditions, when stomata are closed, water loss through cuticle and lenticels can be considered important.

MECHANISM OF STOMATAL TRANSPIRATION

The water absorbed by root hairs enters xylem vessels of the root and rises up to reach the xylem vessels of the stem. Finally it enters the vessels of fine veins of leaves through the mid-rib. These vessels are surrounded by the mesophyll cells which have large intercellular air spaces among them. These spaces are filled with air.

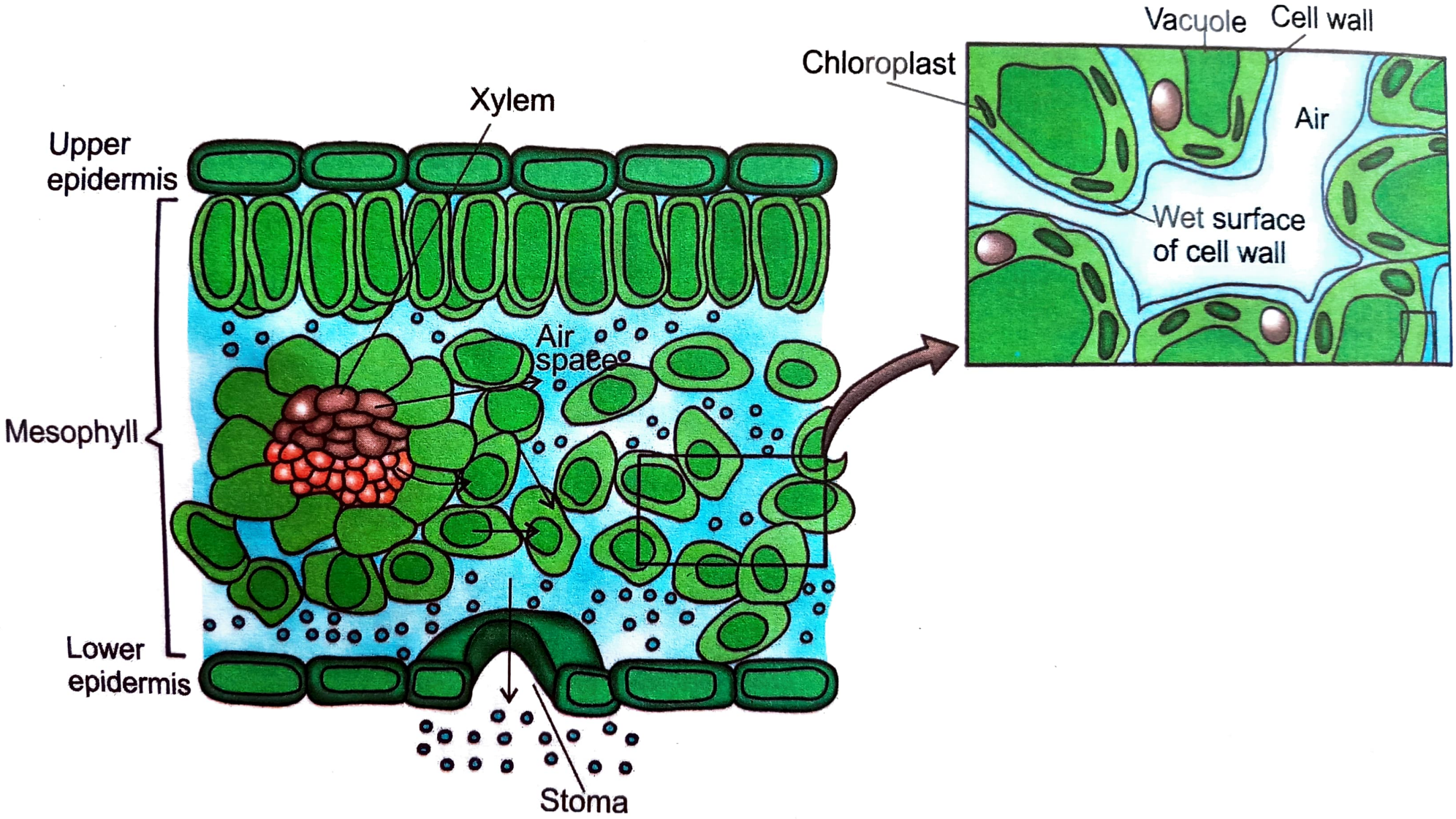
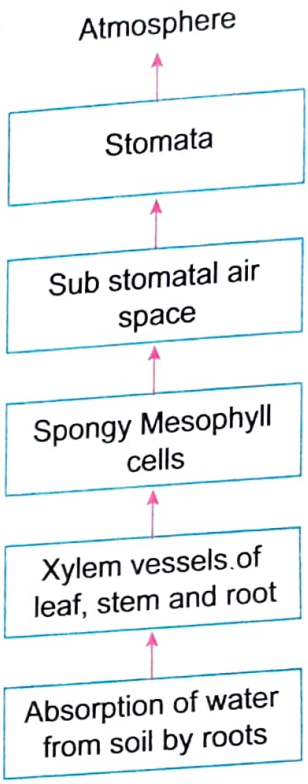


Fig. 6. Loss of water vapour through stoma in a dicot leaf.

Since, the tracheids and vessels are always saturated with water, they transfer the water to the mesophyll cells. As a consequence, the mesophyll cells are always saturated with water. From the exposed surfaces of their cell walls, water evaporates and the water vapours accumulate in the intercellular spaces. Since the intercellular spaces are interconnected, these vapours diffuse through them and reach the sub-stomatal air spaces. Generally, in the terrestrial habitats the atmosphere is less humid than the air in the air spaces. Consequently, vapour from the air spaces diffuses out into the atmosphere along a concentration gradient.



Opening and Closing of Stomata : The opening and closing of the stomata depends upon the turgidity and flaccidity of the guard cells respectively. Remember, each stoma is surrounded by two kidney-shaped *guard cells* which, in turn are surrounded by *accessory cells* or *subsidiary* cells. The stomatal aperture, guard cells and the subsidiary cells together constitute the stomatal apparatus.

Each guard cell has chloroplasts and its inner wall, *i.e.*, the wall towards the stoma is *thick*, whereas the outer wall, *i.e.*, the wall towards accessory cells is *thin*.

During day time, guards cells carry out photosynthesis and produce sugar. As a consequence, the osmotic pressure of guard cells increases, making them hypertonic. Therefore, they absorb water from the surrounding cells by endosmosis and become turgid.

When the turgor pressure of the guard cells increases, their outer wall is pushed out towards the periphery. As a result, a tension is created on the inner wall of these cells. Consequently, the inner wall of the guard cells moves towards the periphery. This causes opening of the stoma. On the opposite, when the guard cells lose *turgidity* and come under a *flaccid state,* their outer wall returns to its original position, relieving the tension on the inner wall. This causes movement of the inner walls of the two guard cells towards the stomatal opening which is then closed.

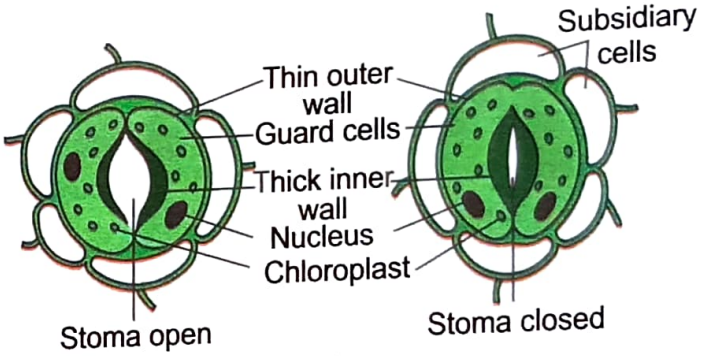


Fig. 7. Stomatal apparatus.

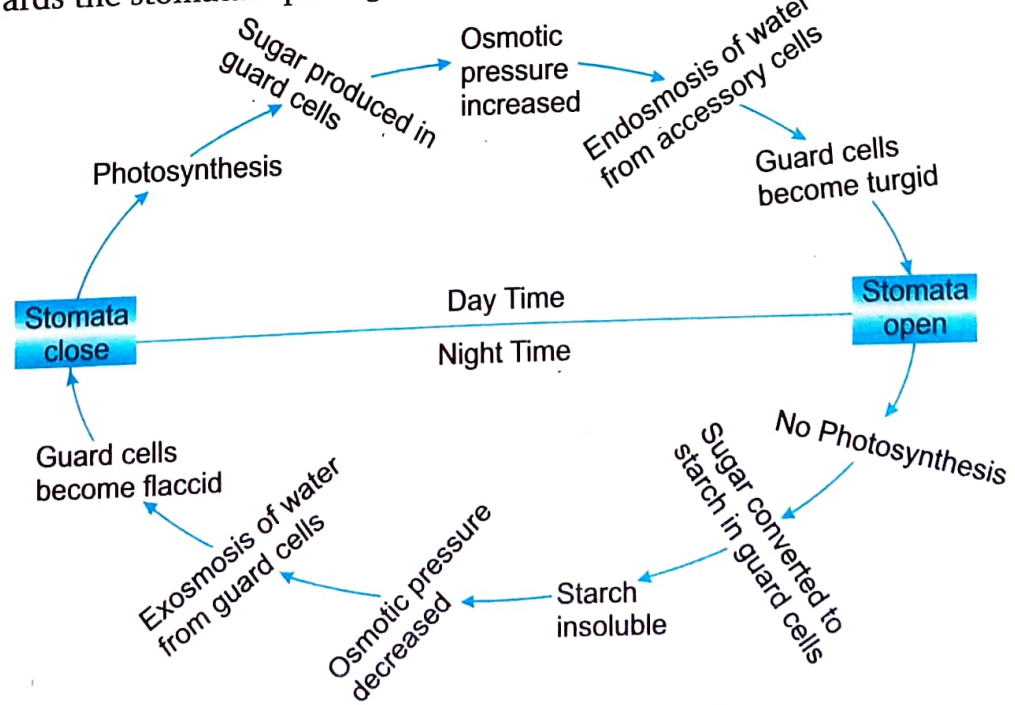


Fig. 8. Mechanism of opening and closing of stomata.

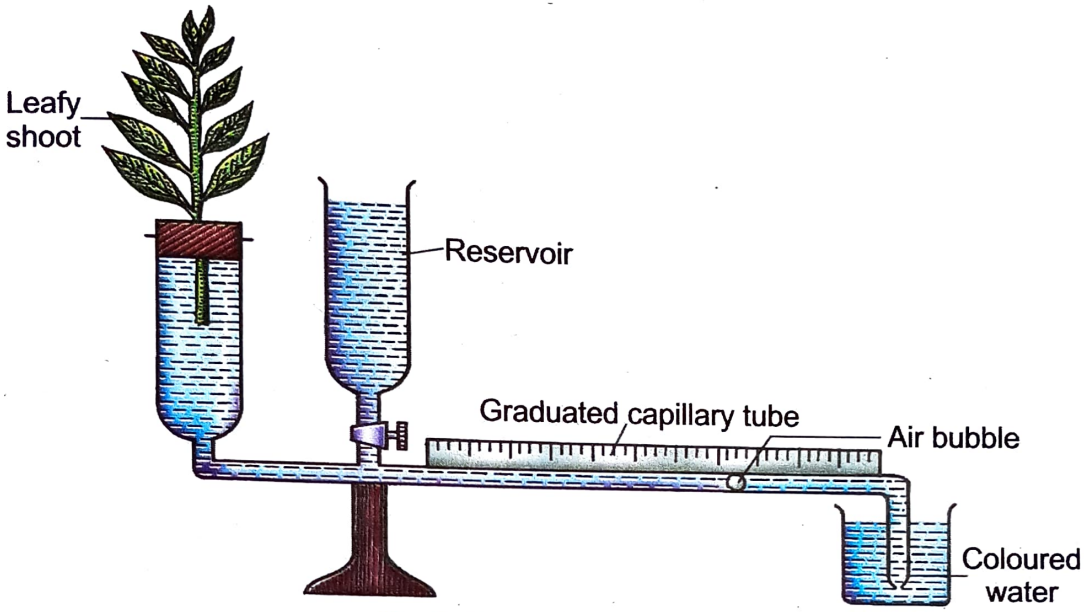


Fig. 5. Ganong's potometer.

Ganong's potometer is used to measure the rate of transpiration by measuring the water taken up by a leafy shoot.

A fresh leafy shoot is cut in water. It is inserted into the upper wide tube of the Ganong's potometer with the help of a cork. The entire set up is filled with water and made airtight by applying paraffin wax at every point. The narrow bent end is dipped in a beaker filled with coloured water. An air bubble is introduced by gently lifting the narrow end. The narrow end is placed again in the beaker.

The bubble introduced into the horizontal tube moves forward towards the twig due to a pull created due to loss of water by transpiration. This gives an idea about the amount of water lost in a particular time by reading the scale.

Precautions

1. The twig of the plant must be cut under water to avoid the entry of air bubbles in xylem vessels.
2. The entire apparatus must be made air-tight.
3. The atmospheric conditions (e.g. wind velocity and temperature) around the potometer should be maintained constant.

Limitations

1. Introduction of air bubble is difficult.
2. Changes in the environmental conditions like temperature, humidity, wind velocity etc., may influence the position of the bubble.
3. The leafy shoot may not remain alive for long to make proper observations.

Plant Features Affecting Transpiration

Root-Shoot Ratio

Transpiration increases with the increase in root-shoot ratio. If the rate of water absorption is less than the transpiration rate, a water deficit occurs in the plants, which reduces transpiration.

Leaf Area

Greater leaf area leads to greater magnitude of water loss. However, on per unit area basis, smaller plants transpire at a higher rate than the larger plants.

Leaf Structure

Plants growing in dry habitat (xerophytic plants) exhibit a number of structural modifications in leaves that reduce the rate of transpiration, for example, thick cuticle, thick cell wall, well-developed palisade parenchyma, sunken stomata and a thick covering of dead epidermal hair.

FACTORS AFFECTING TRANSPIRATION

External Factors

These are atmospheric factors, for example :

1. Light : During day the stomata open due to synthesis of glucose in the guard cells. More transpiration occurs during the mid day time. On a cloudy day stomata get partially closed thus reduce transpiration.

2. Temperature : Increase in temperature increases transpiration (upto a particular limit) as warm air can hold more water than cold air.

3. Wind : Fast blowing wind removes the water vapour from the surface of the leaves, thus increases transpiration.

4. Humidity : If the atmosphere is more humid transpiration reduces as the outward diffusion of water reduces.

5. Water Content of Soil : Lesser is the water content of the leaves lesser is the transpiration. At the state of lesser water content the leaves wilt and the stomata get closed so transpiration also reduces.

6. CO_2 Concentration : If the atmospheric carbon dioxide increases above its normal (0.03%) then stomata get closed and transpiration reduces.

7. Atmospheric Pressure : When atmospheric pressure increases transpiration rate decreases and vice versa.

Internal Factors

These are the plant-related factors, for example :

1. Arrangement of leaves : If the leaves are directly exposed to sunlight, they lose more water.

2. Thickness of cuticle : Thick layer of cuticle tends to reduce the rate of transpiration.

3. Number and distribution of stomata : A leaf bearing more number of stomata will transpire more water than a leaf with lesser number of stomata. Consequently the upper surface of a dicot leaf (dorsi-ventral leaf) transpires slowly than its lower surface where the stomata are more numerous.

NOTE The upper surface of a dicot leaf is called adaxial or the ventral surface and the lower surface is called abaxial or dorsal surface.

4. Anatomical features of the leaf : If the leaf is modified into spines or tendril, the stomata are sunken (e.g. *Nerium*), or the epidermis is covered with hair (e.g. *Geranium*), the rate of transpiration is significantly reduced.

5. The root : shoot ratio : If the root-system of a plant is more efficient, the rate of transpiration is more.

METHODS TO REDUCE EXCESSIVE TRANSPIRATION

Sunken stomata are observed in xerophytes or desert plants, *e.g.*, *Nerium* (oleander). These are covered by hairs. It reduces transpiration.

Lesser number of stomata also reduces transpiration.

In some cases leaves turn wavy, rolled or folded that reduces the open surface area to reduce transpiration.

Plants like oleander have narrow leaves that reduce surface area and thus transpiration as well.

Thick cuticle of the xerophytes or desert plants and some evergreen plants reduces transpiration.

In some plants the leaves fall down or dropped and in some plants like cactus the leaves are modified in the form of spines to reduce transpiration.

Anti–transpirants : These are the physical or chemical agents which reduce or stop transpiration.

For example : wax emulsion, plastic film, aspirin, dimethyl silicon etc.

TRANSPIRATION IS A NECESSARY EVIL

Importance of Transpiration (Necessary)

(a) Transpiration helps in reducing the increased temperature of the leaf surface and keeps the enzymes intact and active.

(b) Transpiration also creates a suction force or transpirational pull which plays an important role in ascent of sap.

(c) It also helps in distribution of water and mineral throughout the plant as the leaves are situated at the top and tend to pull the water towards them thus distributing it throughout.

(d) Transpiration also plays an important role in water cycle.

Disadvantages of Transpiration (Evil)

(i) It causes loss of water from the plant which may cause wilting.

(ii) Plants have to waste a huge amount of energy to develop the methods to reduce transpiration.

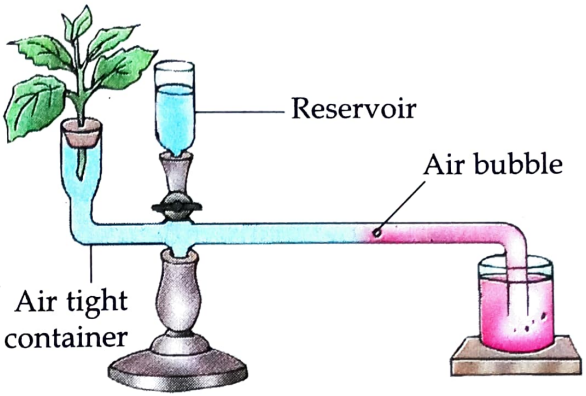
DIRECT WATER LOSS

Guttation : Loss of water in the form of water droplets through special openings at the end of the veins of the leaves called hydathodes is called guttation. It is due to the root pressure. It is commonly seen in the monocots and herbs.

Bleeding : When the plant part or parts get injured or ruptured the sap oozes out through these injuries or ruptured regions. This process is called bleeding. It is due to the root pressure.

1. Discuss the mechanism of transpiration in a typical plant.
2. Write the steps involved in the mechanism of stomatal transpiration. (2007)
3. 'Transpiration is a necessary evil.' Justify the statement.
4. Explain how the rate of transpiration is affected on
   (*i*) a sunny day. (*ii*) a foggy day. (2009)
5. Describe an experiment to prove that transpiration occurs more from the lower surface than from the upper surface of a leaf. (2003)
6. How is transpiration affected by
   (*i*) intensity of light? (2001) (*ii*) humidity in the atmosphere? (2001)
   (*iii*) availability of soil water? (*iv*) temperature?
7. Differentiate between the following:
   (*i*) Transpiration and evaporation (*ii*) Stomata and lenticels
   (*iii*) Bleeding and guttation. (2011)

1. The given diagram is an apparatus to study a particular phenomenon in plants.



(*i*) Name the apparatus.

(*ii*) Mention two limitations of the apparatus.

(*iii*) Which phenomenon is studied with the help of this apparatus?

(*iv*) Write the function of the part marked 'reservoir'.

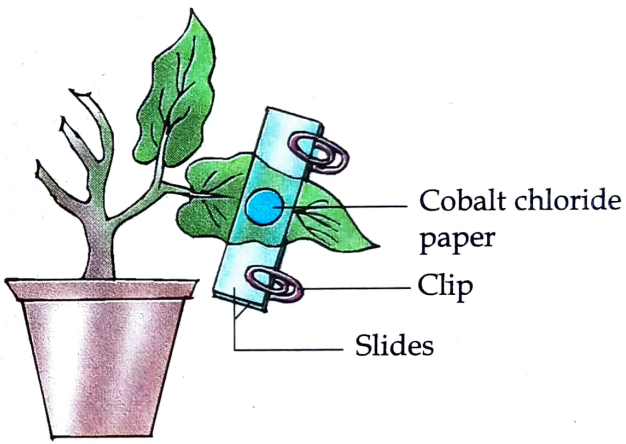
(*v*) What is the role of the air bubble in the experiment?

(*vi*) What happens to the movement of the air bubble if the apparatus is kept

(*a*) in the dark? (*b*) in sunlight? (*c*) in front of a fan? Give reasons in each case.

(2007, 2016)

2. The given diagram is an experimental set-up to study the process of transpiration in plants. Study the same and then answer the questions that follow:



(*i*) What is the colour of dry cobalt chloride paper?

(*ii*) Is the experimental leaf a monocot or a dicot? Give a reason to support your answer.

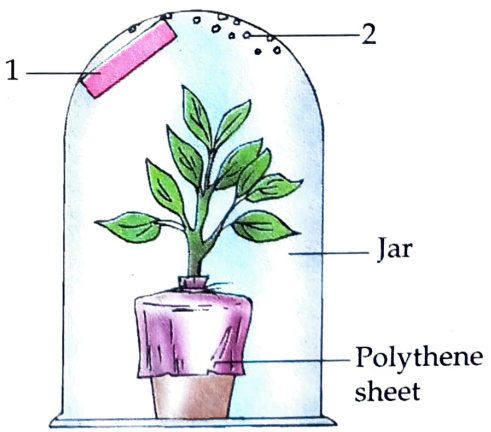
(*iii*) Why are glass slides placed over the dry cobalt chloride papers?

(*iv*) After about half an hour, what change, if any, would you expect in the cobalt chloride paper placed on the dorsal and ventral sides of the leaf? Give a reason to support your answer.

(*v*) Define the term 'transpiration'.

(2003)

3. Study the given apparatus and answer the following:



(*i*) What does the experiment demonstrate?

(*ii*) Write the significance of the polythene sheet wrapped around the pot.

(*iii*) Label 1 and 2 in the set-up.

(*iv*) Is there any change observed in 1 after some time? Give reasons.

(*v*) What does the presence of 2 in bell jar depict?

(*vi*) What would you observe if a pot with a leafless shoot is kept under the jar?